Hydrocarbon Development In The Beaufort Sea - Mackenzie Delta Region

VOLUME 4 BIOLOGICAL & PHYSICAL EFFECTS

ENVIRONMENTAL IMPACT STATEMENT

1982

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FOR

HYDROCARBON DEVELOPMENT

IN THE

BEAUFORT SEA - MACKENZIE DELTA REGION

VOLUME 4
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BEAUFORT SEA-MACKENZIE DELTA ENVIRONMENTAL IMPACT STATEMENT

The Beaufort Sea Production Environmental Impact Statement was prepared by Dome Petroleum Limited, Esso Resources Canada Limited and Gulf Canada Resources Inc. on behalf of all land-holders in the Beaufort Sea-Mackenzie Delta region.

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ENVIRONMENTAL IMPACT STATEMENT

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CHAPTER 1

INTRODUCTION

The purpose of this volume is to assess the possible physical and biological impacts associated with proposed Beaufort Sea-Mackenzie Delta hydrocarbon developments described in Volume 2. It describes potential impacts of proposed development on Canadian environments and resources north of 60°N latitude. The socio-economic impacts are addressed separately in Volume 5, while potential impacts of accidental spills of oil or other materials are discussed in Volume 6.

Major emphasis is placed on examining the possible impacts of developing the first four offshore oil fields (assumed to be Tarsiut, Koakoak, Issungnak and Kopanoar) and two onshore oil fields (Adgo and Atkinson). Depending on the actual time required for first production to begin, and the rate of subsequent development, developing these fields alone could represent the bulk of production-related activity between 1983 and 1995. However, to estimate the nature of impacts that may occur over the longer term, data generated by the Beaufort Planning Model (described in Volume 2) have also been used. These data assist in projecting certain impacts which may occur as a result of a range of production development rates extending to the year 2000.

To transport the oil from the region to markets, two modes of transportation, namely icebreaking tankers and overland pipelines, are under active consideration. Since both have merit, and eventually both may actually be employed, the possible impacts of each are examined.

As suggested in the Environmental Assessment and Review Panel (EARP) guidelines, this volume discusses the potential impacts by region (Figure 1-1): the Offshore Beaufort Sea Production Region (Chapter 2), the Onshore Mackenzie Delta Production Region (Chapter 3), the Northwest Passage Transportation Region (Chapter 4) and the Mackenzie Valley Overland Pipeline Region (Chapter 5). The

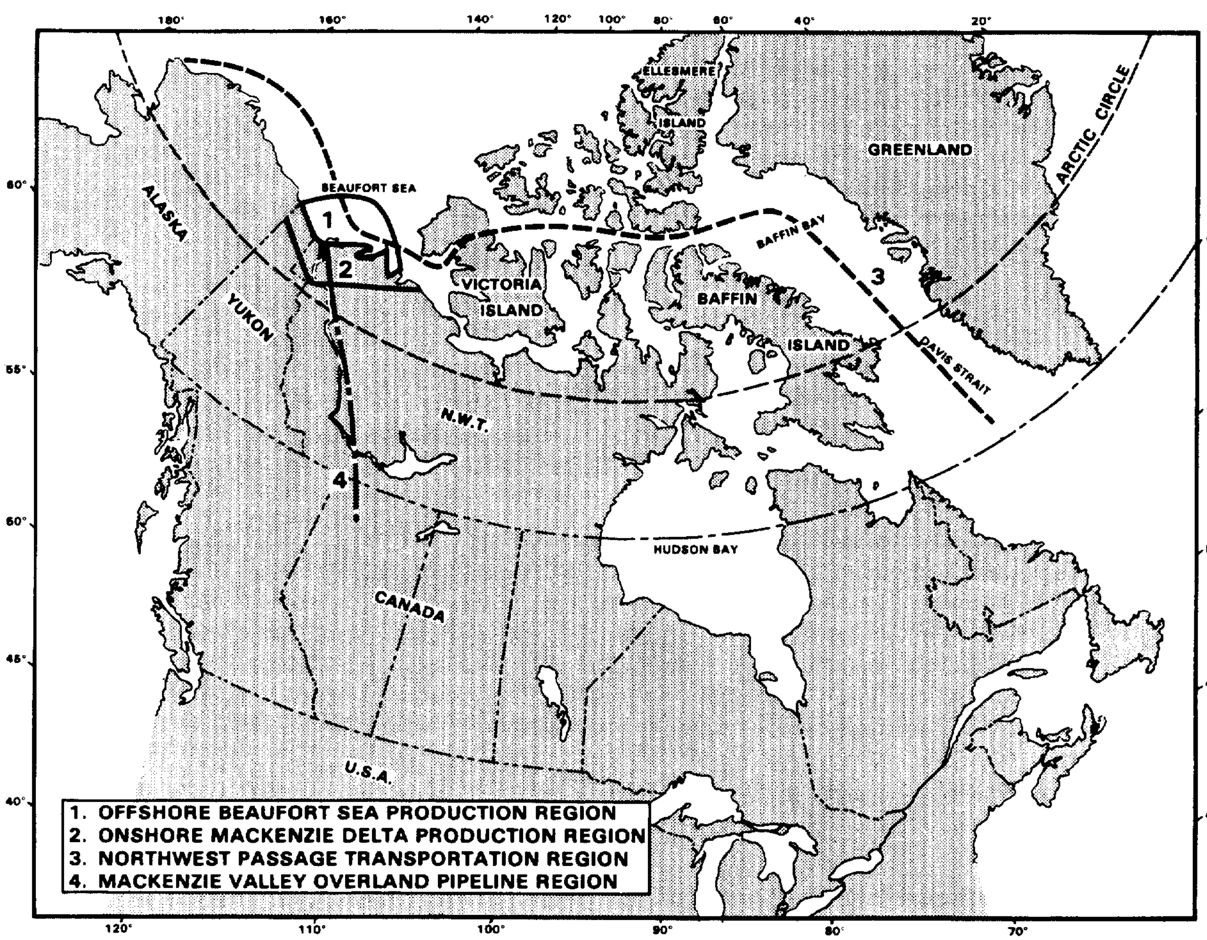


FIGURE 1-1 *Volume 4 discusses possible impacts which may occur within the four regions illustrated on this map.*

environmental setting of the tanker and pipeline transportation corridors is described in Volumes 3B and 3C, respectively, while the biophysical environments of onshore and offshore production zones are described in Volume 3A. Within each of the following chapters, a summary of existing and projected facilities and activities is provided. The environmental assessments for each region first discuss those wastes and disturbances which are common to a number of activities such as sewage disposal, air emissions and noise. Then other environmental effects which may be associated with only some development components such as dredges and offshore platforms are examined.

1.1 IMPACT ASSESSMENT METHODOLOGY

The following describes the overall approach and impact assessment methodology. Within each regional subsection, the possible impacts of various proposed development components or activities are assessed. Summaries and matrices are provided to identify the most significant possible impacts of the development on the more important natural resources. Reviewers interested in an overview of the potential impacts of the proposed development on one particular resource (eg. whales or seals) in a region are referred to these summaries.

Many of the activities and sources of impact anticipated from future development in the Beaufort Sea-Mackenzie Delta region have been investigated not only in this region but elsewhere in the world. As a result, there is an extensive data base describing most activities. This volume is not intended as a comprehensive literature review, although certain topics, which have been perceived as issues or were considered of importance in the judgement of the proponents, are addressed in greater detail. Since some technical reviewers may require more comprehensive information, supporting documents have been prepared and referenced as appropriate.

To assist with this broad-scale evaluation, an assessment methodology was employed which provides a relatively consistent approach from region to region, with the aid of standardized criteria to define degrees of potential impact. The basic assessment methodology used is illustrated in Figure 1-2.

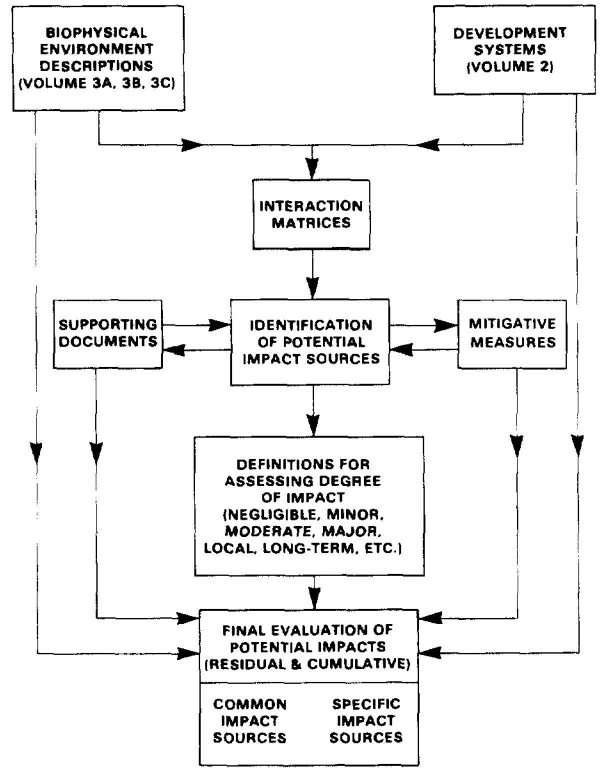


FIGURE 1-2 *General procedures used to identify and assess environmental impacts.*

1.1.1 INTERACTION MATRICES

The first step in this assessment was to determine where interactions could occur between various development activities and selected resources present in each region (Figure 1-2). Matrices were constructed for each development region: the Offshore Beaufort Sea Production Region, the Onshore Mackenzie Delta Production Region, the Northwest Passage Transportation Region and the Mackenzie Valley Overland Oil Pipeline Region. These were based on the description of Development Systems (Volume 2) and Biophysical Environmental Settings (Volumes 3A, 3B and 3C). At this point, possible interactions were identified, irrespective of the season when they might occur, their local or regional significance, or whether possible effects were direct or indirect.

1.1.2 IDENTIFICATION OF POTENTIAL IMPACT SOURCES

This process identified those development components which might affect various biophysical resources. Two supporting documents were prepared to summarize the available information. The first reviewed existing information on the potential physical and biological effects associated with offshore petroleum hydrocarbon exploration and production, as well as those which may result from the transport of petroleum by tankers (ESL, 1982). The second reviewed literature on the possible effects of onshore hydrocarbon development and the transport of oil by pipelines (Esso Resources Canada Limited, 1982).

1.1.3 IMPACT DEFINITIONS

The next step was to determine a method for defining the degree of the potential impacts given the interactions identified in the matrices and the material provided in the supporting documents (Figure 1-2).

The definitions used to assist in assessing the degree of possible **biological impact** throughout this volume (excluding terrestrial vegetation sections) were modified from definitions used by Imperial Oil and partners in their Davis Strait EIS (Imperial Oil *et al.*, 1978) and are shown in Table 1-1. These definitions were modified to focus the biological assessment on regional populations of specific resources, rather than on local groups of individuals, and to remove any references to resource use since these impacts are discussed in the socio-economic impact assessment (Volume 5).

Possible **physical impacts** of various development components, as well as **biological impacts on terrestrial vegetation** were assessed according to a separate series of criteria shown in Table 1-2.

Like all such definitions, the ones used in this EIS must have the built-in flexibility to allow their use for a wide range of biophysical resources, as well as sources and durations of potential impact. As a result, the definitions are primarily a set of guidelines rather than a fixed and inflexible mechanism to determine degree of impact. For the purposes of establishing a clear and consistent basis for the impact assessment, it was also important to differentiate between possible local and regional effects. In view of the large geographic area considered, this volume primarily addresses **regional impacts**. Potential impacts were consistently evaluated on a regional basis to place the development plans in a broader perspective. It is emphasized, however, that regional assessments still necessitated examination of the potential effects of **individual** development components or activities on the **local** environment prior to assessing their regional significance.

1.1.4 IMPACT ASSESSMENT

The impact assessment was completed by the proponents with the assistance of the consultants identified in Table 1-3. Throughout the assessment, it was assumed that mitigative measures to prevent or minimize impacts of various development components were an integral part of the development and would be employed to the extent feasible. Consequently, unless otherwise indicated, all statements of degree of possible impact refer to **residual impact.**

The guideline nature of the impact definitions shown in Tables 1-1 and 1-2 was considered throughout the assessment. The three principle considerations em-

TABLE 1-1

DEFINITIONS USED FOR DETERMINING THE DEGREE OF IMPACT ON BIOLOGICAL RESOURCES (EXCLUDING TERRESTRIAL VEGETATION) IN EACH DEVELOPMENT REGION

A **MAJOR IMPACT** exists when a regional population or species may be affected to a sufficient degree to cause a decline in abundance and/or a change in distribution beyond which natural recruitment (reproduction and immigration from unaffected areas) would not likely return that regional population or species, or any population or species dependent upon it, to its former level within several generations.

A **MODERATE IMPACT** exists when a portion of a regional population may be affected to a sufficient degree to result in a change in abundance and/or distribution over more than one generation of that portion of the population or any population dependent upon it, but is unlikely to affect the integrity of any regional population as a whole.

A **MINOR IMPACT** exists when a specific group of individuals of a population in a localized area and over a short time period (one generation) may be affected, but other trophic levels are not likely to be affected in a manner which is considered regionally significant, or the integrity of the population itself is not significantly affected.

A **NEGLIGIBLE IMPACT** exists when the degree of the anticipated biological effects are less than minor.

TABLE 1-2

DEFINITIONS USED FOR DETERMINING DEGREE OF IMPACT ON PHYSICAL RESOURCES AND VEGETATION IN EACH DEVELOPMENT REGION

A **LOCAL IMPACT** exists when any physical or chemical changes (or alterations in vegetation patterns) are only expected to be detectable within 1 km of proposed facilities and/or linear transportation corridors.

A **REGIONAL IMPACT** exists when physical or chemical changes (or alterations in vegetation patterns) are expected to be detectable beyond 1 km of proposed facilities and/or linear transportation corridors.

A **SHORT-TERM IMPACT** is likely to persist less than 5 years from the onset of the disturbance.

A **MEDIUM-TERM IMPACT** is likely to persist for 5 to 10 years from the onset of the disturbance.

A **LONG-TERM IMPACT** is likely to persist more than 10 years from the onset of the disturbance.

TABLE 1-3

PARTICIPANTS IN THE ENVIRONMENTAL IMPACT ASSESSMENTS FOR VARIOUS DEVELOPMENT COMPONENTS

Development Component/Region	Discipline(s)	Firm
Offshore Beaufort Sea Production Region (Chapter 2)	All	ESL Environmental Sciences Limited
	Birds and Mammals	LGL Limited
Onshore Mackenzie Delta Production Region (Chapter 3)	Geology and Soils; Hydrology and Water Quality; Atmospheric Environment; Vegetation	Hardy Associates (1978) Ltd.
	Fish and Aquatic Resources	Aquatic Environments Limited
	Birds	LGL Limited
	Mammals	McCourt Management Ltd.
Shorebases (Chapter 3)	Aquatic/Atmospheric General	ESL Environmental Sciences Limited
	Terrestrial (Yukon Coast)	LGL Limited
Northwest Passage Transportation Region (Chapter 4)	All	LGL Limited
Mackenzie Valley Overland Oil Pipeline Region (Chapter 5)	Geology and Soils; Hydrology and Water Quality; Atmospheric Environment; Vegetation	Hardy Associates (1978) Ltd.
	Fish and Aquatic Resources	Aquatic Environments Limited
	Birds	LGL Limited
	Mammals	McCourt Management Ltd.

ployed were the spatial (aerial extent), magnitude (e.g. proportion of the population) and duration, of effects. The adequacy of the data base, both in terms of biophysical information and the effects of various activities and impact sources on biophysical resources, was also carefully considered throughout the environmental assessment. When a lack of data hampered evaluation of potential impacts, a 'worst case' approach was followed to assure that such assessments were conservative. Important data deficiencies were also identified, and are discussed in Volume 7 (Research and Monitoring).

1.1.5 REFERENCES

ESL Environmental Sciences Ltd. 1982. The biological effects of hydrocarbon exploration and production related activities on marine flora and fauna of the Beaufort Sea region. Prep. for Dome Petroleum Limited, Calgary, Alberta.

Esso Resources Canada Limited. 1982. Additional environmental data — Mackenzie Valley and Beaufort Sea Region. Submitted to Beaufort Sea Environmental Assessment Panel.

Imperial Oil Ltd., Aquitaine Co. of Canada Ltd., and Canada-Cities Service Ltd. 1978. Environmental impact statement for exploratory drilling in Davis Strait region. Imperial Oil Ltd., Calgary, Alta.

CHAPTER 2
OFFSHORE BEAUFORT SEA

The offshore Beaufort Sea region is where most of the hydrocarbon resources and particularly oil are expected to be produced in the Beaufort-Delta region, consequently the scale of future activities will be much greater offshore than on the Delta. This chapter begins with a brief description of past and current offshore petroleum exploration activities in the region. This is followed by a brief description of proposed future offshore components in Section 2.2

The assessments of possible impacts are structured in two separate ways. First, in Section 2.3, the possible impacts of common wastes and disturbances are described. These are common because most of the proposed activities and facilities will discharge similar wastes, such as sewage, and will create similar disturbances, such as underwater noise. Secondly, in Section 2.4 the possible impacts associated with only certain activities and facilities are examined. Finally, Section 2.5 summarizes possible impacts on each biophysical resource and highlights those of regional or local significance. Where feasible, cumulative impacts have also been identified.

2.1 THE EXPLORATION PHASE

The initial stage of petroleum industry activity in the Beaufort Sea consisted of the gathering of seismic data. Throughout the 1970's, seismic data acquisition took place offshore, and is presently continuing in areas where operators anticipate finding major hydrocarbon accumulations. These data have led to the discovery of many subsurface structural anomalies which warrant further exploration by drilling. In the offshore area alone, more than 90 potential hydrocarbon-bearing structures have been identified.

The first well in the Canadian offshore Beaufort Sea was drilled in 1973 at a shallow water artificial island site called Immerk (Figure 2.1-1). This island was constructed in 3 metres of water. Since then island building technology has evolved, and subsequent islands have been built in progressively deeper water. To the end of 1981, 20 islands have been constructed, in water up to 22 metres deep. Twenty-four wells have been drilled from these islands, resulting in oil discoveries at Adgo and Issungnak and gas discoveries at Netserk, Isserk, Adgo and Issungnak (Figure 2.1-1).

Three of the island wells were delineation wells on the Adgo discovery, and one was a directional well to delineate the Issungnak discovery (Plate 2.1-1). Over

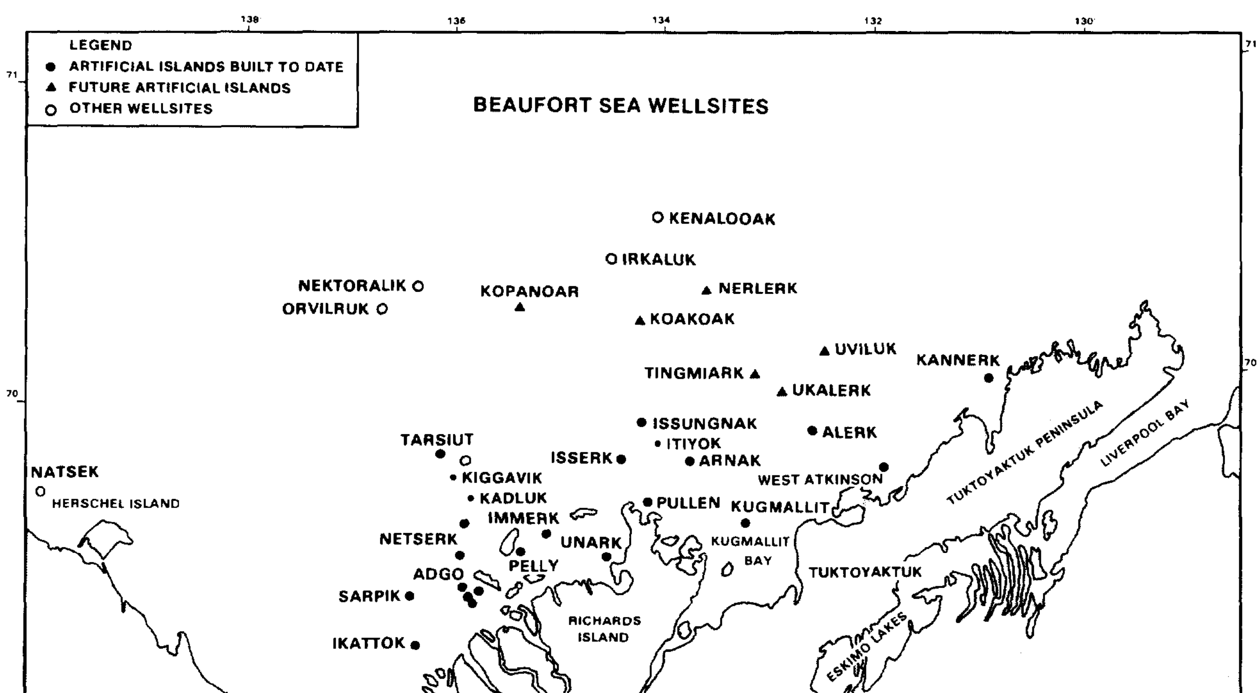


FIGURE 2.1-1 *Wellsites in the offshore Beaufort Sea.*

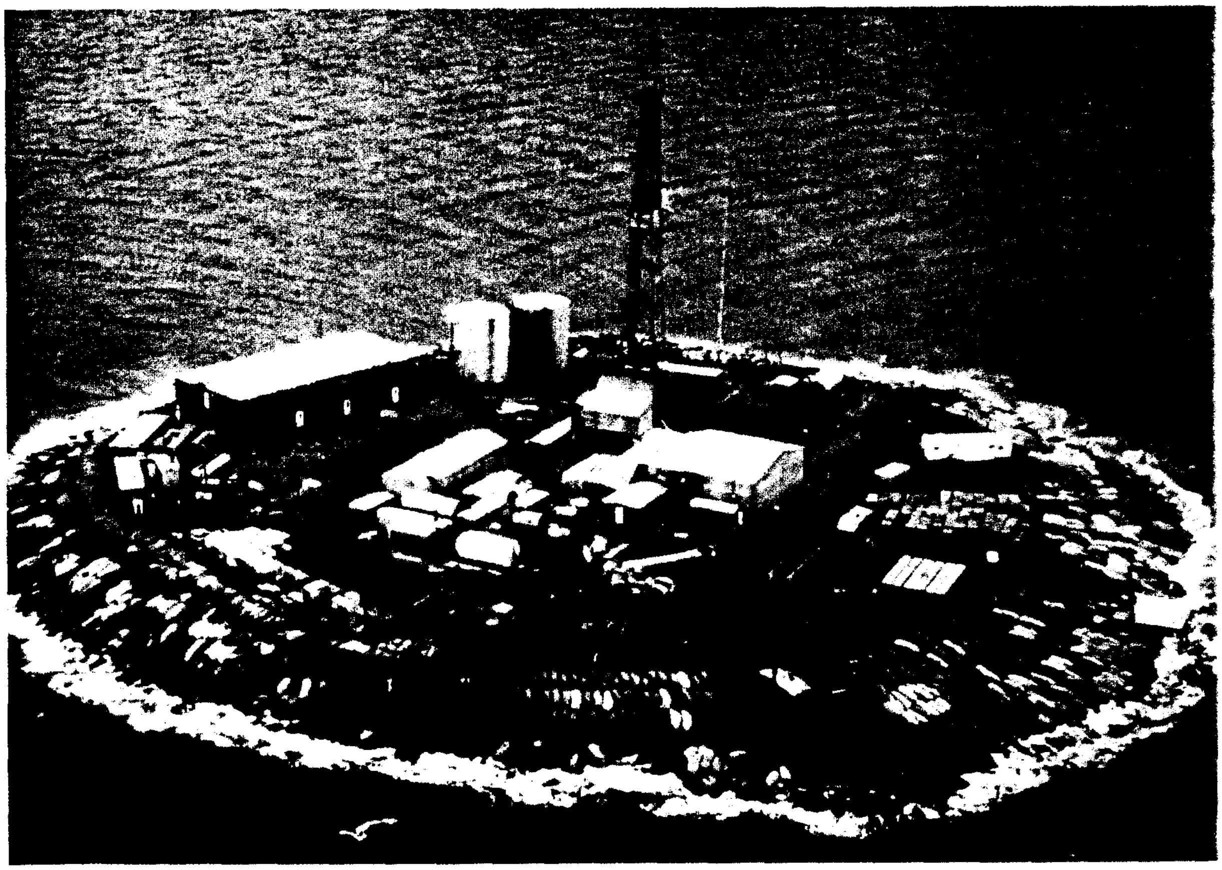


PLATE 2.1-1 *The Issungnak artificial island was the site of one of the offshore oil and gas discoveries in 1980.*

the winter of 1981-82, a successful delineation well to the original Tarsiut oil discovery (drilled from a drill-ship) was completed from the new Tarsiut caisson-retained island (Plate 2.1-3). Further wells will be drilled from this platform in 1982.

In 1976, two drillships, specially reinforced to operate in the ice of the Beaufort Sea, were brought into the area to commence exploration drilling in deeper waters (Plate 2.1-2). These were subsequently supplemented by two more drillships. These ships are capable of operating only 3 to 5 months each year because of the thick, moving ice found in the Beaufort Sea during the rest of the year. To date, these ships have drilled 15 wells in water depths ranging from 23 metres to 70 metres. There have been 4 oil discoveries: Nektoralik in 1977, Kopanoar in 1979, Tarsiut in 1980, and Koakoak in 1981; and 2 gas discoveries: Nektoralik in 1977 (same well as the oil discovery, but in a different geological zone), and Ukalerk in 1977 (Figure 2.1-1). Only one of the 15 wells has been abandoned as a dry hole; the others include two delineation wells, five wells requiring additional drilling and/or testing, and one well that had to be abandoned due to mechanical problems.

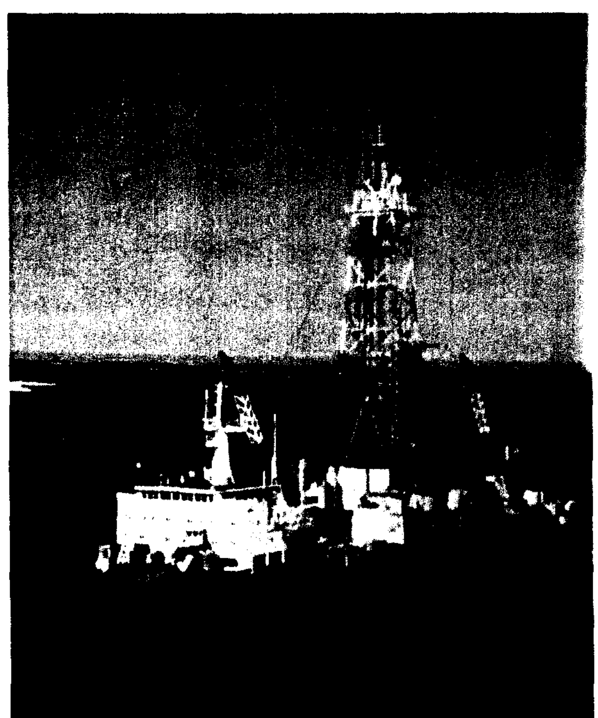


PLATE 2.1-2 *Drillships such as the EXPLORER 3, shown here, have extended offshore drilling into the deeper waters of the Beaufort Sea.*

Based on drilling results both onshore and offshore, various operators in the area have put forward esti-

PLATE 2.1-3 *The Tarsiut caisson-retained island has been the site of successful delineation drilling on the Tarsiut geological structure.*

mates of ultimate recoverable oil, ranging from 0.9 billion cubic metres (6.3 billion barrels) to 5.1 billion cubic metres (32 billion barrels). The oil discoveries made offshore indicate that, unlike the Mackenzie Delta area, this area is much more prone to oil than gas.

2.2 THE DEVELOPMENT PHASE

Delineation drilling is presently underway at Tarsiut with the intent of establishing the commercial viability of production from this geological structure by the end of 1982 or early 1983. Assuming this goal is accomplished, plans are being developed, which if implemented, could lead to first production of oil from this location by 1986. Similar drilling programs are also being developed for other offshore discovery locations such as Koakoak, Issungnak and Kopanoar. Assuming they too will be successful, several Beaufort Sea fields could be producing oil over the next 10 to 15 years.

Volume 2 of the Environmental Impact Statement provides a thorough review of all aspects of present and proposed activities in the offshore Beaufort Sea and should be consulted for details. This section will briefly summarize the major components comprising future activities in the offshore area.

2.2.1 FLOATING DRILLING PLATFORMS

Throughout the future development phase, drilling of exploration, delineation and some production wells will continue to be conducted from floating platforms. The platforms will include the four conventional drillships presently in use, supplemented by a new generation of Round Drillships and Conical Drilling Units (Figure 2.2-1). The first of these, operated by Gulf, is scheduled to join the Beaufort fleet in 1983. Thereafter, depending on various factors, 2 to 4 more could be drilling in the area by the year 2000.

These drilling units are being designed to withstand winter ice forces, and with icebreaker support, will be able to drill in the offshore Beaufort for approximately 8 months per year.

2.2.2 ARTIFICIAL ISLAND DRILLING PLATFORMS

Most drilling operations will be carried out from one or more types of artificial islands. Exploration drilling will be conducted from various forms of "temporary" islands such as Issungnak (Plate 2.1-1) and Tarsiut (Plate 2.1-3). Over the next two years several other types of exploration islands will be employed using a variety of caissons such as those illustrated in Figures 2.2-2 and 2.2-3. The lifespan of exploration

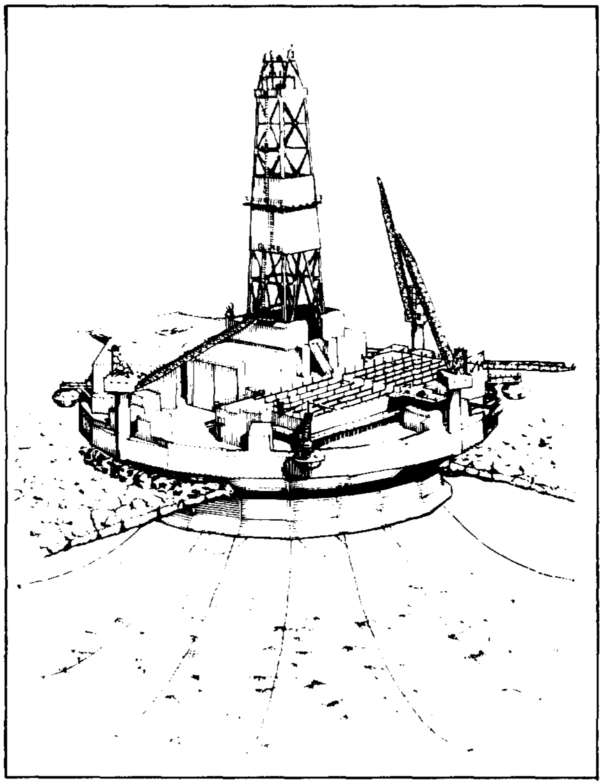


FIGURE 2.2-1 *The Conical Drilling Unit is a specialized drill system that has been developed for the Beaufort Sea and presents an icebreaking profile, like the bow of an icebreaking ship, around its entire periphery so that it can resist much greater ice forces than a conventional drillship.*

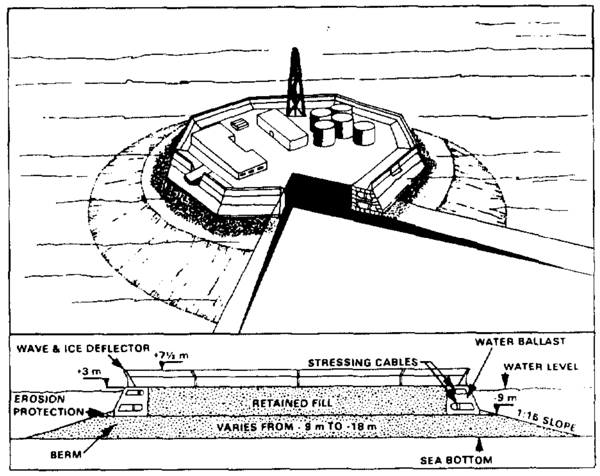


FIGURE 2.2-3 *The Caisson Retained Island is another self contained mobile drilling system that will be used for drilling exploratory wells.*

islands will vary, depending upon drilling success, but they could exist for more than two years. Upon completion of the drilling program at a specific location, topside facilities would be removed and the sand berm foundation permitted to erode through natural processes. For caisson islands, the caissons would be removed to a new location, leaving the top of the remaining sand berm at a depth of 5 to 15 metres below the sea surface.

Some exploration islands could eventually be modified and expanded into production islands, as illustrated in Figure 2.2-4. Production islands will generally be larger than exploration islands and will be designed to withstand the forces of the Beaufort Sea for the life of the production operation, which could

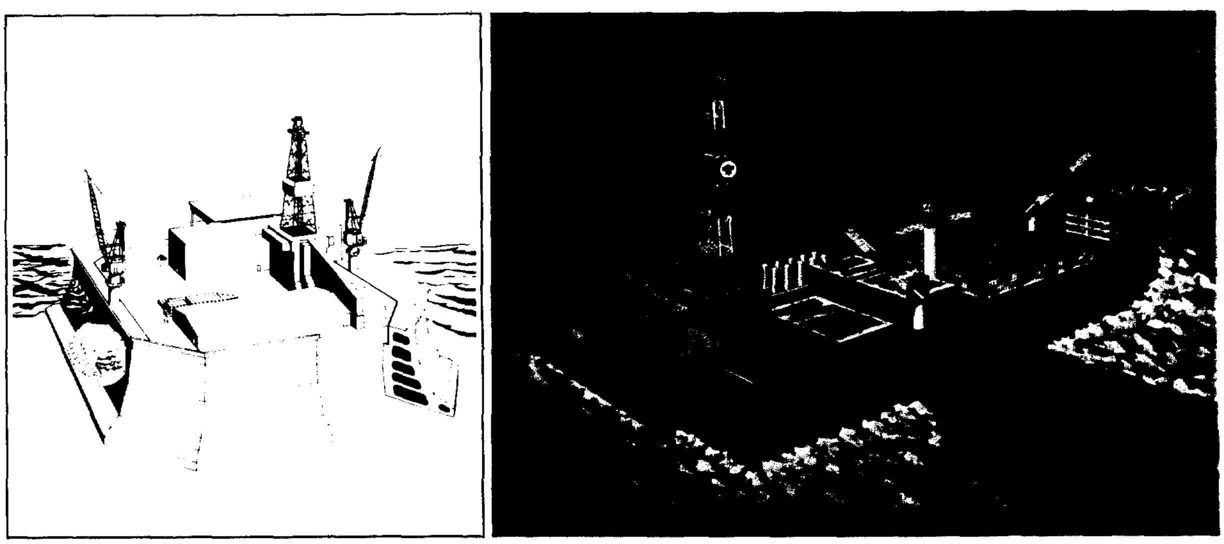
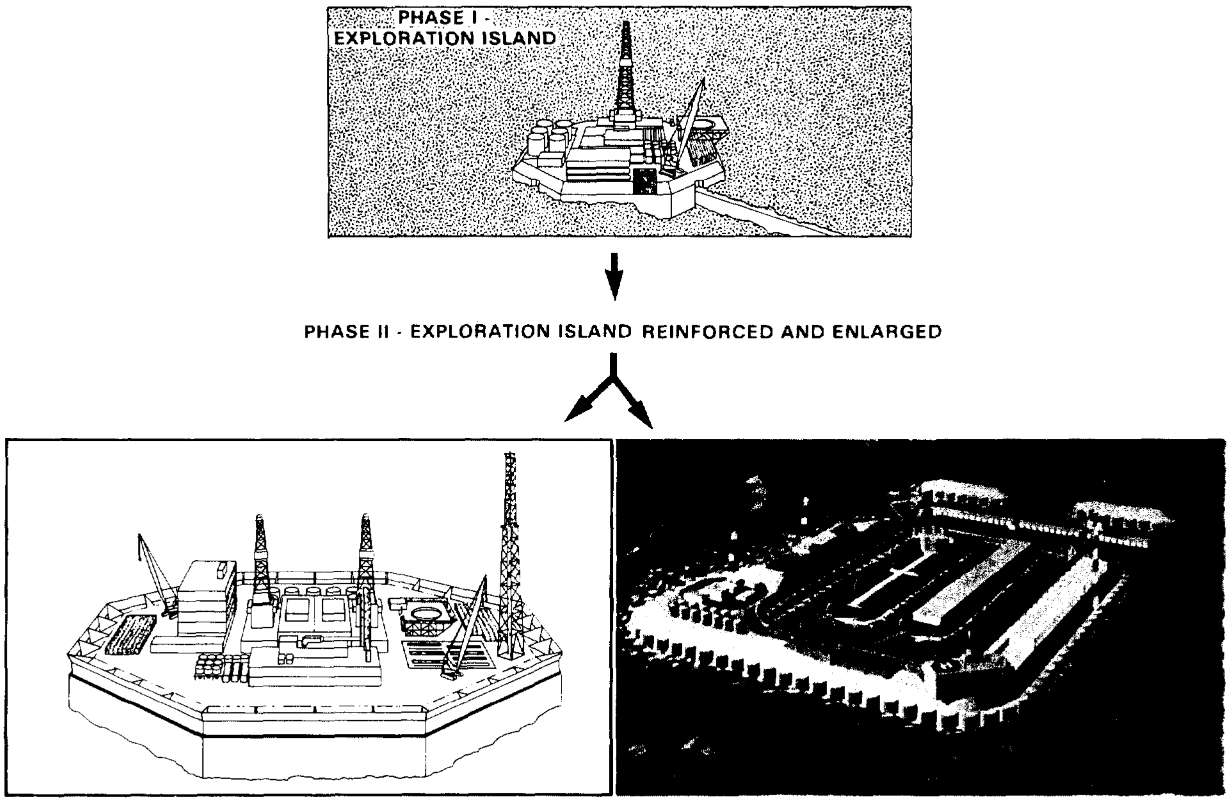


FIGURE 2.2-2 *Mobile Arctic Caissons can be towed to a drilling location and ballasted down onto a prepared berm. The drilling system is moved to a new location when exploratory drilling is completed.*



PHASE III - PRODUCTION ISLAND PHASE III - PRODUCTION ISLAND

FIGURE 2.2-4 *An exploratory island such as Tarsiut could be expanded into a larger permanent production island by additional dredging and the installation of more caissons.*

range from 15 to perhaps 30 years. A future production island in the shallow waters of the Beaufort Sea (0 to 20 m) would likely appear very similar to those being used off the coast of California but without the decorations (Plate 2.2-1). At this particular location off Long Beach, they have been decorated to make them more attractive to the viewing public.

In water depths ranging from 20 to about 60 metres, caisson-topped production islands (Figure 2.2-4) are expected to be the main type used for the foreseeable future. Assuming that oil is transported to market by icebreaking tankers, one or eventually two Arctic Production and Loading Atolls (APLA) may be built in the region (Figure 2.2-5). The main purpose of these larger islands would be to provide a protected harbour for loading icebreaking tankers. However, they may also be used as platforms for production drilling, the processing and storage of hydrocarbons, and as an offshore base of operations.

2.2.3 MARINE SUPPORT SYSTEMS

Exploration, construction and production activities in the Beaufort Sea-Mackenzie Delta region require an extensive marine support system. A large part of this fleet is comprised of supply ships used to transport goods and materials from the main support bases to offshore locations. This fleet also includes seismic vessels, dredges used to build artificial islands, icebreakers to support winter operations, and a variety of barges and other vessels.

Supply boats (Plate 2.2-2) are used to transfer drilling consumables and other supplies from shorebases to offshore drillsites. As extended season drillships such as Conical Drilling Units come into use, there will be a requirement for more supply boats with greater icebreaking capabilities. For example, Gulf is currently building two Class 4 supply vessels which are scheduled to go into service in 1983 to support their new drilling systems. Likewise icebreakers will be required to assist with year-round marine operations. The prototype KIGORIAK (Plate 2.2-3) was the first industry icebreaker to operate in the Beaufort region. In the future, more powerful ships, ranging from Class 4 to perhaps Class 10, will be required to assist with year-round drilling, production and marine operations.

Dredges will continue to be required to construct foundations for artificial islands, to excavate har-

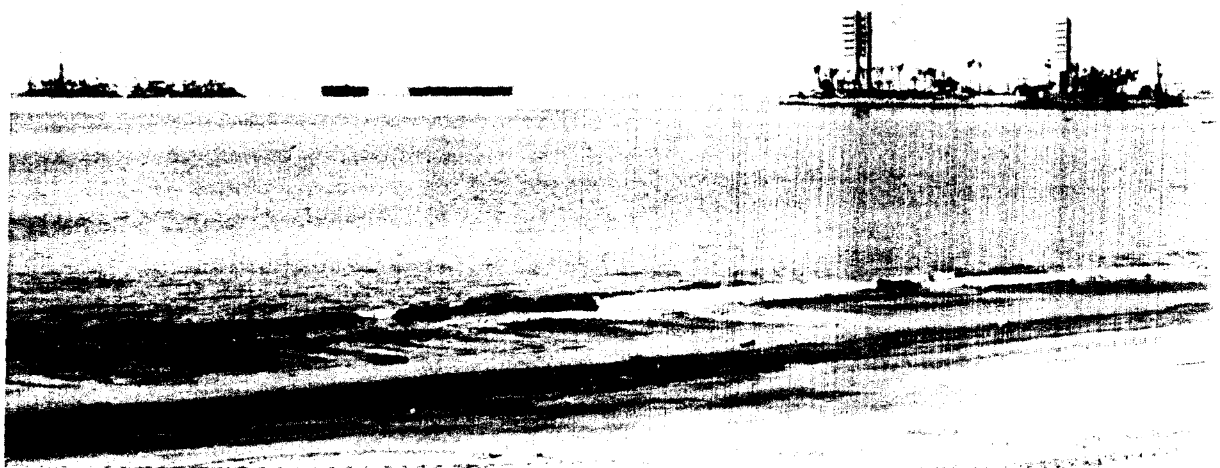


PLATE 2.2-1 *Future production islands in the shallow waters of the Beaufort Sea (0 to 20 m) would appear very similar to those being used off the coast of California. At this particular location, the topside facilities have been decorated to make them more attractive to the viewing public.*

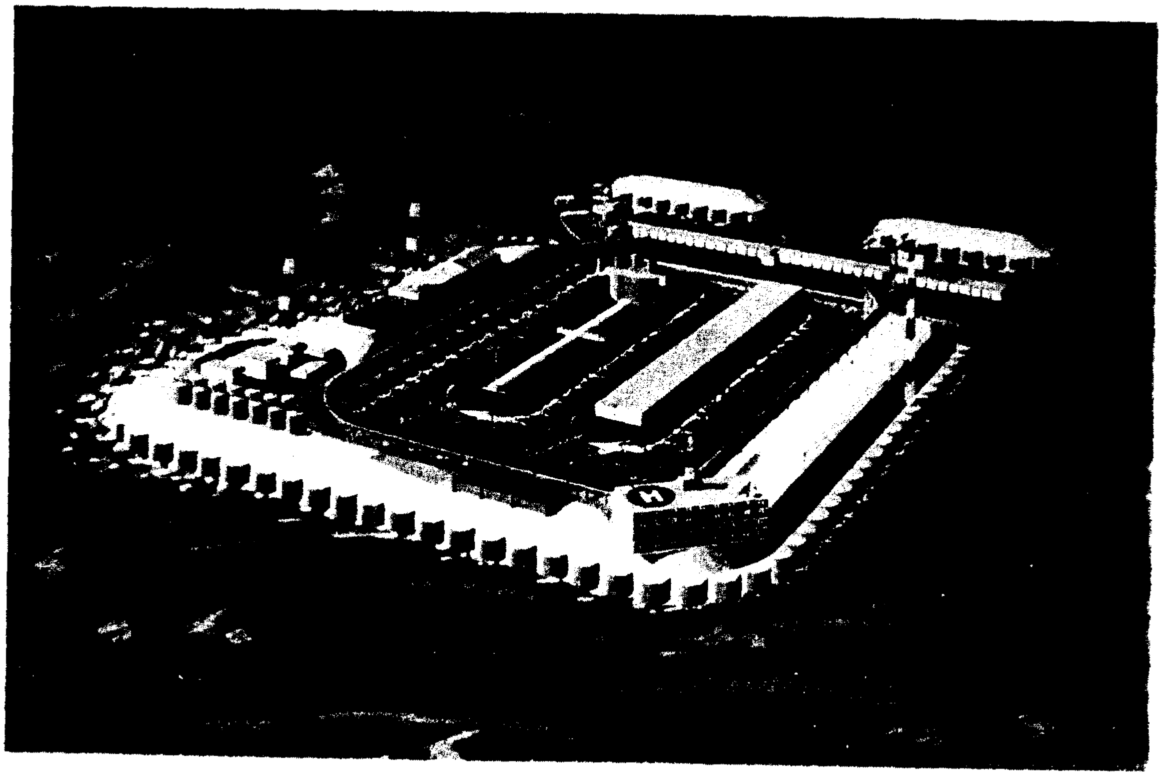


FIGURE 2.2-5 *One or two Arctic Production and Loading Atolls, such as the one illustrated here, may eventually be built. These islands would provide a protected harbour for the loading of icebreaking tankers.*

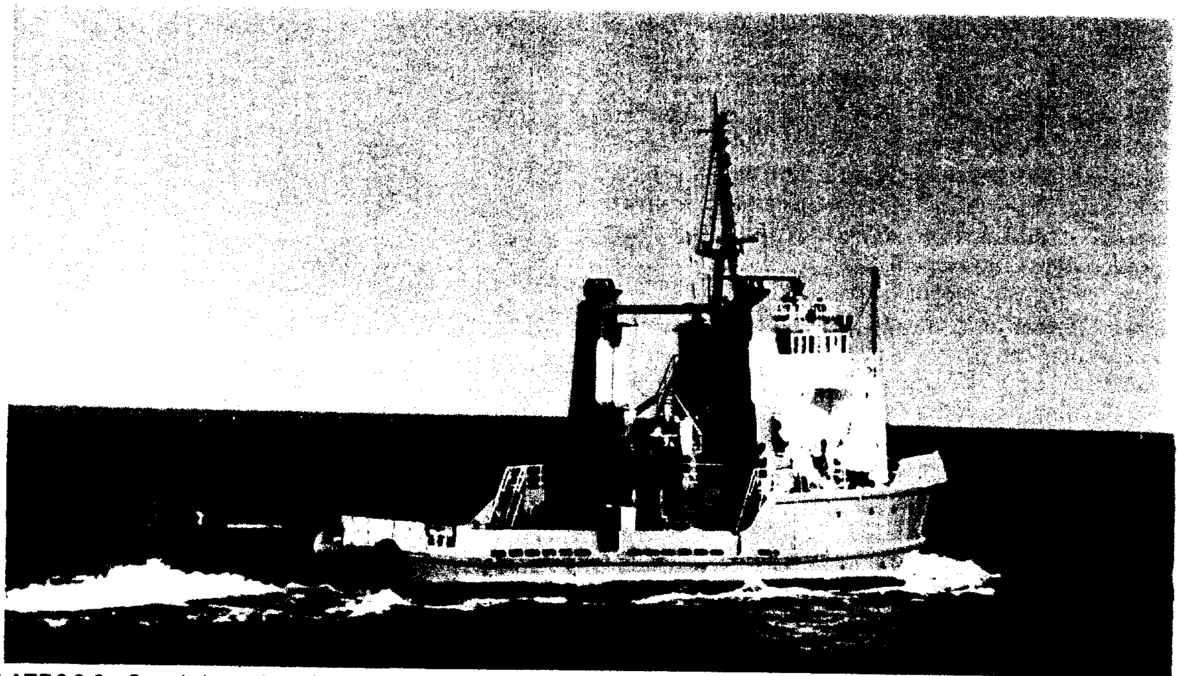


PLATE 2.2-2 *Supply boats have been in regular service in the Beaufort Sea and have domonstrated a tremendous capability to work in first year ice.*

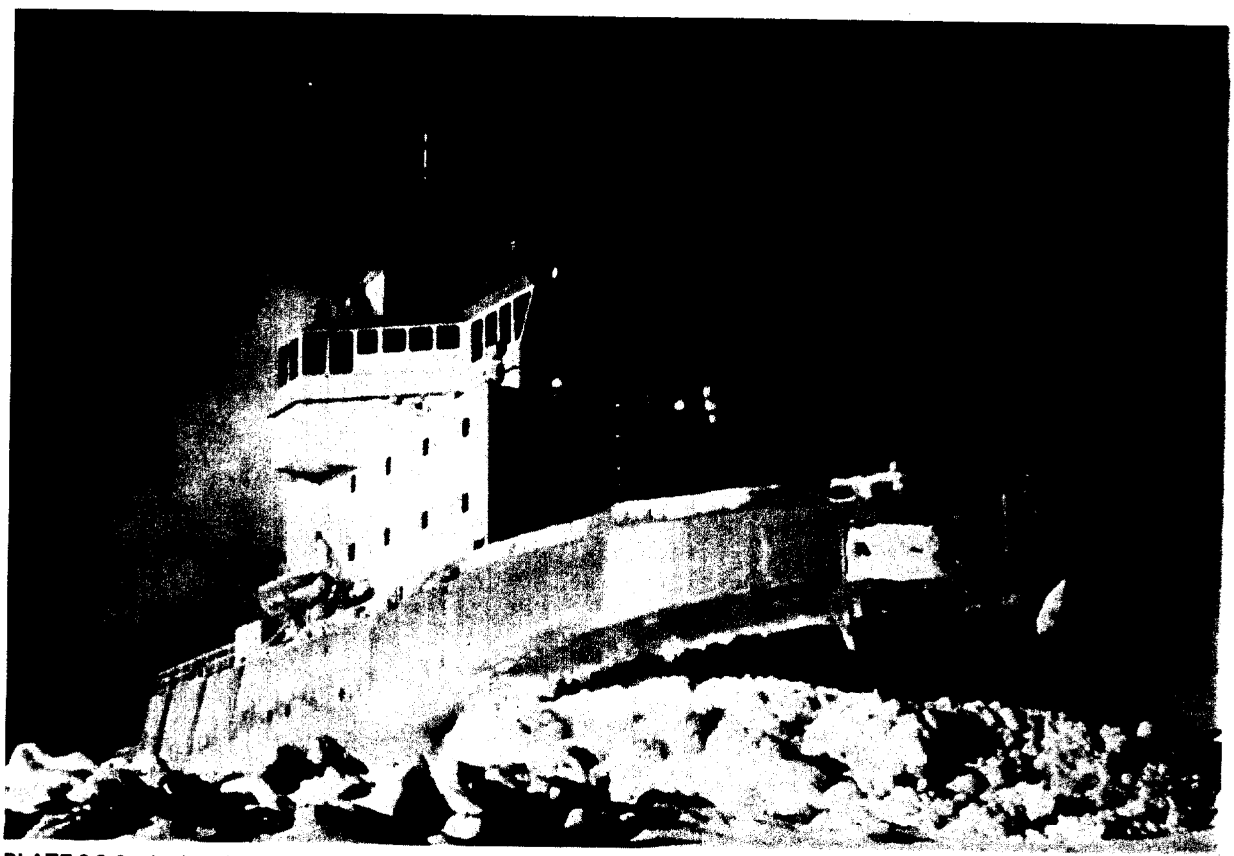


PLATE 2.2-3 *Icebreakers are required to assist oil industry operations offshore in the Arctic. The KIGORIAK, which started operations in 1979, was the first icebreaking vessel to be built specifically for the Beaufort Sea. It is used both to support drillships and for research purposes.*

bours and to dig trenches for submarine pipelines. Several types of dredges are presently employed in the Beaufort operations including stationary suction dredges such as the BEAVER MACKENZIE (Plate 2.2-4), trailing suction hopper dredges such as the HENDRIK ZANEN (Plate 2.2-5) and the cutter suction dredge AQUARIUS (Plate 2.2-6). These vessels will be used in the future and are likely to be supplemented by additional dredges as required to meet approved construction schedules.

To build production islands in the deeper waters of the Beaufort Sea, where local sand supplies appear to be scarce, it may become necessary to use a larger type of trailing suction hopper dredge. Accordingly, design work has been carried out on a 25,000 cubic metre icebreaking dredge referred to as an Arctic dredge (Figure 2.2-6). If built, dredges such as this would be capable of operating in water depths up to 80 metres through most of the year.

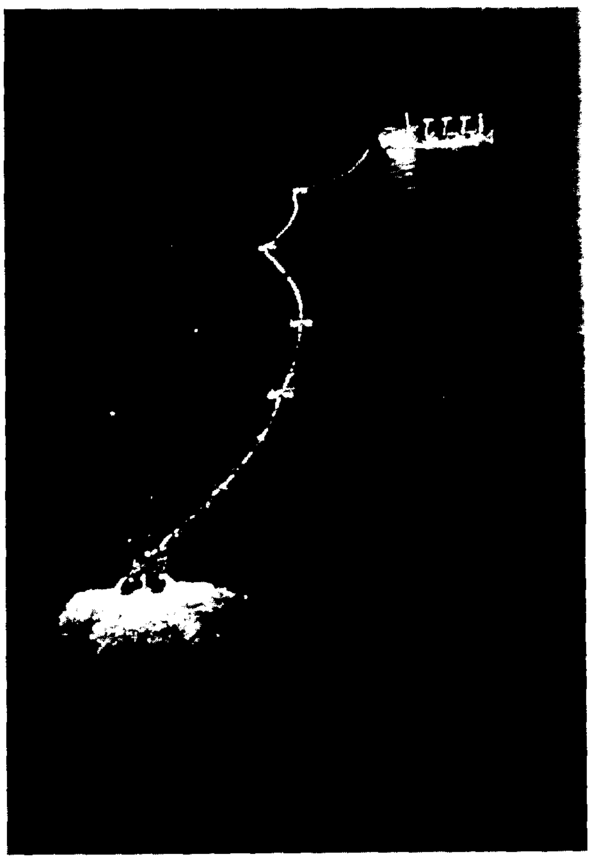


PLATE 2.2-4 *The BEAVER MACKENZIE is a stationary suction dredge. It was the first large dredge to enter the Beaufort region and has been used to build many of the offshore artificial islands.*

PLATE 2.2-5 *The HENDRIK ZANEN, a trailing suction hopper dredge, has self-contained hoppers for carrying dredged material to distant construction sites. The dredge is shown here returning empty to the borrow site.*

PLATE 2.2-6 *The AQUARIUS is a cutter suction dredge that has been working in the Beaufort Sea since 1979. This dredge cuts a channel in the sea floor and pumps the dredged material through a pipeline to an island location or disposal area.*

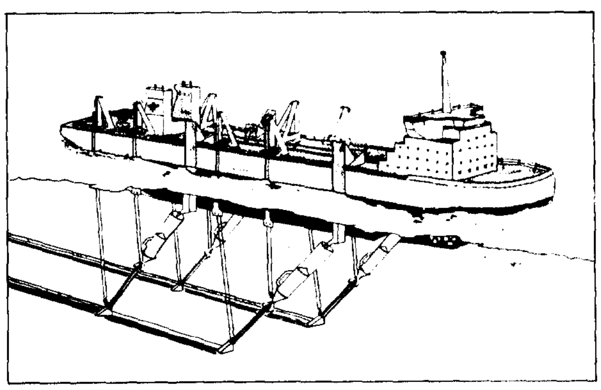


FIGURE 2.2-6 *Dredges will play an important role in the construction of production islands. A new class of Arctic dredge which will be able to operate in ice and in deep water has been fully designed. If built they would be the largest dredges in the world. Material would be dredged from the sea floor at appropriate sites where gravel or sand is present and transported to the site where an island is being built*

2.2.4 HYDROCARBON TRANSPORTATION SYSTEMS

To transport hydrocarbons from the Beaufort region to markets, either tankers or pipelines, or a combination of the two systems may eventually be used.

Assuming tankers are used to transport at least the early production from the region, they would be Class 10 double-hulled vessels (Figure 2.2-7) capable of operating year-round in the offshore Beaufort Sea. The ships would load their cargo at central offshore platforms such as an APLA and proceed out of the region through the Northwest Passage.

The number of tankers required would be dependent upon the production rate achieved over time. On the basis of the tankers being 200,000 DWT* ships, one tanker would be required for every 50,000 barrels of oil produced per day. Projecting this into the future, the number of tankers could increase from 1 by the end of 1985 or early 1986 to between 6 and 9 tankers by 1990 and 16 and 26 tankers by the year 2000.

If the oil was delivered to market by an overland pipeline, offshore oil would be transported by subsea pipelines from the artificial production islands to a landfall such as North Point (Figure 2.2-8). A tank farm and the northernmost pump station of the overland pipeline would be located at the landfall.

* a 200,000 Deadweight Ton (DWT) ship is one which can carry 200,000 tons of cargo, in this case oil.

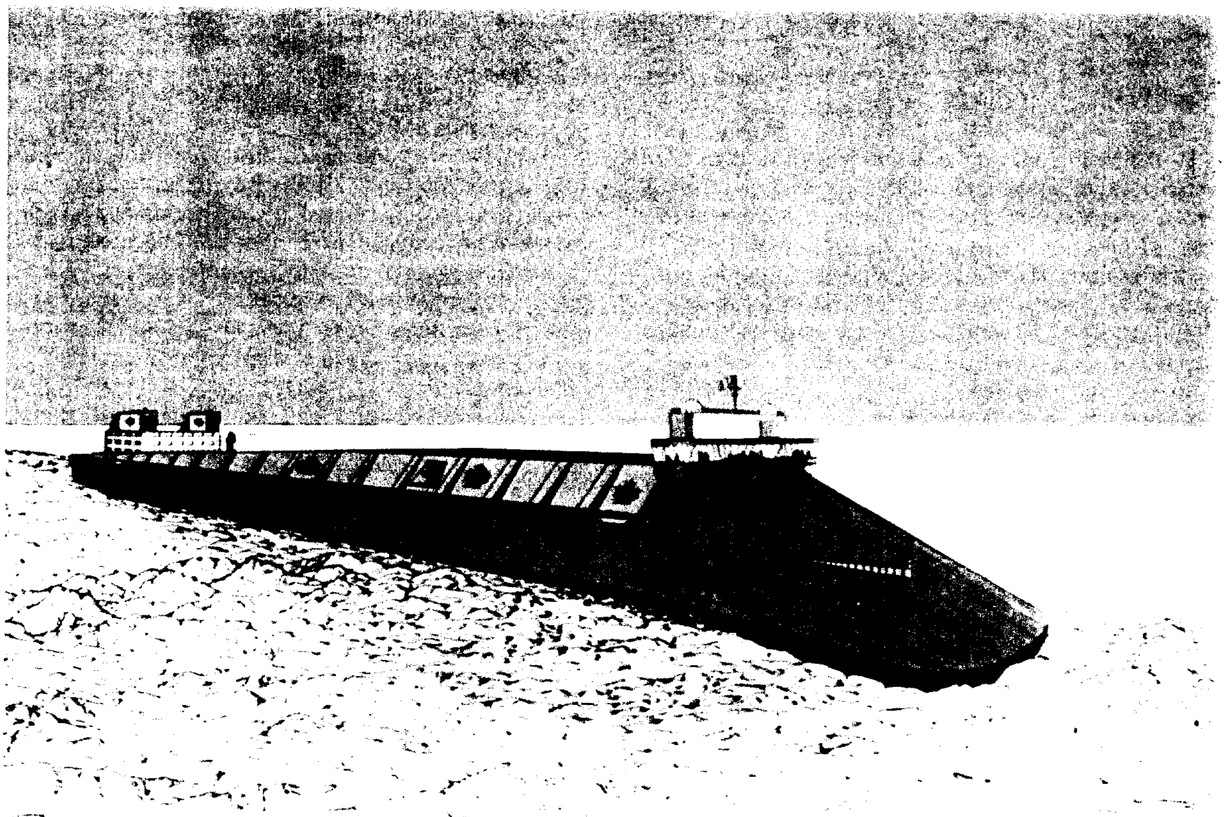


FIGURE 2.2-7 *Arctic tankers will have many special features not found in conventional tankers. These include a Class 10 icebreaking capability, separate oil and water ballast tanks and a double-bottomed hull to minimize the risk of oil spillage in the event of an accident.*

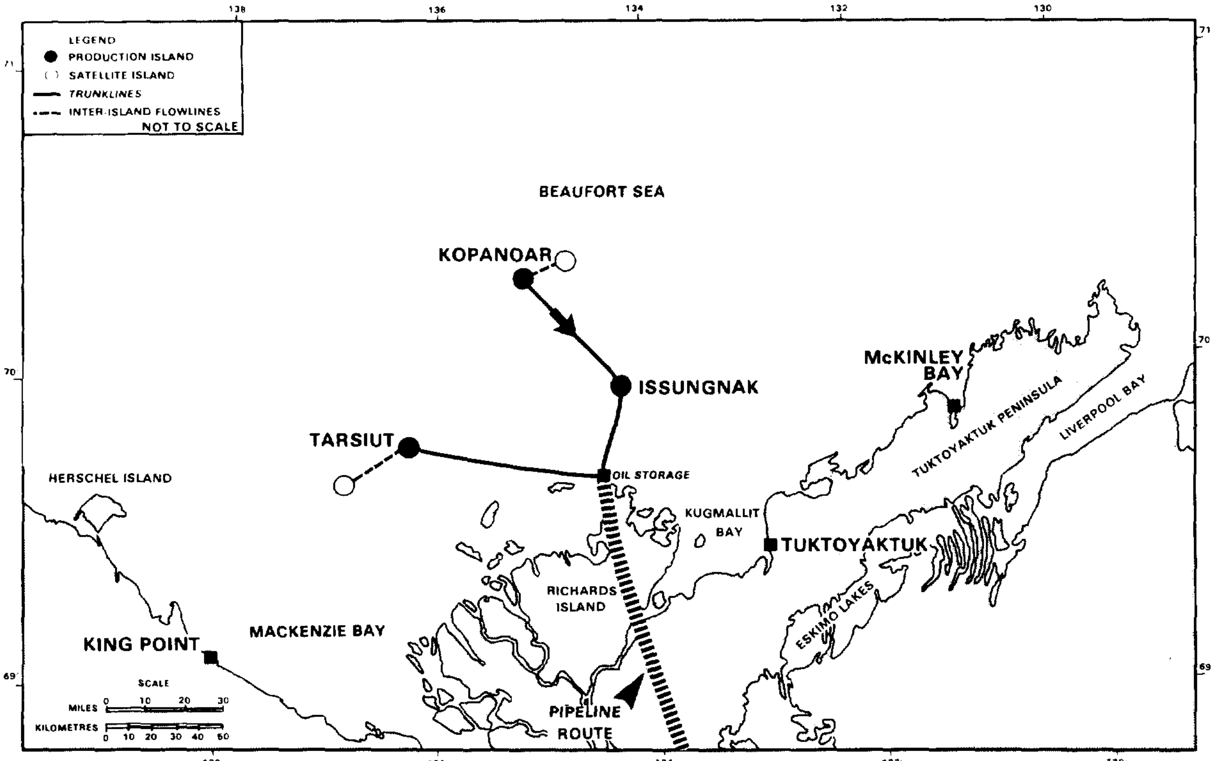


FIGURE 2.2-8 *Projected oil gathering subsea pipelines for the overland pipeline option.*

2.3 IMPACTS OF COMMON WASTES AND DISTURBANCES

The following section assesses possible effects of wastes and disturbances which are common to many of the existing and proposed activities in the Beaufort Sea. Common wastes and disturbances discussed below include those associated with: human presence, solid waste disposal, discharge of treated sewage, atmospheric emissions, airborne and underwater noise and artificial illumination.

2.3.1 HUMAN PRESENCE

The development of Beaufort Sea region hydrocarbon resources will result in gradual but relatively dramatic increases in the numbers of industry personnel in the region. Assuming the intermediate development rate (Volume 2, Chapter 3), the on-site personnel would number about 5,000 by 1990 and 8,500 by the year 2000. These numbers exclude those required for construction and operation of a gas pipeline and assume tanker transportation of oil. Similar estimates exist for overland pipeline transportation of oil (see Volume 5, Chapter 7). Most on-site personnel will be on offshore platforms, support vessels or at base camps situated at Tuktoyaktuk, McKinley Bay and possibly at a shorebase on the Yukon coast such as King Point or Stokes Point. Permanent administrative personnel will be located in Inuvik.

The main effects from the increased number of personnel will be of a socio-economic nature, and are discussed in Volume 5. The majority of the possible biophysical effects related to the presence of these numbers of industry personnel are expected to be indistinguishable from other disturbances such as those associated with aircraft, sewage discharge , vehicular traffic, other sources of noise, and the physical presence of offshore platforms and facilities.

The remaining biophysical concerns related to the presence of humans are the on-foot encroachments into sensitive habitats, such as caribou calving, fox denning, and geese or swan nesting or staging areas, which could pre-empt use, and increased recreational hunting and fishing pressures. Such encroachments and pressures may be expected to a limited extent once industry administrative personnel, their families and service company personnel establish permanent residences at Inuvik, and after the construction of roads which may be associated with Yukon shorebase development. With the exception of polar bear monitors, petroleum industry employees will be prohibited from discharging firearms or having them in their possession while on shift or at company facilities. The proponents will cooperate with government agencies in developing guidelines and ensuring employee adherence to good fish and wildlife management practices. Impacts on sensitive habitats and fish and wildlife resources are therefore expected to be NEGLIGIBLE.

2.3.2 SOLID WASTES

Solid wastes include sludges, packing boxes, metal garbage and generally any wastes that cannot be piped in liquid form or be vented to the atmosphere. Construction activities will generally produce larger volumes of solid wastes than will the operation of facilities. Estimates of solid waste produced by offshore and shorebased facilities are provided in Volume 2, Chapter 5. Each offshore platform may produce 900 kg/day of solid waste, while dry docks and marine base facilities may each produce 4,150 kg/day of solid waste, based on 3.6 kg of waste per man-day. During the construction of a subsea pipeline system, about 770 kg/day of solid wastes would also be generated from each flowline construction camp. In addition, oil, gas and water separators, possible natural gas liquefiers and water treatment systems would produce sludges consisting of sand and salts. The oil and gas processing facilities, in total, are expected to produce about 65 kg of sludge daily, assuming a daily production rate by the year 2000 according to the intermediate development assumption. Fourteen percent of these solids are expected to be incombustible. Combustible solids produced at both offshore and onshore facilities will be incinerated, while incombustible solids will be transferred to approved landfills. Sludges from hydrocarbon processing and water treatment facilities will be discharged to the sea in accordance with regulatory requirements.

Possible impacts resulting from solid wastes will vary with both the location and method of disposal. It is unlikely that air emissions from the incineration of wastes will produce significant impacts (see Section 2.3.4). Also, landfill operations will conform to applicable regulatory requirements in order to minimize effects on water quality. The physical presence of waste incineration and landfill sites would constitute a LOCAL but LONG-TERM impact of the proposed development.

Although some species of birds and mammals, particularly polar bears, foxes, rodents and gulls (ESL, 1982), may be attracted to solid waste disposal sites, few individuals in the regional populations of these species would likely be affected. The degree of possible impact of solid waste disposal on polar bears in the Beaufort Sea region could be MINOR, since nuisance animals attracted to these sites may have to be removed from the area or destroyed. Impacts on other mammals and birds are expected to be NEGLIGIBLE.

The disposal of sludges from offshore oil and gas processing facilities may have local direct and indirect impacts on benthic fauna and some demersal fish species. These sludges are expected to settle rapidly to the sea floor and would smother local benthic infauna. Continuous sludge disposal would also prevent use of the local area by epibenthic invertebrates and bottom-feeding fish such as flounders. However, since the benthic habitat lost would be insignificant compared to available offshore habitat, the degree of possible regional impact of sludge disposal is considered to be MINOR.

2.3.3 DISCHARGE OF TREATED SEWAGE

Sources of domestic sewage would be vessels, exploratory drilling platforms, oil production and storage facilities and shorebases. All domestic sewage will be discharged to the sea after treatment. It will consist of flush water plus waste water from showers, sinks, kitchen and laundry facilities. The quantities of sewage that could be produced have been estimated at 0.25 m^3/person/day for ships, and from 0.12 to 0.5 m^3/person/day for shorebased facilities (Montreal Engineering Co., 1979).

Typical reductions in major constituents of raw sewage following primary and secondary treatment, are described in ESL (1982). The following sections separately describe the quantities and possible impacts of domestic sewage which could be discharged from vessels, offshore exploration and production platforms and shorebases.

2.3.3.1 Vessels

Vessels operating year-round in the Beaufort Sea will include icebreaking tankers and icebreakers, while those operating during the open water season will include work boats and supply vessels. Estimated annual volumes of sewage that may be discharged by marine vessels by the years 1990 and 2000 are summarized in Table 2.3-1 (Drillships are considered to be exploration platforms - see Table 2.3-2). These estimates assume the intermediate development rate and include both the marine and pipeline cases. By the year 2000, about 23% more effluent is expected in the marine case than in the pipeline case. The totals by the year 2000 - 148,600 m^3/year for the marine case and 121,200 m^3/year for the pipeline case - are similar to the annual sewage discharge from a town with a population of 1,000. Discharges from vessels, however, will be widely dispersed and discontinuous.

Ships will be equipped with holding tanks of sufficient size to handle the effluent produced over several days. Wastes will be retained in these tanks while the offshore vessels are in harbours or confined waters, and will only be discharged in open waters. Effluents

TABLE 2.3-1

ESTIMATED VOLUMES OF DOMESTIC SEWAGE FROM MARINE VESSELS

a: Intermediate development, marine case
b: Intermediate development, pipeline case

Vessel Type	Each Vessel Personnel On Each Vessel	Each Vessel Operating Days/Year	1990 No. of Vessels Operating/Year a	1990 No. of Vessels Operating/Year b	1990 Effluent/Year* 10^3m^3/Year a	1990 Effluent/Year* 10^3m^3/Year b	2000 No. of Vessels Operating/Year a	2000 No. of Vessels Operating/Year b	2000 Effluent/Year* 10^3m^3/Year a	2000 Effluent/Year* 10^3m^3/Year b
Class 10 icebreakers	34	315	1	0	2.7	0.0	2	0	5.4	0.0
Class 6 icebreakers	22	335	10	7	18.4	12.9	10	7	18.4	12.9
Class 3 icebreakers	20	335	8	6	13.4	10.0	8	6	13.4	10.0
Supply vessels	12	165	19	19	9.4	9.4	29	29	14.4	14.4
Conventional dredges	43	165	7	7	12.4	12.4	7	7	12.4	12.4
Arctic dredges	54	300	1	0	4.0	0.0	1	1	4.0	4.0
Crane barges	12	165	4	4	2.0	2.0	4	4	2.0	2.0
Pipelaying barges	106	165	1	1	4.4	4.4	2	2	8.7	8.7
Accommodation barges	15	365	5	5	6.8	6.8	10	10	13.7	13.7
Large process barge	16	365	3	3	4.4	4.4	7	7	10.2	10.2
Small process barge	8	365	4	4	2.9	2.9	8	8	5.8	5.8
Storage barge	12	365	3	0	3.3	0.0	7	0	7.6	0.0
Floating drydock	60	365	2	2	11.0	11.0	2	2	11.0	11.0
Tankers	30	28**	6	0	1.3	0.0	16	0	3.4	0.0
Work boats	10	165	19	18	7.8	7.4	23	22	9.5	9.1
Tugs	10	165	18	14	7.4	5.8	21	17	8.7	7.0
Totals					111.6	89.4			148.6	121.2

*Based on 0.25 m^3 sewage/person/day (Montreal Engineering, 1979).
**Operating days in the Beaufort region including 1 day for loading.

from new ships will generally undergo secondary treatment using an activated sludge sewage treatment plant, and excess sludge will be stored for incineration or land disposal.

The small quantities of treated wastes discharged from vessels would undergo rapid dilution and degradation in offshore waters so that zones of increased organic loading and nutrient enrichment would be small. As a result, the degree of possible impact of domestic sewage discharges from marine vessels on marine flora and fauna of the Beaufort Sea is expected to be NEGLIGIBLE.

2.3.3.2 Offshore Platforms

In contrast to vessels, drillships and islands will discharge effluent relatively continuously in the vicinity of the platforms. Exploration islands will operate year-round, for about two years with approximately 100 personnel. Conventional drillships, with approximately 100 people aboard, are expected to operate for about 5 months per year. Round drillships, or conical drilling units, may operate for 8 to 10 months per year with about 116 people aboard. Drilling at production islands will be continuous for a number of years, and once drilling begins, each production island will support about 150 people year-round. A tanker loading terminal with producing facilities is expected to have up to 200 on-site personnel once operating. Table 2.3-2 shows estimates of the quantities of treated domestic sewage which would be discharged into the Beaufort Sea in the years 1990 and 2000.

Table 2.3-2 indicates that the quantities of effluent which would be discharged annually would be similar for either the marine or pipeline transportation case. The estimated total volume in the year 2000 of about 336,000 m^3/year is roughly double the volume generated by vessels (Table 2.3-1).

Domestic sewage from artificial islands will generally receive secondary treatment. When ice is on the sea, effluent may be discharged either on the ice or below it. Discharge of the effluent on top of the ice may be preferable where the water is shallow and does not circulate well (AES, 1980).

The discharge of treated sewage from exploration and production platforms and tanker terminals is not expected to have any significant detrimental effects since the wastes will be rapidly diluted. Impacts on water quality will therefore be LOCAL but LONG-TERM since they would persist throughout the duration of the development. Although unlikely at offshore locations, an area of organic enrichment, some oxygen depletion and possibly slight enhancement of primary production may occur in the immediate vicinity of a particular discharge location (ESL, 1982).

TABLE 2.3-2

ESTIMATED VOLUMES OF DOMESTIC SEWAGE FROM OFFSHORE PLATFORMS

a: Intermediate development, marine case
b: Intermediate development, pipeline case

			1990				2000			
Facility	**Each Facility**		**No. of Facilities Operating**		**Effluent/Year* 10³m³/Year**		**No. of Facilities Operating**		**Effluent/Year* 10³m³/Year**	
	Personnel On Each	**Operating Days/Year**	**a**	**b**	**a**	**b**	**a**	**b**	**a**	**b**
Conventional drillships	100	150	4	4	15.0	15.0	4	4	15.0	15.0
Round drillships	116	300	5	5	43.6	43.6	5	5	43.6	43.6
Exploration islands	100	365	6	6	54.8	54.8	6	6	54.8	54.8
Shallow production Island	150	365	6	6	82.2	82.2	7	7	95.9	95.9
Deep production Island	150	365	1	1	13.6	13.6	5	5	68.0	68.0
Gas production Island	150	365	1	1	13.6	13.6	3	3	40.8	40.8
Tanker terminal	200	365	1	0	18.2	0.0	1	0	18.2	0.0
Totals					241.1	222.8			336.3	318.1

*Based on 0.25 m³ sewage/person/day (Montreal Engineering, 1979)

To avoid this, wherever possible, disposal into quiet and restricted waters (such as the inside of an APLA) would be avoided. The impacts on marine flora and fauna are therefore expected to be local and NEGLIGIBLE.

2.3.3.3 Shorebases

Hydrocarbon production in the Beaufort region will likely require the continued use of the Tuktoyaktuk shorebases, expansion of the artificial island base within McKinley Bay, and the construction or expansion of a shorebase on the Yukon coast between 1983 and 1990. About 400 on-shift personnel are eventually expected to work at each major shorebase. The volumes of sewage produced at each of these shorebases would be about 160 m^3/day or 58,400 m^3/year. Wastes at all bases will be treated in accordance with regulatory requirements. All sludges produced from the treatment plants would be either incinerated or transferred to approved landfills.

The discharge of domestic wastes into coastal marine waters is an acceptable method of disposal, and long-term detrimental effects of even very large discharges to marine systems have been minimal (ESL, 1982). Of primary importance is to maximize dilution and dispersion in the receiving waters. In confined waters, waste build-up can create areas of high organic loading, thereby reducing oxygen levels, while increased nutrient levels may stimulate primary production.

In nitrogen-limited receiving waters such as the Beaufort Sea, the effects of nitrogen enrichment from effluent would only occur in a small area surrounding the outfall. The greatest effect of nitrogen enrichment would be a slight increase in the rate of primary production by phytoplankton, although the impact is expected to be MINOR. Increased production by phytoplankton is unlikely to significantly increase the food available for herbivorous zooplankton, since both phytoplankton and zooplankton would be rapidly advected out of the zone of increased primary production. Therefore, the impact of sewage disposal on the zooplankton is expected to be NEGLIGIBLE.

Eighty percent of the solids in the raw sewage will be removed by the treatment plants, and the remainder will eventually settle out as the effluent plume moves away from the outfall. Since the quantities of solids are expected to be very small - approximately 15 kg/day for a major shorebase - impacts on the benthic community are expected to be MINOR. When secondary treatment is employed, after the removal of most of the solids and aeration of the effluent, BOD levels will be low, resulting in a slight, if any, decrease in the dissolved oxygen content of the receiving waters.

2.3.4 ATMOSPHERIC EMISSIONS

The following sections assess the characteristics of atmospheric emissions from typical sources associated with proposed development. Approximate emission levels from various sources are provided in Volume 2.

Air emissions are addressed according to five distinct sources, regardless of geographic location within the region, and are discussed individually. These sources are: liquid fuel combustion, gas flaring, solid waste incineration, gas turbines and fuel tanks. Emissions from fuel combustion, for example, include all those associated with drilling, marine operations, shorebases and aircraft operations. Similarly, air emissions from solid waste incineration include the combined total from construction activities, offshore platforms, and the three assumed major marine bases at Tuktoyaktuk, McKinley Bay and on the Yukon coast. Two further sections describe the potential for ice fog formation and the creation of odours. These are followed by a summary.

2.3.4.1 Liquid Fuel Combustion

By 1986, about 225,000 tonnes of liquid fuel per year is expected to be used by drill rigs, ships, shorebases and aircraft (Dome, 1982a). As oil production begins, associated gas produced with the oil will begin to replace liquid fuel for power generation on production platforms so that liquid fuel combustion emissions are not expected to increase significantly between 1986 and the year 2000. On the basis of emission factors available for the combustion of diesel fuel (Belyea *et al.*, 1966; Work and Warner, 1981), the total quantity of various emissions has been estimated and is listed in Table 2.3-3.

The air emissions resulting from the combustion of diesel fuel would be released to the atmosphere from a large number of widely separated sources. Consequently, long-term changes in ambient air quality are unlikely to result, and any potential impacts would be LOCAL. If necessary, dispersion modelling could be undertaken to predict ground level concentrations of pollutants resulting from larger single sources to ensure that air quality guidelines are met.

2.3.4.2 Gas Flaring

Emissions from production islands are expected to occur when associated gas is flared. Gas is only expected to be flared during the initial stage of oil production from each field. The unused associated gas will later be reinjected or processed and transported to southern markets. The amount of gas flared will increase incrementally as each new oil well is completed, during approximately the first 2 years of each field development. Maximum flaring is estimated to occur during 1989 when oil production could range between 22,000 and 27,000 m^3/day for the intermediate development rate. Based on the assumption that associated gas will be produced at the rate of 100 m^3 for each m^3 of oil extracted, total daily associated gas production could range between 2.2 and 2.7 million m^3 per day, and some of this gas would be flared. Between 0.7 and 0.9 million m^3/day would be used as fuel. Nitrogen oxides are the emissions of concern associated with gas flaring, although minor quantities of particulates, carbon monoxide and hydrocarbons are also released. Sulphur emissions are not expected since Beaufort Sea gas analyzed to date is sweet. Emission factors from the combustion of natural gas indicate that a maximum (worst case) of 3,680 kg of nitrogen oxides would be emitted for each million m^3 of gas burned. Therefore, total emissions of nitrogen oxides from all flares are expected to range between 5,500 to 6,600 kg/day, but would be released from 2 or 3 production platforms in the offshore development zone. As a result, changes in air quality should be limited to SHORT-TERM and LOCAL effects during unfavourable meteorological conditions. (Possible biological impacts of gas flares are discussed in Sections 2.3.7 and 2.4.1.11.)

2.3.4.3 Solid Waste Incineration

The quantity of solid waste produced by all shore-based facilities will increase as development proceeds and could reach 1.4 million kg/year by the year 2000. To this would be added about 5.3 million kg/year of solid waste from about 80 offshore platforms and construction activities. As indicated in Section 2.3.3, 86% of these wastes are expected to be combustible and would be incinerated, while the remaining non-combustible fraction would be disposed of in approved landfills. Thus, about 5.8 million kg of solid wastes would be incinerated annually by the turn of the century. Based on emission factors for solid waste

TABLE 2.3-3

ESTIMATED EMISSIONS FROM THE COMBUSTION OF 225,000 TONNES/YEAR OF DIESEL FUEL (Assumed to be combusted in 1986)

Pollutant	Emission Factors* (percent wt. of fuel)	Approximate Emissions tonnes/year	tonnes/day
Particulates	1.69	3,800	10.5
Sulphur Oxides	0.69	1,600	4.4
Nitrogen Oxides	3.38	7,600	20.8
Hydrocarbons	4.92	10,400	28.5
Carbon Monoxide	0.92	2,100	5.8

*Source: Belyea et al. (1966); Work and Warner (1981) combustion, the estimated daily quantity of various emissions resulting from incineration of solid wastes at that time are provided in Table 2.3-4.

Since these total emissions would be released from several shorebased and offshore sources, it is expected that only LOCAL and SHORT-TERM impacts on air quality would occur, and would usually occur only during unfavourable meteorological conditions.

2.3.4.4 Gas Turbines

By the year 2000, about 2.7 million m^3/day of gas would be used as fuel, mostly for power generation using turbines (Dome Petroleum Limited, 1982a). Electrical power will be generated at each offshore platform and some shorebases by gas turbine driven generators. In addition, compressors to produce LNG would be driven by natural gas turbines. The sum of exhausts from various power generators throughout the region are expected to total about 27 million m^3/day. Emissions would include carbon dioxide, excess oxygen, water vapour, nitrogen and nitrogen oxides. Nitrogen oxides may comprise about 0.07% by weight of flue gases. Therefore, total emissions of nitrogen oxides may be about 24 tonnes/day by the year 2000. This quantity of nitrogen oxides is about the same as that expected in emissions from liquid fuel combustion (Table 2.3-3). Once engineering plans have been formulated, dispersion modelling of major emission sources can be conducted if necessary.

2.3.4.5 Fuel Tanks

Evaporation of volatile light-ends from liquid fuel storage tanks may release an estimated 50 tonnes of hydrocarbons per year by the year 2000. These volatile hydrocarbons would be rapidly dispersed in the atmosphere surrounding storage sites, and would not pose a safety hazard or have adverse impacts on local biological resources.

2.3.4.6 Ice Fog

Ice fog can form when exhausts containing large quantities of water vapour are emitted where air temperatures are less than -30°C. Ice fog will then persist when there are temperature inversions and periods of calm. Under these conditions, there will be a reduction of visibility at ground level which could affect air traffic.

Meteorological data required to identify conditions during which ice fog may accumulate include frequency and duration of periods with sustained temperatures less than -30°C (Table 2.3-5), occurrence of calm wind conditions and mean maximum afternoon mixing heights (Table 2.3-6) and frequency of temperature inversions (see Table 2.1-2, Volume 3A). Although not all these data are available for various parts of the Beaufort development zone, some general statements can be made regarding the frequency of ice fog formation.

Ice fog is most likely to form from December to March when temperatures less than -30°C are most frequent (Table 2.3-5). Also, ice fog is more likely to accumulate at inland locations rather than along the coast where calm conditions are less frequent (Table 2.3-6). In general, mixing heights tend to be low in the Arctic, and are at a minimum from December through February at Inuvik (Table 2.3-6). This is also when there are frequent temperature inversions which would favour the accumulation of ice fog. As new bases are developed, detailed analysis of emission characteristics and integration with climate data can be carried out to accurately predict the frequency and duration of ice fog at specific sites if necessary.

2.3.4.7 Odours

Odours may persist locally throughout the year from the evaporation of chemicals or hydrocarbons, combustion of fuels or wastes and camp cooking exhausts.

TABLE 2.3-4

EMISSIONS FROM THE COMBUSTION OF 5.8 × 10^6 KG/YEAR OF SOLID WASTE

Pollutants	Emission Factors* (percent wt. of combustible waste)	Approximate Emissions (tonnes/day)
Particulates	0.62	99
Sulphur Oxides	0.12	19
Nitrogen Oxides	0.22	35
Hydrocarbons	0.12	19
Carbon Monoxide	1.49	237

*Source: Belyea et al. (1966); Environment Canada (1978); Work and Warner (1981)

TABLE 2.3-5

NUMBER OF OCCURRENCES OF AIR TEMPERATURES LESS THAN -30° C WITH VARIOUS DURATIONS IN DAYS

	November			December			January			February			March			April			Max*
Duration (days)	**1-6**	**7-12**	**>12**	**1-6**	**7-12**	**>12**	**1-6**	**7-12**	**>12**	**1-6**	**7-12**	**>12**	**1-6**	**7-12**	**>12**	**1-6**	**7-12**	**>12**	**(days)**
Sachs Harbour (1955-1970)	9	0	0	30	2	2	35	5	2	36	4	2	38	4	0	4	0	0	20
Cape Parry (1957-1970)	3	0	0	17	0	2	32	4	2	28	3	2	31	1	1	0	0	0	17
Tuktoyaktuk (1957-1970)	14	0	0	23	2	1	34	5	2	24	6	0	21	2	0	0	0	0	20
Shingle Point (1957-1967)	3	0	0	10	1	0	16	0	0	8	1	0	8	0	0	1	0	0	12
Aklavik (1926-1962)	28	0	0	77	7	0	76	9	2	61	4	0	13	0	0	0	0	0	16

*Longest duration (days) with temperatures below -30° C.

Source: *Environment Canada (1975)*

TABLE 2.3-6

FREQUENCY OF CALM WIND CONDITIONS AND MEAN MAXIMUM AFTERNOON MIXING HEIGHTS AT INUVIK AND CAPE PARRY

	December	January	February	March
Frequency of Calm* (%)				
Inuvik (1960-1972)	29	29	27	16
Cape Parry (1959-1972)	10	11	14	8
Mean Mixing Heights** (m above surface)				
Inuvik (1965-1969)	159	119	162	288

*Source: Environment Canada (1975)
**Source: Portelli (1976)

However, odours will only be noticed near their sources so that long-term changes in regional ambient air quality are unlikely. A possible effect of odours is the attraction of wildlife, particularly polar bears and Arctic foxes. This effect is discussed elsewhere in the chapter in relation to airborne noise (Section 2.3.5), human presence (Section 2.3.1), and artificial illumination (Section 2.3.7).

2.3.4.8 Summary of Possible Impacts of Atmospheric Emissions

Proposed hydrocarbon development in the Beaufort region will result in various facilities and processes emitting a variety of gaseous and particulate emissions. Offshore sources will generally be widely separated geographically and the wind climate over the Beaufort Sea will rapidly disperse most emissions. Any effects will likely be SHORT-TERM and LOCAL.

Two primary concerns related to atmospheric emissions are: visibility limitations due to ice fog formation; and possible cumulative effects of multiple emissions, for example from production platforms, tanker loading terminals and shorebases. The ice fog potential and possible cumulative effects of emissions can be determined for the largest emission sources when emission levels become available to ensure compliance with ambient air quality guidelines.

The EARP guidelines identified concerns related to the possible effects of construction and operation activities on long-term climatic change, and the possible effects of particulate air emissions on snow and ice melt characteristics. Based on the foregoing assessment, neither effect would be expected to occur. However, monitoring programs can be initiated as deemed appropriate in order to assess these and other possible concerns related to atmospheric emissions.

2.3.5 AIRBORNE NOISE

Airborne noise will be produced during most offshore and onshore exploration, construction and production activities. Offshore, the major mobile sources of airborne noise will be aircraft, ships and on-ice vehicular traffic. The main stationary sources of airborne noise will be artificial island construction and operation activities, dredges and drillrigs. This section describes the possible impacts of airborne noise on the marine resources of the Beaufort Sea. (The possible impacts of airborne noise from harbours, shorebases and onshore oil and gas production in the Beaufort Sea coastal zone are described in Chapter 3.)

2.3.5.1 Air Traffic

As development proceeds, the volume of offshore air traffic will increase. Table 3.2-1 in Chapter 3 summarizes the estimated number of aircraft which may be required in the Beaufort region during the next 20 years. Of these, helicopters and small STOL aircraft, such as Twin Otters, will be the most common forms of aircraft flying offshore.

Helicopters will be needed for transferring emergency supplies and personnel originating from Inuvik, Tuktoyaktuk, McKinley Bay, and possibly from a major shorebase on the Yukon coast, to offshore island construction sites, such as Tarsiut, Koakoak, Kopanoar, and Issungnak. By the year 2000, assuming the intermediate development rate (Dome Petroleum Limited, 1982a), five deep water production islands and seven shallow water production islands would need helicopter support. In addition to these facilities, helicopters will continue to support the exploration activities of exploration islands and floating drilling platforms. One to two exploration islands (in waters 10-30 metres deep) may be constructed every year and operate for two years each, while the four conventional drillships and up to five extended season drilling vessels (round drillships and conical drilling units) may be operating by 2000.

STOL aircraft would transport personnel between the shorebases, and if an overland pipeline is constructed, between the pipeline terminal facilities (probably at North Point on Richard's Island) and the Administrative Centre in Inuvik. They would also continue to be used for offshore ice reconnaissance missions.

It is estimated that by 1986, personnel movements could require approximately 15 return flights per day from shorebases by Sikorski S-61 helicopters and 10 to 15 flights per day by STOL aircraft. In addition, there would be regular supply and ice reconnaissance flights as well as numerous unscheduled flights. For example, Boothroyd and Karasiuk (1981) described the frequency of flights associated with "break-out" from McKinley Bay and dredging of its mooring basin in 1980. There were 430 helicopter flights to or from McKinley Bay or between locations within the bay between June 8 and July 2, 279 helicopter flights in July and 132 in August.

Passengers, food and emergency supplies are currently delivered on a regular basis to Tuktoyaktuk by Boeing 737 jet and by Electra turboprop aircraft. On occasion, Lockheed C130's are chartered to deliver supplies to both Tuktoyaktuk and, in the spring, to a sea ice landing strip in McKinley Bay. Later (Table 3.2-1), larger cargo jets such as Boeing 767's could be employed 7 days per week between major shorebases and southern supply points. Numerous flights by executive jets are also expected. All these aircraft will normally fly at high altitudes except when landing and during take-off. Therefore coastal and offshore disturbances to birds and mammals would occur only in the vicinity of the airports.

All development-related aircraft operating in the Beaufort region will comply with altitude (greater than 305 m asl) and corridor guidelines whenever possible. Such guidelines are presently in use and new ones are readily implemented in response to problems as they arise. For example, in 1981 as a result of concerns expressed by whale hunters in the Hendrickson Island area in Kugmallit Bay, minimum aircraft flight altitudes over this area were increased from 305 m to 450 m. If this altitude was not feasible because of weather, aircraft followed a route that went around the area of concern. Due to limited visibility conditions common in the Beaufort Sea during summer and early fall (Volume 3A), helicopters and STOL aircraft operating under visual flight regulations (VFR) would likely fly at relatively low altitudes for slightly less than 30% of the time. Flying under these conditions is legal, safe, and a standard procedure, although flights at these lower altitudes may increase the possibility of noise-related impacts. Exclusion of aircraft from flying over certain sensitive areas and the restriction of aircraft to some flight corridors may be required to reduce or eliminate possible impacts.

A review of the possible effects of airborne noise from aircraft on marine mammals and birds in the Beaufort region is provided in ESL (1982). This review of information available from both Arctic and temperate latitudes indicates that the effects of aircraft noise will depend on a number of factors including species and life cycle stage, altitude of aircraft, frequency and route of flights, as well as the type of aircraft and time of year. In general, birds are more vulnerable to disturbance from aircraft than are marine mammals. The following describes the possible impacts of aircraft noise on regional populations of marine mammals and birds in the Beaufort Sea and along its shores.

(a) Impacts on Marine Mammals

Marine or marine-associated mammals which may be affected by airborne noise from aircraft operating in the Beaufort region are those species that occur on the sea ice during certain periods of their life cycle, including ringed seals, bearded seals, polar bears and Arctic foxes. In general, the degree of possible impact of air traffic associated with development on these species is expected to vary from NEGLIGIBLE to MINOR with the application of appropriate mitigative measures.

Ringed and bearded seals may be susceptible to aircraft noise during the breeding period, and when they are hauled-out on the sea ice. Primary pupping habitat for ringed seals is in the large bays of Amundsen Gulf and off the west coast of Banks Island (Volume 3A: Section 3.2). Pups are born during late March or early April in subnivean lairs on the landfast ice (Smith and Stirling, 1975), and remain in their lairs for 6 to 8 weeks (McLaren, 1958; Smith, 1973). Bearded seal pups are born on moving pack ice during late April or early May, and lactation lasts for 12 to 18 days (Burns and Frost, 1979). Aircraft overflights may disturb breeding seals, particularly ringed seals due to the longer lactation period, by causing the tending females to temporarily leave their pups. The possibility of such a response by ringed seals may be very low, as the audibility of aircraft to seals in snow-covered subnivean lairs would likely be low, particularly when wind and moving snow will tend to obscure aircraft sounds. Nevertheless, the numbers of seals which may be affected would be small compared to the total regional populations. This is because primary pupping habitat for ringed seals does not occur in the proposed offshore production zone, and because bearded seal pups are widely distributed, precocious at birth and not tended by the female for an extended period. The impact of this disturbance on the regional seal populations is expected to be NEGLIGIBLE to MINOR.

Ringed seals in the Canadian Beaufort haul-out in largest numbers for 2 to 3 weeks in June on the landfast ice near Cape Parry, along the southwest and west coasts of Banks Island, and off the Tuktoyaktuk Peninsula and Yukon coast (Stirling *et al.*, 1981a). Bearded seals prefer to haul-out on transition zone ice, and most are found off the east coast of Cape Parry and off the Tuktoyaktuk Peninsula (Stirling *et al.*, 1981a). Frequent overflights may cause hauled-out seals to dive, since this behaviour has been observed in both species when survey aircraft were flying at an altitude of 100 m (W.G. Alliston, pers. comm.). The diving response was more pronounced during helicopter flights (Hughes 500D). During five years of aerial surveys in Cessna 337's flying at an altitude of 152 m (91 m in fog) and an air speed of 220 km/hr, Stirling *et al.* (1981a) found that a small proportion of the hauled-out seals always dove when the aircraft was overhead. The percentage of seals that dive has not been quantified, but appears to be dependent on air speed, flight altitude and type of aircraft (I. Stirling, pers.comm.).

The possible effects of repeated immersions in response to aircraft are not known, although much of the haul-out behavior of seals is apparently related to thermoregulatory adjustments (McLaren, 1958; Smith, 1973; Finley, 1979), and repeated diving may induce temporary thermoregulatory stress. However, it is also possible that the hauled-out seals will become habituated to frequent aircraft overflights.

In view of the origin and destination of helicopters and STOL aircraft operating offshore in the Beaufort Sea (Figure 2.3-1), a small proportion of the seals hauled-out on ice may dive in response to STOL aircraft and helicopter overflights during 2 to 3 weeks in June. Seals would probably not dive when aircraft altitudes are maintained above 450 m (1,500 ft) (I. Stirling, pers.comm.) Flights at 305 m (1,000 ft.) and lower are expected to cause some seals to dive, probably well before the aircraft is overhead, however the impact of this reponse on the regional seal populations is expected to be NEGLIGIBLE to MINOR.

Polar bears and Arctic foxes foraging on the sea ice during winter and spring may also be disturbed near airstrips and by low-flying aircraft operating between the shorebases and offshore platforms. Polar bears overflown by survey aircraft at altitudes of 100 m usually retreat, but will occasionally react aggressively (W.G. Alliston, pers. comm.). Stirling (pers. comm.) reports that most bears would look up at a Cessna 337 flying overhead at an altitude of 152 m, but suggests that they would probably not react to STOL or helicopter flights at the guideline altitude of 305 m. Arctic foxes may also retreat from aircraft flying below 100 m altitude, but would probably not be disturbed by aircraft at altitudes of 305 m or greater.

Adherence to altitude guidelines of greater than 305 m (1,000 ft.) will eliminate or substantially reduce the effects of aircraft overflights on polar bears and Arctic foxes, while non-adherence to guideline altitudes on occasions may cause short-term aggressive or fleeing responses. Based on these observations, routine aircraft operations offshore in the Beaufort Sea are likely to have a NEGLIGIBLE impact on the regional polar bear and Arctic fox populations.

(b) Impacts on Birds

Disturbance of birds by helicopters and STOL aircraft is of some concern in view of the increasing use of these craft in the future to support Beaufort development, and the susceptibility of some species to

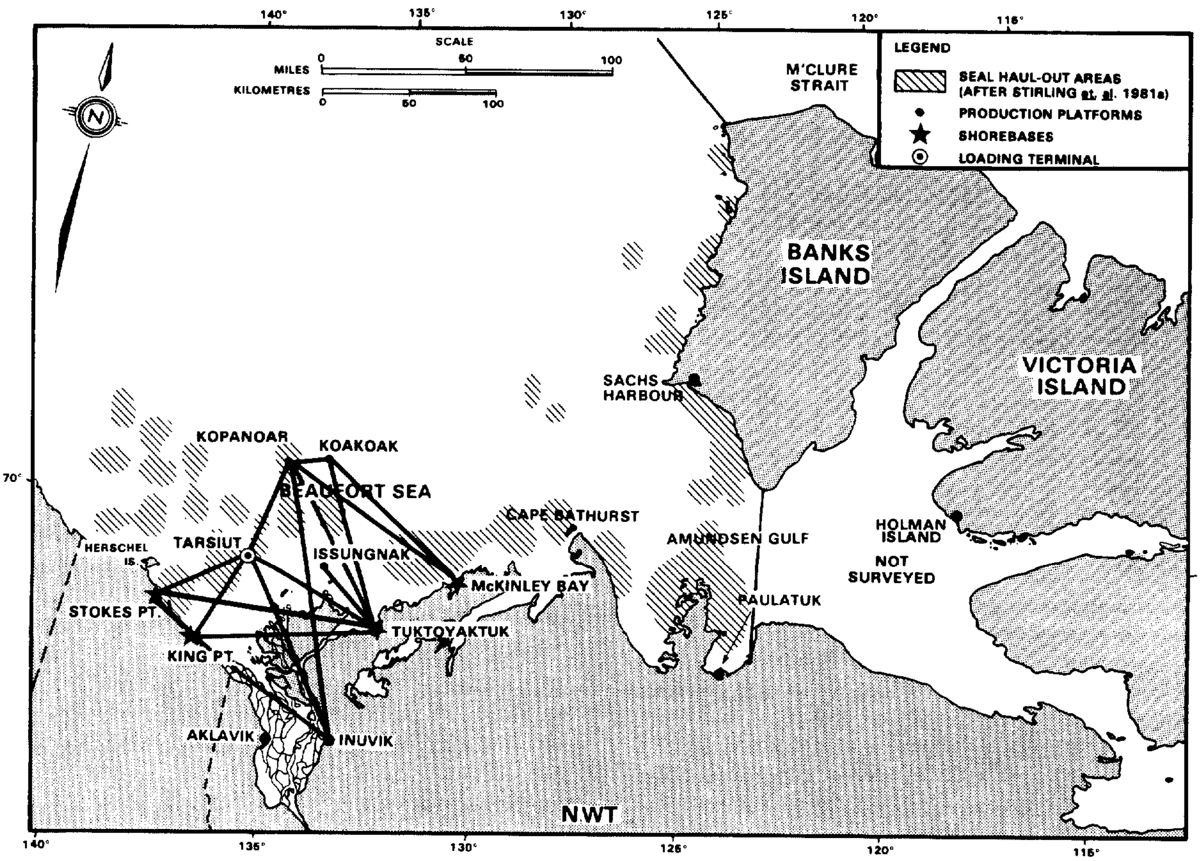


FIGURE 2.3-1 *Distribution of hauled-out ringed seals (1974-1979) in relation to location of helicopter origins and destinations.*

noise (ESL, 1982). Helicopters and STOL aircraft operating under visual flight regulations (VFR) may have to fly at low altitudes fairly frequently (estimated at approximately 30% of the time) during summer and early autumn due to visibility restrictions. Airborne noise produced by large passenger and executive jets is of lesser concern because these aircraft cruise at high altitudes except during landing and take-off, and disturbance would be confined mainly to the area surrounding airstrips (see Volume 2, Chapter 5).

In recognition of the important areas for birds outlined in Section 4.3 of Volume 3A, as well as the documented susceptibility of some species to aircraft disturbance, the proponents will comply with aircraft flight guidelines, weather and safety considerations permitting, to reduce or eliminate disturbances. Flight guidelines, which will be reviewed and refined in consultation with appropriate government agencies, will include the following:

- flight altitudes of at least 305 m agl (or asl as applicable) will be maintained in all areas when weather conditions permit;

- overflights of certain important concentration areas for birds will be avoided or be flown at altitudes of at least 600 m agl at specific times of the year (e.g. snow goose spring staging areas during May, nesting colonies during June and July.

The reactions of birds to aircraft varies with species, the stage of the annual life cycle, previous exposure to aircraft, type of aircraft, and the vertical and horizontal distance of the aircraft from the birds. The mechanisms by which disturbance in general may influence bird populations include: effective loss of habitat by exclusion of birds from areas where the disturbance is too great; increased energy expenditure which could lead to decreased productivity and possibly increased mortality of adults and young; and behavioural reactions that may increase mortality rates of young such as increased exposure to chilling, predation or injury, abandonment of nests by adults or a delay in the onset of nesting.

Species most likely to be affected by aircraft travelling between shorebases and offshore platforms are birds that nest at traditional nest sites, in colonies or gather in large concentrations while brood-rearing, staging or moulting in either offshore or coastal areas. These groups include several species of waterfowl and raptors, glaucous gulls, Arctic terns and thick-billed murres.

Spring Staging Birds: The biological significance of repeated disturbance of staging birds is subject to speculation. Geese, in particular, accumulate fat reserves while staging so that increased energy expenditures caused by disturbances could reduce the fat accumulated. This, in turn, could reduce their productivity in spring or fitness for fall migration. Repeated disturbance of pre-nesting birds could interfere with their copulatory behaviour, cause loss of energy reserves and possibly decrease their productivity.

Concentrations of spring staging snow geese can occur in the Kittigazuit Bay area (up to 75,000; T.W. Barry, pers. comm. cited in CWS, 1972), 80 to 100 km inland along the Anderson River (65,000; Barry, 1967), and at the base of the Parry Peninsula in Darnley Bay (LGL and ESL, 1982). Birds most likely to be disturbed by Beaufort region development are those that stage in the Kittigazuit Bay area, except that in 1981 and 1982 few snow geese staged in this area as the result of a naturally caused eastward shift of spring staging birds to the Kugaluk-Anderson River areas (T. Barry, pers. comm.). In addition to snow geese, up to 20,000 white-fronted geese may also stage in the same general area of Kittigazuit Bay (CWS, 1972). Implementation of mitigative measures described earlier is expected to result in a NEGLIGIBLE to MINOR impact on both snow geese and white-fronted geese during the spring staging period.

Glaucous gulls, common eiders, king eiders and oldsquaws are species that frequently stage in greatest numbers during spring in leads and along the edge of the landfast ice. Yellow-billed, red-throated and Arctic loons are also present in these habitats, as well as in river leads and cracks in the ice along shorelines. The main aircraft disturbance to these birds would be from helicopters supporting offshore development and fixed-wing aircraft conducting ice reconnaissance surveys. A large proportion of these birds would probably be transients en route to nesting areas to the north and east. The remainder would likely be birds that nest in the Mackenzie Delta-Tuktoyaktuk Peninsula area. The latter group is likely to remain in staging habitats longer than transients and could therefore be exposed to more aircraft activity. In general, the largest concentrations of sea ducks occur to the east of the development area, and loons and gulls tend to be widely distributed. Hence with the altitude guidelines, the possible impacts of aircraft noise disturbance on spring staging sea ducks, loons and gulls, including local populations that nest in the Mackenzie Delta-Tuktoyaktuk Peninsula area are expected to be NEGLIGIBLE.

Nesting Birds: The effects of aircraft on nesting birds will vary with species. Many tundra nesting species are widely dispersed and are not particularly susceptible to aircraft overflights at altitudes greater than 305 m. Also, a large proportion of some waterfowl, shorebirds, loons and jaegers are widely dispersed and occupy coastal and backshore areas that are less susceptible to aircraft disturbance from offshore flights. Consequently, possible impacts on these populations are expected to be NEGLIGIBLE. On the other hand, species that nest in high densities in relatively confined areas, and/or are known to react adversely to aircraft overflights, may be more seriously affected. Possible effects on this group, which includes two species of geese and several species of raptors are assessed. Possible impacts on whistling swans, glaucous gulls, Arctic terns and Sabine's gulls during the nesting period are also assessed.

Geese in the Beaufort region that nest colonially and are considered to be particularly susceptible to aircraft noise disturbance include brant and snow geese. Most snow geese in the region nest on western Banks Island (99,000 pairs), while relatively small colonies exist at Kendall Island (500 pairs) and on the Anderson River delta (4,200 pairs; R. Kerbes, pers.comm.) The Kendall Island colony may be most susceptible to development-related aircraft disturbance due to its location. Periodic low altitude overflights could reduce the productivity of this colony, or if disturbances become intense and mitigative measures are not implemented, the colony could be abandoned. Gavin (1980, cited in Welling *et al.*, 1981) suggested that helicopter overflights were responsible for the abandonment of a snow goose colony in northern Alaska, although the birds returned to the colony during the following year when there was no disturbance. However, the mitigative measures described earlier will be implemented, and the possible impact on the regional populations should not exceed MINOR.

In the Beaufort region, most brant nest along the Alaskan North Slope (17,000 birds; Bellrose, 1976) and on western Banks Island (10,000 birds; CWS, 1972). Although these birds would not be subject to frequent aircraft disturbance, about 4,000 brant that nest in coastal areas between Demarcation Bay and Darnley Bay could be subjected to aircraft noise. Approximately half of these birds (2,000; CWS, 1972) breed in the vicinity of the Anderson River Delta, while smaller colonies occur near Paulatuk (500 birds), at the mouth of the Kugaluk River (400 birds), near Atkinson Point (500 birds), on small islands (500 birds) and at Denis Lagoon in the outer Mackenzie Delta (CWS, 1972; Slaney, 1974a). In view of the origin and destination of most offshore helicopter and STOL aircraft overflights, brant nesting at colonies in the Anderson River delta, Kugaluk River and near Paulatuk will not be exposed to frequent aircraft overflights. Brant nesting at Atkinson Point, the

Mackenzie Delta, and elsewhere along the coast adjacent to the production zone may be exposed to aircraft flights during adverse weather when VFR aircraft cannot adhere to regulatory flight altitudes. Although the reactions of nesting and brood-rearing brant to repeated aircraft noise disturbance have not been documented, they may react similarly to snow geese. Implementation of mitigative measures such as those described earlier, is expected to result in an impact from aircraft noise on the regional population of between NEGLIGIBLE and MINOR.

The white-fronted goose is the most abundant species of goose nesting on the mainland coast of the Beaufort Sea (King, 1970; Bellrose, 1976). Post-nesting population estimates of 90,000 birds, or about one third of the North American population, may summer in the Beaufort region. Of these, roughly 50,000 occur on the North Slope of Alaska (King, 1970) and are unlikely to be affected by logistics aircraft traffic in the Canadian Beaufort. Although white-fronted geese do not nest colonially, relatively large numbers of nesting, brood-rearing, and moulting birds occur in favoured coastal habitats. Of the estimated 40,000 (post-nesting) white-fronted geese that occur from Demarcation Bay to Darnley Bay, about 25,000 to 30,000 are concentrated in the Kugaluk - Anderson River areas (Barry, pers. comm., cited in Bellrose, 1976). However, most aircraft flights would link shorebases with offshore platforms (Figure 2.3-1), and would therefore not fly over the Kugaluk-Anderson River area. Consequently, the possible impact on the regional population of white-fronted geese is expected to be NEGLIGIBLE.

About one third (30,000 birds) of the world population of whistling swans nest in Canada, of which two thirds (20,000) summer between the Mackenzie Delta and the Anderson River (Bellrose, 1976). Although swans do not nest colonially, repeated noise from air traffic over areas with high densities of nesting birds could affect the regional population. Overt reactions of nesting and brood-rearing whistling swans to aircraft disturbance do not appear to be as marked as those of geese. Consequently, the aircraft altitude and routing guidelines described earlier are expected to result in a possible impact from aircraft noise of between NEGLIGIBLE and MINOR.

Glaucous gulls, Sabine's gulls and Arctic terns nest singly and in small colonies at numerous inland locations and along the Beaufort Sea coast (Salter *et al.*, 1980; Barry *et al.*, 1981). Repeated low altitude aircraft overflights of nesting colonies could result in decreased productivity. However, with the altitude guidelines the impacts are expected to be NEGLIGIBLE.

Although they do not generally nest on the outer coast, raptors could be subjected to noise from aircraft flying between shorebases. Pre-nesting and nesting raptors are known to be sensitive to disturbance from low-flying aircraft.

Species most likely to be affected by aircraft noise are the peregrine falcon, gyrfalcon and golden eagle, some of which occur near areas which may be subjected to development-related aircraft noise. These species nest on cliffs or along river cutbanks. Nests typically exist in the British and Richardson mountains, in cutbanks along rivers of the Yukon North Slope, in cutbanks of rivers east of the Tuktoyaktuk Peninsula, particularly the Anderson, Horton and Hornaday rivers, and in the Campbell Hills near Inuvik. Of these raptor species, most concern is for the peregrine falcon (*Falco peregrinus*), in particular the subspecies *F. p. tundrius*, which is considered "threatened" and nests in most of these areas. The subspecies *F. p. anatum* is considered "endangered" and nests in the Campbell Hills (Volume 3A). The rough-legged hawk is also a common nesting raptor on cliffs of the areas identified, while tree-nesting raptors, including the bald eagle and osprey, are found in very small numbers in riparian habitats south of the treeline. Nest sites of all these species tend to be traditional, and some may be used for many generations. Consequently, repeated disturbance by low-flying aircraft could result in abandonment of nest sites or decreased productivity of young in each of these species. However, the reactions of nesting pairs to airborne noise varies, and some raptors, including peregrine falcons, have been known to habituate to repeated over-flights.

The greatest concentration of nesting raptors within the coastal area likely to be overflown by air traffic, occurs along the North Slope of the Yukon and the Northwest Territories and in the adjacent British and Richardson mountains. Air traffic to and from a Yukon coastal shorebase could affect raptors in this general region. The possible impacts, mitigative measures to be adopted, and residual impacts of all sources of disturbance associated with possible Yukon coast developments on nesting raptors are reviewed in Chapter 3, and are discussed in detail in LGL (1982). Airborne noise from expected aircraft logistics traffic over raptor nesting areas in the region west of the Tuktoyaktuk Peninsula should not result in impacts on regional populations greater than NEGLIGIBLE or MINOR. Nevertheless, to ensure that raptors, particularly peregrine falcons, are not adversely affected by development-related activity including aircraft, potential raptor nesting sites will be identified beforehand, and aircraft flights restricted accordingly (Volume 7, Chapter 3).

Moulting and Brood-rearing Birds: Geese and swans moult during the brood-rearing period on or near their nesting areas, while non-nesting or unsuccessful nesters may congregate in large numbers in traditional moulting areas away from nesting habitats.

Repeated aircraft noise could place an energetic stress on moulting non-breeding waterfowl and, in extreme cases, lead to abandonment of traditional moulting areas. With the aircraft altitude and route guidelines, the potential impacts of aircraft noise on all geese and swans during the moulting period should range between NEGLIGIBLE and MINOR.

Moulting areas are generally coastal, and several exist along the Canadian Beaufort Sea coast between Shallow Bay and Franklin Bay, where birds may be affected by aircraft noise (LGL and ESL, 1982). For example, a few hundred to 1,000 whistling swans have been recorded at several coastal locations, while concentrations of 1,000 to 4,000 moulting white-fronted geese have been observed in coastal areas between the Anderson and Kugaluk rivers. Concentrations of moulting Canada geese have been observed in several areas, although large numbers (25,000) have only been recorded at the Kugaluk and Smoke river deltas (Barry, pers. comm., cited in Sterling and Dzubin, 1967). McKinley Bay, an area affected by aircraft noise, is where substantial numbers (700) of moulting, non-breeding brant have been observed (CWS, 1972).

Moulting sea ducks have not been found to abandon marine areas disturbed by aircraft (Gollop *et al.*, 1974a). Observations in McKinley Bay suggest that areas subjected to an average of two to six overflights per day from late July through August, 1980, continued to be used by moulting ducks (mostly oldsquaws and scoters; Ward, 1981). In 1981, large numbers of ducks again used McKinley Bay despite considerable helicopter activity in the area (Scott-Brown and Allen, 1981). Moulting and non-breeding ducks (primarily scaup), have been observed to abandon small lakes after repeated disturbance by landing float planes (Salter and Davis, 1974). Although certain areas are consistently used by moulting ducks each year, (Volume 3A, Section 4.3), numbers of birds using them varies from year to year. Based on these observations and experience to date, the potential impacts of aircraft noise produced by logistics air traffic on regional populations of sea ducks during the moulting period are not expected to exceed MINOR.

Autumn Staging Geese: From mid August through late September, large numbers of geese stage in some areas where there may be repeated logistics overflights. For example, during this period most of the entire western Canadian populations of snow geese, numbering 200,000 to 500,000 birds, move from their nesting, brood-rearing and moulting areas to staging areas, where they feed and accumulate fat reserves in preparation for autumn migration. Young-of-the-year complete their summer's growth at these staging areas. Snow geese may remain in these areas until late September, during which time they are sensitive to disturbance by aircraft (ESL, 1982). Aircraft noise may interrupt their feeding and cause the birds to use energy when they flush. Repeated disturbance could possibly cause them to abandon an area, resulting in a loss of staging habitat.

The primary staging areas for snow geese include the Yukon and eastern Alaskan North Slope and to a lesser extent, the Mackenzie Delta. Adults with young tend to remain in the Yukon, while birds that do not nest or are unsuccessful nesters may fly farther west into Alaska (Koski and Gollop, 1974). However, in some years when an early freeze-up precludes staging on the North Slope, the snow geese remain in the Mackenzie Delta area (Koski, 1977a, b). White-fronted geese from the Alaskan and Canadian Beaufort populations stage on the Mackenzie Delta between mid August and late September. By early September, between 20,000 and 25,000 white-fronted geese may be on the outer Mackenzie Delta (Volume 3A). In most recent years, the North Slope of the Yukon and Northwest Territories is used by relatively few white-fronted geese, although Koski (1977b) estimated that 18,000 white-fronted geese were present in upland areas on the North Slope in 1976. With appropriate altitude and corridor guidelines developed in consultation with government agencies, the degree of impact for both of these species is expected to be MINOR.

2.3.5.2 Other Mobile Noise Sources

Mobile sources of airborne noise other than aircraft include ships, dredges and on-ice vehicular traffic. The general specifications, function and numbers of marine vessels which may be required for operations in the Beaufort Sea region are described in Volume 2, Chapter 5. In addition, a number of vehicles may travel on winter roads over landfast ice between shorebases. Vehicular traffic will use a winter road over the landfast ice between McKinley Bay and Tuktoyaktuk, and the winter road between Inuvik and Tuktoyaktuk. Traffic may also occur on an all-weather road which is proposed to link a possible Yukon coastal shorebase, such as King Point, to the Dempster Highway at Fort McPherson, and on an all-weather road proposed between this shorebase and a rock quarry at Mount Sedgewick. The impacts of winter and all-weather roads on terrestrial biota are discussed in Chapter 3.

(a) Impacts on Marine Mammals

Ringed seals, bearded seals, polar bears and Arctic foxes may only be susceptible to these other sources of airborne noise when they are on the landfast or transition zone ice within the development area. The possible regional impacts of airborne noise on all marine or marine-associated mammals in the Beaufort region are likely to be NEGLIGIBLE.

Ringed and bearded seals may be affected by mobile sources of airborne noise during the breeding season or during the annual moulting period when they are hauled-out on the sea ice. However, airborne noise produced by icebreakers operating in the landfast ice zone is not expected to disturb breeding seals or cause hauled-out ringed seals to dive repeatedly or in large numbers, because most icebreaking during spring would be confined to two or three 100 to 150 m wide channels extending from McKinley Bay and possibly from a Yukon shorebase to the transition zone (Section 2.4.4 and 3.5.2). The disturbance would be local, and only a small proportion of the regional seal population could be affected in landfast ice areas.

Airborne noise from mobile dredges is not expected to significantly affect the ringed seal population because the dredges will operate mainly in the transition ice zone where breeding or hauled-out ringed seals are less common. Breeding and hauled-out bearded seals in the transition zone may respond to the noise by diving. However, the numbers affected would be small because the species is widely distributed, and icebreaking and dredging would be limited to offshore platforms, dredge borrow sites and routes between sites in the development zone.

Ringed and bearded seals may also be disturbed by airborne noise from vehicular traffic on the landfast ice, although effects would be local and are expected to be inconsequential.

Although polar bears are frequently observed in the transition zone off the Mackenzie Delta and Tuktoyaktuk Peninsula (Stirling *et al.*, 1981b), the largest proportion of the regional population occurs in Amundsen Gulf and off the west coast of Banks Island. Arctic foxes from coastal populations are believed to be widely distributed on the fast ice during winter and spring. In general, airborne noise produced by dredges and icebreakers operating in the transition zone may affect polar bears, while airborne noise from icebreakers and on-ice vehicular traffic in landfast ice areas could affect Arctic foxes. The physical presence of a vessel and its characteristic airborne noise may cause a fright-flight response in both species, or cause an aggressive reaction by polar bears (ESL, 1982). However, these disturbances would be temporary and short-term, and the number of individuals affected would be a small proportion of the regional population.

(b) Impacts on Birds

Unlike airborne noise produced by aircraft, noise from on-ice vehicles, dredges and vessels is expected to have NEGLIGIBLE impacts on birds in the Beaufort Sea region. Few or no birds would be present when vehicles would be travelling on winter ice roads, but limited disturbance may be caused by icebreakers, dredges and other vessels to some marine species during their spring migration. Ducks and loons particularly, rely on open water where they rest and feed during migration. Icebreaking vessels that take advantage of thin ice and open water areas could disturb these migrants staging in the leads during spring. Icebreaker tracks generally remain filled with broken ice, and therefore would not provide extensive open water habitat for these migrants. However, where small 'polynyas,' usable by loons and ducks, are created by icebreaking, perhaps in late spring, there may be beneficial primary and secondary production.

The few other species of birds that forage in offshore areas during the summer are widely distributed and are unlikely to be affected by noise produced by vessel traffic or operating dredges. Moulting ducks in coastal areas may be temporarily disturbed by vessels entering and leaving harbours. However, because this disturbance would be local and confined to specific travel corridors, the impacts are expected to be NEGLIGIBLE.

2.3.5.3 Stationary Sources of Airborne Noise

Industrial machinery will be the major source of stationary airborne noise during Beaufort region development. Noise from the construction and operation of offshore platforms will persist on a 24 hour basis throughout the year, while noise from stationary dredging operations may be continuous or intermittent. Gas flares will also generate noise, although the flare tips will be designed to minimize noise.

(a) Impacts on Marine Mammals

Noise from stationary offshore sources may affect the local distribution of polar bears, Arctic foxes, and breeding and hauled-out ringed and bearded seals during winter and spring. The effects of stationary airborne noise may, however, be indistinguishable from the collective effects of all activities including the physical presence of platforms. Airborne noise from stationary sources will be perceptible only in the vicinity of the sources to those species on the sea, on the ice or in the air. Beneath the sea-surface, airborne noise is coupled poorly so that any effects will again be local. Consequently the possible impacts of fixed sources of airborne noise on regional populations of all species of marine and marine-associated mammals are expected to be NEGLIGIBLE.

Stationary sources of airborne noise plus cookhouse odours, artificial illumination and human presence may alert and attract polar bears and Arctic foxes to the sources, or result in avoidance responses. Inuit are routinely employed in the Beaufort Sea as polar bear monitors to alert personnel to the presence of bears for safety reasons. From November 1, 1981 to April 1, 1982, there were 23 sightings of polar bears near the Tarsiut exploration island, although some observations may have been repeated sightings of the same individuals (J. Ward, pers. comm.). Assuming each sighting was a different bear, this represents about 1.3% of the regional polar bear population, which was estimated at 1,700 to 1,800 from 1972 to 1974 (Stirling, 1978). Preliminary results of a Northwest Territories study of polar bears and artificial islands indicate that bears were not more abundant around Tarsiut than in adjacent control areas (G. Stenhouse, pers. comm.) The policy of all proponent companies towards polar bears is that they only be destroyed as a last resort to protect human life. The polar bear monitoring programs carried out by the proponents serve as a first line alert measure.

During the winter of 1981-82, one polar bear had to be destroyed for safety reasons. In the future, as more islands are built, there could be more interactions between bears and man. However, with prudent mitigation measures in place, few polar bears should have to be destroyed and the number of animals involved would always be insignificant compared to the total regional population. Similarly, attraction of Arctic foxes by a combination of noise and other attractants is not expected to affect more than a few animals of the regional population.

Stationary sources of airborne noise may lead to a change in the local distribution of breeding and hauled-out ringed and bearded seals in the vicinity of structures in the offshore production zone. However, the effects would likely be local and the numbers affected small.

(b) Impacts on Birds

The effects of airborne noise from stationary sources on birds will be indistinguishable from the combined effects of noise, human presence, presence of machinery and artificial illumination. The only relevant information comes from experiments with gas compressor simulators and birds in terrestrial areas (see ESL, 1982). However, geese and swans do not stage offshore, and therefore would not be affected by stationary noise sources at drillships, and offshore islands. (The possible impacts of shorebases on marine resources of the Beaufort Sea region are assessed in Chapter 3.)

Marine birds that could be exposed to airborne noise from offshore sources are mainly loons, diving ducks and gulls. However, the effects of noise from these sources would likely be indistinguishable from effects of other activities at these sites, particularly movements of boats and aircraft.

2.3.5.4 Summary of Possible Impacts of Airborne Noise

The possible impacts of mobile and stationary sources of airborne noise on most marine mammals of the Beaufort Sea are expected to be NEGLIGIBLE in most instances when aircraft adhere to altitude and routing guidelines developed to minimize interactions with wildlife. An exception to this may occur if ringed and bearded seals repeatedly dove in response to frequent overflights during their 2 to 3 week haul-out period in June. Although the biological implications of this response remain unknown, the proportion of the regional population which may be affected in this manner should be small, and as a result, the possible degree of impact is expected to be MINOR. This impact could be reduced or eliminated by increasing flight altitudes to 458 m (1,500 ft) whenever possible during the haul-out period.

Stationary and mobile airborne sources, other than aircraft, are expected to have NEGLIGIBLE effects on birds. With appropriate mitigative measures to reduce the disturbance of birds by aircraft, possible impacts of airborne noise on all species are likely to range between NEGLIGIBLE and MINOR.

2.3.6 UNDERWATER NOISE

Industrial sources of underwater noise have the potential to affect marine fauna in the Beaufort Sea. These sources would include icebreaking tankers, icebreaking support vessels, ships, barges, tugs, aircraft, vehicles on ice, dredges, drilling activities, and oil and gas production and processing facilities. However, underwater noise would only disturb marine fauna if the animals can detect the noise produced. It can be assumed that no disturbance or masking effects would occur at distances where the noise attenuates to natural ambient noise levels. The distance at which industrial noise would be detected by a marine animal depends on several factors including: noise generating characteristics of the noise source; how these noises are attenuated between the noise source and the animal; the natural ambient noise level where the animal is located; and the hearing sensitivity of the animal. These factors will be discussed in the following sections and are described in more detail in ESL (1982). Information summarized in these sections is then used to estimate zones of influence within which noise may affect marine fauna. These zones form the basis for assessing the potential impacts of future industrial noise on marine mammals and fish in the Beaufort Sea.

In the following sections, underwater noise levels (pressures or intensities) are given in decibels (dB) with respect to a reference sound pressure of 1 micro-Pascal (1 uPa). Also, for broadband noise it is usual to reduce measurements to an equivalent 1 Hz band width in order to define spectrum levels and hence the shape of a noise spectrum. Thus noise spectrum levels are quoted in dB re (1 uPa)^2/Hz. For a single frequency underwater sound, such as a propeller blade-rate tone (a spectral line), its sound level is quoted in dB re (1 uPa)^2. A special case is where sounds are assumed to come from an equivalent point source. Where the distance from this point source is reduced to 1 m, the spectrum level is termed a source level. Its units are quoted in dB at 1 m re (1 uPa)^2/Hz.

2.3.6.1 Source Noise Levels

(a) Mobile Sources of Underwater Industrial Noise

The major mobile sources of industrial underwater noise currently in operation or proposed for use in the Beaufort Sea include icebreaking tankers, local marine logistics traffic, dredges and aircraft. The numbers of vessels which may be required during the proposed development, their seasonal use and estimated underwater sound source levels, where available, are summarized in Table 2.3-7. Table 2.3-8 lists the numbers of aircraft that are projected to be required, their seasonal use, and estimates, where available, of underwater noise spectrum levels measured when the aircraft flew over the hydrophone at various altitudes.

Class 10 icebreaking tankers proposed for the transport of oil to southern markets are projected to initially follow the eastern route shown in Figure 2.3-2, loading cargo in the Beaufort Sea possibly at Tarsiut as early as 1986 and later from other fields

TABLE 2.3-7

INDUSTRIAL SOURCES OF MOBILE UNDERWATER NOISE IN THE BEAUFORT SEA PRODUCTION ZONE

Source	Number Operating Existing	1990 a,b,c	2000 a,b,c	Season of Operation	Source Level dB at 1 m re (1uPa)^2/Hz
Class 10 Ice-Breaking Tanker	0	9,6,0	26,16,0	Year-round	Estimated Free Field** for APP carriers at 100Hz -165dB: half power in open water -172dB: full power in heavy ice (see Figure 4.4-1 for complete spectra).
Arctic dredges	0	2,1,0	4,1,1	Year-round	Not available
Conventional dredges	5	7,7,7	7,7,7	June-Nov	Not available
Ice-strengthened supply vessels	9	19,19,19	29,29,29	June-Nov	Canmar Supplier VIII; measured as 144 to 167 dB at 56 Hz Beaufort Sea (Fraker *et al.*, 1981)
Class 3 Icebreakers	1*	8,8,6	8,8,6	Year-round	158dB at 100 Hz under 16 inches of ice
Class 6 Icebreakers	0	13,10,7	13,10, 7	Year-round	Not available
Class 10 Icebreakers	0	1,1,0	3,2,0	Year-round	Not available
Tugs	5	28,18,14	22,21,17	June-Nov	Tug and barge; measured as 151 to 164 dB at 200 to 1150 Hz, Beaufort Sea (Ford, 1977)
Misc. work boats	10	22,22,18	25,23,22	June-Nov	Not available

* MV CANMAR KIGORIAK (Class 3)
a: Technically achievable development; Arctic tankers.
b: Intermediate development; Arctic tankers.
c: Intermediate development; overland pipeline.
** Free field source levels assume that the source is in an infinite unbounded water body.

TABLE 2.3-8					
Source	**Number Operating***			**Season of Operation**	**Underwater Sound Spectrum Level dB re (1uPa)^2/H2**
	Existing	**1990**	**2000**		
Helicopters	6	18	28	Year-round	Hughes type 369d at 30 m asl; 60 dB 500 Hz recorded under 1.2 m of ice near Barrow (Holliday *et al.*, 1980)
STOL aircraft	3	12	22	Year-round	Britten-Norman Islander -305 m asl, 94dB at 70Hz -458 m asl, 92.4dB at 70Hz (Fraker *et al.*, 1981)
Executive jets	2	8	13	Year-round	Not available
737 or 767 jets	1	5	5	Year-round	Not available

* Intermediate development (tanker or pipeline)

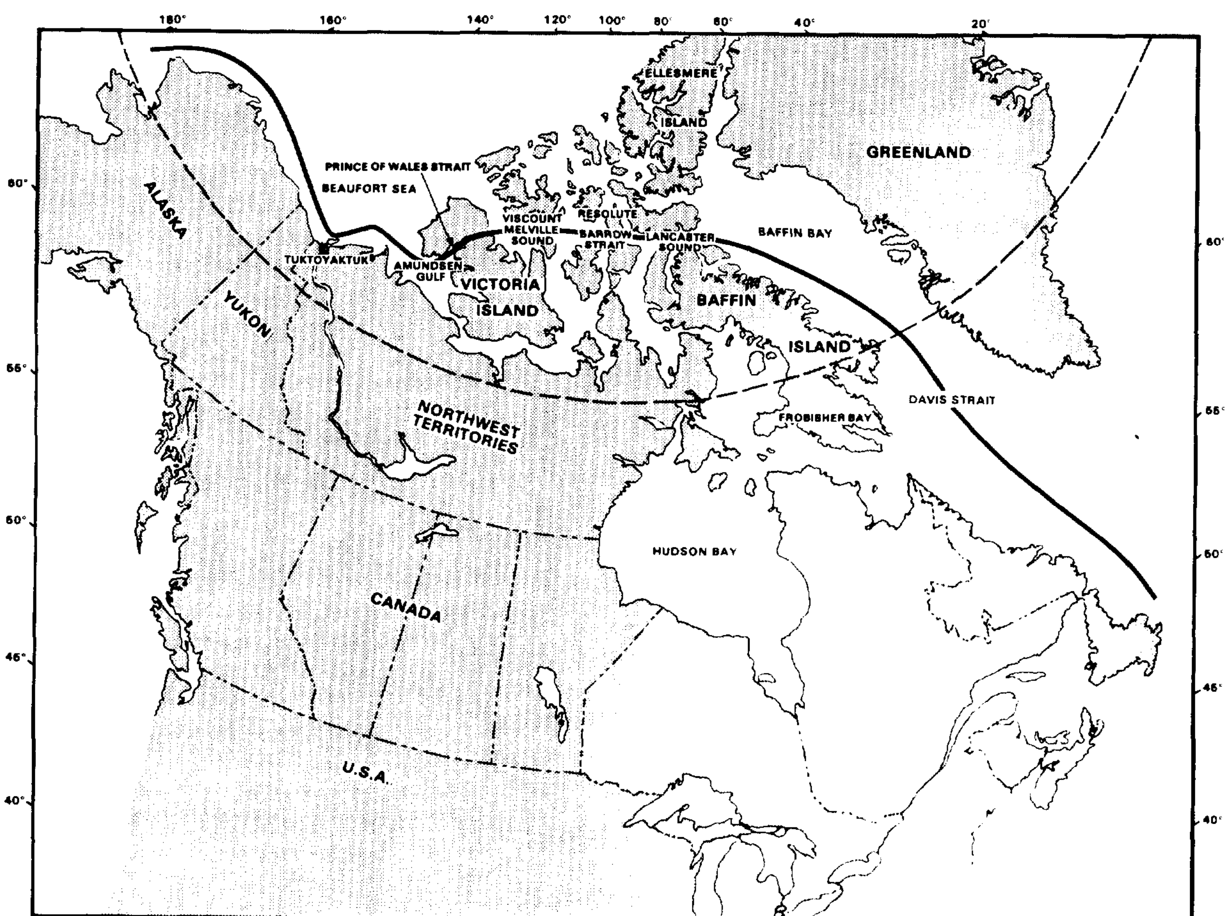


FIGURE 2.3-2 *Class 10 icebreaking tankers proposed for the transport of oil to southern markets are projected to initially follow an eastern route through the Northwest Passage. Many other ships such as freighters and tugs with barges will enter and leave the Beaufort area through the western route around Alaska.*

(Figure 2.3-3). Two sources of underwater noise produced by icebreaking tankers are the sounds of icebreaking, and noise from the vessel itself. Ship-radiated noise is generated by machinery and propellers, however, propeller noise caused by cavitation is expected to dominate the ship's source spectrum. Cavitation noise occurs when numerous small water cavities or bubbles, which form on the low pressure side of a propeller under power, collapse randomly.

Icebreaking tankers proposed for use in the Beaufort Sea have not yet been constructed, so measurements of underwater sound generated by the physical breaking of ice by this class of vessel are not available. However, noise from icebreaking will likely be insignificant in comparison to noise levels from propeller cavitation (APP, 1982).

Estimated underwater sound levels* produced by twin propeller Class 7 icebreaking APP carriers (75,000 SHP) are shown in Figure 4.4-1 of Chapter 4. These estimates will be used during the present assessment in the absence of estimates for Class 10 icebreaking tankers (APP, 1982). Both vessel types are of similar design and specifications (Volume 2, Section 6.3). At full power in open water or in ice, estimated noise levels of the LNG carriers are comparable to container ships and passenger ships at comparable speeds. At half power in open water, estimates are lower than for most merchant ships and comparable to those of a trawler (APP, 1982).

Figure 4.4-1 shows that the APP carriers are expected to have a free field source level of 172 dB at 100 Hz while travelling at a speed of 22 km/h under full power in heavy ice. The source level of the carriers is expected to be reduced to about 165 dB at 100 Hz while travelling at a speed of 31.5 km/h under half power in open water. At increasing frequencies to 10 kHz, source levels are expected to decline at 6 dB per octave.

* Free-field source levels, assume that sound pressures are measured 1 m from an equivalent point source of sound in an infinite waterbody. Effective source levels, used in estimating noise at a distance, must take account of the Lloyd mirror effect which considers the presence of the water surface boundary. This results in effective source levels being considerably less than free-field source levels at low frequencies.

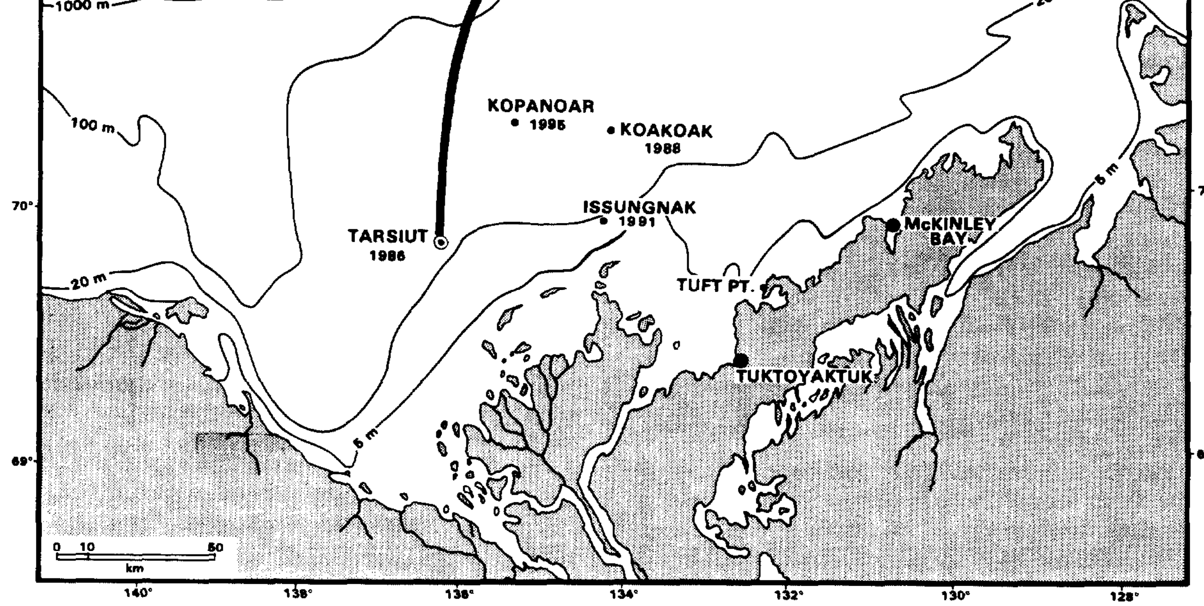


FIGURE 2.3-3 *Location of projected initial production platforms in the Beaufort Sea development zone.*

In addition to broadband cavitation noise, propellers generate intense single frequency blade-rate tones which are a function of propeller revolution rate and the number of blades. For the APP carriers, the fundamental blade-rate frequency in the full power icebreaking mode is expected to be 5.33 Hz, with progressively less intense higher harmonics. Although it is not yet possible to determine the sound levels for each harmonic or the number of harmonics which may occur, the expected maximum free field source level of the blade-rate tone for an APP carrier operating in heavy ice is 191 dB (see Chapter 4, Section 4.4), which reduces to an effective source level of 164 dB when the Lloyd mirror effect is taken into account.

Assumed locations of offshore producing platforms and a possible tanker loading facility in the development zone to 1990 are indicated on Figure 2.3-3. Marine vessels, including icebreakers and dredges are expected to operate along direct routes between offshore platform sites, shorebases and proposed dredge sites. From shorebases, excursions through the landfast ice would be confined to single corridors from McKinley Bay, Tuktoyaktuk and the Yukon coast to the transition ice zone (see Volume 3A). STOL aircraft and helicopters would transfer personnel and supplies between the shorebases and helicopters would support offshore platforms. As indicated in Section 2.3.5, aircraft will comply with altitude restrictions and corridor guidelines whenever possible to minimize possible disturbances to wildlife.

(b) Stationary Sources of Underwater Industrial Noise

The major stationary sources of underwater industrial noise currently in operation or proposed for use in the Beaufort Sea are summarized in Table 2.3-9 and discussed in ESL (1982). Noise levels from island drilling activities in the Canadian Beaufort have not been documented, although Malme and Mlawski (1979) describe some characteristics of underwater noise from drilling rigs on natural and artifical islands in the Prudhoe Bay area during an icebound period. Most recorded noise was at frequencies below 200 Hz, with tonal components predominating below 100 Hz. The broadband noise level was highest when the rotary table was turning. Diesel engines and other rotating machinery produced the tonal components. Source noise levels produced by major industrial operations in the Beaufort Sea will be the subject of future study (Volume 7, Section 3.3).

2.3.6.2 Sound Propagation

Numerous factors influence propagation loss of underwater sound. In the sea, sound is attenuated by spreading, absorption and scattering. The general principles of sound propagation in Arctic waters are discussed in more detail in ESL (1982). In the shallow Beaufort Sea, propagation loss due to spreading probably ranges between spherical spreading loss, at 6 dB per distance doubled, to cylindrical spreading loss, at 3 dB per distance doubled depending on distance and water depth (Fraker *et al.*, 1981). Losses of sound energy due to absorption are insignificant at low frequencies. Scattering losses in deep water are low at low frequencies, and depend on the roughness of the under-ice or water surface compared to the wave length of the sound waves. Propagation loss also varies with water depth, with losses being considerably greater in shallow water than in deep water for low frequencies. Transmission losses at low frequencies are especially marked in shallow areas over the continental shelf (less than 200 m deep) where sand or mud substrates tend to absorb sound energy (Leggat *et al.*, 1981). This is an important point since several species of marine mammals are concentrated in shallow coastal waters where sound at frequencies which might affect them would be rapidly attenuated.

Sound propagation in the Beaufort Sea varies with the seasons. Since lowest temperatures occur at the surface during periods of solid ice cover, a positive sound speed gradient (higher speeds at greater depths) and a resultant upward refraction of sound waves occurs in winter. In summer, sound velocity speed gradients become negative because solar heating and wave mixing form a surface layer with higher sound speeds (Fraker *et al.*, 1981). Bottom sediments can absorb sound waves when propagation paths include bottom reflections. This can occur with negative sound speed gradients in summer. In some cases, very low frequencies may propagate well within bottom sediments and can be detected in the water column at considerable distances from the source (Fraker *et al.*, 1981).

Rogers (1981) demonstrates the extreme difficultly in predicting propagation losses in shallow waters with a negative sound speed gradient since losses can depend on at least 24 factors including: water depth, sound speed profile, sediment characteristics, etc.. Figure 2.3-4 illustrates extremes in propagation loss which can occur with different bottom materials for water with a negative sound speed gradient. In all cases shown, propagation losses exceed those which would occur due to spherical spreading. Bottom sediments in the Beaufort Sea are largely of the "clayey-silt" category, thus propagation losses would be great. Figure 2.3-5 illustrates a case where extreme losses occur at 200 Hz in 25 m of water with isospeed properties. Propagation losses would be even greater in water with a negative sound speed gradient such as exists in the Beaufort Sea in summer (Rogers, 1981).

Greene (1981) measured sound transmission characteristics of the shallow, 50 m deep, Chukchi Sea during winter with 100% ice cover and during summer with about 50% ice cover. During the winter,

TABLE 2.3-9

STATIONARY SOURCES OF UNDERWATER SOUND IN THE BEAUFORT SEA PRODUCTION ZONE

Source	Number Operating Existing	1990 a,b,c	2000 a,b,c	Season of Operation	Underwater Sound Spectrum Level dB re $(1uPa)^2/Hz$
Conventional drillship	4	4,4,4	4,4,4	June-Nov	Strongest tone was 97 dB at 147 Hz at a range of 1.8 km (Fraker *et al.*, 1981).
Round drillship	0	5,5,5	5,5,5	Year-round	Not available
Large drill barge	0	2,1,1	10,5,5	Year-round	Not available
Small drill barge	0	0,1,1	0,0,0	Year-round	Not available
Stationary Suction Dredge	1	1,1,1	2,2,2	June-Nov	Dredge plus attending equipment and boats: - Issungnak: 90 to 100 dB at 1,000 Hz at a range of 1.2 km (Fraker *et al.*, 1981) - Arnak: 164 dB at 1390 Hz at a range of 1 m (Ford, 1977) - Tuft Point: 152 to 157 dB at 500 to 1,000 Hz at a range of 1 m (Ford, 1977) - Alerk: strongest tone was 101 dB at 73 Hz at a range of 7.4 km (Fraker *et al.*, 1981)
Process barge	0	10,7,7	22,15,15	Year-round	Not available
Accommodation barge	0	6,5,5	14,10,10	Year-round	Not available
Storage barge	0	4,3,9	12,7,0	Year-round	Not available
Crane barge	2	5,4,4	5,4,4	June-Nov	Not available
Floating drydock	1	2,2,2	2,2,2	Year-round	Not available
Shallow water oil production islands	0	7,5	9,7	Year-round	- Niakuk 3 artificial island, Prudhoe Bay: 64 dB at 80 Hz at a range of 1.6 km and 34 dB at 3.8 km. (Malme and Mlawski, 1979).
Deep water oil production islands	0	2,1, 1	10,5,5	Year-round	Not available
Gas production islands	0	2,1,0	10,8,10	Year-round	Not available
APLA's	0	1,1,0	1,1,0	Year-round	Not available

a: Technically achievable development; Arctic tankers.
b: Intermediate development; Arctic tankers.
c. Intermediate development; overland pipeline.

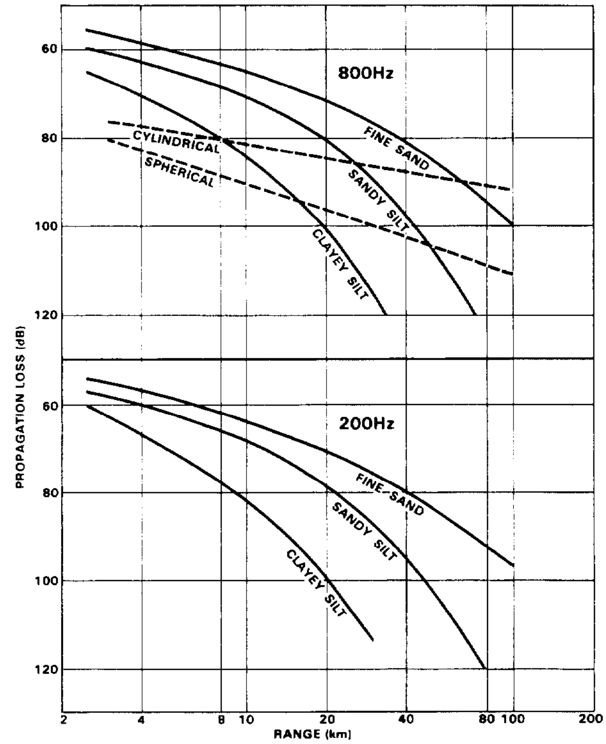


FIGURE 2.3-4 *Propagation losses versus range for a 100 m water depth with a -0.2/sec sound speed gradient. Losses are depth averaged for frequencies of 800 Hz and 200 Hz and for three different bottom sediment types. For comparison purposes, cylindrical (3 dB per distance doubled) and spherical (6 dB per distance doubled) spreading losses are plotted on a relative dB scale (Source: Rogers, 1981).*

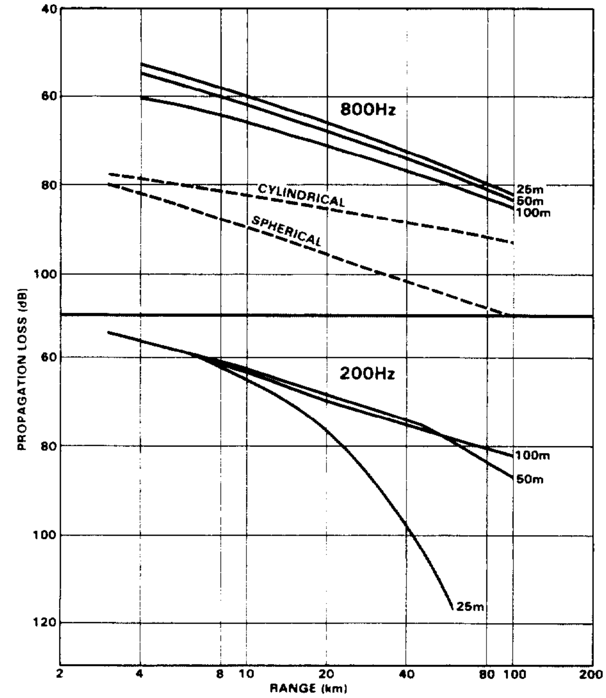


FIGURE 2.3-5 *Propagation losses versus range for water depths of 25,50 and 100 m and for frequencies of 800 Hz and 200 Hz. In each case bottom sediments are fine sand and losses are depth averaged. For comparison purposes, cylindrical (3 dB per distance doubled) and spherical (5 dB per distance doubled spreading losses are plotted on a relative scale (Source: Rogers, 1981).*

low frequencies of 5 to 20 Hz propagated well, and showed lower losses than that predicted by spherical spreading. Propagation losses at frequencies of 75 to 500 Hz were less than spherical spreading to ranges of about 5 to 10 km, beyond which transmission losses increased. In summer, transmission losses at all frequencies between 15 and 400 Hz were less than predicted by spherical spreading over ranges of less than 15 km, while losses were greater than spherical spreading at longer ranges. For example, the transmission loss at 250 Hz was 110 dB at a range of 60 km, 14 dB greater than that predicted by spherical spreading, and 62 dB more than cylindrical spreading. For most frequencies, propagation was better in summer than winter.

APP (1981) estimates of propagation losses for an LNG carrier travelling over the 2,000 m deep waters of Baffin Bay are provided in Chapter 4, and will be used in the present assessment in the absence of empirical data for the Beaufort Sea. It is emphasized, however, that the use of these deep water propagation loss estimates for the shallow continental shelf waters of the Beaufort Sea will result in underestimating propagation losses and overestimating distances where tanker noise would be detected above natural ambient noise. Figures 4.4-2 and 4.4-3 for Baffin Bay indicate propagation losses less than predicted by spherical spreading for frequencies between 100 Hz and 1 kHz. For the shallow water cases shown in Figures 2.3-4 and 2.3-5, for 200 and 800 Hz, propagation losses exceed those predicted by spherical spreading, as is the case in shallow water for other propagation losses described previously. The expected noise levels at distances up to 60 km at frequencies of 100 Hz, 1 kHz and 5 kHz, and for receiver depths of 3 m and 20 m are shown in Figures 4.4-2 and 4.4-3. At low frequencies, less than 500 Hz propagation losses at most ranges would be greater when the receiver was nearer the surface. For example, at a receiver depth of 20 m, noise at 20 km produced by a carrier operating at half power in open water would be 78 dB at 100 Hz. At a receiver depth of 3 m, however, the noise level would be reduced to 72 dB. Although the estimated zone of influence of tanker noise discussed in subsequent sections is based on assuming a receiver depth of 20 m, levels of low frequency sound, less than 500 Hz, received by marine mammals at shallower depths would generally be lower.

2.3.6.3 Ambient Noise

Ambient noise, both natural and man-caused is one factor that limits the hearing sensitivity of marine animals and therefore, the effectiveness of vocalizations as communication or orientation signals. The level of natural ambient noise is also a factor in defining the zones of possible influence of industrial noise where the artificial noise is above natural ambient levels. A discussion of ambient noise in the Beaufort Sea is provided in ESL (1982).

The three main sources of ambient noise in the ocean are: water motion caused by winds, tides, surf, rain and hail; ship noise; and soniferous (sound-producing) marine organisms (Knudsen *et al.*, 1948; Wenz, 1962; Myrberg, 1978). During the open water season, ambient noise is dominated by wind-dependent sea noises and biological noise. In areas with little industrial activity, ambient noise spectra are relatively flat from 20 to 500 Hz, and decrease above this frequency at about 5 dB per octave (Ross, 1976). Increased wind speed and sea state result in increased noise levels across the spectral range. Shipping noise in temperate oceans is also a major component of low-frequency ambient noise, with its peak energy being below 100 Hz (Wenz, 1962; Ross, 1976). However, shipping noise in the Beaufort Sea is probably negligible at the present time (Fraker *et al.*, 1981).

Fraker *et al.* (1981) measured ambient noise in August under calm sea conditions in about 25 m of water off the Tuktoyaktuk Peninsula (Table 2.3-10).

TABLE 2.3-10

QUIET SUMMER AMBIENT NOISE LEVELS RECORDED OFF THE TUKTOYAKTUK PENINSULA

Frequency (Hz)	dB re (1uPa)²/Hz
100	52
1,000	40
2,000	36
4,000	32
8,000	24

Source: Fraker et al., 1981

Comparable ambient noise measurements are not available for the Canadian Beaufort Sea in winter, although Holliday *et al.* (1980) made a number of ambient noise recordings in water depths from 8 to 45 m under 100% ice cover at several locations near Point Barrow and Prudhoe Bay during May. Spectrum levels averaged about 50 dB at 100 Hz and generally decreased at higher frequencies at a rate of 3 dB per octave. During brief quiet periods, noise levels were as low as about 30 dB at 100 Hz. In a small open water lead, ambient noise spectrum levels increased to 68 dB at 100 Hz and 50 dB at 1 kHz, while at the edge of the landfast ice under calm conditions, levels were about 54 dB and 57 dB at 100 Hz and 1 kHz, respectively.

2.3.6.4 Vocalizations and Hearing Thresholds

There is concern that industrial underwater noise could disturb, mask communication, navigation or echolocatory signals, or damage the hearing mechanisms of some marine mammals and fish in the Beaufort region. The vocal and hearing abilities of marine mammals and fish are factors which will determine the extent to which they may be affected by underwater industrial noise in the Beaufort Sea.

Vocalizations of marine mammals are used for echolocation and for social communication. All odontocete (toothed) whales are believed to echolocate, probably to aide in feeding and for orientation when there is poor visibility. Echolocation signals generally occur at high frequencies, greater than 20 kHz, and have a short detection range mostly less than 100 m. The white whale is the only species of odontocete common in the southeastern Beaufort Sea, and has been reported to echolocate (Ford, 1977; Wood and Evans, 1980). On the other hand, it is generally agreed that baleen whales such as bowheads, or pinnipeds such as ringed and bearded seals do not echolocate.

Vocalizations of odontocetes and pinnipeds used for social communication occur primarily above 1 kHz, while baleen whales emit signals at frequencies mainly below 1 kHz and frequently below 100 Hz. The latter sounds are propagated well in deep water, and have the potential for use in communication over long distances such as 100 km. In addition, all marine mammals are probably passive listeners to environmental sounds for navigational cues.

The hearing thresholds of several species of marine mammals have been determined for various frequencies and are the lowest intensities at which the animal can hear pure tones under quiet experimental conditions. However, ambient noise levels in the ocean are often greater than the absolute hearing thresholds determined in the laboratory, and the lower hearing threshold in the ocean is therefore determined by the ambient noise. In order for a marine mammal to hear and discriminate a signal, it must be louder than the background noise at that frequency. The factor by which it must be louder is called the "critical ratio" of detection. This ratio, expressed in dB, has been determined for a bottlenosed porpoise (Johnson, 1968), a harp seal (Terhune and Ronald, 1971), two ringed seals (Terhune and Ronald, 1975a) and humans (Hawkins and Stevens, 1950) (see Figure 4.4-4, Chapter 4). The results of Terhune and Ronald (1975a) suggest a critical ratio for ringed seals of 30 to 35 dB in the 4 to 32 kHz range. In other words, at an ambient level of 90 dB at 32 kHz, a signal at 32 kHz must have a level of 120 to 125 dB to be detected by a ringed seal. Terhune (1981) suggests that critical ratios of phocid seals and odontocetes in the 100 to 2,000 Hz range are probably similar to that measured in humans.

Payne and Webb (1971) speculated that the large brains of baleen whales may have sophisticated signal processing capabilities which allow them to detect pure tone calls of conspecifics at critical ratios of 0 dB (or at similar intensities as background noise). Although this ability has not been demonstrated experimentally in marine mammals, Payne and Webb (1971) reviewed studies which indicate that humans can detect signals at signal-to-noise ratios of 0 dB.

As a result of the ability of the mammalian auditory system to process sounds at different frequencies independently, vessel-induced underwater noise at low frequencies theoretically will not affect hearing at higher frequencies. This is known as the 'critical band' concept. The reception of a pure tone, for example, is primarily affected by noise at frequencies equal to or adjacent to the tone (Johnson, 1968; Terhune and Ronald, 1972; Popper, 1980). Noise outside this 'critical band' would have little or no masking effect on discrimination of the tone. Terhune and Ronald (1972) estimated that the critical band of the harp seal was within 10 and 30% of the test frequencies. However, it should be emphasized that the concept of critical bands in marine mammal hearing has not been experimentally confirmed. Critical bands described to date have been derived from critical ratio data obtained during experiments using wide-band (or 'white') noise sources. The masking effect of low-frequency noise on high-frequency sound reception (or high-frequency noise on low-frequency reception) has not been directly investigated with marine mammals.

The vocalizations and hearing sensitivities (where available) of marine mammals and fish which may be affected by underwater industrial noise in the Beaufort Sea are described in detail in ESL (1982) and summarized in Chapter 4, Table 4.4-2.

(a) White (Beluga) Whale

White whales in the Beaufort Sea region produce a variety of sounds for communication, and emit two types of echolocation clicks used for general orientation and for discrimination (Ford, 1977). In the highly turbid waters of the Mackenzie River estuary, white whales probably rely extensively on underwater acoustics for orientation as well as communication over short distances. There is no evidence which suggests that long distance communication between white whales may be important.

The auditory thresholds of two captive white whales were determined by White *et al.* (1978), and are discussed in ESL (1982). Although hearing sensitivity at frequencies less than 1 kHz has not been tested in the white whale, lower frequency thresholds have been determined for the bottlenose porpoise by Johnson (1967). He reported a sensitivity of 98 dB (re 1 uPa) at 1 kHz, which diminished steadily to 132 dB at 75 Hz, the lowest test frequency. Since the audiogram of the white whale is similar to the bottlenose porpoise at higher frequencies (White *et al.*, 1978), these figures are likely representative of white whale sensitivity to low frequency sound.

(b) Bowhead Whale

The characteristics of sounds produced by bowhead whales are shown in Table 4.4-2 in Chapter 4, and can be classified as tonal in the 100 to 300 Hz band, and pulsive in the 50 to 600 Hz band (Johnson and Clark, in prep., cited in APP, 1981). Sound intensity levels for bowhead vocalizations have not been documented. The hearing sensitivity of the bowhead whale has not been determined, but it is assumed that maximum sensitivity occurs in the frequency range of their vocalizations (i.e. 50 Hz to 600 Hz, Wursig *et al.*, 1981; Ljungblad *et al.*, 1980).

Bowhead vocalizations are thought to serve primarily as social or communication signals. There is no evidence of a well-developed echolocation system in baleen whales, although it has been suggested that the echos of loud calls may be employed to orient themselves relative to the sea bottom topography or other large targets (Herman and Tavolga, 1980). These authors also suggest that mysticetes possess highly sensitive hearing, and it has been postulated that these species use environmental sounds such as surf noise and the vocalizations of other marine animals as navigational aids (Norris, 1967).

(c) Pinnipeds

The frequencies of ringed and bearded seal vocalizations, and the hearing sensitivity of ringed seals are listed in Table 4.4-2 in Chapter 4. Stirling (1973) describes four types of communication and social sounds in ringed seals: high and low pitched barks, yelps and chirps. These vocalizations were produced at all times of the day and night, as well as during all seasons. There is no direct evidence of a well developed echolocatory system in pinnipeds, although like most marine mammals, they are probably passive listeners to environmental sounds.

Terhune and Ronald (1975b) measured the hearing sensitivity of ringed seals at frequencies from 1 to 90 kHz, and found that the maximum sensitivity was at frequencies between 11 and 15 kHz (see ESL, 1982). Terhune and Ronald (1976) subsequently found that the upper frequency hearing limit for ringed seals was 60 kHz. Although the hearing sensitivity of bearded seals has not been examined, the similarity in the audiograms of five species of pinnipeds discussed by Myrberg (1978) suggest that the hearing sensitivity of bearded seals is probably like that previously described for ringed seals.

(d) Fish

The significance of hearing in fish is not well understood, but many fish produce sounds, and intraspecific communication in temperate seas has been documented in several of the few species investigated (Myrberg, 1978). In general, hearing in most fish is thought to be used for sensing and locating approaching animals (e.g. prey or predators) or obstructions, and maintaining orientation in the water column (Tavolga, 1971). The sensitivity of fish hearing depends on a complex relationship between the frequencies and intensities of sounds. Most fish are sensitive to a range of frequencies, usually up to 2,000 Hz, and a few species (including herring) can distinguish sounds beyond 5 kHz (Myrberg, 1978).

2.3.6.5 Impacts on Marine Mammals

(a) Nature of Possible Impacts

The possible effects of industrial underwater noise on Beaufort Sea marine mammal populations appear to centre on the following concerns:

- the presence of unfamiliar sounds may disturb or alarm mammals and cause a startle response (Fraker, 1977a,b; Ford, 1977);

- noise could interfere with or mask reception of marine mammal communication or echolocation signals, or interfere with natural environmental sounds used by marine mammals for navigation (Penner and Kadane, 1979; APP, 1981; Terhune, 1981); and,

- intense noise may damage the hearing of marine mammals or cause other physical or physiological damage (Norris, 1981).

Numerous factors influence the possible effects of underwater industrial noise on marine mammals; for example, different species use acoustic signalling for different purposes, and vocalize at various source levels and frequencies, and some species may be more vulnerable to noise disturbances during certain life history stages such as breeding, feeding, moulting and migration. The duration, frequency and source level of the sound source are also important in assessing the possible effects of underwater noise. For example, loud noise at frequencies less than 500 Hz may affect the ability of bowheads to communicate, but not white whales. Also, industrial noise can occur at different times, in different locations, and can be cumulative, so that the distribution and abundance of marine mammals within an ensonified area is of importance.

Mobile and stationary sources of industrial underwater noise may affect some species differently (Fraker *et al.*, 1981). Evidence to date indicates that mammals do not habituate to intermittent sounds as readily as they do to continuous sounds (Evans, 1982). Although speculative, it is possible that some marine mammals may compensate for temporary increases in ambient noise, such as those which occur naturally, by increasing the intensity of their vocalizations. Also, it is possible that they may shift the frequency of their vocalizations in order to communicate between high intensity spectral peaks in the ambient noise spectrum.

Some marine mammals become habituated to low-level background noise from ship traffic and offshore petroleum activities (Geraci and St. Aubin, 1980; APP, 1982). For example, humpback and gray whales, harbour and elephant seals, bottlenose porpoises, walruses and sea lions apparently coexist well with industrial activities, and most are accustomed to background noise from ships and industrial activities (see Geraci and St. Aubin, 1980). Existing industrial activities in the southeastern Beaufort Sea region, including marine logistics traffic and the construction of 20 artificial islands to date, have had no apparent long-term effects on regional populations of marine mammals (Fraker and Fraker, 1979, 1981; Fraker *et al.*, 1981).

(b) Zones of Influence

Underwater noise from icebreakers breaking ice is expected to be similar to sounds from natural ice fracturing and cracking. Arctic marine mammals are likely well adapted to this type of noise. As indicated earlier, noise levels produced by breaking ice would be insignificant compared to noise from propeller cavitation (APP, 1982).

For estimating possible zones of influence of noise from icebreaking tankers and other marine vessels operating in the Beaufort Sea, noise level estimates for APP LNG carriers and estimated propagation losses in deep water areas of Baffin Bay are used (APP, 1981). These estimates are shown in Figures 4.4-2 and 4.4-3 of Chapter 4. As stated earlier, these levels are undoubtedly overestimates for the Beaufort Sea. There would be higher propagation losses in shallow water and increased losses when sound travels from deep water to shallow water on coastal shelves (Leggat *et al.*, 1981). Another factor is that ambient noise levels in the Beaufort Sea may be lower than in Baffin Bay. As a result, the zone of influence of various sound sources may remain comparable to those in Baffin Bay.

By 1990, assuming the intermediate development rate using tankers (see Table 2.3-7), there may be 6 Arctic tankers in operation transporting oil from the Beaufort Sea, equivalent to about one tanker return trip every 5 to 6 days. However, the number of tanker trips could gradually increase until by the year 2000, 16 tankers may be in operation (assuming intermediate development). At this time, the frequency of maximum possible noise disturbance could increase to once daily based on a stationary receiver, such as a whale encountering an inbound or outbound tanker. The important point is that the zone of influence for tanker underwater noise will be roughly circular and will move along a route from or to a tanker loading terminal. The zone will have a radius which will depend on the hearing sensitivity and critical ratio of the animal being influenced, natural ambient noise levels, tanker power, whether or not it is operating in ice or open water, and the noise frequency of interest.

For reasons discussed in Section 2.3.6.2 (Propagation) there are uncertainties in prescribing zones of influence of noise from local marine logistics traffic in the Beaufort Sea. However, site-specific data collected by Ford (1977) and Fraker *et al.* (1981) provide some approximate distances at which underwater industrial noise from dredging and island construction activities reaches ambient levels. Operations at Tuft Point and Arnak each included a suction dredge and various combinations of tugs and crew boats (see ESL, 1982). During late July 1976, industrial noise reached ambient levels at a distance of 3.6 km from Tuft Point, and 5 to 6 km from Arnak (Ford, 1977). Fraker *et al.* (1981) recorded composite underwater sounds from Issungnak island construction operations, which included a dredge, tugs, and barge camps, that were well above ambient noise levels to a range of 4.5 km north into deeper water. When the dredge was operating, sounds received at a distance of 1.2 km, at frequencies up to 8 kHz, were 20 to 50 dB above quiet ambient levels (Fraker *et al.*, 1981).

Malme and Mlawski (1979) found that low frequency drilling noises from drilling rigs on an artificial island and on a natural island in the Beaufort Sea off Prudhoe Bay were detectable between 6.4 to 9.6 km away, under quiet ambient noise levels, and 1 to 6 km away under noisy ambient conditions. Low frequency (5 to 29 Hz) drilling sounds received at a distance of 8 km and less in open water were equivalent to ambient levels resulting from a 22 km/h (12 kt) wind. These recordings of noise sources at Prudhoe Bay were made in shallower waters (e.g. 2 to 12 m) than depths characteristic of the offshore drilling sites in the Canadian Beaufort Sea. Distances at which noise produced by marine logistics traffic reaches ambient levels in the Beaufort Sea have not been documented, however depths are generally greater than near Prudhoe Bay and sounds would therefore tend to travel further.

The frequency ranges of marine mammal vocalizations, their hearing sensitivities (where available) and some samples of frequencies and intensities of underwater industrial noise in the region are compared in Figure 2.3-6. The vocalizations, and therefore assumed hearing sensitivity, of the bowhead whale corresponds most closely to industrial noise frequencies. There is also some overlap between the hearing sensitivities of ringed seals (and probably bearded seals) and white whales and the frequencies of industrial sound. However, the hearing sensitivities of these species at frequencies below 1 kHz are still largely unknown. Although many industrial underwater sounds are emitted at frequencies which these species can detect, the significance of any effects would depend on the sensitivity of the species at that frequency, their critical ratios, and ambient noise levels.

(c) White Whales

White whales of the Mackenzie stock will occur within the zone of influence of underwater noise produced by icebreaking tankers, local marine transport, aircraft and stationary sources from mid May through September (Volume 3A; Section 3.2). The proposed tanker route intersects known spring migration corridors and late summer habitat of the white whale (Figure 2.3-7). At frequencies greater than the 20 kHz used by this species for echolocation, maximum tanker noise (e.g. full power in ice) would be below the absolute hearing threshold for white whales within 10 km of the tanker. At the lower frequency of 5 kHz used for social signalling, the maximum ship noise (full power, thick ice) would also be below hearing threshold at 10 km, and therefore is not expected to have effects at greater distances. At a frequency of 1 kHz, the maximum ship noise at 1 km (92 dB) would be below the absolute hearing threshold of 103 dB at that frequency. Although the hearing sensitivity of white whales at frequencies less than 1 kHz is unknown, the threshold of about 130 dB at 100 Hz determined for the bottlenose porpoise (Johnson, 1967) is likely representative. At this sensitivity level, maximum tanker noise of 102 dB at 100 Hz would also be below white whale absolute hearing thresholds at 1 km. During the open water period, noise from vessels operating at full or half power would be below the hearing threshold at 4 km at a frequency of 5 kHz, while noise at 100 Hz and 1 kHz would be below the hearing threshold at 1 km. It is unlikely that white whales would be affected by the low frequency blade rate tonals produced by the tankers.

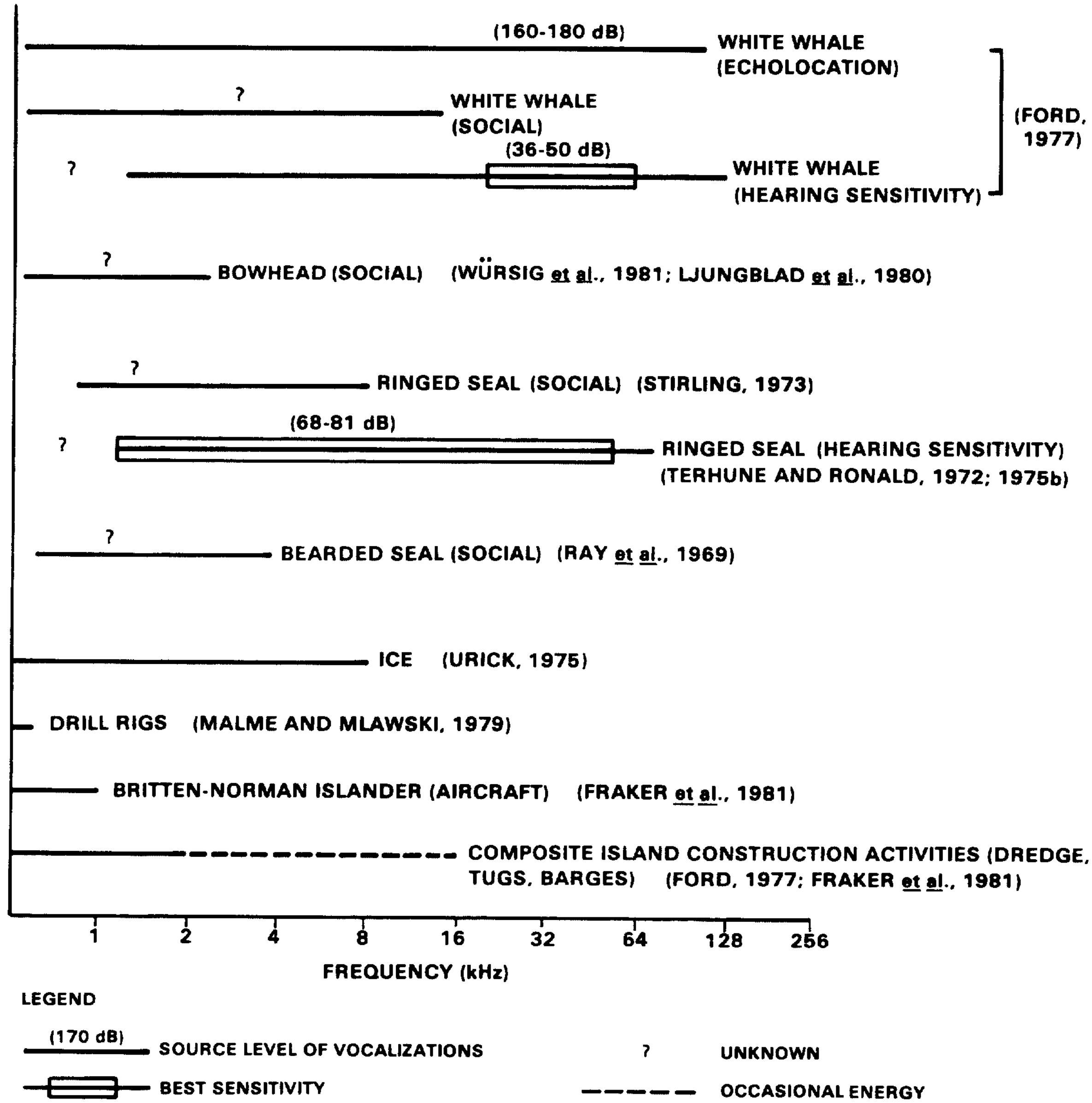


FIGURE 2.3-6 *Frequency ranges of waterborne sounds produced by marine mammals and industrial activities, and hearing sensitivities of white whales and ringed seals (adapted from ESL, 1982).*

For full power in thick ice, tanker speed assumed is 22 km/h, so that with one tanker return trip every 5 to 6 days in the year 2000 (for the intermediate development rate), tankers may be separated by about 1,000 km on both inbound and outbound tracks. On average, the separation would be about 500 km for the centres of tanker zones of influence. This situation is illustrated in Figure 2.3-7 which shows approximate zones of influence for two tankers approaching each other in the Beaufort Sea. Assuming equal tanker spacings along the route, other tankers would be located well off the map area shown. For white whales, zone radii are 10 km for frequencies from 5 kHz to 20 kHz, and 1 km for 100 Hz and 1 kHz.

In summary, given a "worst case" situation with maximum (full power) tanker noise such as would be required in spring, coupled with an unrealistically low transmission loss (i.e. that calculated for deep waters in Baffin Bay), white whale signals may be masked by tanker noise at frequencies between 5 to 20 kHz within a distance of 10 km (Figure 2.3-7). At frequencies below 1 kHz, tanker noise would be below the absolute hearing threshold of white whales at distances less than 1 km. It is emphasized that zones of possible influence are expected to be smaller in the shallow Beaufort Sea waters for the reasons discussed earlier. Masked hearing thresholds for this species have not been determined, but may be similar

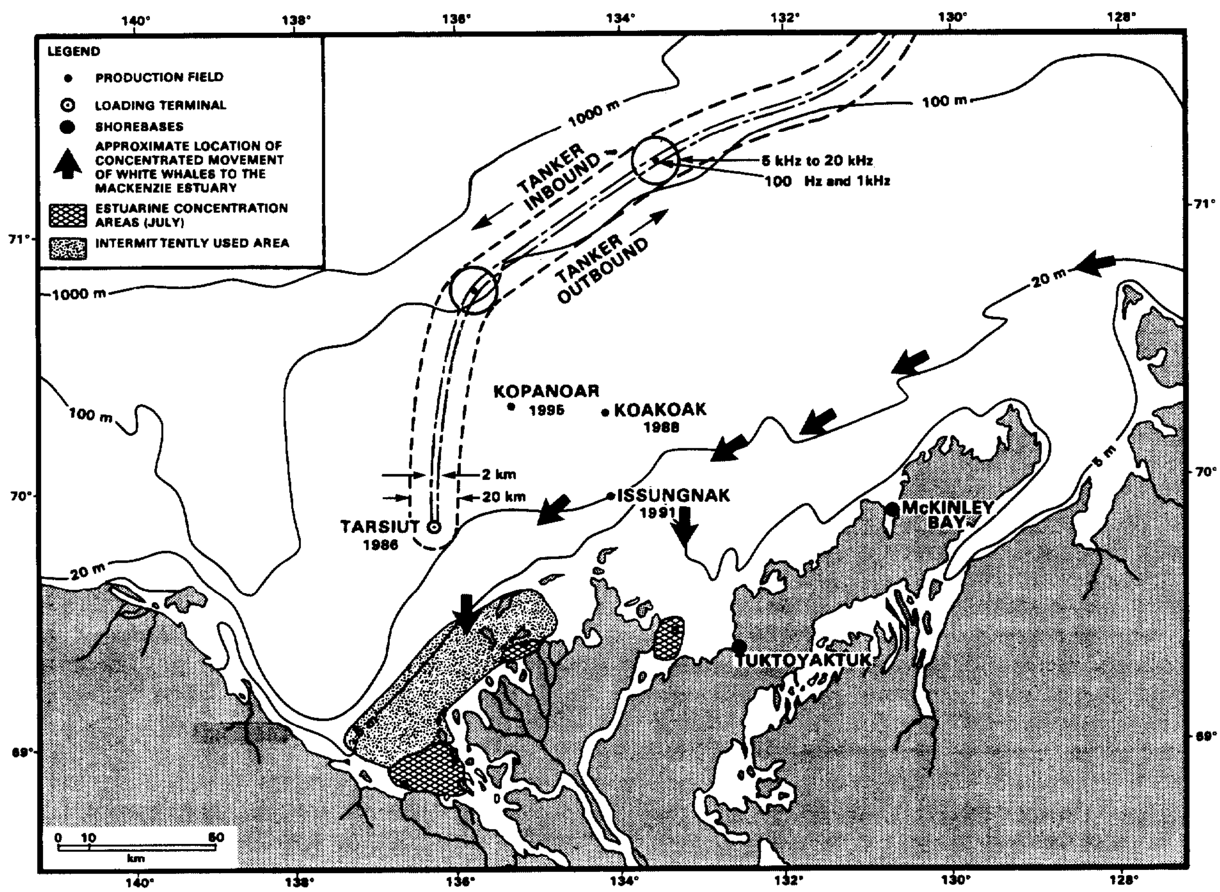


FIGURE 2.3-7 *Estimated zones of influence on white whales from tankers travelling at full power through ice at 22 km/h. By the year 2000, there would be about two tankers in the Beaufort Sea at any one time, assuming the intermediate development rate.*

to those of ringed seals (Section 2.3.6.4). If this assumption is correct, the zone of influence would be substantially smaller than indicated in Figure 2.3-7.

Uncertainties exist in assessing the possible effects on white whales of underwater noise from local marine transport, stationary activities and aircraft in the proposed production zone. This is because noise levels are available for only a few sound sources and knowledge of sound transmission characteristics is imprecise for the shallow Beaufort Sea. Masking of white whale communication signals by underwater sound from marine logistics traffic may occur at frequencies less than 5 kHz when natural ambient levels are low. On the other hand, interference with echolocatory signals would be unlikely because most industrial sounds are at frequencies lower than those used for echolocation (Figure 2.3-6). The zone of influence of low frequency noise would vary depending on source levels, ambient noise and water depth, and may be greater than the zone of influence of icebreaking tankers when a large number of vessels, islands, aircraft and other associated activities are emitting noise within a relatively confined area.

Ford (1977) calculated the range at which white whales may find industrial noise audible at 2 kHz from composite island construction activities and marine logistics traffic in the southeastern Beaufort Sea. These ranges from the Arnak and Tuft Point sites were 2.9 km and 1.8 km, respectively. Ford (1977) also calculated that tugs pushing full barges in the Tuft Point area could have been audible to whales at distances of between 2.5 to 3.3 km, while a tug pushing an empty barge, and a crew boat, were expected to have been audible to white whales within 2.3 km and 1.8 km, respectively.

It is expected that industrial noise will be audible to some spring migrants enroute toward Amundsen Gulf during May and June, to some migrants during their westward migration along the landfast ice edge off the Tuktoyaktuk Peninsula in late June or July, and to some during August when they leave concentration areas in the Delta (Volume 3A; Section 3.2). The proportion of the population which may be affected along the landfast ice edge would vary with the level of activity, number of tankers, the timing of the trips, and the final location of tanker loading facilities. During peak production, tanker movements into the Beaufort Sea could occur on a daily basis. At this time, it is conceivable that a large proportion of the population could pass within 10 km of tanker routes and a loading terminal during their residence in the Beaufort. However, tanker noise would not be audible to the white whale population during July when they congregate in the shallow waters of the Mackenzie estuary where they would be well outside the 10 km zone of influence (Figure 2.3-7). At the same time, some of these whales may be disturbed and have their communications masked by underwater industrial noise from mobile logistics traffic and air traffic.

Since icebreaking tankers have not yet been constructed, there have been no interactions between white whales and tankers. In general, white whales appear tolerant of stationary activities such as drilling and dredging, but avoid concentrations of marine logistics traffic (Fraker and Fraker, 1981). Noise generated by drilling operations on artificial islands has had no obvious effect on white whales to date (Fraker and Fraker, 1979). In addition, white whales have frequently approached stationary barge camps and dredges (Fraker 1977a, 1978). Also, helicopters and STOL survey aircraft flying at altitudes of 457 m (1,500 ft) and higher do not appear to disturb white whales. Behavioural responses of white whales to industrial activities and marine logistics traffic in the Beaufort Sea are reviewed in ESL (1982).

The possible impacts of underwater sound generated by icebreaking tankers operating in the transition zone of the southeastern Beaufort Sea on the regional white whale population would probably be NEGLIGIBLE during early production in the Beaufort Sea. This results from expecting only 1 or 2 tankers per month to travel through areas which are migration corridors or summer feeding habitat of this species, and from the estimate that tankers under full power under quiet ambient conditions would not affect white whales at distances greater than 10 km in spring and 4 km in summer (Figure 2.3-7). In addition, the possibility for disturbance or masking would exist for short time intervals not exceeding 1 hour in spring and 12 minutes in summer, assuming the whales remain stationary and that tanker speeds are 22 km/h in spring and 41 km/h in summer. Beyond the early production phase, the potential impacts of increasing tanker traffic on white whales could be between NEGLIGIBLE and MINOR because of the increased frequency of tanker traffic.

As discussed earlier, whales within several kilometres of drillships, dredges, marine traffic corridors and artificial islands in shallow water areas will be able to detect underwater industrial noise. If, during July, vessels are prohibited from using western areas of Kugmallit Bay and excluded from Shallow Bay, and aircraft altitude and corridor guidelines are adhered to as a mitigation measure, impacts on white whales in this area are expected to be NEGLIGIBLE. July is when white whales are concentrated in these waters. Although current industrial activity in the Beaufort Sea has occasionally resulted in some local temporary disturbances (ESL, 1982), the overall effects appear to have been NEGLIGIBLE. Increasing the spatial and temporal extent of mobile sources of underwater sound as development proceeds may enhance masking and disturbance over the long term. Marine mammals are probably able to tolerate and become habituated to underwater noise of certain levels and characteristics, but it is possible that they may avoid high noise areas once some tolerance limit is surpassed. Avoidance of high noise areas by white whales during late June could result in delayed or altered migration to the Mackenzie estuary. However, since traffic control measures will continue to be employed, possible long-term impacts of underwater sound as a result of future increases in local marine transport activities and tanker traffic on the regional white whale population, are expected to be MINOR. Potential effects of underwater noise on white whales will be the subject of continuing studies as the proposed development proceeds (Volume 7, Section 3.3.1).

(d) Bowhead Whale

As indicated in Figure 2.3-6, there is considerable overlap between the low frequency vocalizations of bowheads and underwater noise produced by most industrial activities. Except in shallow water, low frequency sounds propagate well and it is assumed that bowhead hearing sensitivity is within the frequency range of their vocalizations. Therefore, this species may be disturbed and have its sound transmissions and receptions masked by underwater noise produced by most industrial activities. The biological significance of such effects are not well understood and are subject to speculation.

The expected zone of influence on bowheads of low frequency noise produced by local marine transport, aircraft and stationary sources of underwater noise in the production zone would vary depending on source levels, ambient noise levels and water depth. In aggregate it could be greater than for tanker traffic. As described under "zones of influence" earlier, low frequency noise at less than 2 kHz, produced by shallow water island construction activities, using dredges, crew boats, tugs, and barges, reached ambient levels at distances ranging from 3.6 km to 6 km (Ford, 1977). Bowheads in waters shallower than 10 m may be affected by underwater noise from similar sources within comparable ranges, depending on level of activity, natural ambient noise and the factors affecting sound propagation. Noise in deeper water, and cumulative noise levels from several activities or vessels in close proximity, could extend this zone of influence considerably.

Responses of bowhead whales to underwater industrial noise in the Beaufort Sea were studied by Fraker *et al.* (1981). Various anecdotal accounts suggest that artificial island construction, dredging and drilling activities have not resulted in obvious disturbances to bowheads (Section 2.4.2). Bowheads were observed as close as 800 m to these stationary activities during August 1980 (Fraker *et al.*, 1981, Figure 2.4-4)). Likewise, bowheads have only been observed to react to moving ships when vessels have approached to within a few hundred metres of the whales. Large groups of bowheads totalling about 750 animals, were recorded in the Beaufort Sea during 1980 within 20 to 100 km of 9 supply vessels, 8 tugs, 4 stationary but operating drillships, 3 dredges and support aircraft (Renaud and Davis, 1981).

Bowhead whales of the western Arctic population may be affected by industrial underwater noise: during their May to June spring migration enroute to Amundsen Gulf; during July and August when they tend to remain in the gulf and later when they move offshore or occupy waters off the Tuktoyaktuk Peninsula; and during September when they usually begin their westward fall migration (Volume 3A; Section 3.2). Based on data provided in Fraker and Fraker (1981) and Fraker *et al.* (1981) the present level of industrial activity in the region has probably had NEGLIGIBLE impacts on bowhead whales to date. However, the possible effects from increasing industrial activities, which would generate low frequency noise at sites shown in Figure 2.3-3, remain unclear because the biological significance of underwater acoustic masking on bowheads is poorly understood. Adherence to restricted corridors will tend to reduce the potential for interactions of local vessel traffic with bowheads, while stationary activities are not expected to cause significant disturbance of this species. Nevertheless, underwater noise generated by future increases in industrial activities in the production zone, in aggregate, could increase the impact rating to MINOR on the regional bowhead population. This is likely to be a conservative impact rating based on observations to date that there have been no significant disturbances to individual bowheads of the regional population as a result of normal industrial operations.

Aircraft flying at altitudes 100 to 150 m asl may cause a temporary disturbance or avoidance response by bowheads (diving). However, aircraft will normally maintain flight altitudes of 305 m (1,000 ft) or more so that potential impacts of this noise source on bowheads are expected to be NEGLIGIBLE.

During most of the five months bowheads are in the region, there is open water. At this time, tankers will use one-half power or less. The natural ambient noise levels will, on average, be greater than under ice cover so that the zone of influence for tankers under half power and in open water would probably range between 30 to 60 km at 100 Hz most of the time. The latter result assumes the low propagation losses exhibited in Figure 4.4-2 for Baffin Bay deep water. Ambient noises in open water depend mainly on wind speed (see ambient noise in coastal waters in Urick, 1975) so that a zone of influence at 100 Hz with a radius of 60 km might be expected for light winds (5 km/h) and a smaller 10 km radius zone for stronger winds (about 45 km/h). In addition the tankers, travelling at speeds of 32 km/h, would be moving noise sources separated by about 1,300 km on both inbound and outbound tracks (for the intermediate development case). The average separation between them would be about 650 km so that with light winds (5 km/h) the noise level along the track of the vessels could be above ambient about 20% of the time at 100 Hz but with stronger winds (about 45 km/h), only 3% of the time. Further to the side of the track of the vessels, the duration of noise above ambient would be progressively shorter in each case.

Figure 2.3-8 illustrates a possible situation for two tankers approaching each other, one leaving and the other heading toward a loading terminal. Open water is assumed. Estimated zones of influence are shown for light winds (about 5 km/h) and for stronger winds (about 45 km/h) at a frequency of 100 Hz. Similar zones of influence are expected over the band of frequencies expected to be of importance for bowheads. (Note that a further hypothetical situation exists when tankers pass close to each other; then the zones of influence combine to produce a single zone with a doubled radius). Most of the time, however, there will be only one tanker in the Beaufort Sea due to the 1,300 km separation between them both on inbound and outbound tracks.

It is emphasized that Figure 2.3-8 illustrates possible zones of influence that are largely speculative. Wind-dependent open water noise spectra have not been measured in the Beaufort Sea and propagation loss is likely to be greater than assumed. Likewise, tankers may operate under less than half-power in open water and ice intrusions in summer may radically modify the simple assumptions made that open water and bowheads are contemporary in the Beaufort Sea.

Nevertheless, possible noise influence on bowheads from tankers is expected to be intermittent and of a relatively minor nature on a portion of the population. In particular, the possible influence will diminish with wind-driven seas. These factors, to which can be added the apparent insensitivity of bowheads to current Beaufort Sea operations, make it likely that possible impacts on bowhead whales from Beaufort development to the year 2000 will not exceed MINOR.

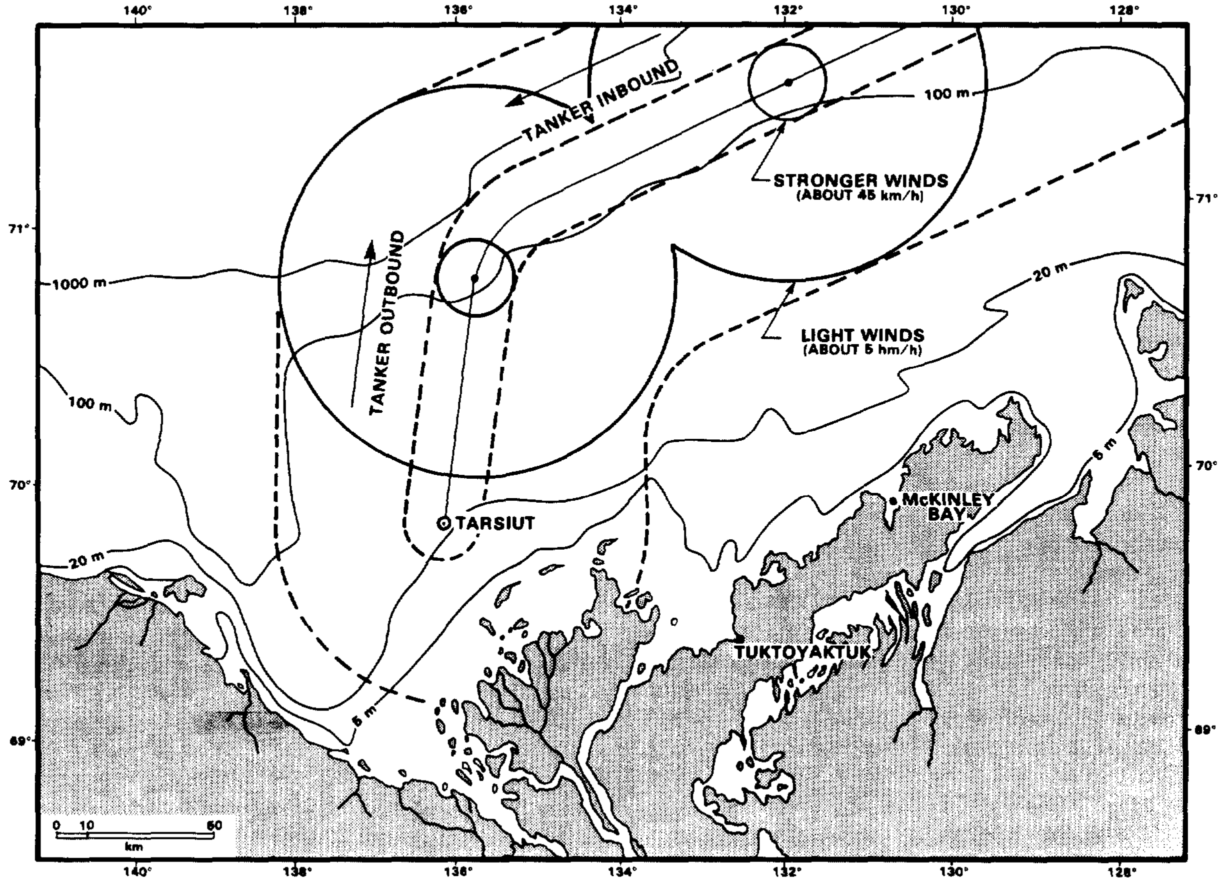


FIGURE 2.3-8 *Estimated zones of influence at 100 Hz on bowhead whales. A possible situation is illustrated where one tanker is inbound and one outbound. Open water is assumed. Zones are estimated for light winds (5 km/h) and stronger winds (45 km/h). For intermediate wind speeds, zone radii are expected to fall between the two limits shown.*

(e) Ringed and Bearded Seals

The possibility that ringed and bearded seals in the Beaufort Sea could be affected by underwater noise from tankers and offshore industrial activities in the region will be examined. This examination is hampered by the lack of information on the function of seal communications, however, both ringed and bearded seals are widely distributed in the region, so that at any one time only a relatively small proportion of the regional populations might be affected. In addition, there is evidence that these species tolerate marine industrial activities. For example, Ward (1981) observed ringed seals near an operating dredge in McKinley Bay during July and August 1980, and industry personnel regularly observe ringed seals around operating drillships (R. Hoos, pers. comm.).

During the open water season, and considering offshore development to the year 2000, possible impacts on ringed and bearded seals from underwater noise produced by local marine transport, aircraft and stationary sources are expected to be NEGLIGIBLE. This is because the number of individuals possibly affected would be few in a regional context and because these animals do not appear to be disturbed by existing marine industrial activities.

During winter and spring, however, adult ringed seals and pups could be affected by icebreakers operating in the landfast ice. As described earlier, it is believed that ringed seals are territorial during their breeding period, and it is possible that those occupying territories in the vicinity of an icebreaker's track may be displaced. Stirling (1973) reported increased ringed seal vocalizations under ice cover, and suggested that these may be necessary for maintaining social order at breathing holes. Therefore, the importance of possible disturbance or masking may be greater during periods of ice cover, particularly under the landfast ice where the seals maintain territories. Also, natural ambient noise levels are lower than in open water and there are fewer loud transient sounds under landfast ice than in the transition ice. However, icebreakers operating in the landfast ice would be restricted to specific corridors (Section 2.4.4), so that possible impacts of their underwater noise on ringed seals would be local and probably MINOR.

Bearded seals and subadult ringed seals may be affected by noise from local icebreaking in the same manner, possibly resulting in short-term disturbance or masking of communication sounds. However, they seldom fequent areas of landfast ice where the effects of underwater noise from local icebreaking could be most pronounced. Instead the transition zone and pack ice, which are naturally noisy, are common habitats of bearded seals and subadult ringed seals. Thus, low frequency sounds must be proportionately louder to elicit a disturbance response or to increase the masking of underwater communication. Therefore, the possible impacts of masking and disturbance of bearded seals and subadult ringed seals during winter are expected to be NEGLIGIBLE to MINOR.

Tankers, which may be used to transport crude oil from the Beaufort region, will operate in waters generally deeper than 25 m and will be restricted to specific corridors on the continental shelf, especially in areas where pingo-like features are prevalent. Further offshore, they will operate in the transition ice zone where they will take advantage of leads and polynyas in ice seasons. Assuming the intermediate development rate with tanker transportation, 16 tankers could be in use by the year 2000. With round trips of 30 to 36 days, depending on the season, a tanker will only appear in the Beaufort Sea every second day. However, counting inbound and outbound tankers, they could be encountered about once a day, on average, along their route. Therefore, noise generated by tankers is expected to reach peak intensities on average once a day by the year 2000, while possible effects on seals will depend on the zone of influence of these sounds. For defining zones of influence from tankers, Baffin Bay deep water propagation of sound is assumed and tanker noise versus range from Figures 4.4-2 and 4.4-3 were used.

The hearing sensitivity of ringed seals is relatively uniform between 1 and 45 kHz, with a peak sensitivity of 68 dB at 16 kHz (Section 2.3.6.4). Masked hearing thresholds are about 30 to 35 dB higher than ambient for pure tones. During late winter and spring when tankers would operate at full power through thick ice, tanker noise levels at 1 kHz are expected to be lower than the absolute hearing threshold of ringed seals at a distance of 50 km from a tanker, however, seals within this distance could have their hearing masked. At 5 kHz, tanker noise under ice is expected to be below the 76 dB absolute hearing threshold of ringed seals at 4 km. Thus, the size of a circular zone of influence is based on the ringed seal's hearing sensitivity rather than on natural ambient noise levels.

Expected zones of influence during winter and spring, for frequencies of 1 kHz and 5 kHz are illustrated in Figure 2.3-9. A hypothetical case is shown where one tanker is inbound and another outbound. (Tankers both inbound and outbound would be separated by about 1,000 km, on average, assuming a speed of 22 km/h in ice, so that no others would appear in the Beaufort Sea). When the tankers pass each other, the zone radii will double, assuming cylindrical spreading of tanker noise.

During the open water season, the 5 kHz zone of influence would shrink to a range of less than 1 km where tanker noise is expected to be below the absolute hearing threshold of a ringed seal. Similarly, the 1 kHz zone of influence would have a range of less than 4 km in open water. These zones are illustrated in Figure 2.3-10 for tankers in the position shown in Figure 2.3-9. When tankers pass, the zones would briefly increase in area because of the doubled acoustic power generated.

For frequencies less than 1 kHz, the zone of influence may be larger where the tanker noise level is higher and sound propagation is improved; however, the lack of data on the ringed seal's low frequency hearing threshold prevents estimation of zones of influence at frequencies less than 1kHz.

As described in Section 2.3.6.4, masked hearing thresholds between 4 and 32 kHz for the ringed seal are about 30 to 35 dB higher than ambient for pure tones. This means that a ringed seal would have to be much closer to a tanker than the radius of the zone of influence in order to hear it even though tanker noise would be affecting its ability to hear sounds. For example, a tanker travelling at full power through ice is expected to produce a noise spectrum level at 1 kHz of 87 dB at 4 km, and 84 dB at 10 km (Chapter 4, Figure 4.4-1). Assuming an ambient noise level of 57 dB at 1 kHz, and a masked hearing threshold of 30 dB, tanker noise would have to be at least 87 dB (the sum of 30 dB and 57 dB) to be heard by a seal. Consequently, seals within 4 km of the vessel would hear it, while those at 10 km would not.

Although the hearing sensitivities and critical ratios at various frequencies for bearded seals are assumed to be the same as for ringed seals, possible impacts of tanker noise may differ because of their different habitats during seasons when the sea is ice-covered. Ringed seals prefer to inhabit the landfast ice, whereas bearded seal habitat is primarily in transition zone ice and at ice edges. Figure 2.3-9 shows that noise in winter and spring is not likely to influence ringed seals in the landfast ice zone; also, in summer (Figure 2.3-10) the zones of influence are likely to be small. Consequently, possible impacts from tanker generated noise on ringed seals are expected to be NEGLIGIBLE if 16 tankers are operating by the year 2000.

The population of bearded seals in the Canadian Beaufort Sea is estimated at approximately 2,000

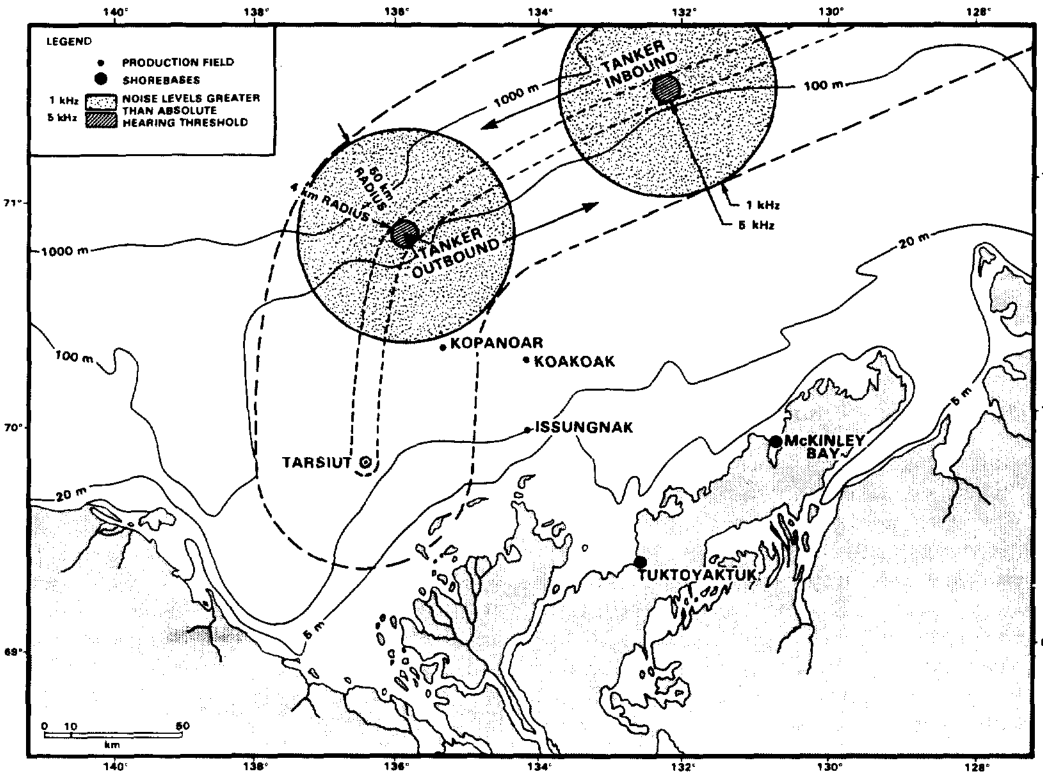


FIGURE 2.3-9 *Approximate zone of influence of underwater noise (at 1 and 5 kHz) produced by tankers operating at full power through thick ice during winter and spring on ringed seals of the southeastern Beaufort Sea (ship speed 22 km/h).*

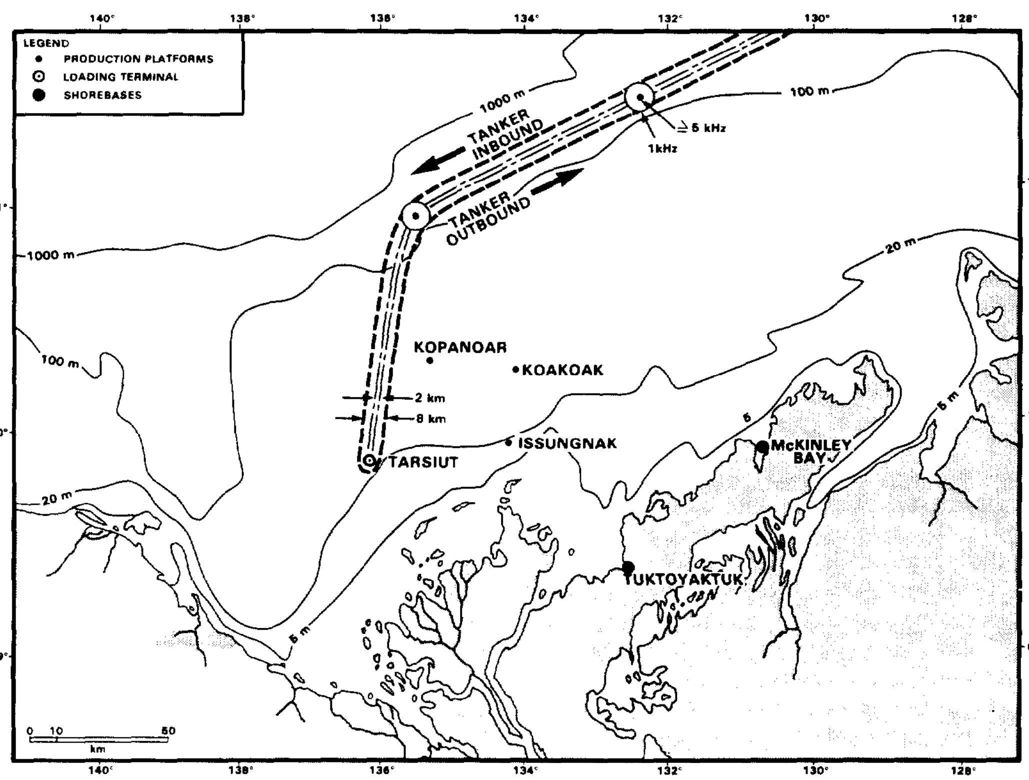


FIGURE 2.3-10 *Approximate zone of influence of underwater noise (at 1 and 5 kHz) produced by tankers operating at half power during open water periods on ringed seals of the southeastern Beaufort Sea (ship speed 31.5 km/h).*

animals, compared to an estimate of 50,000 ringed seals (Volume 3A). However, bearded seals are considered ubiquitous in transition zone ice and therefore, a fraction of their population could be influenced by tanker noise in winter and spring. The influence would, however, be brief since by the year 2000 those few animals located on the tanker route could encounter tanker noise for an average of up to 20% of the time. Elsewhere, this time would diminish. Considering the small fraction of the bearded seal population that could be affected, and the likely mobility of the animals that could be disturbed, possible impacts on bearded seals due to tanker traffic in the year 2000 are expected to be NEGLIGIBLE.

2.3.6.6 Impacts on Fish

The ecological significance of industrial sound perception by fish is not clear since variable responses and habituation to underwater sound have been observed in a number of instances. Olsen (1976) and other authors have demonstrated that fish may habituate to noise sources. The presence of fish within active harbours has been documented, while fish have been reported near active dredges in the Beaufort Sea (Byers and Kashino, 1980). On the other hand, some authors have suggested that fish avoid noise from dredging operations and large vessels (Neproshin, 1978; Konagaya, 1980). In a review of literature describing the reaction of fish to sound, Chapman and Hawkins (1969) concluded that intermittent high amplitude sounds at low frequencies generate avoidance responses. For example, they indicated that whiting (*Merluccius sp.*) reacted quickly by diving after the firing of an airgun, but habituated to its continuous firing in less than 1 hour. Olsen (1976) reported that herring will locate and avoid similar noise sources, but also habituate to noise relatively rapidly if the signals occur less than several minutes apart. Popper and Clarke (1976) reported that goldfish exposed to intense sound (149 dB) for 4 hours experienced a 24 hour hearing loss, while Chapman (1976) suggested that fish may be generally tolerant of high intensity sounds (130 to 140 dB) within their hearing range.

Overall, the available information describing the effects of noises generated by industrial activities on fish is ambiguous, and this hampers assessment of the potential impacts of underwater sound on species present in the Beaufort Sea. It is likely that fish will hear noise from drilling, vessels and other sources over distances of several kilometres, and while some fish may avoid the immediate areas of chronic intermittent high amplitude sounds, very few individuals are likely to be affected in a regional context. In addition, it appears probable that many species will become habituated to stationary and relatively continuous noise sources. As a result, the degree of regional impact of underwater sound on fish in the offshore Beaufort Sea is expected to be NEGLIGIBLE.

2.3.6.7 Summary of Possible Impacts of Underwater Sound

At this time, the possible effects of underwater sound on marine mammals are of biological concern with respect to development of offshore hydrocarbon resources in the Beaufort Sea. The assessments of possible effects were based on available literature concerning: underwater sound propagation and source spectrum characteristics; hearing sensitivities; and behavioural responses of whales and seals to past hydrocarbon exploration activities. There are a lack of data on the ecological significance of auditory masking or disturbance and the functions of vocalizations in some species. There is little doubt that all marine mammals in the Beaufort Sea will be able to detect underwater noise resulting from a range of industrial activities depending on their location, although the extent to which they may become naturally habituated to noise from nearby sources remains unknown. These data deficiencies have dictated a conservative approach throughout this assessment. As indicated by the summary of potential impacts provided in Table 2.3-11, some MINOR impacts of underwater sound on some species of marine mammals are considered possible by the year 2000 assuming an intermediate development rate. However, the impacts of this level of industrial activity could also be NEGLIGIBLE if seals and whales in the region habituate to increased background noise levels. Nevertheless, since this potential area of concern cannot be fully resolved on the basis of the existing data, the proponents of this development will continue to support additional monitoring programs on the interactions between marine mammals and industry activities in the Beaufort Sea region (Volume 7, Section 3.2.1).

2.3.7 ARTIFICIAL ILLUMINATION

Offshore and coastal sources of artificial illumination (lights)are likely to include 2 or 3 gas flares at any given time in the production zone, and a variety of lights at shorebases, offshore platforms and construction camps, as well as on barges, support vessels, drillships and tankers. The possible impacts of gas flares on mammals and birds are discussed separately in Section 2.4.1.11.

Lights may attract some marine-associated mammals to sites of human activity, although the species affected would vary with the time of year. During the winter and spring before break-up, polar bears are often observed in the transition zone off the Mackenzie Delta and Tuktoyaktuk Peninsula (Stirling *et al.*, 1981b), although most of the regional population occurs in Amundsen Gulf and off the west coast of

TABLE 2.3-11

SUMMARY OF POTENTIAL IMPACTS OF UNDERWATER SOUND IN THE BEAUFORT SEA PRODUCTION ZONE ON REGIONAL MARINE MAMMAL AND FISH POPULATIONS

	Tankers		Marine Logistics, Aircraft, Stationary Sources	
	Early Production	Peak Production	Early Production	Peak Production
White Whale (SP*,S,F)	Negligible	Minor	Negligible	Minor
Bowhead Whale (SP,S,F)	Negligible	Minor	Negligible	Minor
Ringed and Bearded Seals (SP,S,F,W)	Negligible	Minor	Negligible	Minor
Fish (SP,S,F,W)	Negligible	Negligible	Negligible	Negligible

*Season affected:
SP = spring; W = winter; S = summer; F = fall.

Banks Island. Arctic foxes are widely distributed on the landfast ice during the winter and spring.

Lights on offshore exploration and production platforms and at some shorebases may attract foraging bears and foxes . Additional attractants may be human presence and cookhouse odours. However, the numbers of bears and foxes which may be attracted to offshore platforms is likely to be an insignificant proportion of their regional populations. For example, 23 polar bears were observed in the general vicinity of the Tarsiut exploration island between November 1, 1981 and April 1, 1982 (J. Ward, pers. comm.).

Although the numbers of bears and foxes attracted would probably be small, increased industrial activity in the Beaufort region is expected to increase encounters with these species, and necessitate expansion of the existing bear monitoring program. The degree of possible impact of light-related attraction (or avoidance) responses on the regional Arctic fox population is expected to be NEGLIGIBLE. Possible impacts on polar bears as a result of the combined attraction of odours, artificial illumination, airborne noise and human presence would likely be MINOR because nuisance animals would have to be removed. Although mitigative measures include sedation and removal of live bears, some may have to be destroyed for reasons of human safety.

Some species of birds may also be attracted to lights and flares at offshore operations and shorebases. Those most likely to be either attracted to or collide with lighted offshore structures include loons, king and common eiders, oldsquaws, glaucous gulls, thick-billed murres and black guillemots, since these species migrate offshore at low altitudes and some are not very manoeuvrable in flight (ESL, 1982). There are occasional records of waterfowl and seabirds being killed after colliding with illuminated structures (R.D. Jones Jr., cited in Avery *et al.*, 1978; Dick and Donaldson, 1978).

Since spring migration over the Beaufort Sea occurs during May and June when daylight is continuous, attraction of birds to sites with artificial lighting is unlikely. An exception to this may occur during times of poor visibility (ESL, 1982). Attraction of birds to light sources is more likely during the late summer and autumn when days are shortening, limited visibility is more common, and many species of birds begin their fall migration out of the region (Volume 3A; Section 4.3). Although a few birds may collide with the superstructure of offshore facilities during darkness or low visibility, the degree of potential impact of these losses on regional populations is expected to be NEGLIGIBLE.

2.3.8 SUMMARY OF POSSIBLE IMPACTS OF COMMON WASTES AND DISTURBANCES

2.3.8.1 Air Quality

Gaseous and particulate emissions generated by ships, shorebases and offshore platforms are expected to conform to regulatory guidelines. The effects of these emissions on air quality are likely to be LOCAL and SHORT-TERM, although the cumulative impacts of multiple emission sources to the year 2000 cannot be reasonably predicted at this time. The generation of ice fog may be of some concern in areas such as near airports. However, emission sources will be widely separated geographically, and the wind climate over the Beaufort should rapidly disperse emissions under most conditions. As development proceeds, air quality monitoring programs and dispersion modelling, if deemed necessary, can be conducted in order to ensure adherence with air quality guidelines.

2.3.8.2 Water Quality

The discharge of treated domestic sewage from ships, exploration and production islands and shorebases is not expected to have significant effects on the regional water quality of the Beaufort Sea. The sewage which would be discharged from all shorebases, vessels and production and exploratory platforms by the year 2000 would be equivalent to that discharged from a town with a population of about 5,000.

Sewage discharges in offshore waters will be rapidly diluted and degraded, and zones of increased organic loading and nutrient enrichment will be confined near outfalls. Possible impacts on water quality are therefore expected to be LOCAL, and SHORT-TERM from vessels or LONG-TERM from offshore platforms. Similarly, the effects of treated sewage discharge from shorebases are expected to be limited to the area surrounding the outfalls. Possible impacts of future sewage discharges at shorebases on water quality would be LOCAL and LONG-TERM.

2.3.8.3 Marine Mammals

There is concern that underwater industrial noise may disturb or mask the communicatory or echolocatory signals of some species of marine mammals in the Beaufort Sea. Lack of information on hearing thresholds and function of vocalizations for some species hampers assessment of possible effects. The possible impacts of most other common wastes and disturbances from the proposed development on marine mammals would generally be NEGLIGIBLE, either because a particular species is not considered susceptible to the activity, or because the number of individuals which may be affected would be small compared to the size of the regional populations.

Bowhead whales may be the mammal most susceptible to disturbance or masking from underwater noise, because of the low frequencies of their vocalizations, and presumably their hearing sensitivity. These low frequencies correspond most closely with the low frequency underwater sounds generated by most industrial machinery. However, studies to date in the Beaufort Sea indicate that bowheads are not visibly or obviously disturbed by stationary sources of underwater noise and it is concluded that the present level of underwater noise in the region has probably had NEGLIGIBLE impacts on bowheads. The potential long-term implications of increasing levels of marine vessel traffic, tanker activities and aircraft operations are uncertain, but may have impacts ranging from NEGLIGIBLE to MINOR on this population. The bowhead monitoring program will be continued by the petroleum industry as indicated in Volume 7, Chapter 3, to evaluate possible effects as development proceeds.

White whales may also be affected by industrial sources of underwater noise in the offshore production zone. Vessel and aircraft activities will be restricted in the Mackenzie River estuary whenever possible to avoid interaction with this species where they concentrate in July. Studies indicate that white whales are generally undisturbed by existing stationary sources of underwater noise in the Beaufort Sea, but may locally react to mobile logistics traffic in some instances. The present level of industrial underwater sound appears to have had NEGLIGIBLE impacts on white whales to date, although the long-term impacts associated with increasing industrial activity could range from NEGLIGIBLE to MINOR.

By 1986, when oil production begins, the possible impacts of underwater industrial noise on ringed and bearded seals in the Beaufort Sea would probably be NEGLIGIBLE, since only a small proportion of the regional population would be affected and seals have frequently been observed close to operating drillships and dredges. However, increases in the number of noise sources by the year 2000 may have NEGLIGIBLE to MINOR impacts on seals through masking or disturbance.

Ringed and bearded seals may dive repeatedly in response to frequent low overflights during their 2 to 3 week haul-out period in June. The proportion of the regional population which may be affected in this manner would be small and the impacts would likely be MINOR. This impact rating would be reduced to NEGLIGIBLE by minimizing the number of flights over haul-out areas and increasing flight altitudes to 458 m (1,500 ft) during the haul-out period.

Polar bears and Arctic foxes may be attracted to sites of human activity including offshore structures, shorebases, and landfill sites. Attraction would probably result from a combination of several factors including human presence, cookhouse odours, airborne noise, and artificial illumination. The bear monitoring program described in Chapter 3 of Volume 7 will be continued to reduce direct human interactions, although some nuisance bears may have to be destroyed if sedation and live removal proves ineffective. The current degree of impact on bears resulting from the removal of nuisance bears from offshore sites of industrial activity is NEGLIGIBLE. However, an increase in the frequency of encounters and the number of bears removed could result in a MINOR impact on the regional population. The number of Arctic foxes which may be attracted to sites of human and industrial activity would be small in a regional context, and the potential impacts on this species would likely be NEGLIGIBLE.

2.3.8.4 Birds

Airborne noise produced by helicopters and STOL aircraft, particularly when flying at altitudes lower than 305 m asl (or agl), may have adverse effects on some species of birds in the Beaufort region. These effects could include habitat loss, increased energy expenditures, and behavioural reactions that may increase mortality of adults and young. The potential impacts of all other common wastes and disturbances on birds are expected to be NEGLIGIBLE.

During spring, snow geese and white-fronted geese may be disturbed by aircraft overflights when they are on their staging grounds in the Kittigazuit Bay area, while snow geese nesting at Kendall Island and brant nesting at colonies in the outer Mackenzie Delta and near Atkinson Point may also be affected by airborne noise during their breeding period. White-fronted geese, whistling swans, raptors, common eiders, black guillemots, glaucous gulls, Sabine's gulls and Arctic terns could also be disturbed by aircraft during the breeding season because they nest colonially and are susceptible to disturbance by aircraft. Moulting, non-breeding geese and swans, and moulting and brood-rearing ducks may be disturbed by aircraft during summer and late fall, while snow geese and white-fronted geese staging along the Yukon North Slope and in the Mackenzie Delta during September may be disturbed by aircraft flying to and from a Yukon coast shorebase (Chapter 3).

To reduce or eliminate impacts of airborne noise on birds, the proponents will adhere to accepted aircraft flight restrictions when and where possible. These mitigative measures would include flight altitudes of at least 305 m agl (or asl as applicable) in all areas when weather conditions permit; complete avoidance of overflights of certain important concentration areas for birds at specified times of the year, and maintenance of at least the minimum guideline altitude during overflights of other important areas for birds; or avoidance of these areas if a minimum altitude of 305 m cannot be maintained. Restricting aircraft operations in this manner will limit possible impacts of airborne noise on regional bird populations to between MINOR and NEGLIGIBLE.

2.3.8.5 Fish and Lower Trophic Levels

The disposal of sewage from offshore oil and gas processing facilities and the settling of solids at shorebase sewage outfalls may eliminate some sea bottom habitats and adversely affect local benthic invertebrate populations and demersal fish species for the duration of development. However, the areas affected would be insignificant in relation to available habitat, and the degree of regional impact of these wastes on fish and benthic fauna is expected to be MINOR.

Fish would likely detect industrial underwater noise within several kilometres of drilling platforms, vessels and dredges, and both avoidance and attraction to these sites of activity are considered possible. However, since mortality would be unlikely and areas in which altered behaviour of some fish species occurs should be limited, the regional impact of underwater noise on fish would probably range between NEGLIGIBLE and MINOR. The possible impacts of all other common wastes and disturbances on the regional fish populations are expected to be NEGLIGIBLE.

Nitrogen enrichment in the vicinity of sewage outfalls from shorebases may cause a slight increase in the rate of primary production by phytoplankton, however, resultant beneficial effects would probably be MINOR, and local. All other wastes and disturbances common to most industrial activities in the region are expected to have NEGLIGIBLE impacts on members of lower trophic levels.

2.4 IMPACTS OF OFFSHORE EXPLORATION AND PRODUCTION ACTIVITIES AND FACILITIES

This section focuses on the possible impacts of the proposed development which are expected to be unique to offshore exploration and/or production facilities and activities, with emphasis, wherever possible, on the initial four offshore oil fields (Tarsiut, Koakoak, Issungnak, and Kopanoar). Possible impacts of many of the wastes and disturbances which are common to a number of proposed activities in the Beaufort region (including those at offshore platforms), such as treated sewage and solid waste disposal, airborne and underwater noise, and air emissions were examined in Section 2.3 of this chapter.

2.4.1 OFFSHORE EXPLORATION AND PRODUCTION PLATFORMS

The following describes the possible impacts of specific activities associated with offshore exploration and production platforms including artificial islands, floating drill rigs (drillships and conical drilling units) and tanker loading facilities. The projected numbers of exploration wells and artificial islands, and descriptions of the offshore production facilities are provided in Volume 2 of this Environmental Impact Statement.

The initial phases of development are reasonably well defined and are assumed to include the Tarsiut, Koakoak, Issungnak and Kopanoar fields. A chronological summary of the major activities which are projected to take place during the development of these four fields is provided in Table 2.4-1. During this time, additional exploration islands will be built, and the first tanker loading facility will be constructed, likely at Tarsiut. In the longer term, additional offshore fields will be developed, but their locations cannot be clearly defined at present and will depend on the results of continued exploration programs.

2.4.1.1 Seismic Programs

Extensive seismic programs have been conducted in the offshore Beaufort for about ten years to delineate promising geological structures for exploratory drilling. At present, broad-scale seismic investigations of the southeastern Beaufort Sea are essentially complete. Future seismic programs will largely focus on relatively small areas for the purpose of refining information in previously surveyed areas or for delineating structures in smaller unsurveyed regions. In addition, seismic programs will be completed in conjunction with offshore island construction programs to provide detailed information on the geological character and bearing capacity of the sea floor below artificial structures, as well as for defining permafrost zones, and for locating subsea sources of granular materials for island construction and other purposes. Several seismic vessels would continue to operate during open water periods throughout the period under review.

Seismic programs will employ air guns, sleeve exploders or vibrosis units, rather than seismic explosive charges (Volume 2). Both air guns and sleeve exploders use compressed air expansion to generate sonic impulses. Air at about 1,380 Pa (200 PSI) is released from air gun chambers in arrays of from 10 to 20 air guns varying in size from 164 cm^3 to 1,640 cm^3 and generating a pulse at frequencies from 15 to

TABLE 2.4-1

CHRONOLOGICAL SUMMARY OF HYDROCARBON PRODUCTION RELATED ACTIVITIES AT THE FOUR INITIAL OFFSHORE FIELDS PROJECTED TO BE DEVELOPED IN THE SOUTHEASTERN BEAUFORT SEA

Field	Discovery Date	Assumed Recoverable Oil (million cubic metres) Per Island	Per Field	Date Wells Drilled	Production Islands Required & Completion Date	First Production Date
Tarsiut	1979	20		2 in 82	1 (85)	86*
		20		1 in 83	2 (86)	87
		20		1 in 85 & 86	3 (87)	88
		20		1 in 87	4 (88)	89
		20	100	1 in 88	5 (89)	90
Koakoak	1981	95		1 in 83	1 (88)	89
		95		1 in 85, 86	2 (91)	92
		95	285	1 in 87, 88	3 (95)	96
Issungnak	1981	32		1 in 83, 84	1 (91)	92
		32	64	1 in 85	2 (92)	93
Kopanoar	1979	80		1 in 83, 84	1 (95)	95
		80	160	1 in 85	1 (97)	97

*Using an early production system.

80 kHz (Brooks, 1980). A sleeve exploder has a rubber cylinder that receives a charge of propane and oxygen, which is ignited by an electrical spark and then generates a compressed air wave. Shock waves produced by air guns and sleeve exploders differ from those of conventional explosives in that peak pressures are low, and both the rise time of the shock pulse and the time-constant of the pressure decay are comparatively long (Geraci and St. Aubin, 1980). Although no source level measurements are available for air gun pulses in the Beaufort Sea, Fraker *et al.* (1981) recorded one seismic signal from a 'sleeve exploder' in August, 1980. Frequencies recorded 13 km from the survey vessel ranged from 160 to 500 Hz, although higher frequencies were probably present in the received signal but were filtered out by the recording equipment. The received spectrum level at 300 Hz was between 135 and 146 dB re (1 uPa)^2/Hz at a distance of 13 km.

Almost all of the environmental concerns associated with seismic exploration in the past were due to the shock waves from the large explosions used before development of air gun equipment. Shock waves produced by these explosions were compressional and had an almost instantaneous rise to a very high peak pressure, followed by a rapid decay to ambient (or below ambient) hydrostatic pressures. ESL (1982) reviewed the available information regarding the potential effects of air gun equipment on marine mammals and fish and concluded that mortality or long-term physiological stress is unlikely for any species. Most of the effects of air guns are similar to the effects of industrial underwater sound, and may include temporary behavioural disturbances of some species as a result of the sudden noise produced (see Section 2.3.6). As a result, the impacts of the continued relatively small scale seismic programs on regional populations of fish and marine mammals will probably be NEGLIGIBLE.

2.4.1.2 Physical Presence

The continued construction of artificial islands in the Beaufort Sea for exploration and production activities will increase the number of relatively long-term standing structures in the offshore area. The types of islands required, their general locations and methods of construction are described in Volume 2.

The artificial islands constructed in the Beaufort Sea have been predominantly sacrificial beach islands in shallow waters (less than 15 m), and these structures have been allowed to erode after abandonment. However, many of the proposed islands will be built farther offshore in waters up to 65 metres deep, and all of these will employ caisson type structures placed on a dredged berm. Although the sizes of islands will vary, depending on their specific purpose and on the water depth, the approximate basal areas of typical exploration or production islands and tanker loading facilities are given in Table 2.4-2, along with the maximum number of structures which could be constructed and the total area they would occupy. Assuming the technically achievable production rate, approximately 80 platforms could be constructed between 1982 and the year 2000, and these structures would occupy a combined area at the waterline of approximately 50 km^2.

The potential effects of the presence of artificial islands on the physical and biological environments

TABLE 2.4-2

PROJECTED CUMULATIVE NUMBER OF FIXED OFFSHORE PLATFORMS REQUIRED FOR THE TECHNICALLY ACHIEVABLE PRODUCTION RATE IN THE BEAUFORT SEA[1]

Year	Exploration Islands[3]	Production Islands[2]			Total
		Shallow (<20 m)	Deep (>20 m)	APLA's (20 m only)	
	No./area (km^2)	No./area	No./area	No./area	No./area
1985	6/2.5	1/0.5	0	0	7 7/3
1990	15/7.5	7/3.2	3/3	1/2.3	26/16.7
1995	30/15	12/6	12/12	2/4.6	56/37.6
2000	50/25	15/7.5	13/13	2/4.6	80/50

[1]The Technically achievable production rate assumes maximum production rate of 194,000 m^3/day (1.22 × 10^6 BOPD) by the year 2000.
[2]Assumes approximately 0.5 km^2/shallow island base, 1.0 km^2/deep island base, 2.3 km^2/APLA base.
[3]Some may be converted to production islands, depending on reserves.

of the Beaufort Sea region were reviewed in ESL (1982). Generally, there are few identifiable impacts strictly associated with the physical presence of artificial islands, and in some cases, positive effects may occur. Most of the potential impacts are associated with various disturbances or activities during construction or operation of these structures. For example, the attraction of certain animals to the islands may, in some cases, expose them to hazardous materials on the site. All of these various disturbances and activities associated with offshore structures are discussed elsewhere in this chapter.

Regionally significant alterations in oceanographic patterns due to artificial islands are considered unlikely, although some local changes in existing currents, sedimentation patterns, and wave action would occur around the islands. In addition, ice rubble fields would develop along the up-current face of many structures, while areas of thin ice and open water could also occur in the lee of structures. Ice rubble grounded around artificial islands is likely to remain attached for several days after local break-up, but should generally be restricted to within 300 m of the island (Plate 2.4-1) (Tuk-Industry Task Force, 1982). Consequently, the small areas affected by each island are not expected to be regionally significant, but as indicated earlier, these local alterations would be LONG-TERM due to the projected duration of hydrocarbon development in the Beaufort region.

Concern has been raised by residents of the Mackenzie Delta and adjacent coastal areas that artificial islands built beyond the outer edge of the landfast ice may cause an extension of the landfast zone and a delayed break-up. However, reviews of satellite photographs have indicated that marked natural fluctuations in the extent of the landfast zone occur (e.g. up to 25 km variation among years) in the region (Plate 2.4-2). Likewise, satellite photographs of existing islands near the landfast zone (Issungnak, Tarsiut) have not demonstrated any extension of landfast ice or delay in general break-up in comparison with historical data (Tuk-Industry Task Force, 1982). However, at Tarsiut in the spring of 1982, it appeared that the landfast ice in the vicinity of this location may have been held up by the physical presence of the island. To ensure that break-up in this area would not be unduly delayed, the KIGORIAK was used to loosen the ice around the island. This measure proved to be successful, and can be employed in the future as required at other island sites. On this basis, it is believed that the physical presence of islands will have only LOCALIZED impacts on the ice regime

PLATE 2.4.1 *Artificial islands in the offshore Beaufort Sea will cause local effects on the ice regime but are not expected to cause significant problems.*

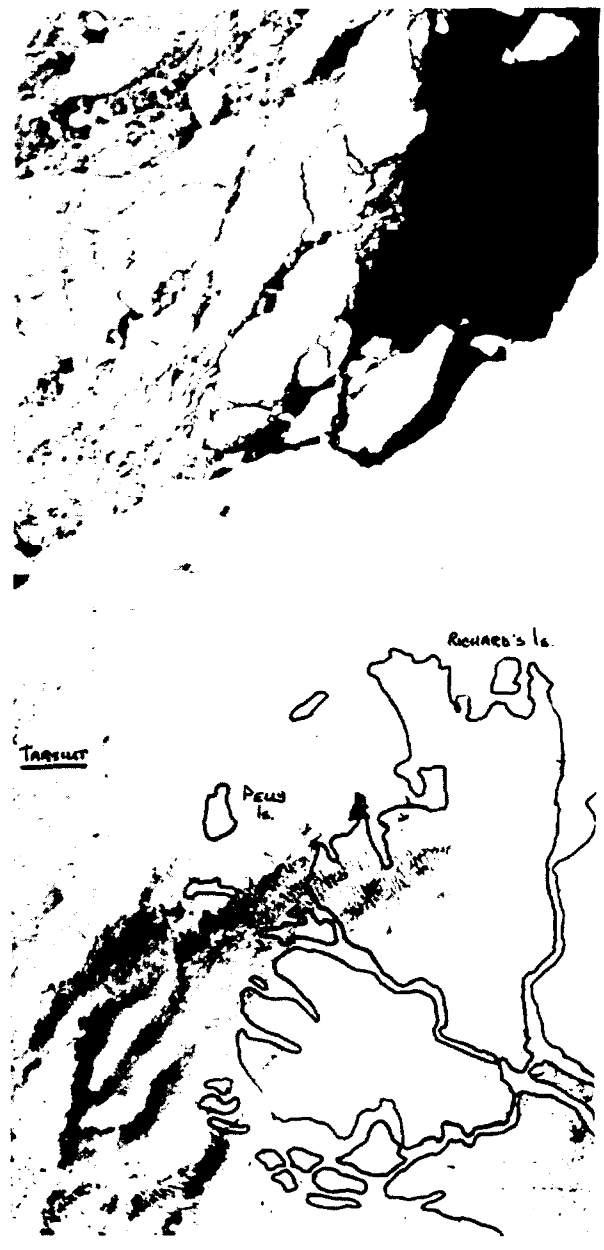


PLATE 2.4-2 *Extent of landfast ice along the Mackenzie Delta in 1982. The winter of 1981-82 was colder than many previous winters, therefore the landfast ice extended quite far out and well beyond the location of the Tarsiut artificial island.*

and that possible impacts such as delayed break-up can be mitigated by the judicious use of icebreakers.

A potentially greater threat to the natural break-up cycle of the landfast ice may be posed by proposed dams on the Liard River of the Mackenzie System. Although it is not the purpose of this Environmental Impact Statement to assess the impacts of other unrelated developments, damming of the Liard River would likely affect the flow of the Mackenzie River itself. According to Environment Canada (1981), damming of the Liard will result in greater winter flows, resulting in thicker ice in the Mackenzie River during winter, and lower flows in spring during freshet, due to the fact that water will be collected behind dams during this time. Since the Mackenzie River has such a great influence on break-up of the landfast ice in the area around the Delta (Volume 3A), the aforementioned effects, if they were to occur, would likely contribute to delayed break-up of the landfast ice. This, in turn, could delay the arrival of beluga whales into the estuary, with unknown, but possibly negative side-effects.

Upon completion of drilling, many of the exploration islands would be abandoned. At islands where caisson construction is employed, the caissons would be removed, leaving only a subsea berm well below the sea surface. The remaining berms would be indistinguishable in the long-term from many pingo-like features which already exist on the Beaufort Sea floor (Volume 3A; Section 1.4). Abandoned sacrificial beach islands may remain as surface features for longer periods, but will undergo gradual erosion from ice and wave action. All island sites are considered as potential hazards to shipping, and as such are marked on nautical charts as required by the Navigable Waters Protection Act.

In general, the presence of artificial islands in offshore waters of the Beaufort Sea will not have greater than NEGLIGIBLE impacts on regional marine benthic invertebrate and fish populations, and may result in some localized positive effects. Shelter produced by some production platforms such as tanker loading facilities, and hard surfaces associated with protective material such as rock, may promote benthic colonization and attract fish, and therefore may increase benthic invertebrate and fish diversity at these sites. For example, videotape records (by Can-Dive Ltd.) of a BOP stack (Orvilruk) in the Beaufort Sea which had been abandoned for approximately one year, indicated the presence of a colonizing epibenthic community that was considerably more diverse than that observed in adjacent soft substrate areas.

Most of the effects of the physical presence of offshore artificial islands on mammals and birds would be indistinguishable from the impacts of other activities and disturbances at the sites. A discussion of these impacts can be found in Section 2.3. Impacts on birds and mammals solely attributable to the physical presence of islands are generally expected to be NEGLIGIBLE. For example, artificial islands present in the Beaufort Sea to date have not been found to have any obvious or visible effects on whales (ESL, 1982). Some birds may collide with the superstructures of islands during periods of poor visibility, but even these effects would be MINOR on a regional basis.

2.4.1.3 Water/Glycol BOP Control Fluid Discharge

Drilling regulations require that blowout preventers (BOP stacks) be tested approximately every 2 weeks. Each test results in the release of approximately 0.45 m^3 of BOP control fluid per discharge per wellhead while exploratory drilling is in progress. Although released BOP fluid can be recovered and stored on bottom-founded drilling platforms such as artificial islands, there is no practical means of recovering the fluid from subsea wellheads below floating drilling units, and it is therefore released directly into the water column. Assuming the technically achievable production rate, during the period from 1982 to the year 2000, approximately 3 wells will be drilled per year by the four conventional drillships (which operate for only 3 to 4 months), while a total of 10 to 15 wells would be drilled per year by up to 5 conical drilling units, operating for 8 to 10 months of the year with icebreaker support. These units are projected to be brought into operation in 1983, 1985, 1988, 1989 and 1991. On this basis, approximately 0.4 to 0.6 m^3 (2.6 to 3.6 bbls) of BOP fluid could be released per day from all vessels during periods of open water (4 months), and a maximum of 0.3 to 0.5 m^3 (2.0 to 3.0 bbls) per day by 1991 during winter periods when the full complement of conical drillships may be operating. The annual input of BOP control fluid to the offshore Beaufort would depend on the actual operational period of each type of floating drill rig, but would not exceed 130 to 190 m^3 (800 to 1,200 bbls) when the entire fleet is operating.

Studies on the potential effects of BOP control fluid on flora and fauna of the Beaufort Sea were reviewed by ESL (1982). The primary constituent is ethylene glycol which is only moderately toxic to most organisms and is degraded by a wide variety of microorganisms. The most significant biological concerns would probably be associated with localized accumulations of the fluid in the glory hole surrounding each BOP stack and depressed oxygen levels where the fluid is slowly biodegraded. On the basis of a 0.45 m^3 discharge of fluid per function-test and approximate glory hole water volumes of 50,000 m^3, it is unlikely that concentrated glycol would spread beyond the glory hole. Both microbial degradation and dilution in surrounding waters would tend to prevent its accumulation elsewhere. As a result, the routine discharge of BOP control fluid on water quality is expected to be LOCAL and SHORT-TERM. Glory holes are disturbed habitats where localized dredging would have removed all benthic infauna, most epifauna and possibly some demersal fish (Section 2.4.2), although some benthic recolonization and use of the area by fish would be expected, even while exploratory drilling is in progress. Consequently, the relatively small discharges of BOP fluid may have a MINOR impact on benthic fauna and fish in the glory hole, but these impacts would not be regionally significant. Since marine mammals are not likely to occur within glory holes and plankton species are ubiquitous, the impacts of BOP control fluid on these resources will likely be NEGLIGIBLE.

Once each exploration well is completed and the discharge of BOP control fluid ceases, more rapid recolonization by benthic invertebrate species and fish may be expected in the localized areas surrounding the BOP stacks. Fish could also be attracted to these habitats and benefit from increased food availability, although from a regional perspective, this effect would probably be insignificant.

2.4.1.4 Drilling Fluids and Formation Cuttings

During both exploratory and production drilling for oil and natural gas, drilling fluids (commonly referred to as 'drilling mud') play a very important role. It not only flushes the broken rock away and lubricates the bit, but the weight of the drilling mud column provides the pressure that prevents the fluids in the rock formation from flowing into the hole. Since the drilling mud is a continuous column from the bottom of the hole to surface, it exerts pressure at the bottom of the hole and throughout its length.

Because the drilling fluid serves a number of functions, and because large volumes are pumped considerable distances down the drill pipe and up the outside, the properties must be carefully controlled. The critical properties of drilling fluid are density, viscosity, resistance to shear, and the tendency to cause the rock face to deteriorate.

Drilling mud is usually a complex mixture of water, thickening agents, corrosion inhibitors, lubricating components, thinners, freeze dispersants and clay inhibitors. Because of these additives the fluid is always heavier than water. Additional weight is created by adding an inert dense solid called barite (barium sulphate). When properly mixed with the other mud materials, it is possible to increase the density of drilling mud to twice that of water, and under special circumstances even higher. In addition to barite, chemical additives consist primarily of clay, potassium chloride, sodium bicarbonate, and small quantities of organic materials.

The drilling fluid, which is usually water-based, is transported from a surface reservoir by mud pumps and forced down the centre of the steel drill pipe as the drilling progresses. It enters the bore hole through nozzles in the bit, picking up the formation cuttings, and returns to the surface between the drill pipe and the walls of the bore hole and/or the casing. When this material reaches the surface, it is diverted through a shale shaker screen to remove the larger formation cuttings which may reach a diameter of 4 mm. These cuttings are sprayed with water as they move down and fall off the slanted, vibrating shale shaker, and are then released to the surrounding water. The larger drill cuttings typically settle close to the point of discharge (Zingula, 1975). These accumulations may be resuspended and dispersed over time, particularly in shallow high wave energy environments (Meek and Ray, 1980). Drilled solids which are too fine to be separated from the drilling fluid by screening are generally removed by gravity segregation and centrifugation, and then discharged with solids removed on the shale shaker. When oil-based drilling muds are required for a specific drilling program (e.g. when formation temperatures are very high or when damage to the formation must be minimized), other equipment such as a cuttings washer is used to remove hydrocarbons from the cuttings prior to their disposal. Free hydrocarbons are usually gravity separated and then returned to the mud system.

After separation and disposal of the cuttings, the drilling mud is returned to the reservoirs ('mud tanks') for recirculation down the bore hole. Relatively small volumes of drilling mud are continuously lost through disposal with the cuttings, while larger amounts are discharged when water or additional solids are added to adjust the properties of the mud as the drilling program progresses. When a completely different mud system is needed, such as after installation of casings, or when the properties of the mud must be completely changed for deeper formations, the old drilling fluid is discharged to the sea, in the case of offshore operations, and into a sump on land. The water based drilling mud is also typically discarded at the conclusion of a drilling program.

The volume of fluids used during the drilling of exploratory and production wells will vary from well to well, depending on factors such as the depth of the hydrocarbon formations and the need to change the formulation of the mud system as drilling progresses through different geological strata. Based on drilling experience to date, approximately 1,500 m^3 of water-based drilling mud are used and discharged during the drilling of a typical 4,000 m well in the Beaufort Sea. This figure will be used in the following discussion to estimate the quantities of drilling fluids which may be released to the environment over time. However, it is a conservative figure since many wells will not be drilled that deep (for example, the primary hydrocarbon bearing zones at Tarsiut and Issungnak are located at 1,500 m.); once development drilling proceeds more of the drill mud can be re-used; and where oil-based drill muds are used, the fluids will be almost completely recycled.

Assuming the intermediate development rate, approximately 50 wells could be drilled by 1985, 275 by 1990, 570 by 1995 and 725 by the year 2000 (Volume 2). By comparison, in the Gulf of Mexico, between 1954 and 1980 more than 17,000 wells had been drilled (Guice and Hendricks, 1980). If one then assumes that 1,500 m^3 of drill mud was discharged per well, the cumulative quantities of drill mud involved would amount to 75,000 m^3 in 1985, 412,500 m^3 in 1990, 850,000 m^3 in 1995, and 1,100,000 m^3 by the year 2000. On an annual basis this would work out to approximately 18,000 m^3/year between 1982 and 1985 and 65,000 m^3/year between 1990 and the year 2000.

The bulk of the drill muds would be released to the environment at production islands, where between 30 and 80 wells may be drilled per island, depending on various factors. Therefore, at the Tarsiut field for example, assuming there will eventually be five islands, and further assuming that 50 wells are drilled per island, then 250 wells, or approximately 375,000 m^3 of drill muds could be released to the sea in this area.

In addition to the drilling mud, approximately 400 m^3 of formation cuttings are estimated to be released per well. Assuming an average of 40 wells per year over the next 18 years, and a maximum of 80 wells in 1990, approximately 16,000 m^3 of cuttings could be generated on an average annual basis, and 32,000 m^3 during the peak year of 1990. On this basis, the cumulative total of cuttings released by the year 2000 could amount to 290,000 m^3. When combined with the projected quantities of drilling fluids to be used, the total amount of both drilling fluids and formation cuttings which could be released to the environment by the year 2000 would approach 1.4 million cubic metres. By comparison, the volume of tailings discharged from metal producing mines to the sea in British Columbia may exceed 20 million m^3 per year (Goyette and Nelson, 1977).

The main environmental concerns associated with the disposal of drilling fluids and formation cuttings are the potential toxicity of certain chemical additives such as volatile organics, increased turbidity in the water column, smothering of benthic infauna, and the possible accumulation of trace metals in sediments and food chains. These concerns have been the subject of considerable research by both government and industry, and were reviewed in detail in ESL (1982).

While the major constituents of drilling fluids used in the Canadian north and virtually all drill cuttings are inert and relatively non-toxic, some minor additives to mud systems such as metal chlorides, lignosulphonates, biocides, rust inhibitors and defoamers may be toxic to some species. Nevertheless, laboratory bioassays of whole muds used in Arctic drilling programs indicate relatively low toxicity values (96-h LC_{50}* values from 0.4 to 13%) with many marine invertebrates and fish (McLeay, 1975). It should also be recognized, however, that several studies have indicated that larval forms are more susceptible to toxic effects of many chemicals than are the adults, which tend to be most commonly used in bioassays. Drilling wastes are normally diluted rapidly in receiving waters, further reducing potential toxic effects, except in shallow waters (less than 5m) or when ice cover limits effective water depth and/or restricts adequate dispersal of wastes. Dilutions of several thousand times the discharge concentrations usually occur within 100 m of drill mud disposal sites (Hammer, 1982). Therefore, any impacts of toxic chemical additives to drilling fluids on water quality of the Beaufort Sea would be LOCAL and SHORT-TERM. There is also general consensus in the literature that significant acute toxic effects of drill fluids and cuttings on marine organisms are not likely to occur in the areas of drilling waste disposal.

The discharge of particulates contained in drilling wastes will alter bottom sediment composition, bury some benthic organisms, and create localized areas of high turbidity and suspended solid concentration. However, most of these effects would be relatively insignificant in relation to similar effects associated with dredging, which would occur over a much wider regional scale (Section 2.4.2). For example, approximately 1.5 million m^3 of drilling muds and formation cuttings may be discharged during the entire development to the year 2000, while between 500 and 700 million m^3 of bottom materials may be dredged during the same period.

The results of numerous studies on drilling fluid disposal in various parts of the world suggest that most solids from the drilling wastes settle relatively quickly, and are largely confined to a radius of approximately 25 to 200 m surrounding the discharge site (Zingula, 1975; Hammer, 1982). Usually about 5 to 7% of the solids remain suspended in the liquid phase and become part of the turbidity plume after drilling wastes are released to the marine environment (Osborne, 1982). The size of the plume and concentrations of suspended solids may vary with water depth, currents, wave action and the particle size composition of the muds and cuttings. However, Hammer (1982) indicates that under normal discharge conditions in temperature and northern environments, background suspended solid levels appear to be reached within 100 to 500 m of the outfall, depending on discharge rates. Nearshore areas which are affected by the discharge of the Mackenzie River are normally characterized by wide fluctuations in suspended sediments, and are less likely to be significantly affected by suspended solids from drilling waste disposal. As a result, changes in water quality associated with drilling waste-related turbidity increases would be LOCAL and SHORT-TERM. Within these localized areas, adverse effects on marine flora and fauna would be similar to those described in the following section dealing with impacts of dredging (Section 2.4.2), although confined to smaller areas.

The discharge of formation cuttings and waste drilling fluids from exploration and production platforms would result in localized burial of benthic organisms. Data collected in the Beaufort Sea and elsewhere suggest that the area affected by larger solids present in drill muds and the drill cuttings released from shale shakers is generally less than 200 m from the discharge site (ESL, 1982). Within this or a smaller radius, benthic infauna and sessile epifauna would either be directly buried by solids which settle through the water column, or experience a change in the substrate in which they are living, resulting from a decrease in the sediment particle size composition (ESL, 1982). The latter effects would tend to occur outside the immediate area where the formation cuttings rapidly settle to the sea floor, since clays present in the drilling muds and fines not removed by the shale shakers would be transported greater distances from disposal sites before they eventually settle. Demersal fish and mobile epibenthic invertebrates would probably be able to avoid burial by drilling wastes, and therefore would not be affected to the same extent as benthic infauna and sessile epifauna.

The concentrations of trace metals in formation cuttings and in drilling fluids used in the Beaufort Sea region were discussed in ESL, (1982), and in a recent report by the Offshore Drilling Fluid Disposal Industry/ Government Steering Committee (1982). In areas of low current velocity, cuttings and their associated metals would accumulate on the sea floor close to the exploration or production platforms. Although trace metal content varies with the geological formation being drilled, all metals are bound within the mineral lattice structure and are not readily available for biological uptake. However, they may become soluble under certain conditions, producing increased concentrations of biologically available metals in the bottom waters (ESL, 1982). Trace metal concentrations in the upper portions of the water column are unlikely to be affected by formation cutting disposal.

Trace metals are also present in most drilling fluid constituents, but the majority are associated with barite (a weighting agent) and are not readily available for biological uptake. Metals may be incorporated into the barite structure or they may form insoluble sulphide minerals. On the other hand, some constituents of drilling fluids such as ferro-chrome lignosulphonate, may contribute dissolved trace metals

*96-h LC_{50} is the concentration of a chemical which will kill half of the organisms in a bioassay test in a period of 96 hours.

to the marine environment: these metals are found within the interstitial water of drilling fluids. Thomas (1978a) measured dissolved trace metal concentrations in the interstitial waters of a drilling fluid used in the Beaufort Sea and compared these levels with those reported for seawater in the Beaufort Sea and world coastal oceans, as well as recommended levels for environmental protection. Only the concentration of mercury in drilling fluid interstitial water exceeded the range for unpolluted seawater, although it did not surpass the level considered hazardous by the Environmental Studies Board (1972). Concentrations of cadmium, iron and nickel exceeded minimum risk levels, but did not surpass levels considered a hazard, and were within the observed ranges for either the Beaufort Sea or world coastal oceans. Consequently, the degree of concern regarding the effects of trace metals from drilling fluids, even in undiluted form, appears to be minimal.

In a study comparing total trace metal concentrations in a drilling mud with background sediment levels in the Beaufort Sea, Crippen *et al.* (1980) reported that concentrations of mercury, lead, zinc, cadmium and arsenic in the drilling mud exceeded background sediment levels by factors of 185, 35, 15, 9 and 2.4, respectively. A potential for metal accumulation in sediments surrounding drilling operations is suggested by these results, and is supported by studies completed at Tingmiark K-91 in the Beaufort Sea (Thomas, 1978b). The latter author reported that total mercury, lead, zinc, cadmium and chromium, as well as copper concentrations decreased with increasing distance from the wellhead.

The possible bioaccumulation of these metals in benthic fauna, and subsequent effects related to the ingestion of contaminated benthic organisms by higher members of the food chain, have been the subjects of intensive investigation over the last decade. The potential effects of trace metals from drilling wastes on various classes of marine biota are discussed in detail in ESL (1982). In general, no consistent increases in the concentrations of trace metals in benthic organisms have been documented surrounding drilling waste disposal sites in the Beaufort Sea or in other marine areas (Volume 3A, Section 1.5; ESL, 1982), although elevated metal levels have been frequently reported in marine sediments. A number of laboratory studies have shown that drilling fluids can cause a range of sublethal effects, and in some cases, mortality of test organisms. However, concentrations and exposure times required to produce acute lethal effects are normally well beyond those which could be achieved in marine environments.

In a recent review of the potential concern regarding inputs of mercury, lead, copper and zinc from drilling wastes to the Beaufort Sea, Macdonald (1982) compared the concentrations in background sediments and other natural sources and concluded that, in general, the chemical nature of the mercury, lead and zinc in drilling fluids suggests that they are not particularly mobile and will remain largely incorporated in the sediments near disposal sites. For example, although mercury occurs in relatively high concentrations in drilling muds, it appears to be adsorbed to particulates in the mud (particularly bentonite) in an insoluble inorganic form. Methylation, a process which converts this mercury to an organic and biologically active form, does not appear likely under most circumstances (Kramer *et al.*, 1980; Macdonald, 1982). A number of other studies have also suggested that trace metals in drilling wastes have a low solubility and biological availability under normal conditions (ESL, 1982). Limited uptake of zinc, lead and copper by benthic invertebrates is possible in the immediate vicinity of drilling waste discharge sites, although the affected habitats would be relatively localized and regionally insignificant.

In summary, the degree of impact of drilling waste disposal on benthic invertebrates and possibly some demersal fish species at most offshore exploration and production platforms would probably be MINOR. The most likely effects could include localized mortality of benthos in the vicinity of waste discharges due to direct burial, altered substrate characteristics affecting its suitability as habitat for some species, and possibly sublethal effects of some toxic additives on both invertebrates and fish. However, none of these potential effects would be considered regionally significant because of the small amount of offshore habitat affected by drilling waste discharges. The impacts of long-term disposal of drill muds and formation cuttings on trace metal levels in the marine environment and other biological resources, including planktonic organisms, birds and marine mammals are expected to be NEGLIGIBLE. These predictions support the experiences reported in other parts of the world, such as the Gulf of Mexico (Guice and Hendricks, 1980) and the Forties Field in the North Sea (G. Larminie, pers. comm.), where no significant long-term impacts of the discharge of normal oil drilling wastes into the sea on the aquatic resources have been found to date.

2.4.1.5 Completion and Maintenance Fluids

Completion fluids are the dense, clear fluids used to replace the drilling fluids when completing a well and preparing it for future use as a producer. The fluids serve to keep the geological formation clean so that production can be facilitated when it begins.

During offshore well completion operations, completion fluids will be used to place gravel packing into each well. Compounds which may be used in completion fluids include zine bromide, calcium bromide and calcium chloride. When being used, this fluid is circulated in the same manner as drilling fluid, except that there is no release of solution to the marine environment during placement. In addition, an acidizing process is carried out to clean the formation. Both completion fluids and acidizing fluids, including hydrochloric, hydrofluoric and hydrobromic acid, contain low concentrations of a number of additives such as surfactants and viscosifiers.

Most of the acids and some completion fluids are lost through migration into the subterranean geological structures. However, approximately 80 m^3 (500 bbls) of acidic fluid containing elevated levels of dissolved zinc and bromide may be drawn back out of the formation when the well is re-entered for testing or production purposes, and may be released following dilution into the marine environment. It is estimated that releases of this kind may occur two to three times during the life of a well. Acidic fluids are also released by the fracking process during well workovers, when acids containing various additives are pumped into a producing well to stimulate or maintain a clean flow of oil. This discharge of acidic solutions may occur once or twice in the life of a well. Since these events will be specific to each well and dependent upon several factors, such as the reservoir characteristics, productivity of the well and the rate of petroleum production in the region, it is not possible to estimate the total quantities of completion or maintenance fluids which could be released during the early and long-term production phases of the development.

Hydrocarbon levels in the material drawn from the well would be reduced to 50 ppm prior to discharge of the fluid to the marine environment. Consequently, the principal environmental concerns would be associated with the potential toxicity of certain chemical additives and the possible localized accumulation of trace metals by some flora and fauna. Due to its relatively high density, the acidic fluid would sink and be rapidly buffered and neutralized by the sea. The dissolved zinc (if zinc bromide is used) would tend to chelate with the organic matter and anions normally present in seawater and precipitate out of solution. However, due to the periodic nature of the release, and the relatively limited quantities of solution which would be involved, no significant accumulation of zinc would be expected to occur solely from the release of completion fluid, although there may be some slight addition to levels produced through the release of other drilling wastes. Since these fluids would be diluted prior to release, and rapidly buffered, impacts on water quality and biological resources would probably be LOCAL/SHORT-TERM and NEGLIGIBLE, respectively.

2.4.1.6 Tritiated Water Discharge

To differentiate between formation water and drilling mud filtrate in drill stem tests conducted in the Beaufort Sea, drilling muds used in exploration wells may occasionally be injected with low concentrations of tritiated water as a radioactive tracer. When used, the concentrations of tritiated water in the mud systems average approximately 0.001 uCi/ml drill mud or the equivalent of 3,000 DPM.

The use of tritiated waters in hydrocarbon exploration has been endorsed subject to prescribed guidelines, by the Atomic Energy Board of Canada and the Radiation Protection Division of the Department of National Health and Welfare. Only trained personnel handle the tracer on drilling platforms. Drilling muds would have a tritium concentration of 0.001 uCi/ml prior to discharge into the marine environment, and will be below the maximum permissible discharge level of 0.003 uCi/ml (6,600 DPM). It is anticipated that the impacts of occasional tritiated water discharge on the marine biota of the Beaufort Sea region will be NEGLIGIBLE as long as the present and proposed low concentrations are released to the marine environment.

2.4.1.7 Formation Water (Produced Water)

Formation water is water that is brought up (produced) from the hydrocarbon reservoir, along with the oil and/or gas. Once at the surface, it is separated from the hydrocarbons and then either reinjected into the reservoir or treated prior to discharge, usually to the sea. Although this discussion will address formation water specifically produced by the oil industry, it should be noted that in some parts of the world, formation water is released naturally into the sea through vents in the sea floor (Ballard and Grassle, 1979), and some information on their findings will be presented where appropriate.

Early in the life of an oil field, there will be very little water produced with the oil. Eventually, however, water will be produced and toward the latter half of the life of the field, it will likely be produced in large quantities. In a field that is 20 years old, it is not unusual for a stream produced from the wellbore to contain more than 80% water.

In offshore operations, the methods selected for disposal of formation water will depend on the configuration of the production process and the characteristics of the oil well fluid. At Cook Inlet, Alaska, free water is separated offshore and the remaining water, which is difficult to separate, is transported to shore along with the oil through a subsea pipeline system. The additional water is removed onshore. Since it was deemed impractical to send the water back to the platforms for reinjection, largely because this would have required another pipeline, the water is treated and disposed of into the ocean in accordance with environmental regulations.

At Cook Inlet, as in most offshore operations, the source of water for water injection schemes is seawater since it is available in copious quantities and usually requires little treatment. It is, therefore, more economical to use seawater for all water requirements than it is to process and reinject produced water. In the Beaufort, where practical and feasible, formation water from offshore fields will be reinjected back into the reservoir. This practice will not be feasible in situations where seawater may adversely affect well producibility.

However, since produced water can only be reinjected into the reservoir when injection wells have been drilled, 2 to 3 years after production has begun, the water generated during these years will be treated with oil-water separators to reduce oil concentrations to less than 50 ppm, as required by the Canadian Oil and Gas Production Regulations, prior to discharge to the sea. As injection wells are completed, most of the produced water will be returned to the reservoir, except in those cases where doing so may cause problems to the reservoir, in which case it will also be released to the sea following adequate treatment.

At present, it is not possible to predict the proportions of formation water that would be reinjected or discharged. However, for this assessment it is assumed that the quantity of water produced could range from 81,000 m^3/day when the oil production rate reaches 81,000 m^3/day (500,000 barrels/day) to 200,000 m^3/day when the oil production rate reaches 200,000 m^3/day (1.2 x 10^6 bbls of oil). Nevertheless, formation water would only be discharged to the marine environment following treatment with oil-water separators.

The chemical characteristics of formation water are expected to be relatively constant. It is usually slightly saline with high bicarbonate ion concentrations, low in oxygen (anoxic), and is expected to have a temperature range of 10° to 55°C (Montreal Engineering Co., 1979). Since its average temperature at the point of release may be 20°C, formation water in excess of enhanced recovery requirements would be a potential source of heated water for below-ice discharge in ice management programs, which could be conducted from October to May.

Assuming that formation water is discharged to the sea, the most significant concerns are related to the trace metal and oil content of these discharges, and the potential areas of open water created by ice management programs, which may have some effects on biota during the winter months. The potential impacts of combined thermal discharges from production platforms are discussed in Section 2.4.1.9.

Investigations of formation water flows in the Beaufort Sea (Thomas, 1978b, c) indicate that trace metals which may be present at concentrations exceeding those normally found in the Beaufort Sea or other coastal waters include chromium, lead, zinc, nickel, copper, cadmium, and mercury, although some of the metal concentrations reported by this author may have been affected by the presence of other drilling wastes. The potential impacts of other sources of trace metal contamination from production platforms (i.e. formation cuttings and drilling fluids) were previously discussed in Section 2.4.1.3, but it should be emphasized that metals in formation water are generally present in a biologically available (ionic) form. On the basis of formation water sampled during flows from Kaglulik A-75 (Thomas, 1978c), daily inputs of dissolved nickel, zinc, copper, cadmium, chromium, lead and mercury during the peak technically achievable production level (200,000 m^3/day) could approach 17.2, 11.4, 7.0, 0.62, 0.20, 0.03 and 0.01 kg, respectively. These trace metals, however, would enter the marine environment at geographically separated production platforms rather than at a single location, and would be rapidly chelated and diluted in the surrounding waters. Even with these conservative assumptions, impacts on water quality would be LOCAL, but depending on the duration of produced water release from specific fields could range from SHORT-TERM to LONG-TERM. These predictions would be similar, in some respects, to the findings of Ballard and Grassle (1979), while examining natural formation water discharges into the Pacific Ocean near the Galapagos islands. At this location, excessively hot (350°C), mineral and sulphide-laden water was being discharged to the ocean through vents in the sea floor. Under these extreme conditions, the minerals precipitated out to form "chimneys" (Plate 2.4-3) and blanketed the area to a distance of approximately 25 metres around.

Any hydrocarbons present in formation water following treatment with oil-water separators would be in a weathered, emulsified form and would be rapidly diluted in receiving waters, although the continuous or intermittent discharge of formation water would represent a localized chronic source of hydrocarbon input to the offshore waters of the Beaufort Sea. In the unlikely event that all produced water was released to the marine environment and contained 50 ppm of oil, the maximum allowed by the Canadian Oil and Gas Production Regulations, the quantities of oil entering the Beaufort Sea could approach 3.6 m^3/day when offshore fields are producing oil at a rate of 81,000 m^3/day, and 8.3 m^3/day when fields are producing oil at a rate of 200,000 m^3/day. As with the trace metals, these hydrocarbons would enter the marine environment in widely separated areas. The anticipated development of more efficient oil-water separators, particularly for the removal of emulsified oil, would also likely decrease the quantities of oil, if it is assumed to be released to the marine environment.

PLATE 2.4-3 *Naturally produced formation waters are released into the sea in various parts of the world. These photos, taken at a depth of 2.5 km in the Pacific Ocean near the Galapagos islands, show very hot (350° C) mineral and sulphide-laden water being released to the ocean through "chimneys" which are formed by the precipitation of minerals. (Courtesy: Woods Hole Oceanographic Institution).*

Before discussing the projected impacts of formation water on the marine biota of the Beaufort Sea, it would again be interesting to briefly examine some of the findings of the Ballard and Grassle (1979) work on natural formation water discharges. Given the extremely hot, contaminated nature of these releases, one might have assumed that no life could live within this zone of influence. However, on the contrary, the "contaminated" areas were found to be "living oases" of giant tube-worms (Plate 2.4-4), galatheid crabs, clams and an entire ecosystem which probably evolved over thousands of years to occupy this unique type of subsea habitat. Although exotic species such as these would not be expected to grow in the vicinity of Beaufort Sea formation water discharges, some small Arctic animals such as worms, clams and crustacea would likely be attracted to the warmer, nutrient-rich discharge points.

The possible effects of formation water on marine flora and fauna of the Beaufort Sea would likely vary at different times of the year, but during all seasons, the areas affected by these discharges should be localized due to the rapid dissipation of heat and the dilution, dispersion and chelation of contaminants. During the open water season, slightly higher water temperatures may locally increase the metabolic rate of planktonic organisms and attract some species of fish and perhaps seals to production platforms. Since planktonic organisms would be continuously transported into and out of waters adjacent to production platforms, possible increases in metabolic rate would be temporary, although the simultaneous presence of trace metals and hydrocarbons could result in some local acute toxic and sublethal effects (including trace metal and hydrocarbon uptake). On the other hand, fish or seals attracted to production platforms could be exposed to contaminants present in formation water for longer periods, and may experience a variety of effects associated with hydrocarbon and trace metal exposure (ESL, 1982). In addition, some species of birds which are attracted to physical structures and sites of human activity (e.g. gulls, jaegers and terns) may be exposed to hydrocarbons, or may ingest prey contaminated with trace metals. It is unlikely that whales would approach production platforms close enough to be affected by the slightly warmer water, trace metals, or hydrocarbons, although they may ingest some plankton or fish which may have been exposed to the formation water. Even in the case of those resources which may be exposed to formation water discharged from platforms, potential effects would be relatively localized and involve a relatively small proportion of the regional populations of affected species. Consequently, the potential degree of impact of formation water discharges during the open water season will likely vary from NEGLIGIBLE (planktonic communities, whales) to MINOR (fish, birds, seals).

During the winter when biological productivity is generally at its lowest level, the possible regional impacts of formation water discharge would also be considered NEGLIGIBLE to MINOR. Some species

PLATE 2.4-4 *Unique ecosystems, probably evolved over thousands of years, occupy this unusual type of subsea habitat near natural formation water vents on the sea floor. Larger life forms found in the area include giant tube-worms, galatheid crabs and clams. (Courtesy: Woods Hole Oceanographic Institution).*

of fish may continue to be exposed to slightly warmer water and contaminants during this period, while a localized impact on epontic flora in early spring and on fauna near production platforms is also anticipated. Depending on the specific gravity and temperature of the formation water, it could have a tendency to accumulate below the ice cover, particularly near shallow water production platforms in the landfast ice zone. Under these circumstances, localized mortality and sublethal responses of epontic organisms may result from the individual or synergistic effects of increased temperatures, trace metals and petroleum hydrocarbons. Localized indirect impacts on fish species which prey on contaminated epontic fauna could also occur during this period.

During the spring, offshore migrant birds (e.g. oldsquaws, eiders, loons and gulls) and some seals may be attracted to the open water areas created by the discharge of warm formation water at production platforms, and these species may then be exposed to trace metals and hydrocarbons. The potential impacts of these contaminants on regional populations of birds and seals would depend on the dilution capacity of the receiving waters, the spatial extent of the open water areas, the species and numbers of individuals that may be attracted, the duration of their presence within these areas and the activities of the attracted individuals (e.g. feeding, preening). However, since most production platforms would be located within the transition ice zone, the areas of open water created by the discharge of warm formation water would likely be insignificant in comparison to the extent of open water which is normally characteristic of offshore waters during this period. The airborne noise associated with production platforms (Section 2.3.5) may also cause most species of birds to use other open water areas available in the region. Consequently, the impact of contaminants in formation water on migrant birds is expected to be NEGLIGIBLE to MINOR. Ringed and bearded seals could be attracted to open water areas around production platforms in the landfast and transition ice zones, respectively. However, since both of the species are widely distributed throughout the region (Volume 3A), few individuals are likely to be attracted to these open water areas, and the effect of formation water contaminants on the regional populations of these species should range from NEGLIGIBLE to MINOR. If most of the formation water is eventually reinjected into the reservoirs, then the impacts in all instances will naturally be further reduced.

2.4.1.8 Oily Waste-Water

During normal operations, waters containing oil may be discharged to the marine environment through wash-water, precipitation run-off and ship bilge water. Wash-waters containing small quantities of oily waste, drilling fluid additives, grease and detergents will be generated on offshore drilling rigs (drillships, exploration islands, production platforms) and on ships because of the need to keep working areas clean for reasons of occupational safety. Precipitation run-off from rigs and ships will also contain traces of the substances listed above.

Oily waste-water resulting from deck washings and precipitation run-off (approximately 100 m^3/well) and from bilges will be channeled to treatment plants where waste materials will be separated and recovered. Since emulsified oil is not effectively removed by oil-water separators, oil will be discharged in relatively small amounts into the sea. Oil concentrations in the discharged waste-water will be less than 50 ppm as required by the Canadian Oil and Gas Production Regulations. Given that the volumes of oil involved will be small, no regionally significant residual environmental impacts associated with the normal discharge of treated oily waste-water are anticipated. The small volumes of deck washings occasionally discharged from rigs and ships would be rapidly diluted by the receiving waters. Since bilge water, if discharged at all, would only be released while ships are underway, the limited volumes of effluent released would be well mixed in the receiving waters by the ship's turbulence. Back-up oil-water separators and/or adequate storage will generally be provided to handle bilge water should the primary unit fail. In many cases, and particularly with the newer ships and rigs, the oils will be separated and incinerated. The potential impacts on water quality should therefore be restricted to the immediate vicinity of the discharge, and would be considered LOCAL and SHORT-TERM.

Since marine-associated birds such as glaucous gulls and jaegers, which may be attracted to the rigs and ships, spend much of their time in the air, it is anticipated that any potential exposures to oily wastes which may occasionally occur on the water surface would be infrequent, short-term and highly localized. However, due to the exceptional vulnerability of birds to petroleum hydrocarbons, the potential regional impact could approach MINOR. The potential impacts on marine mammals moving through the discharge zones would probably be NEGLIGIBLE since mortality is unlikely, and sublethal effects resulting from the short-term exposure to oily wastes, if they occurred, would likely be reversible (ESL, 1982). Some fish may be adversely affected by the short-term, localized discharge of treated oily waste-water, but the impact on regional fish populations should not exceed MINOR. The potential impacts of these wastes on the planktonic community would also be MINOR since the individuals which may be affected would be rapidly replaced by others transported from nearby uncontaminated waters. It is unlikely that benthic communities would be affected by treated oily waste-water discharges because oil concentrations would probably be diluted to levels below the toxic threshold in the surface layers of the water column.

2.4.1.9 Heated Cooling Water

The major sources of heated water which would be discharged to the Beaufort Sea are cooling water from drill rig machinery and ship engines, excess or all formation (produced) water from offshore production platforms, bilge water and sewage from offshore facilities and vessels, and brine from small desalination plants on offshore platforms. Table 2.4-3 summarizes some of the sources and estimated quantities of heated water projected to be discharged to the offshore Beaufort Sea.

Prior to discharge, heated water, some of which may be contaminated with hydrocarbons (e.g. formation water, bilge water), would be passed through oil-water separators to reduce oil concentrations to 50 ppm or less. When desirable and appropriate, heated water would be used for ice management purposes such as at a tanker loading terminal. Where not required for this purpose, if deemed necessary, it could be discharged at an appropriate depth in the water column to ensure dissipation of the heat at the surface.

No regionally significant impacts related directly to heated discharges would be expected. Heated water released from a moving ship would be rapidly dispersed by the turbulence in the wake. Therefore, potential effects on marine flora and fauna would be SHORT-TERM and LOCALIZED. The discharge plume of warm waste-water from stationary offshore structures would generally be confined to the surface layer of the water column, although this water could be discharged at depths from 0 to 60 m depending on the type of facility and its location. The horizontal area affected by heated cooling water would also be limited. For example, it has been estimated that, depending upon the rate of discharge, the area influenced by the daily release of approximately 16,000 m^3 of formation water at 20°C will be roughly equivalent to solar radiation on an area of water approximately 200 to 400 m in diameter (Montreal Engineering Co., 1979). During the winter, the zone of influence of the heated water would be even less since the heat energy would be rapidly consumed in the melting of the surrounding ice. Release of heat-containing wastes during the summer would probably affect a slightly larger area, but the potential impacts of temperature increases on the physical oceanographic regime would still be LOCAL and SHORT-TERM.

Direct impacts of thermal discharges on birds and

TABLE 2.4-3

SOURCES AND ESTIMATED QUANTITIES OF HEATED WATER DISCHARGE TO THE OFFSHORE BEAUFORT REGION

Facility	Source	Approximate Heat Energy Discharge ($\times 10^6$ Btu/hr)	Average/Range Temperature at Point of Release (°C)
Production Platform	Excess formation water (16,000 m^3/day[1])	ns	20/10-40
	Heated cooling water (10,000 m^3/day)	ns	ns/10-40
Accommodation Barge (120 personnel)	Heated cooling water	19	15/ns
Pile-driving barge	Heated cooling water	19	15/ns
Dredge	Heated cooling water	57	15/ns
Barge tug	Heated cooling water	16	15/ns
Workboat	Heated cooling water	12	15/ns
Icebreaker			
(Class 3)	Heated cooling water	27	15/ns
(Class 10)	Heated cooling water	41	15/ns
Tankers	Heated cooling water	ns	ns/ns

ns = not specified
[1]Assuming remainder is reinjected for recovery enhancement.

Source: Montreal Engineering Co., 1979

mammals are expected to be NEGLIGIBLE, although the possible attraction of some species to thermally-produced open water areas may increase exposure to other facility-associated disturbances and wastes. The potential impact of heated cooling water on regional fish populations would also be NEGLIGIBLE, particularly since most species will be able to avoid waters characterized by abnormally high temperatures (ESL, 1982). Localized effects on planktonic and epontic biota are also possible, although these impacts would not be regionally significant.

2.4.1.10 Cement Slurry, Contaminated Cements and Barites

Cement is used during drilling operations to grout the upper casing to the sea floor at wells drilled from conventional drillships and, in the future, conical drilling units, and to fix the upper casing to the surface of artificial islands used for exploratory or production wells. On islands, no cement would be released to the marine environment, but with floating drill rigs, excess cement slurry may be pumped down the marine riser and released through valves located at the sea floor. An estimated 10 to 30 m^3 of cement slurry could be released during the drilling of each exploration well from a drillship or conical drilling unit (Montreal Engineering Co., 1979), and this slurry would harden into a mass which may extend 5 to 8 m from the riser and cover an area ranging from 80 to 200 m^2. This cement would likely mix with seafloor materials and be diluted with seawater during the hardening process. Hardened cement would probably be covered with silt in a short period of time. In addition, cement which is water-damaged during transport to offshore facilities or barite which has become contaminated with cement is sometimes discharged directly into the water column. It is estimated that up to 150 m^3 of cement may be released to the marine environment for every 200 production or exploration wells drilled to the year 2000 (Montreal Engineering Co., 1979). Since roughly 725 exploration, delineation and production wells may be drilled during this period, the quantity of additional cement released to the Beaufort Sea could reach 540 m^3. Unlike cement slurry released during the grouting of casings, powdered cement would be dispersed over larger areas. Most of the contaminated cements and barites will probably settle within a radius of 100 to 200 m from the disposal site, although finer particles may be carried by local currents to a radial distance of perhaps 1,200 metres.

The physical impact of cement slurry and powdered cement discharges on the seafloor character would be LOCAL, but depending on the rate of sediment deposition in offshore waters, would likely range from SHORT-TERM to MEDIUM-TERM. It is anticipated that the only significant biological impact associated with the release of cement would be the mortality of sessile benthic fauna within areas directly covered by cement slurry or extensively inundated with cement powder. However, these areas would be insignificant in relation to available offshore habitat in the region, and would provide a desirable substrate for various epifauna once the cement hardened. Pelagic organisms and the benthos located in the area between 200 to 1,200 m of contaminated cement disposal sites may be temporarily affected by increased turbidity and pH in the water column as the cement particles settle to the sea floor (ESL, 1982). The potential impact of cement release on all marine resources of the Beaufort Sea is expected to be NEGLIGIBLE.

2.4.1.11 Gas Flares

All produced gas is assumed to be flared for at least the first two years of oil production from a given field, with the quantity of gas flared during this period increasing as more wells within a field are brought into production. Subsea pipelines would be used to move produced hydrocarbons to a single production platform within a field, where a processing facility would separate and then flare the gas. Given the projected schedule of production platform construction and production drilling (Table 2.4-1), a maximum of 2 or 3 flares would likely be in operation at any one time. Gas may be reinjected to enhance recovery from the reservoir after each field has been in production for two years, used as fuel for island and vessel operations in the region, and eventually collected for shipment to commercial markets. During the early phase of project development (to 1990) when most of the associated gas will be flared, approximately 3 million m^3 of gas/day may be flared (Section 2.3.4.2).

Gas flares would be designed to promote complete, continuous combustion, minimize radiant heat reaching the ground and reduce noise levels. Consequently, only small quantities of particulate, smoke or hydrocarbons emissions are expected. Flares on production platforms will be located to prevent any significant melting of ice, heat damage at the platform surface, and hazards to personnel during all production and atmospheric conditions.

All Beaufort Sea gas tested to date has been sweet, containing no hydrogen sulphide. As a result, sulphur dioxide emissions are not expected to be associated with flaring of this gas.

The only potential biological impacts associated with gas flares would be the possible attraction of birds to the light of the flare or other illumination on the platform, although most birds would probably avoid the heat sphere associated with the flare if they approached the production platform. Mortality of birds, including at least one species of seabird, has been reported as a result of incineration in gas flares in the North Sea (Sage, 1979), but most of the birds killed were passerines, that were probably disoriented and likely to have died, regardless of the presence of flares (Bourne, 1979). Numbers of birds (mostly passerines) killed at North Sea rigs have likely been less than a few hundred per platform per year (Bourne, 1979).

In the Beaufort Sea, gas flares are least likely to affect birds during the winter (November to April) since there are generally few in the area at this time of year. They are also unlikely to attract birds during spring since most migrants travel during periods of virtually continuous daylight. Attraction to flares may occur during late summer and autumn, although the routes and numbers of birds which migrate offshore during fall over the Beaufort Sea are not well documented. Some mortality of birds is considered possible, particularly in species which migrate offshore in large numbers during late fall (e.g. eiders). In addition, some mortality of certain seabirds that soar in updrafts (e.g. gulls) is possible if birds attempt to soar in the warm rising air above gas flares. However, the overall potential impact of gas flares on birds in the Beaufort Sea region is expected to be NEGLIGIBLE, or at most MINOR, since only a few flares would be operational at any one time and the number of birds attracted to these sites would likely be small.

Gas flares will also provide a source of artificial illumination, heat and light during winter. The potential impacts of artificial illumination were discussed in Section 2.3.7, and could include the attraction of polar bears and Arctic foxes to the general area of these light sources. The numbers of bears and foxes which may be attracted to offshore gas flares is unknown, although they would likely be an insignificant proportion of the regional populations. Therefore the impact of gas flares on these species would be considered NEGLIGIBLE.

2.4.1.12 Summary of Possible Impacts Associated with Offshore Platforms

The possible release of treated formation waters from offshore producing platforms is the only "new" type of effluent which may be discharged into the Beaufort Sea in the future. If formation waters are continuously discharged from all wells, rather than being reinjected into the geological strata, relatively large quantities of weathered, emulsified hydrocarbons and soluble trace metals will enter local marine waters. Available information for formation water flows in this region indicates that concentrations of several trace metals are likely to be higher in produced water than in the receiving environment. If discharged, these elevated concentrations may result in a variety of localized sublethal effects, possibly bioaccumulation of various metals, and perhaps some localized mortality of marine flora and fauna. The concentrations of oil in formation water will be reduced by oil-water separators, but these devices are presently not very efficient in the removal of emulsified oil, and a considerable, cumulative input of hydrocarbons to the marine environment could occur due to the relatively large quantities of formation waters discharged over the period of development. However, on the basis of available information regarding possible volumes of produced water and experience in other parts of the world, such as Cook Inlet, the North Sea, and the Gulf of Mexico, where formation water is discharged to the ocean, the magnitude of potential regional impacts of these discharges are expected to range from NEGLIGIBLE (plankton, whales) to MINOR (fish, birds, seals). As development proceeds, and assuming that substantial quantities of formation waters are discharged to the sea, environmental quality monitoring programs will be carried out to ensure that impacts, if they occur, are maintained within acceptable limits. It should also be noted that this impact may be further reduced, if in fact most of the produced water is reinjected into the geological structures.

Most of the other activities and disturbances associated with offshore platforms are not expected to cause regionally significant impacts, and would be considered NEGLIGIBLE for most biological resources. Any acute toxic or sublethal effects resulting from other discharges and activities should be confined to extremely localized areas surrounding the wellhead or platform site. MINOR localized impacts on some benthic invertebrates and fish populations are considered possible, particularly due to the discharge of drilling fluids and cuttings. The presence of offshore structures will likely attract some fish, mammals, or birds, and could result in subsequent exposure to disturbances and wastes which may lead to some MINOR regional impacts. The physical presence of offshore platforms will also have LONG-TERM but LOCAL effects on the offshore ice regime. If particular islands appear to be influencing important physical processes, such as the break-up of the landfast ice in a specific area, icebreakers can be employed to ensure that break-up proceeds in the normal manner.

2.4.2 DREDGING

This section describes the possible impacts of dredging activities proposed in conjunction with development of the Beaufort Sea hydrocarbon resources on the physical environment and biological resources of the region. A detailed review of the biological effects of dredging in both temperate and Arctic environments, including studies and monitoring programs conducted during dredging activities and artificial island construction in the Beaufort Sea, is provided in ESL (1982).

Most of the dredging activities associated with artificial island construction, and the excavation for subsea pipelines will occur in offshore areas of the Beaufort Sea. The amounts of bottom materials required for island construction have been estimated, and will be obtained, as necessary, from a number of different borrow sites located in the region (Figure 2.4-1). The total quantity of bottom materials which may be removed for all offshore facilities in the Beaufort Sea development plan to the year 2000 has been estimated to range from approximately 500 to 700 million cubic metres.

On this basis, a maximum of approximately 50 to 70 km^2 of sea floor could be directly disturbed over the entire development (1982 to 2000) if dredging was limited to 10 m deep excavations. In fact, some of the dredging is expected to occur to depths of down to 20 m below the sea floor (Figure 2.4-2), and the actual areas of sea floor directly disturbed in these offshore locations would be substantially less. In a regional context, therefore, the majority of dredging operations will affect only a small fraction of the Beaufort Sea floor. Most of these offshore dredging activities will occur during the open water season, although the dredging season for island construction may extend from break-up to January, assuming that larger Arctic dredges are employed at some time in the future.

More limited but perhaps more biologically important dredging will occur in localized habitats closer to shore, to provide material for shallow water island construction and to complete excavations for the shore approaches of subsea pipelines, as well as mooring basins and dock facilities. Some of these activities may occur during periods of ice cover, particularly nearshore dredging for subsea pipelines. The potential impacts of dredging at specific coastal shorebases are described in Chapter 3 of this volume.

2.4.2.1 Water Quality

In the offshore waters of the Beaufort Sea where most dredging activities will occur, alterations of water quality as a result of dredging will probably not be significant due to the small and localized areas where the disturbance will occur. Several investiga-

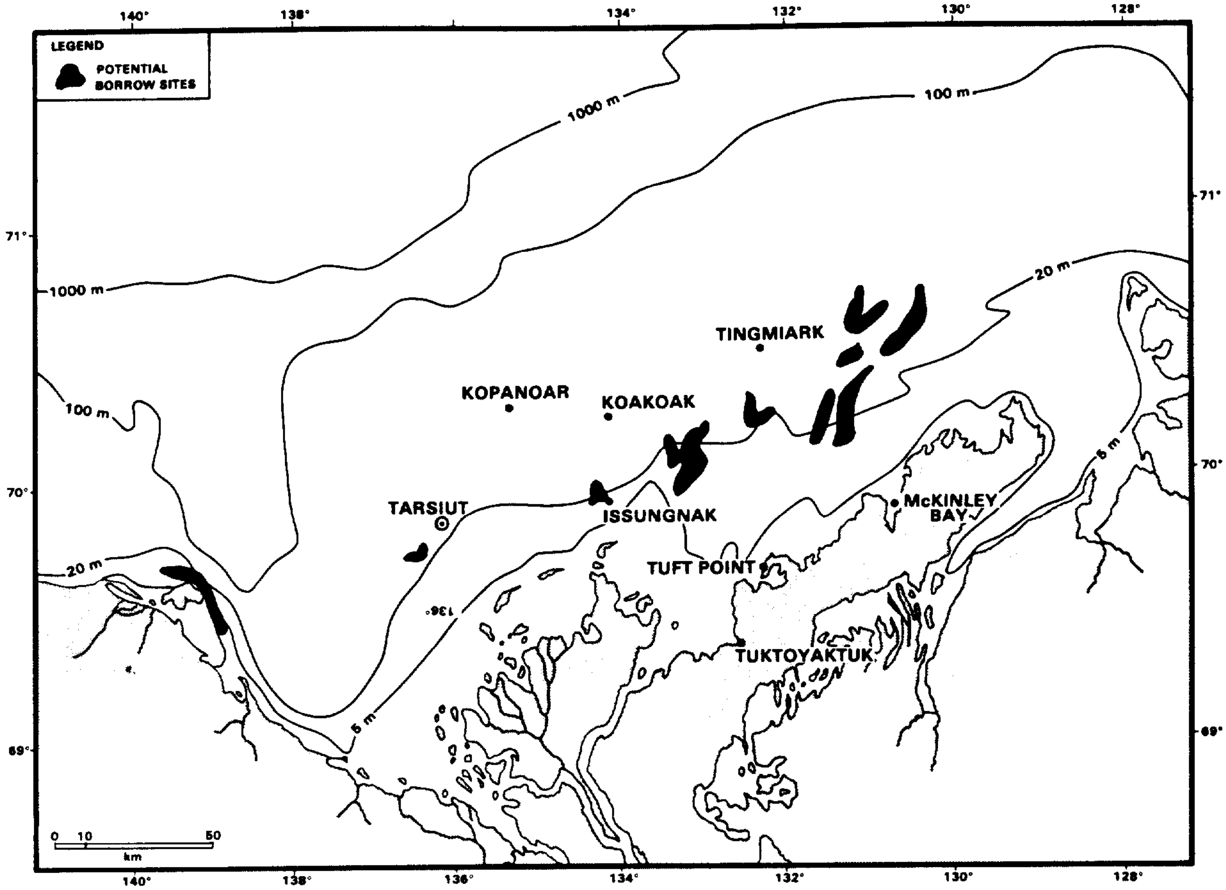


FIGURE 2.4-1 *Known potential borrow sites in the offshore Beaufort Sea.*

tions regarding dredging activities in both Arctic and temperate environments (for review see ESL, 1982) indicate that the most significant changes in water quality will probably be localized increases in concentrations of suspended sediments and increased turbidity levels. Although reduced concentrations of oxygen, increased nutrient levels, and changes in the vertical salinity and temperature profiles may occur during dredging, only minor effects on these parameters are anticipated in offshore areas, since large dilution factors, low background nutrient levels in sediments, and relatively homogeneous temperature and salinity profiles exist in these waters. More significant changes in these parameters are possible in specific nearshore locations where relatively confined waters and nutrient-rich sediments may occur (ESL, 1982).

Investigations of suspended sediment plumes caused by dredging in the Beaufort Sea (Slaney, 1974b,1977a; Envirocon, 1977; Thomas, 1979) have indicated that the size and character of the plumes are affected by the type and volume of materials being removed, the existing background water quality and current regime, local weather conditions and the type of dredge involved in the operation. Turbidity plumes are likely to be most evident when background turbidity is low, water circulation is restricted, and dredged materials are fine, particularly during operations which involve uncontained fill or deposition (Plate 2.4-5). Past studies suggest that under these circumstances, a turbidity plume may be evident over a radius of approximately 5 km from the dredge or spoil release site (Slaney, 1977a; Thomas, 1979). On the other hand, when background turbidities are high, such as within areas affected by the Mackenzie River plume, turbidity increases resulting from dredging have been detectable for less than 2 km from dredge outfalls (Slaney, 1977a; Erickson and Pett, 1981). Studies of the vertical distribution of turbidity plumes also indicate that in some cases the entire water column may be affected, while in other areas the plume may only be detectable in surface, mid-depth or bottom waters (ESL, 1982).

Although the turbidity plume may be visible for several kilometres from dredging sites, concentrations of suspended solids are relatively high only in the immediate vicinity of the activity, and generally decrease rapidly with distance. For example, studies by Slaney (1977a), Envirocon (1977) and Thomas (1979) indicated that during various dredging pro-

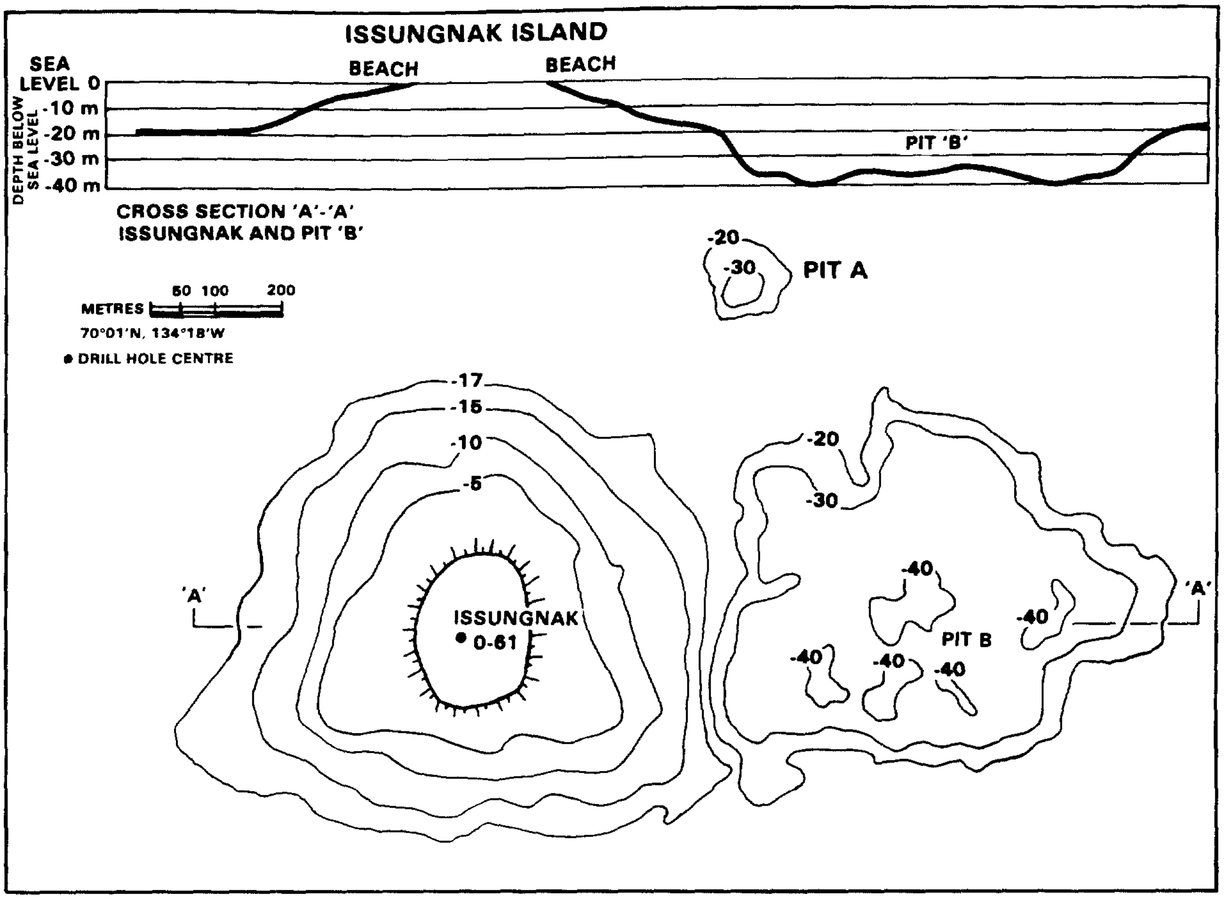


FIGURE 2.4-2 *Areal and cross sectional views of Issungnak 0-61, Beaufort Sea when completed.*

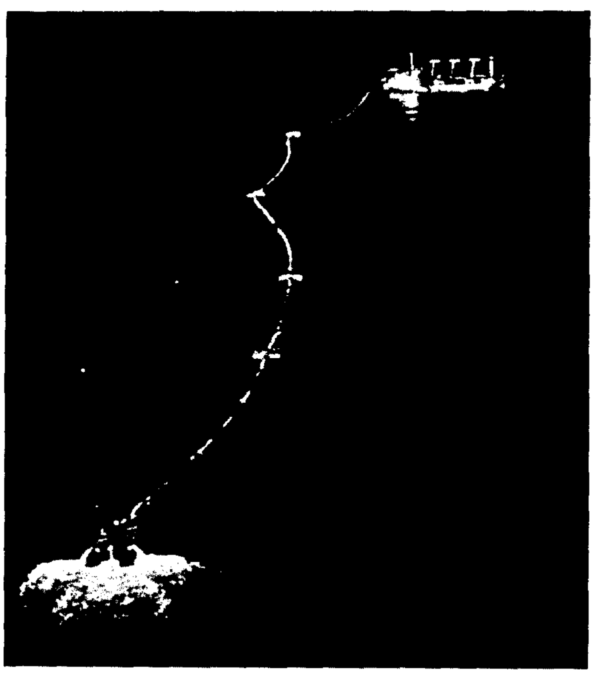


PLATE 2.4-5 *Dredging and the resultant suspension of mud into the water column causes localized short-term turbidity plumes such as shown in this photograph where a stationary suction dredge is pumping sand to a site where an island is being built.*

grams in the Beaufort Sea, suspended solids in the vicinity of the dredge ranged from approximately 200 to 600 mg/L, but were reduced to levels in the range of 14 to 100 mg/L within 500 m of the operation. These latter values were often within the range of naturally occurring suspended sediment concentrations in areas affected by the Mackenzie River turbidity plume.

The duration of the physical and chemical effects associated with dredge-created turbidity plumes is an important factor affecting subsequent impacts on aquatic organisms. Dredge monitoring programs in the Beaufort Sea have clearly documented the spatial extent of the turbidity plumes, but few studies have described the attenuation of turbidity plumes with time. Nevertheless, investigators that have examined dredging in this region agree that turbidity plumes are "short-term," "temporary" (Slaney, 1977a) or "short-lived" (Thomas, 1979). For example, post-dredging sampling in Tuktoyaktuk Harbour indicated that suspended sediment concentrations decreased to pre-dredging levels 10 hours after the termination of the dredging operation (Erickson and Pett, 1981). Turbidity plumes have been monitored following the cessation of dredging in southern latitudes, and have been reported to last for 1 to 2 hours

(Chesapeake Biological Laboratory, 1970; cited in Morton, 1977) and as little as 30 minutes (Wright, 1978). The attenuation of turbidity plumes following the termination of dredging activity is more rapid when coarse bottom materials are involved (in the order of hours), but when fine-grained sediments (e.g. clays and silts) are suspended in quiescent waters, longer periods may be required before turbidities return to normal levels (Slaney, 1975).

The impact of dredging-related turbidity increases on the water quality of the Beaufort Sea would vary with location and season of the activity. The Mackenzie River contributes approximately 15 million tonnes of sediment annually to the Beaufort Sea, and during the period of high discharge, areas affected by the Mackenzie River plume are naturally characterized by a wide range of turbidity. Normal background ranges for turbidity and suspended sediments in nearshore areas may be as large as 5 to 690 mg/L and 20 to 967 mg/L, respectively (Slaney, 1977b). However, during the winter when the Mackenzie River flow is reduced and under ice, water turbidity is relatively low. During these periods, increased suspended sediments and turbidity from dredging may cause more significant local effects on water quality.

In summary, the most significant impacts of dredging on water quality will be increases in turbidity and suspended solids. However, the available information suggests that these changes are usually very localized and disappear relatively quickly following dredging activities. Accordingly, the impacts of dredging on water quality in the Beaufort Sea would be considered LOCAL and SHORT-TERM. In addition, the magnitude of suspended sediment and turbidity increases will be reduced in some areas when the dredge spoil is deposited by direct placement on the sea bottom during artificial island construction. For example, it is anticipated that suction dredges or work barges equipped with floating or submerged pipelines will deposit spoil directly on the bottom during the construction of most deeper island berms, such as those proposed at Tarsiut, Koakoak and Kopanoar.

Nearshore dredging activities other than those required at shorebases (Chapter 3), will be limited to the Tuft Point area for borrow materials necessary for construction of artificial islands in shallow waters and the North Point area where subsea pipeline(s) may be installed and buried. Dredging in the North Point area could occur under ice, but will be relatively localized since the operation would only remove the amount of material necessary for burial of the pipeline. Increases in suspended solids and turbidity during winter dredging should be localized to the area where excavation of the trench and burial of pipe occur, and will not likely affect the relatively productive and biologically sensitive embayments on Richards Island, such as Mason Bay or Mallik Bay (ESL, 1982). At Tuft Point, where dredging has already occurred, natural fluctuations in turbidity and suspended solids are common, and increases in turbidity above background levels have been either slight or were only observed for brief periods following dredging (Aquatic Environments Ltd., 1977; Slaney, 1977a).

In addition to increases in suspended sediment concentrations and turbidity, other impacts of dredging on water quality have been associated with the resuspension of contaminated sediments. However, monitoring programs completed to date in the Beaufort Sea have not demonstrated any changes in trace metal concentrations, pH or other indicators of sediment contamination during dredging operations (Slaney, 1977a,b; Thomas, 1979, Thomas *et al.*, 1982). The greatest potential for release of toxic compounds or elements to the water column would occur around artificial island sites which may require periodic maintenance dredging, and are also sites of sewage, drilling waste, or other effluent disposal.

2.4.2.2 Seabed Contours and Sediment Composition

Other potential impacts of dredging on the physical environment of the Beaufort Sea include: changes in seabed contours and, depending on water depth, subsequent changes in wave patterns leading to shoreline erosion; and changes in sediment particle size distribution. This section describes these general potential impacts in relation to proposed dredging requirements, while potential site-specific impacts of dredging at shorebases and harbours are discussed in Chapter 3.

(a) Altered Bottom Contours

Dredging changes bottom contours and can result in troughs and deep holes at borrow locations, as well as decreased water depths at artificial island or spoil disposal sites. Changes to the sea bottom in deeper offshore areas, where most dredging will be concentrated, are unlikely to affect either circulation or wave patterns. In addition, ice scouring is common at depths from 25 m to 50 m in the Beaufort Sea, and can naturally cause trenches up to 7 m deep, tens of metres wide and hundreds of metres long (Volume 3A; Section 1.4). Studies of ice scours in this region have indicated that some existing scours are very old, suggesting that the energy levels at these depths are low. Consequently, dredge-created trenches and disposal sites are likely to remain distinct bottom features for extended periods, although they would likely be difficult to distinguish from natural ice scours or areas of bottom slumping. A natural feature of the seabed in the Beaufort Sea is the "pingo-like feature" (Volume 3A; Section 1.4), which would be similar in physical appearance to artificially created subsea berms. Thus, while offshore dredging may locally change sea bottom contours, natural processes are also altering the configuration of the bottom on an extensive scale. Impacts of dredging on seafloor configuration would therefore be considered LOCAL and LONG-TERM. The impacts of dredging on the physical shape of the seabed are of greater importance to the biological communities it supports, and these potential impacts are discussed further in Sections 2.4.2.8 and 2.4.2.9.

(b) Altered Sediment Composition

Dredging involves the removal of surface and/or subsurface (depending on the type of dredge) sediment from one location, possibly exposing a different particle size substrate, and subsequent deposition in another area, potentially creating a different bottom type than previously existed. For example, recent investigations by the petroleum industry have confirmed sand deposits overlain with 1 to 5 m of clay in many parts of the Beaufort Sea. In these areas, dredges would have to remove the clay overburden to gain access to the sand. This is a potential area of localized concern where benthic habitat is lost and recreated in both borrow and disposal areas (see Sections 2.4.2.5 and 2.4.2.9), although the areas involved would be extremely small in comparison to available undisturbed habitats.

Sedimentation of suspended solids from turbidity plumes may also cause changes in sediment size distributions in areas adjacent to dredging sites. For example, increased proportions of sediments corresponding to the size of the dredged material have been documented in areas "downstream" of artificial islands (Envirocon, 1977; Beak, 1978). However, changes in sediment size composition *per se* are not a significant concern, since bottom substrates of the Beaufort Sea range from soft to firm clays and silts to medium-grained sand (Volume 3A: Section 1.4), and the active processes of ice scouring, erosion, slumping and sediment transport should cause dredged substrates to resemble adjacent sediments within a relatively short time frame. The potential impacts of these LOCAL and SHORT-TERM changes in substrate composition on benthic fish and invertebrates in the Beaufort Sea are discussed in Sections 2.4.2.5 and 2.4.2.9, respectively.

2.4.2.3 Marine Mammals

The potential effects of dredging activities on marine mammals have been documented and may include: avoidance as a result of the combined influences of underwater noise and other activities associated with dredging; localized reduction in food sources due to removal or burial of benthic organisms; and, reduced foraging capabilities or prey detectibility within the dredge plume. However, the documented localized effects of dredging, the small areas which would be affected, and the concentration of dredging activities in offshore waters suggest that this type of activity will not result in regionally significant impacts on marine mammals.

(a) Avoidance

The combined activities associated with dredging which may cause avoidance responses by marine mammals include underwater noise, vessel movements and other human activities, as well as the direct bottom disturbances at the dredge intake or outfall. The potential impacts of underwater noise, vessel traffic and human presence on marine mammals are discussed in greater detail in Section 2.3.

Observations at stationary dredge sites have suggested that bowhead and white whales may tolerate dredging activities in some instances, but may avoid those operations with more frequent vessel traffic. For example, Fraker (1977a,b; 1978) reported that white whales occasionally avoided dredging operations at distances of up to 4 km, but in other situations approached to within 400 m of active dredges (Figure 2.4-3). These studies indicated that moving vessels may have visible effects on white whales, whereas stationary operations have less noticeable effects. Large numbers of bowhead whales have also been occasionally observed in the vicinity of active dredges during artificial island construction (Fraker *et al.*, 1981). For example, between August 6 and 10, 1981, industry personnel reported at least 9 sightings of from 1 to 6 bowheads approaching, passing or circling the dredge BEAVER MACKENZIE during operations at Issungnak (Figure 2.4-4). These whales were observed as close as 500 m from the dredge on one occasion. Fraker *et al.* (1981) also reported a total of 20 bowheads within 5 km of Issungnak during surveys conducted from August 5 to 22, 1980, and suggested that the bowheads were apparently not visibly disturbed by the construction activities.

The potential major sources of borrow materials indicated on Figure 2.4-1 are all located outside of the nearshore areas where white whales typically concentrate during July (Volume 3A; Section 3.2), suggesting that few potential interactions between offshore dredging and white whales will occur during this period. However, small numbers of white whales may occur in the vicinity of dredge sites during spring migration or during August when they leave the Mackenzie estuary, since some individuals probably move offshore and eastward to waters off the Tuktoyaktuk Peninsula. Therefore, avoidance-related impacts on white whales, as a result of activities and underwater noise from these operations, are unlikely to exceed the MINOR rating.

During August in some years, a large proportion of

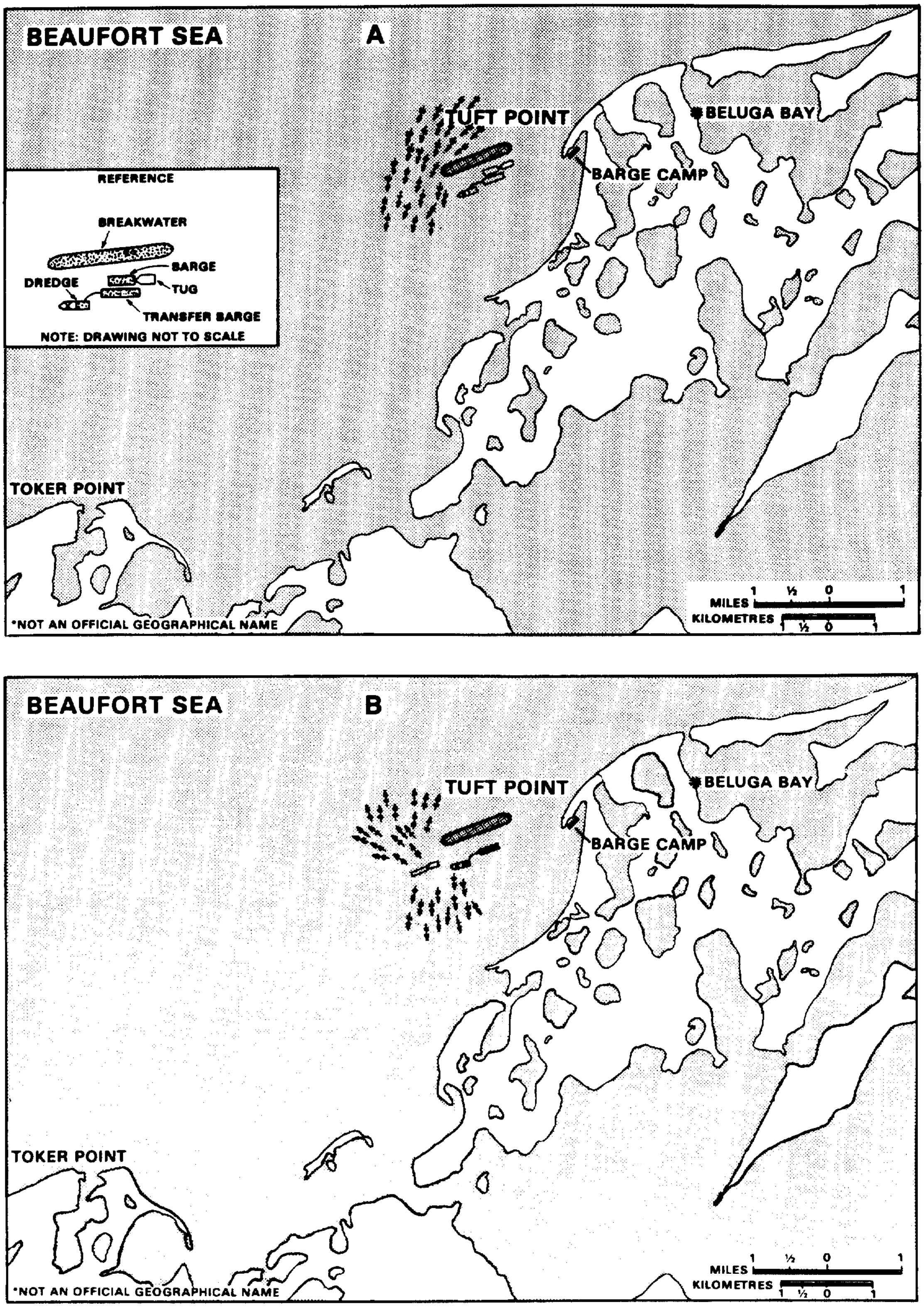
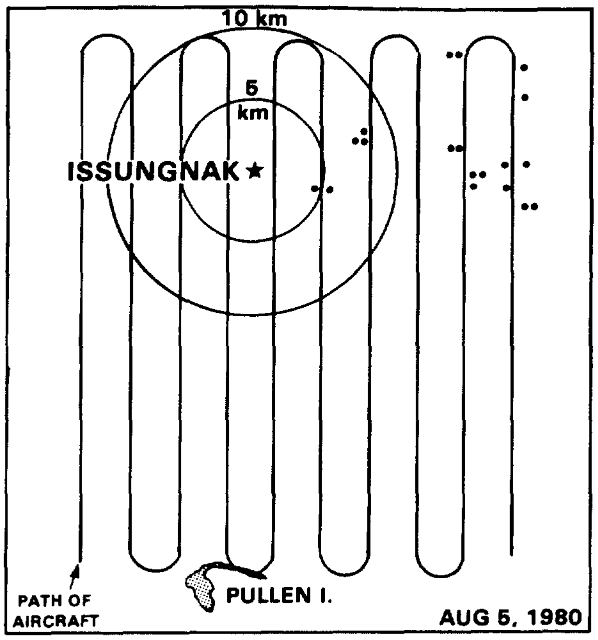


FIGURE 2.4-3 *Presented are two schematic illustrations of an aggregation of whales and how they responded to a dredging and barge/tug operation at Tuft Point on the Tuktoyaktuk Peninsula in early August, 1976. In illustration A large numbers of belugas were moving close to and past the breakwater. In illustration B a tug pushing a barge proceeded to sail through the group of whales, splitting them up. After a few hours the whales regrouped. This kind of localized temporary impact has been reported on occasion but industry is attempting to minimize these interactions through an ongoing monitoring program which controls shipping movements in the vicinity of whales. (Source: Fraker, 1977).*



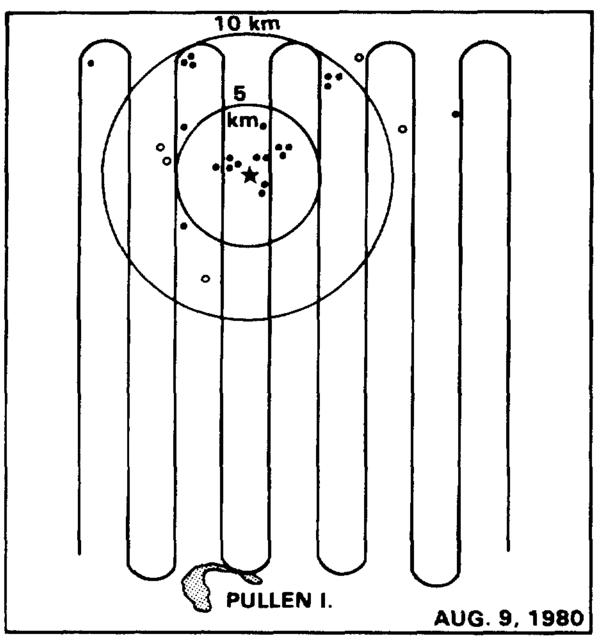


FIGURE 2.4-4 *Observations of bowhead whales made during two systematic surveys of the Issungnak-Pullen Island area. Closed dots indicate individuals within the 0.8 km transect strips; open dots indicate individuals observed outside the transect strip. (Source: LGL Inc., 1981).*

the regional bowhead population feeds offshore of the Tuktoyaktuk Peninsula, and at these times some effects of dredging on this species may occur. However, as indicated earlier, bowheads have been frequently observed near dredging operations in the Beaufort Sea (Fraker *et al.*, 1981). Although the areas actually affected by dredging will be small in relation to the available offshore habitat, low frequency underwater noise generated by dredges may disturb bowheads for several kilometres (Section 2.3.6). Consequently, avoidance-related impacts of offshore dredging on bowhead whales may be MINOR during years when a large proportion of the regional population summers in the production zone.

Ward (1981) reported that dredging activities in McKinley Bay had no detectable effect on the use of the area by seals. Ringed seals were regularly observed in the vicinity of the dredge, with some as close as 50 m. The largest group of ringed seals observed near the dredging operation was a group of 5 who were present in the area for several hours on August 26, 1980, while industry personnel reported 12 seals near the dredge on August 21. Relatively large numbers of ringed seals (1-21/km^2) were also observed by industry personnel during late August in the vicinity of the dredged channel in McKinley Bay. Bearded seals are not abundant in this area, although Ward (1981) observed a single bearded seal on several occasions near the barge camp in McKinley Bay, while another was observed by industry personnel in the dredged channel on August 24. These observations are consistent with other reports of seals near industrial activities such as operating drillships (R. Hoos, pers. comm.). Although a few ringed and bearded seals would probably be present in the vicinity of the proposed dredging sites, the numbers of individuals affected would be relatively small because these species are widely distributed in the region during the open water season when the majority of the dredging would occur. The effects of dredging activities on seals will likely be NEGLIGIBLE.

(b) Decreased Food Abundance

The removal of benthic fauna in dredged areas or smothering of fauna in adjacent areas by settling of suspended solids may cause a localized reduction in food availability for bearded seals, which feed on benthic and epibenthic fauna within the 100 m isobath (Stirling *et al.*, 1977). Bowhead whales also obtain an unknown portion of their diet from benthic habitats (Würsig *et al.*, 1981).

In the southeastern Beaufort Sea, all potential borrow sites (Figure 2.4-1), are located within the probable feeding range of these two species of marine mammals. However, the potential impacts of food source depletion on bearded seals would be NEGLIGIBLE because this species is widely distributed throughout the region. In addition, extensive alternative benthic feeding areas will be available. Waters off the Tuktoyaktuk Peninsula provide a major summer feeding area for the western Arctic population of bowheads during August of some years (Fraker *et al.*, 1981; Renaud and Davis, 1981). Therefore, a temporary local reduction in pelagic and benthic food organisms, coupled with a possible reduction in prey availability within the areas affected by the dredge plume could result in a temporary impact on the regional population of bowhead whales at these times. However, due to the extremely localized areas which would be affected by a plume, disturbances to bowhead feeding would also be NEGLIGIBLE.

(c) Turbidity Effects

Marine mammals that feed on pelagic fish and/or invertebrates may be affected by the localized increase in water turbidity and reduction in prey detectability and/or availability within dredge-created plumes. Marine mammals that may be susceptible to a temporary interference in foraging include ringed seals, white whales and bowhead whales (Stirling *et al.*, 1977; Fraker *et al.*, 1981; Würsig *et al.*, 1981). In addition, bearded seals may be temporarily affected by turbidity plumes since they are also known to feed on pelagic species in some areas (Vibe, 1950; Kosygin, 1971).

Interference with the feeding capabilities of marine mammals as a result of dredge plumes has not been documented in the Beaufort Sea or elsewhere. White whales are likely to be the least susceptible marine mammal species in the region to temporary interference of this type since they have a well-developed capacity for echolocation (Ford, 1977), and are also known to frequent areas of naturally high turbidity within the Mackenzie estuary (Fraker, 1977a, 1978; Fraker and Fraker, 1979, 1981). Bowhead whales have also been observed actively feeding in highly turbid waters about 2 to 3 km from a turbid/clear water interface east of Issungnak in August 1981 (Würsig *et al.*, 1981) The potential impacts of dredge plumes on all marine mammals would probably be NEGLIGIBLE due to the small localized areas which would be affected.

2.4.2.4 Birds

The potential impacts of dredging on birds may result from their contact with resuspended wastes or toxic compounds, disturbance from dredging-related vessel activities, and/or a reduction in foraging success due to the turbidity plume and the removal or smothering of benthic organisms. As mentioned in Section 2.4.2.1, the resuspension of toxic compounds from bottom sediments is not expected to occur throughout most of the Beaufort Sea, since no historical contamination exists in the region. However, there is a potential for future contamination in the vicinity of some routine waste discharges such as drilling muds, BOP control fluids, and formation cuttings which could be resuspended by dredging in areas where they are deposited. The extremely localized nature of these waste deposits, however, suggests that in a regional context, very few birds could be affected in offshore habitats. As a result, the degree of impact of re-suspension of toxic materials on birds will likely be NEGLIGIBLE.

Birds may also be affected by the combined disturbances associated with dredging including marine vessel activities, airborne noise and human presence, although the potential regional impacts are considered NEGLIGIBLE due to the small numbers of birds that may be affected. For example, Ward (1981) concluded that dredging activities in McKinley Bay during 1980 did not affect the abundance of birds using the area. The numbers of diving ducks recorded were as high or greater than numbers observed in years prior to dredging, and geese migrating across McKinley Bay in late August did not react adversely to the operating dredge. Some gulls and shorebirds were attracted to the artificial island, presumably due to increased accessibility of invertebrates, but overall the potential impacts of dredging activities on local bird abundance and behaviour within McKinley Bay were considered minor (Ward, 1981).

Birds in the Beaufort region that dive for food are the most likely species to be affected by the loss of food organisms or turbidity plumes and include thick-billed murres, loons and diving ducks. Murres nest at only one colony (about 800 birds) in the Beaufort Sea region (Cape Parry), and this site is well removed from all of the proposed borrow areas. Since only small numbers of murres occur at sites distant from the colony and within the areas where dredging may occur (Searing *et al.*, 1975), the impacts of dredging on the regional murre population are expected to be NEGLIGIBLE.

During spring and summer, loons and diving ducks occur mainly in coastal areas, with the exception of early June, when large numbers of king and common eiders and oldsquaws, and moderate numbers of loons stage in offshore leads and at the landfast ice edge (Searing *et al.*, 1975; Barry *et al.*, 1981). Dredging activities at most of the proposed marine borrow sites, and for subsea pipelines and gathering systems, would primarily occur several kilometres offshore and therefore would only potentially affect offshore concentrations of birds during the June staging period. Dredging at borrow sites closer to shore (e.g. Tuft Point, and in the southeast portion of the south Tarsiut area) may also affect local populations throughout the open water period since these areas provide summer moulting habitat for diving ducks (Scott-Brown and Allen, 1981; Barry *et al.*, 1981).

Although relatively large numbers of diving birds may be present in some offshore and coastal areas where dredging would occur, only NEGLIGIBLE impacts on most regional populations are expected as a result of reduced food availability, because dredging activities will be localized, intermittent in most cases, and the local loss of benthic organisms would probably not significantly alter their food supply (Section 2.4.2.9). In fact, a positive impact on surface feeding birds may result from the transport of benthic organisms to the surface by dredges. Thayer's and glaucous gulls have been observed feeding (probably on infaunal and epibenthic invertebrates) at the edge of the surface plume caused by dredging in McKinley Bay (Thomas, 1980) (see Plate 3.5-1, Chapter 3), and Harrison (1979) reported feeding by seabirds in the muddy water brought to the surface by bottom-feeding gray whales in the Bering and Chukchi seas. Nevertheless, the degree of positive impact is also expected to be NEGLIGIBLE in view of the localized and relatively short term nature of the increased food availability.

2.4.2.5 Fish

The possible impacts of dredging on fish in the Beaufort Sea include: (1) entrainment of fish in dredge intakes; (2) alteration of nearshore habitats through changes in bottom profiles, water circulation, or sediment transport; (3) direct adverse effects of increased levels of suspended sediments; (4) decreased abundance of food organisms in dredged or spoil deposition areas and lowered fish feeding efficiency within dredge plumes, and (5) interference with migration (ESL, 1982). In general, the proposed location of most large scale dredging operations in offshore areas and the localized effects of dredging suggest that no regionally significant impacts on fish are likely.

(a) Entrainment

Entrainment by a suction dredge can result in mortality of fish by direct physical trauma or by burial in discharged spoil (ESL, 1982). Recent investigations to determine the number of fish entrained by dredging in Tuktoyaktuk Harbour and McKinley Bay were unable to relate the number of fish collected in a subsample of the dredge spoil to the total number entrained, or to determine the significance of entrainment on the local fish population (Pelletier and Wilson, 1981). Nevertheless, it was established that in McKinley Bay, cod (thought to be saffron cod) 7 to 10 cm in length, and fourhorn sculpins 3 to 4 cm in length were entrained by the 90 cm suction dredge, while in Tuktoyaktuk Harbour, least ciscos (5 to 24 cm), Arctic ciscos (6 to 20 cm), inconnu (7 to 24 cm), fourhorn sculpins (5 to 10 cm), lake whitefish (11 to 16 cm), and one saffron cod 34 cm in length were entrained. These results suggest that in some nearshore areas of the Beaufort Sea, a broad range of sizes of several species, including some important in domestic fisheries, may be entrained by suction dredging equipment. The impact on local fish populations would probably be NEGLIGIBLE when only occasional individuals from a dispersed population were entrained, but could be MINOR to MODERATE if dredging operations were located in areas where fish concentrate for migration, spawning, feeding or overwintering such as channels of the Mackenzie River or in some small embayments near the Delta.

The proposed locations of dredging in offshore habitats and in the shallow water environments off Tuft Point and North Point suggest that the impact of entrainment on regional fish populations would probably be NEGLIGIBLE to MINOR, since fish are more widely dispersed in these habitats and the areas affected by dredging will be small in relation to available habitats elsewhere. For example, observations at Tuft Point during dredging activities in shallow water indicated little or no effect on fish, since dredging occurred outside of entrances to or within the coastal embayments where fish were concentrated (Aquatic Environments Ltd., 1977).

(b) Habitat Alteration

The loss of fish habitat through borrow removal and deposition or siltation will occur to some degree during all dredging operations in the Beaufort Sea. The potential effects would be more significant with demersal species and others which spawn, have incubating eggs, or rear in nearshore benthic environments. However, the magnitude of such impacts would obviously depend upon the location of the dredge, the size of the disturbed area, and the time of year. For example, the nearshore "edge" habitats on the lee side of barrier islands and along the mainland shores of the Beaufort Sea such as Tuft Point and probably North Point are used extensively by anadromous and marine species (including juveniles) during the summer (Olmsted, 1977a). On this basis, Poulin (1975) predicted that large scale dredging operations in these areas (e.g. removal of barrier spits) could alter habitat characteristics sufficiently to reduce fish presence for several years. Similarly, during periods of ice cover, some species such as sculpins, herring, flounders, or cod may spawn or have incubating eggs in coastal habitats which are sensitive to material removal or excessive siltation. However, the Tuft Point area has already been used as a borrow site by Esso, and studies of this area during dredging have indicated that there was little or no effect on fish populations (Aquatic Environments Ltd., 1977). Consequently, only NEGLIGIBLE or MINOR impacts to fish in the Tuft Point or North Point site would be expected during open water dredging activities if immediate nearshore habitats and small coastal embayments are unaffected (Aquatic Environments Ltd., 1977).

In offshore waters, where most of the materials required for artificial island construction will be obtained, the impacts of habitat alteration on fish would probably be NEGLIGIBLE because of the relatively small areas affected. One potential borrow site has been identified near Herschel Island (Figure 2.4-1), and dredging operations in this area may impinge on the narrow nearshore corridor utilized by anadromous species. Large scale continuous dredging may have a MINOR impact on the use of these habitats by fish.

(c) Suspended Sediment

Investigations of the effect of dredging in the Beaufort Sea indicate that suspended sediment levels usually do not exceed 200 to 600 mg/L within a few hundred metres of the dredge outfall, although a turbidity plume may extend several kilometres from the site. These observed concentrations are below the range where any acute lethal effects of suspended sediments have been reported with fish (Miles *et al.*, 1979). Although adverse sublethal effects or mortality might be expected after exposure of fish to these levels for ten days or more (Miles *et al.*, 1979), it is more likely that fish would avoid the relatively small areas where elevated levels of suspended sediments occur during the dredging operations. As a result, impacts of increased levels of suspended solids on fish are expected to be NEGLIGIBLE in offshore environments or in coastal areas where dredging is proposed.

The release of toxic materials such as heavy metals or hydrocarbons through suspension of contaminated sediments during dredging has been a concern in more industrialized areas (Section 2.4.2.1). However, potential adverse effects of these contaminants on fish in the Beaufort Sea are not expected to represent a signficant area of regional concern since dredging in areas where the discharge of drilling wastes, oily wastes, or sewage had occurred would not normally be undertaken.

(d) Turbidity

Increased water turbidity in the dredge plume may cause reduced feeding efficiency of visual feeders which are the most common species in the Beaufort Sea , since increased turbidity decreases the reaction distance of fish to all prey sizes (Vinyard and O'Brian, 1976; O'Brian, 1977). Therefore, in the immediate areas where dredging or spoil deposition occur, increased turbidity may limit feeding efficiency. However, in habitats where wide fluctuations in turbidity are normal, such as coastal areas including the Tuft Point and North Point sites, these effects would presumably be less important, since normally occurring turbidity often reaches the level which has been observed following dredging (Slaney, 1975). Even in offshore waters where turbidity is normally low, the relatively small areas affected by the dredge plume and the short-term nature of the disturbance suggest that impacts of turbidity increases on fish would be NEGLIGIBLE.

(e) Food Source Depletion

The indirect effects of food source depletion resulting from dredging will probably not have a significant impact on fish. Although the abundance of invertebrate food sources for fish in the Beaufort Sea coastal environments (particularly epibenthic crustaceans) would decrease in areas of borrow removal or spoil deposition (Section 2.4.2.9), the relatively small geographic areas affected, and the observed abundance of prey in most coastal waters (Volume 3A; Section 3.4) suggest that impacts associated with reduced prey availability due to dredging operations in the Beaufort Sea would be NEGLIGIBLE. In some particularly productive nearshore areas along the coast, such as Mason Bay and Mallik Bay, dredging could temporarily reduce the food availability for relatively large numbers of fish concentrated in these habitats during the summer. However, the past dredging activities at Tuft Point and those proposed for North Point occur outside of these habitats, and the information available from studies conducted at Tuft Point (Aquatic Environments Limited, 1977) suggests that no regionally significant effects of dredging on fish are likely in either of these habitats.

(f) Migratory or Behavioural Effects

The potential that increased suspended solids levels and turbidity, as well as other disturbances (e.g. underwater noise) associated with dredging may alter migratory patterns of fish (particularly anadromous species in the Beaufort Sea) has not been directly examined in any field investigations. However, there is some indirect information which suggests that dredging does not seriously interfere with normal behaviour patterns. For example, the capture of fish by fishermen and scientists in the immediate vicinity of dredge sites in the Beaufort Sea and elsewhere, suggest that fish did not avoid the entire area of disturbance (Hirsch *et al.*, 1978; Poulin, 1975; Byers and Kashino, 1980; Morton, 1977). In addition, as indicated earlier, the levels of suspended solids and turbidity near dredge sites are often within the normal range of background concentrations in habitats affected by the Mackenzie River plume (Poulin, 1975; Thomas, 1979; Hirsch *et al.* 1978). Consequently, it seems likely that dredging would have NEGLIGIBLE impacts on fish migrations unless equipment or spoil deposits in shallow waters prevent or delay fish passage. There is no information which suggests that such obstructions have occurred during dredging activities.

2.4.2.6 Phytoplankton

The potential impacts of dredging on phytoplankton communities of the Beaufort Sea were reviewed in ESL (1982). They may include increases or decreases in photosynthesis and/or changes in species composition as a result of changes in light intensity and spectral composition within turbidity plumes; redistribution of nutrients from the sediments; and mixing of various layers of the water column. However, past studies suggest that the dominant effects of dredging on phytoplankton would be related to turbidity plumes which are common to all dredging operations and are considered unavoidable. Nevertheless, any changes in the species composition and decreases in productivity of phytoplankton communities as a result of turbidity plumes would be extremely localized and virtually insignificant in relation to regional phytoplankton populations and primary productivity of the Beaufort Sea, including the coastal areas of Tuft Point and North Point, where nearshore dredging is proposed. The effect of dredging on phytoplankton would tend to vary with the timing, location and duration of these activities, but would probably be NEGLIGIBLE in the offshore environments where most dredging is expected to occur, since the affected areas will be small in relation to the wide-spread distribution of phytoplankton. In the nearshore environments near Tuft Point and North Point, the influence of the Mackenzie River turbidity plume would tend to minimize any incremental effects of dredging during open water periods, and the impacts of dredging on phytoplankton at these locations would probably also be NEGLIGIBLE. Potential adverse effects associated with resuspension of contaminated sediments do not appear likely in the Beaufort Sea when areas where drilling muds, sewage, or other contaminated discharges are avoided.

2.4.2.7 Zooplankton

The potential impacts of dredging on zooplankton were reviewed in ESL (1982), and may include sublethal effects and some localized mortality as a result of entrainment and increased concentrations of suspended sediments, as well as possible changes in the distribution or species composition in affected areas. Most of the concerns identified in that review were associated with continuous and long-term dredging in specific highly productive nearshore embayments outside of the Mackenzie River turbidity plume, where high standing stocks of zooplankton occur during the summer and where other higher trophic levels (e.g. fish) dependant on zooplankton may also be affected. Other potential concerns were related to dredging in contaminated areas where re-suspension of metals, sewage or other materials could occur and directly or indirectly affect zooplankton.

The proposed dredging activities in both offshore and nearshore environments are expected to have a minimal effect on zooplankton. The relatively small areas affected by dredging, the fact that zooplankton do not appear to be seriously affected by high turbidities, as well as the usually short-term nature of dredging effects on the water column (Section 2.4.2.1), suggest that the impacts of dredging on regional zooplankton populations will be NEGLIGIBLE. This is consistent with at least one study of dredging activities at Tuft Point where Aquatic Environments Limited (1977) reported that the turbidity increases associated with active dredging were unlikely to significantly affect plankton populations in that area. As with phytoplankton, effects of suspension of contaminated sediments on zooplankton do not appear likely in the Beaufort Sea as long as the immediate areas of drilling wastes, sewage, and other contaminated discharges are avoided.

2.4.2.8 Micro-Organisms

The effects of dredging on micro-organisms have not been investigated during previous studies in the Beaufort Sea, and have only been the subject of limited investigation elsewhere. Significant increases in the number and variety of bacteria in the water column, and a subsequent decrease in dissolved oxygen levels due to biochemical oxygen demand and photo-oxidation of reduced sediments, have been reported at dredge sites in temperate latitudes (Morton, 1977). These effects have usually been associated with the suspension of sediments with high organic content and/or sewage and waste-contaminated sediments, particularly at dredge sites with poor water circulation. There was some indirect evidence of potentially increased numbers of bacteria in turbidity plumes at dredging sites in McKinley Bay and Tuft Point, where minor reductions in dissolved oxygen concentrations were reported (Thomas, 1979; Slaney, 1977a). However, during other dredging and artificial island construction operations in this region, dissolved oxygen concentrations have not been affected, suggesting that an increased BOD due to elevated microbial activity did not occur. In addition, Beaufort Sea sediments do not have a high organic content and are relatively free of contaminants. As a result, the potential degree of impact of dredging on the numbers and activity of marine bacteria in the region is expected to be NEGLIGIBLE.

2.4.2.9 Benthic Communities

The possible impacts of dredging on benthic communities in the Beaufort Sea may include: mortality or physiological stress from physical disruption of the sea bottom, including removal or burial of benthos, resuspension of sediments, or other changes in water quality; and altered rates of recolonization in disturbed areas, or changes in community structure as a result of habitat alterations such as long-term local changes in sedimentation patterns, particle size distributions, bottom topography, water flow regimes and salinities (ESL, 1982). In general, major proposed dredging sites will disturb relatively small areas of the Beaufort Sea bottom and no major regional impacts on benthic communities are anticipated. Site-specific assessments of potential impacts of dredging at each of the proposed coastal shorebases are discussed separately in Chapter 3 of this volume.

(a) Physical Disruption of the Sea Bottom

The immediate physical disruption of the sea bottom during excavation and deposition of spoil materials causes the most significant impacts on benthic organisms. Mortality of benthic fauna may occur at various stages of the dredging operation, including entrainment and physical damage during excavation or overburden stripping, suffocation during transport with dredge spoil, and burial beneath the deposited material. The magnitude of the impact of bottom excavations on benthic communities will vary with the sizes of areas affected, the type of dredge used, and the species abundance and diversity of benthic communities in each area. The causes of mortality and the adaptations of various species to the stress associated with burial are reviewed in ESL (1982). Generally, in the zone of dredge spoil removal and deposition, benthic flora and fauna will be destroyed, particularly infaunal organisms (Morton, 1977).

Most of the proposed offshore islands and borrow sites in the Beaufort Sea occur in waters 15 to 40 m deep, coinciding largely with benthic communities which experience frequent scouring by ice keels (Wacasey, 1975; Heath *et al.*, 1982). These areas are not particularly rich in infaunal benthic organisms and the bottom is comprised of many areas in various stages of benthic recovery following natural scouring (Wacasey, 1975; Heath *et al.*, 1982). Although little is known regarding the distribution or abundance of epifaunal organisms (e.g. amphipods, mysids) in these offshore areas, the areas of offshore spoil deposition and removal will not affect a significant portion of the regional benthic habitat. The degree of potential impact, however, would be considered MINOR to MODERATE on a local basis, depending on the recovery time in these habitats, since recolonization over many years will affect more than one generation of most species. Since the sizes of the areas affected are small in a regional sense, no significant impacts on other trophic levels would be anticipated. In most nearshore habitats which are directly influenced by the Mackenzie River, infaunal benthic communities are also relatively impoverished because of low salinities and annual ice scouring, and benthic invertebrates in these areas appear adapted to a heterogeneous environment (Wacasey, 1975; Heath *et al.*, 1982).

Recent observations following dredging in Mackenzie Bay near Herschel Island indicated that disturbances from suction hopper dredges were restricted to the immediate area of the dredging trench and recolonization in dredged areas was relatively rapid, suggesting recovery of benthic populations in approximately 2 years (Heath *et al.*, 1982). On the basis of this study, dredging in areas such as Tuft Point and North Point are likely to result in only MINOR impacts on the benthic community.

(b) Water Quality Changes

Turbidity plumes and relatively high suspended sediment levels are characteristic of dredging programs, although turbidity levels created during dredging in nearshore areas (Tuft Point and North Point) may be within the range of natural background variability. In addition, benthic organisms normally associated with mud or silt substrates, such as those present in the Beaufort Sea, are highly tolerant of most suspended sediment conditions created in the water column by dredging and construction activities (Hirsch *et al.*, 1978). Consequently, direct mortality from suspended sediments is uncommon, although reduced feeding efficiency of filter-feeding invertebrates and mortality of mollusc larvae have been documented elsewhere (ESL, 1982). During winter, when the background turbidity is normally low, dredge-created turbidity plumes may increase the localized effect of suspended sediments on benthic flora and fauna. In addition, during periods of open water, high turbidity levels in shallow waters, where light normally reaches the bottom could also cause some short-term reductions in the rate of primary production by benthic microalgae.

Although the effects of high turbidity and suspended sediment concentrations on benthic flora and fauna of the Beaufort Sea have not been directly investigated, the available information suggests that no regionally significant effects are likely. The magnitude of the documented impacts on water quality discussed earlier (Section 2.4.2.1), also suggest that changes in suspended sediment concentrations and turbidity would be very localized and relatively short-term. Consequently, increased suspended sediment levels and turbidity associated with dredging would probably result in NEGLIGIBLE impacts on regional benthic communities.

Undisturbed marine sediments are typically characterized by a vertical gradient from oxidized surface deposits down to increasingly reduced sediments in deeper layers. The latter can create a chemical oxygen demand when these sediments are exposed to the overlying water body and undergo oxidation during dredging operations. In addition, a biological oxygen demand may be created if the resuspended sediment contains high concentrations of nutrients which stimulate active bacterial metabolism. Hydrogen sulfide, usually present in deeper layers of marine sediments or in buried peat, can also create an oxygen demand when introduced to the water column and can be toxic to various marine invertebrates (Theede *et al.*, 1969).

In general, offshore surface sediments of the Beaufort Sea are highly oxidized and usually contain less organic matter than sediments at similar depths elsewhere in tropic and temperate zones (Carsola, 1954; Naidu and Mowatt, 1974), suggesting that these materials will have relatively low biological and chemical oxygen demands. This is consistent with past studies of dredging operations in the Beaufort Sea which have shown that any oxygen depletions associated with dredging are usually minor and of relatively short duration (Section 2.4.2.1). Since many benthic invertebrates tolerate relatively low levels of dissolved oxygen, the impacts of oxygen reductions associated with dredging in both the offshore and nearshore zones of the Beaufort Sea would probably be NEGLIGIBLE.

The release of toxic materials such as trace metals during dredging is probably not a significant concern at present in the Beaufort Sea region. Sediments here do not contain the magnitude or diversity of contaminants found in sediments adjacent to large industrial and population centres. The only potential area of significant concern would be the release of any toxic materials from areas where drilling muds, oily wastes, or untreated sewage are deposited, and as indicated earlier, these areas will be avoided when possible during proposed dredging programs. In fact, these areas are more likely to be buried, as islands undergo repair or are enlarged during the production phase.

(c) Benthic Habitat Alterations

Alterations in bottom contours, particle size composition of exposed sediments, food availability and possibly temperature and salinity regimes may occur in both excavated and spoil deposition areas. These habitat changes can subsequently alter rates of benthic recolonization, survival and reproduction, and may lead to changes in the structure of the benthic community. Post-dredging studies completed in temperate marine waters have indicated that numbers and species of organisms in dredged and spoil deposit areas are frequently different from those in undisturbed surrounding areas (Morton, 1977). Recolonized dredged areas may also contain different dominant species than spoil deposition areas.

In the Beaufort Sea, there have been several studies of benthic communities following dredging operations. Thomas *et al.* (1982) sampled the sea floor around the Tarsiut artificial island and the South Tarsiut borrow area in September, 1981 in order to determine the distribution and community associations of benthic invertebrates. At the time of sampling, dredging for sand had been completed at South Tarsiut and construction of the island had proceeded to the installation of the cement caissons. The average levels of benthic biomass and population density were found to be higher in borrow site samples than in those from the island vicinity. Biomass and population densities were generally greater at stations located 500 m and 3,000 m from the artificial island than at the stations located 50 m from the island.

Compared to other studied sites in the Beaufort Sea, the East Tarsiut site has sparse populations of benthos with low diversity. A qualitative analysis by the Zurich-Montpellier method distinguished three benthic associations with differing affinities for the two station clusters, one comprising the island site stations and the other the borrow area stations. One group of species was commonly found at the island site but occurred only rarely at the borrow site stations. A second group was rare at the island site but common at the borrow site. A third group comprised species found frequently in samples from both station clusters. Early recolonization of the subsurface plateau of sand around the caissons was evident from the presence of certain species of bivalve molluscs and polychaete worms. The area was resampled in July, 1982 but the results of this work will not be available until later this year.

Beak Consultants Ltd. (1981) described the distribution of benthic invertebrates adjacent to Issungnak artificial island, and concluded that post-dredging alterations in sediment particle size were primarily limited to the area encompassed by the 0.53 km^2 island base and the two borrow pits. Sand sediments located at the outer edge of the island base 300 m away from the shoreline formed a transition zone with some mixture of sand and silt-clay components, while areas 900 to 1,800 m from the site had natural silt-clay substrates. Biological effects of the construction of Issungnak did not extend far beyond the underwater slopes of the island base or the principal borrow pit, and recolonization of the construction zone began immediately. Species colonizing this construction zone included some species from the background zone, as well as three polychaete worm species found only in the construction zone, which probably colonized the area through dispersal of planktonic larvae (Beak Consultants Ltd., 1981).

The Isserk F-27 artificial island was built in 12.8 m of water, and a baseline study was conducted during its construction by Envirocon Ltd. (1977). They reported that sand from either the dredged or barged material was distributed adjacent to the island base, while natural sediments elsewhere in that area were primarily silt and clay. Benthic species diversity and biomass data did not show any statistically significant trends related to island construction. Olmsted (1977b) reported that sediment dispersal associated with the construction of another island (Arnak L-30) in 7 m of water, did not significantly alter either infaunal biomass or abundance at two stations 400 and 500 m from the site, when compared with a control station. Limited sampling during this study also suggested that the physical presence of artificial islands, and perhaps borrow pits, may provide additional habitats for some epibenthic species, particularly mysids and amphipods (Olmsted, 1977b).

In the offshore Beaufort Sea region, excavation of subsea glory holes and borrow pits would create localized depressions or basins in the sea floor (Figure 2.4-4). These deep depressions would expose sand sediments completely devoid of organisms, and are therefore less likely to be quickly colonized. In shallow waters, excavated basins may also have higher salinities, colder temperatures and reduced current velocities, and these factors may similarly reduce rates of colonization. However, sediment deposition from bottom-scouring currents during storms would tend to fill in those basins in waters less than 15 m deep. Dredged basins in deeper waters would likely accumulate these fine materials more slowly and remain as seafloor depressions for prolonged periods. However, bottom ice scouring is common in most of the areas where offshore dredging would occur, and while offshore dredging may create some local deep depressions and change bottom contours, natural processes are also continually altering the sea bottom on a regionally more extensive scale.

Since most offshore dredging and island construction activities in the Beaufort Sea are proposed within a zone characterized by frequent ice scouring, it is likely that benthic communities in these areas contain species adapted to colonizing recently disturbed substrates. This hypothesis is supported by recent studies following suction hopper dredging in Mackenzie Bay (Heath *et al.*, 1982), where only short-term and localized changes in benthic communities were documented in dredged areas. Generally, dredged areas were indistinguishable from naturally ice scoured zones and recovery of benthic fauna in trenches was considered likely within approximately 2 years of this dredging operation. Recolonization in offshore borrow pits may require a period of several years where exposed uninhabited sand slowly accumulates fine particles suitable for colonization by benthic communities. However, these borrow pits will represent an extremely small proportion of the sea floor of the Beaufort Sea.

Over-all, the geographic areas to be affected will be relatively small but the impact of proposed dredging activities on benthic organisms in the Beaufort Sea will likely be locally MODERATE, since the period required for recovery would involve several generations of fauna. In other environments, such as areas surrounding island bases and trenches resulting from suction hopper dredging or subsea pipeline installation, the rapid recovery documented at some sites in the Beaufort Sea suggests that only MINOR impacts would occur.

2.4.2.10 Epontic Communities

The potential impacts of dredging on epontic communities will depend on the extent of the physical disturbance of the ice cover during icebreaking, as well as the effects of dredging on the physical and chemical characteristics of the under ice surface and water column. Present development plans suggest that icebreaking dredges, if employed in the future, could operate until January at offshore borrow sites, while some dredging during the winter will probably occur at North Point and other adjacent nearshore areas where subsea pipelines could be installed.

There is little reason to expect that the physical and chemical changes which have been observed in the water column during open water dredging operations would be substantially different during winter operations, although background turbidity/suspended sediment levels in the nearshore Beaufort Sea would be much lower due to the reduced discharge of the Mackenzie River. Consequently, the potential effects of dredging on epontic communities would likely be associated with changes in dissolved oxygen and nutrient concentrations, increased concentrations of suspended sediment, and alterations in the temperature and salinity profiles in the water column. However, since only relatively small areas of water surface would be affected by dredging, and most effects would be short-term, the potential impacts on regional populations of epontic organisms are expect to be NEGLIGIBLE.

Open water dredging in the Beaufort Sea appears to have no marked effect on nutrient and dissolved oxygen levels in the water column. Nutrient enrichment due to dredging in the Beaufort Sea has been limited to slight increases in total organic carbon and nitrate (ESL, 1982). Phosphates and silicates, which are also important nutrients for diatom growth, have not increased during open water dredging operations. Short-term and minor reductions in dissolved oxygen have been reported several hundred metres from dredge outfalls in the Beaufort Sea during the open water season. However, these reductions would probably not occur during winter since lower water temperatures significantly reduce the biological and chemical oxygen demands.

If suspended sediments adhered to the under ice surface and became trapped in the growing ice, light penetration and subsequent primary productivity of epontic flora may be decreased. However, this scenario seems unlikely since the results of modelling studies indicate that suspended sediment would settle before it could be encapsulated in the ice (Mangarella *et al.*, 1979). In addition, epontic flora are adapted to low light levels and fluctuating light intensities normally associated with varying snow and ice thicknesses (Volume 3A; Section 3.5.8).

Dredging should have no significant effect on the water temperatures and salinities beneath the ice cover. During winter, the water column under the ice in most nearshore and offshore waters is relatively homogeneous with respect to temperature and salinity, and mixing due to dredging would probably have no effect on the temperature or salinity of water immediately below the epontic community. In addition, any changes in these parameters which might occur during early spring and summer (when a freshwater surface layer occurs) would be confined to areas relatively close to where dredges were operating. Consequently, the impact of proposed dredging activities on epontic flora and fauna of the Beaufort Sea would likely be NEGLIGIBLE.

2.4.2.11 Summary of Possible Impacts of Dredging

The available information presented in the previous sections suggests that the possible impacts associated with dredging should be NEGLIGIBLE or MINOR for most marine resources of the Beaufort Sea. The magnitude of impacts would usually be limited by the relatively small geographic areas affected by dredging, the short-term nature of many of the physical-chemical disturbances, and the fact that in most of the areas where major dredging will occur, the sea bottom already experiences frequent scouring by ice keels. MINOR impacts on bowhead and white whales could occur if underwater noise from offshore dredging operations disturbed some individuals by interrupting migration or feeding activities. In some local nearshore environments, MINOR to MODERATE impacts on plankton and fish populations could result where particularly productive coastal embayments supporting large populations of fish were affected. However, other than at coastal shorebases (Chapter 3), the only dredging activities currently proposed for coastal environments (Tuft Point and North Point) will probably not affect these productive nearshore habitats and only NEGLIGIBLE to MINOR impacts on plankton and fish appear likely as a result of the proposed development. Impacts on benthic communities will be at least MINOR due to the direct mortality of infauna and some epifauna in the areas of dredge spoil removal and deposition, and could be locally MODERATE where relatively long periods are necessary for recovery of benthic communities. Nevertheless, where MODERATE impacts occur because of slow recolonization, the sizes of areas affected by dredging would still be insignificant in comparison with available benthic habitat in the Beaufort Sea region. Site-specific impacts of dredging on resources in the vicinity of coastal shorebases could be more significant locally, and are discussed in Chapter 3.

2.4.3 SUBSEA PIPELINES AND GATHERING SYSTEMS

In the offshore Beaufort Sea, subsea pipelines and gathering systems will be used to transport oil from satellite wells located on artificial islands or subsea, to central production facilities, and to transport oil either from offshore to land to be transferred to a main pipeline, or from land to an offshore tanker loading terminal (Volume 2; Section 4.6). Approximately 75 kilometres of subsea pipeline may be required by 1987 (principally to service Tarsiut), 300 kilometres by 1995 and 375 kilometres by the year 2000. The latter two figures assume that subsea pipelines connect the offshore area with the land at Richards Island.

This section discusses the potential impacts of construction and normal operation of these facilities on the physical environment and biological resources of the Beaufort Sea. Volume 6 addresses possible oil spills from these subsea systems. The installation of subsea pipelines and gathering systems will involve dredging, or possibly ploughing, vessel traffic and possibly icebreaking, if winter construction is involved in the installation of these systems. Since these activities are the subject of major sections in this volume (Sections 2.4.2, 2.3.6 and 2.4.4, respectively), only those impacts which may result from pipeline-related activities are described.

The only environmental impacts that are likely to be associated with the normal operation of subsea pipelines are those which result from the physical presence of a hard substrate in an area which is naturally characterized by fine granular sediments. Section 2.4.1.2 discussed the potential for colonization of artificial substrates by benthic invertebrates and algae in the Beaufort Sea, while the relative contribution of proposed subsea pipelines as an artificial substrate in the Beaufort Sea is briefly described in this section.

2.4.3.1 Dredging

Approximately 375 km of subsea pipeline and gathering systems may be required for the proposed development of offshore hydrocarbon resources in the Beaufort Sea. Roughly 40% of the system would be located in water depths less than 20 m, with construction of the majority of deep water pipelines and gathering systems occurring after 1990. It is estimated that the major pipeline installation activities will be completed over a time period of approximately 6 years. A major trunkline connecting onshore production fields with the Issungnak production island is assumed to be the only proposed subsea pipeline that is expected to intercept the shoreline (North Point). The depth of the pipeline trench will vary with the depth to the sea floor to mitigate potential concerns related to ice scour, ice freezing to the pipe and thawing of permafrost. The deepest trenching (5 m deep and approximately 22 m wide) would be required at water depths between approximately 20 to 50 m due to the higher frequency of ice scour in this region. At these depths, the pipeline would rest in the trench without backfill except where it approaches artificial islands. In areas less than 2.5 m deep where the pipeline intercepts the shoreline at North Point, the trench would be shallower, insulated to prevent permafrost thaw and backfilled. Approximately 25 km of pipeline (including inter-island flowlines within fields and major trunklines between fields) may be installed per year between 1984 and 2000, with a maximum of approximately 80 km of the system constructed in any given year. Based on the above maximum trench widths and an average yearly installation rate of 25 km of the system, approximately 0.5 km^2 of sea bottom could be disturbed per year by dredging for pipeline trenches occurs, and a total of approximately 8 km^2 of substrate may be disturbed by the year 2000. The volume of dredged material removed for burial of the subsea pipelines and gathering systems is expected to represent less than a quarter of a percent of the total estimated dredging requirements for the proposed development, or approximately 10 million cubic metres. The physical impacts of subsea pipeline construction in terms of seafloor disturbance would be considered LOCAL and LONG-TERM since trenches are expected to remain as relatively distinct features on the seafloor throughout the duration of development.

The impacts of dredging on marine flora and fauna of the Beaufort Sea were discussed in Section 2.4.2, and ranged from NEGLIGIBLE to MINOR for most resources on a regional basis. The local impact of pipeline-related dredging on benthic communities could be considered MODERATE, depending on the number of generations required for complete recolonization of dredged trenches by benthic infauna. Nevertheless, the disturbed area (8 km^2) would represent a very small portion of the available benthic habitat in the region. It was suggested earlier (Section 2.4.2.5) that large-scale dredging activities in productive coastal embayments could have a MODERATE impact on some species of fish during periods of intensive use of nearshore habitats. However, since nearshore dredging for the subsea pipeline system is only expected to occur in the North Point area and only approximately 0.025 km^2 of sea floor are likely to be disturbed by this operation (Volume 2, Section 4.6), the degree of potential impact of this activity on regional fish populations would probably be NEGLIGIBLE to MINOR.

Trailing hopper dredges would likely be used for trenching in water depths greater than 20 m (Volume 2). Since dredged spoil is contained within these vessels, turbidity and suspended sediment concentrations should not be increased to levels reported during uncontained fill activities associated with the construction of sacrificial beach artificial islands (ESL, 1982). Shallow areas, where cutter suction dredges may be used for pipeline trenching, would generally be in the region where wide-ranging turbidity is common during the open water season due to the influence of the Mackenzie River plume. Consequently, the impacts of these dredging programs on water quality would be LOCAL and SHORT-TERM. For similar reasons, the degree of potential impact of increased turbidity and suspended sediments associated with dredging for subsea pipelines and gathering systems on all marine resources of the Beaufort Sea is expected to range from NEGLIGIBLE to MINOR.

An alternative method of pipeline trenching which may be feasible for the Beaufort Sea area involves the use of a seabed plough. This technique is faster than dredging and associated turbidity levels are lower. The impacts of using this technique would be even lower than those associated with dredging.

2.4.3.2 Vessel Traffic and Underwater Sound

A number of vessels might be used in the laying of subsea pipelines and gathering systems, including cutter suction and trailing hopper dredges, icebreakers, pipe-laying barges which accommodate up to 200 persons, tug boats and support (crew) boats. Details regarding the construction method, location and timing of subsea pipeline installation have not been finalized at the present time (Volume 2, Section 4.6), and these considerations will largely determine the type and number of vessels required for the operation.

The potential impacts of vessel traffic and underwater noise were discussed in detail in Section 2.3.6. Underwater sound associated with construction of subsea pipelines may disturb or mask communicatory or navigational signals of whales and seals. Bowhead whales are considered most vulnerable to the low frequency sounds which would be produced because the low frequency sounds of their vocalizations (and presumably their hearing sensitivity) correspond to the low frequency sounds produced by these industrial activities. Bowheads have been occasionally observed in the vicinity of operating dredges, with no obvious or visible effects (Fraker *et al.*, 1981).

It is expected that underwater noise associated with the installation of approximately 25 km of pipeline on average per year, or 75 km maximum, would not cause a marked disturbance to bowheads, but may cause low-level masking and temporarily reduce local conspecific communication distances. The potential impacts of noise generated during construction of subsea pipelines on the regional bowhead whale population would probably range from NEGLIBIBLE to MINOR, depending on the location of the activity, the concentration and activities of whales in the affected areas, and the acoustic environments.

White whales may also be affected through disturbance or masking by underwater noise from subsea pipeline construction, but the zone of influence would probably be smaller in most cases because this species is less sensitive (than bowheads) to the low frequency noise generated by vessels and dredges. The impacts of subsea pipeline construction on white whales would probably also be NEGLIGIBLE to MINOR in most instances. Exceptions to this prediction could occur if the operations took place in June, July or August, when white whales could be present in the vicinity of operations planned for the North Point area. However, the proponents would schedule construction activities in this area to avoid interactions with white whales.

Ringed and bearded seals in the vicinity of subsea pipeline installation operations would probably be affected by underwater noise produced by various vessels and activities, although potential effects would be localized and limited to the construction months. Since only a small proportion of the regional populations could be affected, the impact of underwater noise associated with subsea pipeline construction on these species would likely be NEGLIGIBLE.

2.4.3.3 Icebreaking

Some sections of the subsea pipeline and gathering system may be constructed during winter in landfast ice areas. The most likely method of laying pipe under ice involves trenching through both ice and sediment in the bottom-fast zone (Volume 2, Section 4.6). This method may necessitate linear icebreaking in some areas, although the location and amount of below-ice pipeline installation have not been finalized. Nevertheless, icebreaking required for subsea pipeline installation would only have a LOCAL and SHORT-TERM impact on the ice regime. The possible impacts of icebreaking on the biological resources of the Beaufort Sea are discussed in detail in Section 2.4.4, and depending on the species and area affected, could range from NEGLIGIBLE to MINOR. The degree of regional impact of icebreaking for construction of subsea pipeline systems would be comparable since these activities would be highly localized and restricted to thin-ice periods.

2.4.3.4 Artificial Substrate

The installation of the major subsea trunklines could result in the creation of approximately 0.05 km^2 of artificial substrate per year (based on installation of 25 km of 76 cm diam. pipe per year, with 75% of the circumference remaining above the sea floor), for a total substrate area of less than 0.5 km^2 by the year 2000. Additional artificial substrate would result from the construction of the inter-island flowline (gathering) systems in each field. These hard surfaces are likely to be colonized by sessile invertebrates and macrophytic algae which are generally uncommon in the Beaufort Sea due to the limited amount of this type of substrate (Volume 3A, Section 3.5). However, the relatively small amount of habitat created suggests that any impacts, although positive, would likely be NEGLIGIBLE. Proposed offshore production islands and loading terminals would provide more extensive areas of artificial substrate, but colonization of their surfaces is also expected to have a NEGLIGIBLE impact in terms of the diversity and abundance of regional populations of benthic organisms.

2.4.3.5 Summary of Possible Impacts of Subsea Pipeline Installation

The possible impacts of subsea pipeline and gathering system installation on the physical environment of the Beaufort Sea would be LOCAL, but generally LONG-TERM. Biological impacts associated with the construction and normal operation of subsea pipelines and gathering systems are generally expected to be local and to range from NEGLIGIBLE to MODERATE, depending on the specific resources affected. MODERATE local impacts on benthic communities are likely due to the potential for relatively long-term habitat disturbances associated with the excavation of subsea pipeline trenches, although the amount of habitat affected is considered regionally insignificant. In addition, since benthic biota will begin to recolonize the trenches immediately, few if any regionally significant long-term impacts on benthic fauna or members of higher trophic levels would be expected. Lack of detailed information regarding construction timing, locations and methods prevents a full assessment at this stage of planning of the degree of potential impact which may be associated with the effects of underwater sound and icebreaking during installation of the subsea pipeline system. Potential impacts of these disturbances on marine mammals would be minimized by arranging the timing and location of activities wherever possible to avoid known sensitive habitats of certain species (e.g. Mackenzie estuary in June, July and August).

2.4.4 MARINE VESSEL ACTIVITIES

The number and types of marine vessels, including icebreakers, which are now in use and proposed for the future are discussed in detail in Volume 2. Concern has been expressed about possible effects of icebreaking in the Beaufort Sea on the stability of the landfast ice sheet and on the timing of breakup. Possible alterations in the regional ice regime which may have occurred in the past due to icebreaking have not been separable from the natural variability that occurs in the area (Volume 3A: Section 1.1). This section examines possible effects that icebreaking may have on ice regimes, on marine mammals, birds, fish and epontic organisms, and particularly on seals, which may be directly affected during spring by icebreakers passing through pupping or haul-out areas. (Possible effects of underwater noise generated by marine vessels while breaking ice are described in Section 2.3.6).

2.4.4.1 Effects of Icebreaking on the Ice Regime

(a) Landfast Ice

There is concern that icebreaking within the landfast ice in the Beaufort Sea may cause the landfast ice to become unstable. If such instabilities have occurred to date, they have been masked by the natural variability in the extent and break-up times of the landfast ice. There is concern that repeated icebreaking within restricted corridors in the landfast ice could precipitate an earlier than usual local break-up, or augment ice growth within corridors that may alter the timing and patterns of local break-up. There is also concern that a ship's track could trap whales or act as a temporary barrier to Inuit hunters and mammals travelling on the sea ice. In the Beaufort Sea production zone, the only species of terrestrial mammal which could be affected by icebreaking is the Arctic fox.

In most years, stable landfast ice extends north of the Mackenzie Delta and Tuktoyaktuk Peninsula to about the 20 m isobath by February or March. This ice is about 0.5 m thick in November, and has a maximum thickness of about 2 m in late April (Volume 3A; Section 1.1). Construction of production islands and a tanker loading facility at Tarsiut is possible by the latter part of this decade. The Tarsiut field is located in water depths ranging from 17 to 22 m, and therefore is located near the outer edge of the landfast ice zone or in the transition zone, depending on annual and seasonal variations in the extent of the landfast ice. Issungnak, on the other hand, is located in 17 to 19 m water depths, and is usually within the landfast ice zone. The Kopanoar, Koakoak and Tingmiark sites are all within the transition ice zone.

Icebreaking in the landfast ice would be done using Class 3 to Class 6 icebreakers, and would be confined within the single traffic corridors connecting the transition ice zone with Tuktoyaktuk, McKinley Bay and perhaps a shorebase along the Yukon Coast. The existing corridor from McKinley Bay to the transition zone is 100 m wide, but may be expanded to 150 m wide within 1 or 2 years. It follows a dredged channel to the 10 m isobath. At some point, a second icebreaker corridor may be required from a shorebase on the Yukon Coast to the transition zone. By the mid 80's, two or three ice strengthened barges may operate along a restricted corridor through the landfast ice to deliver rock for offshore construction from a quarry near Mount Sedgewick via a base on the Yukon coast. From Tuktoyaktuk, shallow draft, ice-strengthened supply vessels are expected to operate until about early November along a single corridor. Icebreakers would be used year-round to transport personnel and supplies between offshore islands and shorebases, and to break-out drilling and dredging vessels in spring from McKinley Bay and eventually from a northern Yukon shorebase, such as King Point or Stokes Point.

Landfast ice remains in place because it is geometrically keyed to the coast and locked to grounded multi-year floes at its offshore edge (Volume 3A, Section 1.1). Offshore of the landfast ice edge there is often open water as part of a flawlead system. Break-up patterns beginning in early summer are determined not only by the ice being weakened by melting but by natural phenomena such as current stress due to the regional circulation, wind stress, and the offshore flow and heat input from the Mackenzie River. These large-scale regional influences on ice break-up make it unlikely that there would be significant break-up effects caused by icebreaking in restricted channels within the landfast ice.

Repeated breaking and refreezing of ice in icebreaking corridors through the landfast ice has been observed to augment ice growth. For example, measurements in the track left by KIGORIAK in McKinley Bay during mid December 1981 indicated that within 46 days of the last passage of the vessel, the average ice thickness in the track was 157 cm. In contrast, the average thickness of undisturbed ice was 116 cm. Ice thickness was also measured in the McKinley Bay mooring basin where the ice had been almost continually disturbed since freeze-up, and a maximum thickness of 330 cm was observed (Danielewicz, 1982). Although ice thicknesses would increase in these disturbed ice areas, it is unlikely that regional break-up patterns would be delayed in view of the small areas of increased ice thickness and the natural variation in ice thicknesses elsewhere. In summary, potential effects of icebreaking on the patterns of break-up and ice stability are expected to be LOCAL and SHORT-TERM, and within the range of natural regional variability.

There is a concern that the track of an icebreaker through an ice field may be a temporary barrier to the travel of Inuit hunters and terrestrial mammals or could create an artificial lead which could refreeze and trap whales (APP, 1981). Another concern is that icebreaking could relieve compressive stress in an icefield and allow a lead elsewhere to form in a manner similar to that observed by Bradford (1978) in Barrow Strait. The extent and persistence of icebreaker-created leads would depend on the prevailing winds, currents, temperature, ice conditions and where the icebreaking occurs.

During trials using KIGORIAK to break landfast ice, the track produced was slightly wider than the vessel, and generally filled with ice floes and rubble (Alliston, 1980; Plate 2.4-6). Trials with KIGORIAK in McKinley Bay during late November, 1981, demonstrated that the slush between the ice blocks in the track created by the icebreaker and 4 supply vessels had refrozen to a thickness of approximately 2 cm within 1 hour of their passage (Plate 2.4-7). Within 2 hours, the slush had frozen to a thickness of 5 cm, and a skidoo and driver with a total weight of 300 kg drove across the track with no signs of ice fracture. A 570 kg loaded komatik towed across the track 2.5 and 3 hours after the passage of the vessels moved easily until it rode up on an ice block and fell about 30 cm onto the refrozen slush. However, the ice did not break through under the komatik, and it continued to move along in a 10 to 20 cm depression. Ice thickness in the new track after 23 hours averaged 60 cm, while ice under older tracks ranged from about 130 to 160 cm thick (Danielewicz, 1981).

During the maiden voyage of KIGORIAK through the Northwest Passage in September, 1979, the vessel produced an ice-free channel in ice up to 75 cm thick, while relatively little ice was cleared out of the track when ice thicknesses exceeded 75 cm (MacLaren Marex, 1979). Also, in ice about 120 cm thick, broken ice completely filled the track. The authors suggested that a man could cross the track of a vessel moving through ice of that thickness by the time it was 200 m away.

General observations are that when a ship breaks ice, the ice is forced under the vessel in large pieces. Some of the ice passes through the propellers where it is broken into smaller pieces. This mixture of ice pieces floats to the surface behind the vessel. The final appearance of the ship's track is a strip of rubble-like pieces ranging to 4 to 5 m in diameter, embedded in smaller ice pieces and slush. At temperatures below freezing, these freeze together rapidly. Only in thin ice and at relatively high speeds would there be appreciable open water in the track, however, in winter this open water would soon freeze.

The results of the above studies and general observations can be applied to determine possible impacts related to the creation of artificial leads in landfast

PLATE 2.4-6 *The track created by an icebreaker through ice is generally slightly wider than the vessel. In the background of this photo, the track is its normal width. In the foreground it is roughly two or three times the width of the vessel because it is moving backwards and forwards as part of an experiment.*

PLATE 2.4-7 *Under all conditions tested during the period from November, 1981 to June 1982 ice in the track consolidated to the point where people could cross it within roughly one hour.*

sea ice. These impacts are considered to be LOCAL and SHORT-TERM in the winter and spring but may be LONGER-TERM in late spring in advance of break-up of the landfast ice.

(b) Transition Zone

The transition or seasonal ice zone is between the seaward edge of the landfast ice and the edge of the polar pack. It deforms rapidly, is heavily ridged and contains ice of various types and concentrations. Due to the north and south movements of the polar pack, the width of the transition zone varies within and among seasons from a few kilometres to up to 300 km wide (Spedding, 1978). First year ice predominates, although substantial multi-year floes also occur in the transition zone. Mean ice drift speeds in this ice zone range from 3 to 13 km/day throughout the year; however, drift speeds offshore from the Mackenzie Delta can exceed 30 km/day. Further details on the morphology of transition zone ice are provided in Volume 3A, Section 1.1.

Icebreaking vessels which would operate in the transition zone include the Class 3 to Class 6 icebreakers that would operate in the landfast ice as well as Class 10 icebreaking tankers and Class 10 support icebreakers. Routes and timing of icebreaking activities would vary depending on development requirements, weather and ice conditions, but would probably exploit periods and areas of thinner ice. The possible effects of icebreaking on the integrity of transition zone ice are expected to be LOCAL, SHORT-TERM and indistinguishable from the natural variability of the ice within this dynamic ice zone.

2.4.4.2 Local Marine Transport

This section discusses possible effects of the physical presence and operational activities of marine logistics traffic on the marine biological resources of the Beaufort Sea region. (Wastes and disturbances associated with marine vessel activity are described in Section 2.3, and include human presence, solid wastes, treated sewage discharge, atmospheric emissions, and airborne and underwater noise.)

(a) Open Water Season

The physical presence of marine vessels operating during the open water season between the shorebases and offshore sites is rarely expected to have impacts greater than NEGLIGIBLE on marine fauna (ESL, 1982). Although fish kills have been documented from propeller entrainment in the Arctic, those instances are limited to short periods when the ships initially start-up and when large concentrations of fish, such as Arctic cod, are attracted to the undersurface of the vessels (ESL, 1982). Nevertheless, the numbers of fish affected would not be regionally significant and the potential impact of entrainment on regional fish populations is expected to be NEGLIGIBLE.

The effects of normal shipping and icebreaking activity on marine-associated birds in the Beaufort Sea are expected to be NEGLIGIBLE because birds are highly mobile, can easily avoid the vessels, and any energy expenditures involved in local movements would probably be inconsequential for most species. The only possible exception may occur during the passage of marine traffic near colonies where birds are highly concentrated during the nesting season. Continual disturbance may result in reduced reproductive success, nest destruction, or abandonment of the colony (APP, 1981). The extent and significance of this form of disturbance would vary with the location and timing of vessel traffic. However, there are no major nesting colonies located near probable offshore vessel routes, and potential impacts would likely be NEGLIGIBLE. (Possible impacts as a result of occasional vessel activity in the vicinity of some of the nesting colonies near shorebases are assessed in Chapter 3.)

(b) The Landfast Ice Zone

Icebreaking by Class 3 to Class 6 vessels in areas of landfast ice would be restricted to single 100 to 150 m wide corridors leading to the transition zone from Tuktoyaktuk, McKinley Bay and from a base on the Yukon Coast, such as King Point. The physical presence of icebreakers in the landfast ice zone is expected to have NEGLIGIBLE impacts on marine fauna other than seals in the region. Movements of icebreakers could cause repeated diving of hauled-out ringed and bearded seals, or crush seal pups during excursions through pupping areas. There is also concern that icebreakers may create artificial leads that could temporarily restrict movements of Inuit or Arctic foxes on the ice, or that could refreeze and trap whales.

There is usually a concentrated westward migration of white whales along the landfast ice edge off the Tuktoyaktuk Peninsula during late June or early July (Volume 3A: Section 3.2), and there is concern that some individuals may enter and follow the channel created by icebreakers bound for McKinley Bay. As discussed earlier in Section 2.4.4.1, the track behind a Class 3 or Class 6 icebreaker operating in the landfast ice during spring would be completely filled with rubble rendering it unusable for whales. In early summer, a track may temporarily clear, however, entrapment at this time is unlikely since breakup would be almost complete and whales are well adapted for navigation through extensive ice-covered areas where the location of open leads is constantly changing as a result of natural forces. Consequently, the degree of impact from icebreaking in the landfast zone on the regional white whale population is expected to be NEGLIGIBLE.

Ringed and bearded seals were observed to dive in response to the approach of KIGORIAK in the Northwest Passage during September, 1979, at distances of 1.6 km and less (MacLaren Marex, 1979), suggesting that seals in icebreaking corridors in the Beaufort would probably avoid icebreakers. Mortality of adults through collisions is not anticipated, although ringed seal pups in subnivean birth lairs in the landfast ice may be crushed by icebreakers passing through breeding areas from late March to late May. During the early development phase, most icebreaking in the landfast ice would be limited to the months of November and June when the seasonal vessels are broken out from their winter moorages. Later, icebreaking corridors in landfast ice may be maintained throughout the winter, raising the possibility of kills of ringed seal pups in the icebreaking corridors during the spring pupping period. However, the primary pupping areas do not occur within the proposed icebreaking corridors (Stirling *et al.*, 1977), hence, the number of pups which may be lost each year would probably be a small proportion of the young-of-the-year. In addition, breeding females may eventually avoid pupping sites in the icebreaking corridors. On this basis, the impact of icebreaking in the landfast zone on regional ringed seal populations during breeding would not likely exceed MINOR because of the relatively small numbers of individuals affected. Bearded seals would not be significantly affected by icebreaking activity in the landfast ice zone during the breeding period because their pups are usually born on moving pack ice or on transition zone ice. Therefore, impacts on this species are considered to be MINOR.

Ringed and bearded seals haul-out each June for 2 to 3 weeks during the annual moulting period. Highest densities of hauled-out ringed seals on the landfast ice occur off the Yukon coast, the Tuktoyaktuk Peninsula, Cape Parry and the southwest coast of Banks Island (Stirling *et al.*, 1981a). Bearded seals prefer haul-out areas in the transition zone, and are most abundant off the Tuktoyaktuk Peninsula, Cape Bathurst and Cape Parry (Stirling *et al.*, 1981a). Mortality of moulting seals through collisions with icebreakers is unlikely because they have the ability to avoid the vessels.

Alliston (1980) examined the effects of limited winter icebreaking by KIGORIAK in the landfast ice off McKinley Bay on the distribution of ringed and bearded seals during the winter and during the spring haul-out period. Comparison of breathing hole densities did not indicate any significant differences between use of the experimental and control areas by ringed seals during winter. During haul-out, seal use of icebreaker tracks was as great or greater than use of the undisturbed control area. In addition, both wintering and hauled-out ringed seals exhibited an apparent preference for the refrozen icebreaker tracks. The expected redistribution and influx of seals from the local population is consistent with the hypothesis that seals are attracted to late freezing cracks in the ice (Smith and Stirling, 1975). Although the number of bearded seals recorded during the surveys was not sufficient to determine any statistically significant trends, movement of at least 32 individuals into the break-out track was observed on one occasion during haul-out (Alliston, 1980). The results of this study suggest that the proposed icebreaking activities in the landfast ice zone may provide additional habitat for bearded seals in June. If the frequency of passages is low, ringed seals may also preferentially maintain breathing holes in the track. However, frequent use of the track by ships may result in a movement out of the track both because of disturbance and because breathing holes would be repeatedly destroyed. Nevertheless, any effects would be local, and possible impacts would be MINOR at most. The distribution and abundance of wintering and breeding seals in proposed icebreaker corridors through the landfast ice will be the subject of further study as icebreaking activity increases in the future (Volume 7, Section 3.2).

Tracks made by icebreakers through landfast ice corridors from either McKinley Bay or a base on the Yukon coast could possibly form temporary barriers to Arctic foxes which roam the landfast ice. As indicated earlier in Section 2.4.4.1, icebreaker tracks in landfast ice in winter and spring would be filled with rubble and quickly refreeze. Since the results of trials with KIGORIAK in the Beaufort during November 1981 indicated that the channel refroze within 1 to 2 hours (Danielewicz, 1981), any barrier to Arctic fox movements created by icebreakers would be local and temporary. Consequently, the potential impact of icebreaking in the landfast ice on the regional Arctic fox population will be NEGLIGIBLE.

The creation of temporary ice-free artificial leads or pools by icebreaking vessels operating in landfast ice in early summer may provide additional staging habitat for migrants such as oldsquaws, eiders, loons, and glaucous gulls. However, possible impacts on birds associated with creation of artificial leads in landfast ice or alteration of the timing of break-up would be NEGLIGIBLE in view of the marked annual variability in landfast ice extent and break-up dates (see Volume 3A). In addition, birds have adapted to the presence of ship traffic throughout the world, and some species, such as gulls, are attracted to ships and follow in their wakes (MacLaren Marex, 1979; Wahl and Heinemann, 1979). Several species of birds would feed within the ice rubble in the track behind icebreakers operating in early summer in the landfast ice because of the increased availability of amphipods and fish.

The possibility that a significant proportion of the pelagic fish in an icebreaker's track in the landfast ice would become entrained in the propellers is considered remote. Stranding of some fish on overturned ice in the ships' tracks and attraction of fish to under-ice irregularities may occur in the icebreaking corridors. However, icebreaking is a local activity and significant numbers of fish are unlikely to be entrained in the propellers of moving vessels. The possible impacts of icebreaking in the landfast ice on the regional pelagic fish populations are therefore expected to be NEGLIGIBLE.

Effects of icebreaking in landfast ice on phytoplankton may include a local and temporary increase in primary production and phytoplankton growth due to increased light availability in the icebreaker tracks. This could in turn result in a local increase in food availability for zooplankton and ichthyoplankton. However, impacts on planktonic communities under landfast ice are expected to be NEGLIGIBLE because the physical effects would be local and short-term.

The possible effects of icebreaking on epontic communities include localized mortality of epontic flora and fauna on overturned ice in the vessel's track, decreased primary production of epontic flora under thick or rafted ice, as well as the possibility for enhanced productivity on the irregular surfaces created in the track. In a regional context, however, both the positive and negative impacts of icebreaking in the landfast zone would be NEGLIGIBLE because of the relatively small geographic areas likely to be affected and the availability of extensive areas of under ice habitat throughout the region.

(c) Icebreaking in the Transition Zone

In the future, Class 3 to Class 10 icebreakers are expected to operate year-round to support offshore platforms, drillships and dredges in the transition ice zone. As indicated earlier, some ringed seal pups may be crushed by icebreaking vessels passing through landfast ice breeding areas during the 6 to 8 week lactation period in late April or early May. However, in the transition ice zone the number of pups which may be affected by icebreaking operations would be small since breeding ringed seals prefer to inhabit landfast ice (Volume 3A, Section 3.2). Bearded seal pups are born on moving pack or transition zone ice during late April or May, but unlike ringed seal pups, they are precocious and may be able to avoid a vessel soon after birth. In view of the extent of available habitat, the restricted areas in which icebreaking would take place, and the potential for avoidance of the vessels, few bearded seal pups of the regional population are likely to be affected. Consequently, the regional impact of icebreaking in the transition zone on bearded seal pups is not likely to exceed NEGLIGIBLE, but could approach MINOR for ringed seal pups in the local area. All other age classes are likely to avoid an icebreaker, and may even be attracted to areas of thin or broken ice in the ship's track (Alliston, 1980).

During June, large numbers of bearded seals haul-out to moult on the transition zone ice off the Tuktoyaktuk Peninsula. Ringed seals prefer to haul-out on the landfast ice, but they also moult on transition zone ice (Volume 3A; Section 3.2). Mortality of moulting seals through collisions with icebreakers is unlikely because they have the ability to avoid the vessels, and have been observed to do so (MacLaren Marex, 1979). As a result of their ability to avoid icebreakers, the availability of extensive unaffected moulting areas in the region, and the fact that seals have been observed to occupy and maintain breathing holes in icebreaker tracks (Alliston, 1980), the degree of possible impact of icebreaking in the transition zone on both moulting ringed and bearded seals is expected to be NEGLIGIBLE.

Icebreaking in the transition ice zone is likely to have NEGLIGIBLE effects on birds, fish, plankton and epontic communities similar to those expected in the landfast ice zone.

2.4.4.3 Tanker Traffic

(a) Icebreaking

Class 10 icebreaking tankers are being proposed to deliver crude oil from Canadian Beaufort Sea oil fields to southern markets. Their prime corridor would lead from an offshore loading terminal, likely initially at the Tarsiut site, along a route within the transition ice zone to Amundsen Gulf and onward through the Northwest Passage. Assuming the intermediate development rate, by the year 2000 there could be 16 tankers operating. By this time, there could be a tanker loaded every second day based on a 30 to 36 day round trip. This section describes the possible effects of icebreaking by these vessels in the Beaufort Sea.

There is concern that white whales and possibly bowhead whales on their spring migration into the Beaufort Sea or in Amundsen Gulf during May and June may follow artificial leads created behind an icebreaking tanker, and subsequently become trapped when the leads refreeze. Entrapment of whales has been documented in the Eskimo Lakes area (Barry, 1967), off west Greenland and in the High Arctic (see ESL, 1982). However, tracks left by large vessels breaking thick ice during spring will be filled with heavy ice rubble and refreeze quickly. The possibility that white and bowhead whales would enter and become trapped in artificial leads in the transition zone during spring is therefore remote. They are well adapted for orientation and navigation where extensive ice cover exists such as on their wintering areas in the Bering Sea and on their spring migration routes to the Beaufort Sea. Consequently, the possible impact of tanker icebreaking on whales in the Beaufort region is expected to be NEGLIGIBLE.

Although some ringed seal pups in their subnivean birth lairs could be killed by icebreakers operating in the landfast ice zone, the icebreaking tankers would generally operate seaward of this ice zone in most years. Transition zone ice is not primary ringed seal pupping habitat. Consequently, only an insignificant fraction of the regional ringed seal population would likely be affected by the icebreaking of tankers, although the degree of impact may still approach MINOR, since some individuals may be lost from the local population. On the other hand, bearded seal pups are usually born on transition zone or pack ice, and are probably more likely to be affected by tankers moving through breeding areas. However, bearded seal pups are widely distributed, precocious at birth, and the lactation period ranges from 12 to 18 days. Therefore, the probability that large numbers of individuals from the population would be lost is remote. Nevertheless, a small number of bearded seal pups may be affected by icebreaking tankers, and the possible impacts on their regional population may also approach MINOR.

Tanker icebreaking may cause local changes in the distribution and abundance of hauled-out adult ringed and bearded seals along the transportation corridor from the production zone to Amundsen Gulf. No mortality through collisions is expected because moulting seals would be able to avoid tankers and ringed and bearded seals may be attracted to broken ice areas in the ship track after the passage of the vessel. It is not known whether ringed seals would preferentially use frequently travelled icebreaker tracks but hauled-out bearded seals have been observed on pan ice in the break-out track from McKinley Bay. Since impacts would be expected to be local, the effect of icebreaking tankers travelling through the region on seals during the moulting period are expected to be NEGLIGIBLE.

As described earlier, the effects of icebreaking by support vessels on birds, pelagic fish, plankton and epontic communities are expected to be NEGLIGIBLE because of the highly local and short-term nature of the disturbances and the widespread distribution of these resources. No additional impacts are considered likely as a result of the movements of icebreaking tankers.

(b) Discharge of Ballast Sea Water

To maintain stability when a tanker is not carrying cargo, up to 200,000 m^3 of ballast water would be carried in separate tanks located outside of oil storage compartments in the proposed icebreaking tankers (Volume 2, Section 6.3). Most of the ballast water would be loaded at or near the southern terminal, and the remainder would be pumped aboard before entering ice-infested waters, possibly in Davis Strait or Baffin Bay. At the Beaufort Sea offshore tanker loading terminal, this ballast water would be discharged to the sea at a rate of between 13,000 and 25,000 m^3/hr, as crude oil is loaded. Based on the assumption that each tanker will complete approximately 12 round trips annually, it is estimated that by 1990 when six tankers may be in operation (assuming the intermediate development rate), about 14.4 x 10^6 m^3 of ballast water would be discharged each year into the Beaufort Sea, while 38.4 x $10^6 m^3$ could be off-loaded annually by the year 2000 when 16 tankers may be in use.

Seawater would be pumped into the tanker through a pipe or pipes equipped with screens to prevent the entrainment of larger marine invertebrates and fish (Volume 2, Section 6.3). The quality of the incoming seawater could be monitored to ensure that only clean water is loaded, and the ballast would be carried in segregated tanks and should therefore not become contaminated with hydrocarbons. If accidental leakage occurs between the ballast and crude oil storage compartments, the ballast water would be passed through an oil-water separator to reduce its oil concentration to 50 ppm or less prior to discharge.

No regionally significant biological effects are expected as a result of the normal discharge of ballast water. Although the ballast water would probably have a specific gravity different from that of Beaufort Sea water, it would be quickly diluted by a factor of 150 times in a 1 km^2 area around the tanker loading area. There is a potential for the introduction to the Beaufort Sea of exotic marine species not filtered out by the on-loading pump system. However, for exotic species from temperate or subarctic waters to successfully colonize waters of the Beaufort Sea, they would have to survive in the ballast tanks, and survive and reproduce once they are in the Beaufort Sea. It has also been suggested that communicable parasites and several viral and bacterial diseases could have severe effects when transferred to a new host in a different environment (ESL, 1982). However, both of these areas of concern are speculative, and unlikely to occur, thus the possible effects of the discharge of ballast water in the Beaufort Sea are expected to be NEGLIGIBLE.

2.4.4.4 Summary of Possible Impacts of Marine Vessel Activities

The degree of regional impact of icebreaking activities in the Beaufort Sea on most marine flora and fauna is expected to be NEGLIGIBLE. This results from the small areas which would be disturbed in relation to the available habitat for most resources.

The physical effects of future icebreaking on the stability and timing of break-up on the landfast ice, are likely to be masked by the inherent natural variability of the landfast ice regime resulting from various environmental factors. It is expected that any changes induced by icebreaking on the ice regimes in the landfast zone or transition zone would be indistinguishable from the annual variations characteristic of ice in this region (Volume 3A, Section 1.1). Therefore, detectable effects would likely be LOCAL and SHORT-TERM.

The icebreaking activity restricted to corridors in the landfast ice zone may have a MINOR impact on the regional ringed seal population due to some pups being crushed in their birth lairs. Support icebreakers and icebreaking tankers operating in the transition ice zone may also kill a small number of both ringed and bearded seal pups. The degree of impact of icebreaking in the transition ice zone on both seal species is not expected to exceed MINOR, since the number of pups likely to be killed would represent only a small proportion of the regional populations. These possible impacts of icebreaker movements will be minimized or eliminated by routing icebreakers around known ringed and bearded seal pupping areas during early spring, as well by restricting vessels to specific coastal corridors through landfast ice.

2.5 SUMMARY OF POSSIBLE IMPACTS OF NORMAL OIL INDUSTRY OPERATIONS IN THE BEAUFORT SEA

The following sections summarize possible impacts anticipated from the normal activities associated with proposed hydrocarbon development over the period 1985 to 2000 on the biological resources and the physical environment of the Beaufort Sea. Those possible impacts which may be of greatest regional concern are highlighted. Potential synergistic and cumulative impacts of various aspects of the development are also identified where possible.

As described earlier in Chapter 1, the possible impacts of future offshore facilities and activities are assessed on a regional basis due to the large geographic area encompassed by the proposed development. However, the effects of various activities, wastes and disturbances on local biota are also assessed and in most cases will be where measurable impacts may occur. A description of each significant resource-development interaction is provided in previous sections of this chapter, while the possible impacts of accidental spills are addressed in Volume 6. Although less likely to occur, in most instances, oil spills would result in more significant impacts on regional resources than activities associated with normal operations.

Matrix 2.5-1 summarizes the biological impacts of construction, exploration and production facilities or activities on most marine resources. Most are expected to be NEGLIGIBLE from a regional perspective, although MINOR, and a few MODERATE impacts are considered possible for some resource-development interactions.

2.5.1 WATER QUALITY AND THE PHYSICAL OCEANOGRAPHIC REGIME

The proposed development will have some effects on LOCAL water quality as a result of discharges of sewage, heated cooling water, drilling muds, BOP fluid, ballast water and produced water. In general, discharges in offshore waters will be confined to the areas surrounding drilling platforms and vessels, and will undergo rapid dilution in the sea. The use of oil-water separators and the appropriate treatment of sewage at all facilities will reduce the concentrations of contaminants in the sea. As a result, the possible effects of most discharges on water quality are not considered to be of significant regional concern. An exception is the possible chronic local contamination of offshore waters with petroleum hydrocarbons from the LONG-TERM discharge of large volumes of formation (produced) water from offshore oil fields. Even following treatment of formation water with oil-water separators, relatively large volumes, perhaps 30 to 70 bbls/day, of emulsified oil could enter the sea if produced water is not reinjected into the geological strata. Formation water is also likely to contain elevated levels of some dissolved trace metals. However, at offshore fields, much of the produced water is likely to be reinjected for reservoir pressure maintenance (see Volume 2, Chapter 4).

Dredging activities and the construction of artificial islands will have relatively LOCAL impacts on water quality as a result of SHORT-TERM increases in suspended sediment concentrations.

Dredging will locally alter the Beaufort Sea continental shelf by creating excavation pits and deposition sites associated with the construction and eventual abandonment of artificial islands. These features may persist for several decades or more in local areas, but are not expected to result in significant changes to bottom currents, and in some instances will be indistinguishable from natural ice scours and pingo-like features which are prevalent in offshore areas. Regionally significant impacts on the physical oceanographic environment of the Beaufort Sea are not expected although the physical presence of artificial islands and dredged depressions in the seafloor would produce LONG-TERM changes.

Artificial islands will not have regionally significant effects on currents or wave patterns. They are also unlikely to alter regional break-up dates or the extent of the landfast ice beyond that encompassed within its year-to-year natural variability. In localized areas, for example in the vicinity of a field where islands are spaced relatively close together, it may become necessary to use icebreakers to assist with break-up, thereby ensuring that localized ice break-up delays do not impact upon whale migrations. Similarly, effects on the ice regime from icebreaking vessels are likely to fall well within the range of natural year-to-year variability, icebreakers will be restricted to specific corridors, and effects will be limited and LOCAL.

Artificial open water leads in the landfast ice are not expected to be formed by icebreaker tracks between November and May. The rapid consolidation of ice rubble in the tracks will allow safe crossings to be made soon after the passage of an icebreaker.

2.5.2 AIR QUALITY

Gaseous and particulate emissions from marine vessels and offshore platforms in the Beaufort Sea production zone are unlikely to affect regional air quality, although the cumulative effects of emissions from multiple sources during peak production periods are uncertain. A main concern is ice fog formation and the resultant decrease in visibility surrounding emission sites. However, emission sources will be widely separated geographically, and the wind climate over the Beaufort should rapidly disperse most emissions and ice fog that may form.

2.5.3 MARINE MAMMALS

2.5.3.1 Whales

The two species of whales common in the Beaufort Sea region are the white (beluga) whale and the bowhead whale. Distinct populations of both species winter in the Bering Sea, and undertake annual migrations through the Chukchi Sea and offshore Beaufort to their summer range in the southeastern Beaufort Sea and Amundsen Gulf. The population of white whales has been estimated to number about 7,000, while the bowhead stock includes at least 2,300 individuals.

MATRIX 2.5-1 POTENTIAL REGIONAL IMPACTS OF NORMAL HYDROCARBON DEVELOPMENT ACTIVITIES ON THE BIOLOGICAL RESOURCES OF THE OFFSHORE AND COASTAL ZONE OF THE BEAUFORT SEA 1982-2000		MAMMALS						BIRDS							FISH			LOWER TROPHIC			
		WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	LOONS	DUCKS	GEESE/SWANS	SHOREBIRDS	JAEGERS/GULLS/TERNS	ALCIDS	OTHER BIRDS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	EPONTIC ORGANISMS	PLANKTON	BENTHIC EPIFAUNA	BENTHIC INFAUNA
COMMON WASTES AND DISTURBANCES																					
HUMAN PRESENCE						◊	○	○	○	○	○	○	○	○	○	○	○				
SOLID WASTES						◊	○					○		○		○				○	◊
TREATED SEWAGE	VESSELS	○	○	○	○			○	○			○	○	○	○	○	○	○	○	○	○
	EXPLOR./PRODUCT. FACILITIES	○	○	○	○			○	○			○	○	○	○	○	○	○	○	○	○
	SHOREBASES	○	○	○	○			○	○	○	○	○	○	○	○	◊	○	○	◊	○	◊
AIR EMISSIONS						○	○	○	○	○	○	○	○	○							
AIRBORNE NOISE	AIR TRAFFIC			◊	◊	○	○	◊	◊	◊	◊	◊	◊	◊							
	OTHER MOBILE SOURCES			○	○	○	○	○	○	○	○	○	○	○							
	STATIONARY SOURCES			○	○		○	○	○	○	○	○	○	○							
UNDERWATER SOUND	MOBILE SOURCES	◊	◊	◊	◊										○	○	○				
	STATIONARY SOURCES	◊	◊	○	○										○	○	○				
ARTIFICIAL ILLUMINATION	OFFSHORE			○	○	◊	○	○	○			○	○	○							
	SHOREBASES					◊	○	○	○	○	○	○	○	○							
OFFSHORE PLATFORMS																					
SEISMIC PROGRAMS		○	○	○	○										○	○	○				
B.O.P. FLUID		○	○	○	○			○	○			○	○	○	◊	◊	◊		○	◊	◊
TRITIATED WATER		○	○	○	○			○	○			○	○	○	○	○	○	○	○	○	○
PHYSICAL PRESENCE		○	○	○	○	◊	○	○	○			○	○	○	○	○	○			○	○
DRILLING WASTES		○	○	○	○			○	○			○	○	○	○	◊	○	○	○	◊	◊
COMPLETION FLUIDS		○	○	○	○			○	○			○	○	○	◊	◊	○	◊	◊	○	○
FORMATION WATER		○	○	◊	◊			◊	◊			◊	◊	◊	◊	◊	◊	○	○	○	○
OILY WASTE		○	○	○	○			◊	◊			◊	◊	◊	◊	◊	◊	◊	◊	○	○
HEATED COOLING WATER		○	○	○	○			○	○			○	○	○	○	○	○	◊	◊	○	○
CEMENT		○	○	○	○										○	○	○		○	○	○
GAS FLARES						○	○	◊	◊			○	◊	○							
DREDGING																					
PHYSICAL OPERATION		◊	◊	○	○			○	○		○	○	○	○	○	◊	◊	○			
TURBIDITY PLUMES		○	○	○	○			○	○		○	○	○		○	○	○	○	○	○	
SUBSTRATE DISTURBANCE			○		○			○	○				○		○	○	○			●	●
SUBSEA PIPELINES																					
DREDGING		◊	◊	○	○	◊		○	○			○		○	○	◊	◊	○	○	●	●
VESSEL TRAFFIC		◊	◊	○	○			○	○			○		○							
ICEBREAKING		○	○	◊	◊		○	○	○			○		○	○	○		○	○		
ARTIFICIAL SUBSTRATES															○	○	○			○	○
SUBSEA COMPLETIONS		○	○	○	○										○	○	○		○	●	●
MARINE VESSEL TRAFFIC																					
LOCAL TRANSPORT	OPEN WATER SEASON	○	○	○	○										○	○	○		○		
	ICEBREAK./LANDFAST ZONE	○	○	◊	○		○	○	○			○			○	○		○	○		
	ICEBREAK./TRANSITION ZONE	○	○	◊	◊			○	○			○			○	○		○	○		
TANKER TRAFFIC	ICEBREAKING	○	○	◊	◊			○	○			○			○	○		○	○		
	BALLAST WATER	○	○	○	○										○	○	○	○	○	○	○

*POTENTIAL IMPACTS (ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT)

LEGEND: ○ NEGLIGIBLE ◊ MINOR ● MODERATE ■ MAJOR

As summarized in Matrix 2.5-1, the possible impacts of most normal activities, wastes and disturbances on white and bowhead whales are expected to be NEGLIGIBLE. The only regional concern with respect to whales are the possible effects of underwater noise which will be produced by development activities, as well as the possibility of cumulative or synergistic effects from multiple sources of wastes and disturbances.

In the offshore production region, underwater noise would be emitted by the construction and operation of islands; installation of subsea pipelines; ships including drillships, icebreakers, tankers, and various support vessels; logistics aircraft; seismic work; and dredging activities. Existing levels of underwater noise in the Beaufort appear to have resulted in NEGLIGIBLE impacts on bowhead and white whales. Lack of data for bowheads on the ecological significance of masking or disturbance, on the hearing sensitivity and function of vocalizations, and habituation to industrial noise hamper the prediction of impacts assumed from increasing levels of industrial activity. Consequently, the present assessment is purposefully conservative in order to compensate for the lack of available and conclusive data. As indicated in Matrix 2.5-1, possible impacts of future levels of underwater noise from all mobile industrial sources, in aggregate, on white and bowhead whales is unlikely to exceed MINOR. This degree of possible impact could be reduced if the whales are able to habituate to increased noise levels, or are able to alter the frequency or intensity of their signals to compensate for industrial noise.

The effects of discharging common wastes including sewage, drilling muds, formation water, heated water, oily waste water, completion fluids, and BOP fluid, will likely be NEGLIGIBLE. This is because of the relative inertness and/or biodegradability of most of the discharges, the tremendous dilution and buffering capacity of the sea, and the relatively small number of individuals which could be affected, given the mobility of marine mammals and the local nature of areas where discharges will occur. It is also possible that the physical presence of platforms and the noise and activity at industrial sites could deter whales from approaching discharge sites. For these reasons, the combination of various waste discharges are not likely to have greater than NEGLIGIBLE cumulative impacts on whales.

2.5.3.2 Seals

The two species of seals common in the Beaufort Sea are the ringed seal and the bearded seal. Both are widely distributed and relatively abundant throughout the region. The estimated size of the Beaufort Sea ringed seal population between 1974 and 1979 has ranged from a low of 23,000 in 1977 to a high of 62,000 in 1978. During the same period, the estimated Beaufort Sea bearded seal population ranged from 1,300 in 1977 to 3,100 in 1978.

Matrix 2.5-1 summarizes the activities of hydrocarbon exploration and production activities which may affect seals to varying degrees. The combined sources of underwater industrial noise may have MINOR impacts on regional ringed and bearded seal populations.

Future icebreaking activities of logistic vessels and icebreakers, in aggregate, could have MINOR impacts on ringed and possibly bearded seals during the spring pupping period. Icebreakers and air traffic may also have a MINOR short-term impact on both species during the 2 to 3 week haul-out period in June by causing animals to dive. With the exception of underwater noise, icebreaking, and aircraft operations, all other normal activities, including the discharge of common wastes and the creation of disturbances, are expected to result in NEGLIGIBLE impacts on both ringed and bearded seals. The only possible exception to this generalization is if formation water is discharged to the sea. Then seals attracted to production platforms could be exposed to trace metals and hydrocarbons in formation water for extended periods, and may experience some sublethal effects as described in Section 2.4.1.2. The possible impacts of the discharge of formation water on regional seal populations are considered MINOR. This impact rating would decrease to the NEGLIGIBLE rating if formation water were reinjected, as is the intention over the longer term at offshore production platforms (Volume 2, Chapter 4).

It is recognized that if seals are attracted to offshore platforms, some combinations of wastes and disturbances could result in possible synergistic or cumulative effects. Several types of wastes may be continuously or intermittently discharged to the sea from offshore platforms. Seals attracted to platforms because of noise or human activity, may then be exposed to the relatively undiluted wastes near outfalls. Such cumulative effects would be limited to those seals actually attracted to the platforms, and would comprise a small proportion of the widespread regional population. Consequently, the possible cumulative impacts of multiple waste discharges and sources of disturbance on seals are not be expected to exceed MINOR.

2.5.3.3 Polar Bears

In the Canadian Beaufort Sea, there are two basic polar bear populations, one associated with the west coast of Banks Island and the other with the mainland coast. The estimated total number in the Canadian Beaufort Sea and Amundsen Gulf was 1,700 in 1972 and 1,800 in 1974. Most of these bears inhabit areas off the west coast of Banks Island and in Amundsen Gulf, and to a lesser extent, areas off the Mackenzie Delta and Tuktoyaktuk Peninsula. During winter and spring, polar bears forage on the transition zone ice, where they prey extensively on ringed seals. Pregnant females den in coastal areas, from November until April, mainly along the coast of Banks Island.

As indicated in Matrix 2.5-1, over the 20 year period, human presence, solid waste disposal, stationary sources of airborne noise, artificial illumination and the physical presence of offshore platforms may have MINOR impacts on the regional polar bear population. This is due to the possibility that wastes and disturbances may alert and subsequently attract bears to offshore platforms. Light, noise and cookhouse odours would probably be the main attraction. Mitigative measures would include continuation of the polar bear monitoring program, and the sedation and removal of problem bears. Nevertheless, some nuisance animals (one in 1981-82) will have to be destroyed for reasons of human safety, and this kind of loss could result in a MINOR impact on the regional population. The cumulative impacts of all sources that may lead to attraction of bears are still expected to be MINOR in a regional context. All wastes and disturbances associated with the development that will not alert or attract polar bears are expected to have NEGLIGIBLE impacts on the regional population.

Changes in the distribution and abundance of ringed seals in the region due to natural causes have been suggested to be the cause of concurrent changes in the abundance and distribution of polar bears. However, normal industrial activities in the region are unlikely to cause extensive seal mortality or marked fluctuations in seal abundance, so that indirect impacts on bears through reduced prey availability are not expected.

2.5.3.4 Arctic Fox

Arctic foxes from coastal populations forage on the landfast ice during winter and spring. As a result, it is possible that some may be affected by on-ice vehicle traffic, icebreakers, and exploration and production facilities operating in the landfast ice area. Possible effects from these offshore industrial activities on Arctic foxes will probably be NEGLIGIBLE.

Foxes in offshore areas may be attracted to, or avoid, industrial sites as a result of noise, artificial illumination, human presence (cookhouse odours), solid waste disposal and the physical presence of structures. However, the combined effects on Arctic foxes are expected to be NEGLIGIBLE because the number of individuals which may be affected would be regionally insignificant and mortality is unlikely.

2.5.4 BIRDS

Over 100 species of birds migrate to or through the Beaufort Sea region annually. The following summary describes the possible impacts on birds of hydrocarbon exploration and production activities in offshore waters.

From about mid May to mid or late June, hundreds of thousands of spring migrant birds stage in offshore leads and polynyas of the southeastern Beaufort Sea and Amundsen Gulf before flying to their coastal or inland nesting areas. They stage in large numbers along the landfast ice edge off the mainland coast, the west coast of Banks Island and in the Amundsen Gulf polynya. Oldsquaws, king and common eiders, glaucous gulls and loons are the most common species. Other species which may also migrate through offshore areas include thick-billed and common murres, black guillemots, brant, phalaropes, jaegers, Arctic terns and some other species of gulls. Most birds move to coastal nesting areas in summer and remain there until their fall migration in late August and September. Some non-breeding bird species including gulls, jaegers, alcids and other marine species, may continue to forage in the offshore Beaufort throughout the summer. Fall migrants that travel offshore probably include mainly king and common eiders, jaegers, glaucous gulls and alcids.

The potential regional impacts on birds of most activities at offshore platforms, and for most of the common wastes and disturbances, including dredging, icebreaking and vessel activities, are expected to be NEGLIGIBLE. MINOR impacts on birds are only considered possible as a result of gas flaring, aircraft disturbances and the discharge of formation water. The only industrial wastes of potential regional concern are the routine discharge of formation water and oily waste water. Due to the possible vulnerability of birds to petroleum hydrocarbons found in formation water and the quantities of this waste which could be discharged into the sea, there is some potential for mortality or sublethal effects on birds on the sea near production platforms. Depending on ice conditions and the distribution of spring staging birds, some spring migrants may be lost or experience sublethal effects due to contact with oil. Nevertheless, the number of birds likely to be affected would be a small proportion of the regional populations and potential regional impacts would probably not exceet the MINOR rating. This degree of impact would reduce to NEGLIGIBLE if formation waters were reinjected, as proposed over the longer term at all offshore production fields (Volume 2, Chapter 4).

The regional impacts of icebreaking and dredging disturbances on birds are expected to be NEGLIGIBLE due to the ability of birds to use adjacent undisturbed areas, because mortality is unlikely, and because only a small fraction of any regional population could be affected. Increased food availability for some species as a result of these activities would also have a NEGLIGIBLE regional impact.

On a local scale, possible impacts of dredging and icebreaking disturbances may range from NEGLIGIBLE to MINOR depending on the species, timing and duration of dredging or icebreaking, and susceptibility of the species to these operations.

Some birds may be attracted to and possibly collide with offshore structures as a result of artificial lighting and gas flares, particularly during the dark or when visibility is low. However, impacts on the regional populations would likely be NEGLIGIBLE, or at most MINOR, over both the short and long-term because the number of individuals affected would be small. Species most likely to be affected by virtue of their migration routes and flight altitudes would include loons, eiders, oldsquaws, black guillemots and thick-billed murres. Gulls will be attracted to offshore platforms by artificial illumination, airborne noise, gas flares, human presence (cookhouse odours), and by solid wastes, but few are likely to be killed. Consequently, the potential regional impact of their attraction to offshore facilities as a result of these factors is expected to be NEGLIGIBLE.

There is concern that airborne noise from helicopters and STOL aircraft operating between shorebases and offshore platforms may affect birds through habitat loss, increased energy expenditures, and behavioural responses that may increase mortality of adults and young. However, with the implementation of mitigative measures described in Section 2.3.5 the possible impacts of airborne noise on all regional populations will be within the range from NEGLIGIBLE to MINOR.

In general, geese are considered to be more vulnerable to aircraft disturbances than other waterfowl and most marine-associated birds. During spring, snow geese and white-fronted geese that stage at Kittigazuit Bay may be disturbed by aircraft overflights. During the breeding period, snow geese nesting at Kendall Island, and brant nesting at colonies in the outer Mackenzie Delta and near Atkinson Point could be disturbed. Under some circumstances, white-fronted geese, whistling swans, peregrine falcons, gyrfalcons, golden eagles, common eiders, black guillemots, glaucous gulls, Sabine's gulls and terns could also be disturbed during the nesting period. During July and August, some moulting and non-breeding geese and swans, and moulting and brood-rearing ducks in coastal areas may be disturbed by aircraft overflights. Of major concern are the thousands of snow geese and white-fronted geese that stage along the North Slope and in the outer Mackenzie Delta during September and early October. These could be subjected to some disturbance from future shorebase activities on the Yukon coast (see Chapter 3).

Some birds could be disturbed by unregulated aircraft resulting in possibly a wide range of impacts on regional populations, but with the implementation of mitigative measures all potential impacts from aircraft noise are expected to fall between NEGLIGIBLE and MINOR. The mitigative measures include adherence to altitude and routing guidelines, and will be reviewed with appropriate government agencies.

Synergistic or cumulative effects on birds could possibly result from specific combinations of wastes and disturbances, and the physical presence of offshore structures. However, the assessment of such effects is highly speculative. The cumulative effects of discharge of all wastes and disturbances associated with the construction and operation of offshore structures could have a MINOR impact on regional populations of some marine birds such as oldsquaws, eiders, glaucous gulls, loons and possibly alcids. Possible cumulative impacts of these effects on most other bird species would likely be NEGLIGIBLE.

2.5.5 FISH

Offshore hydrocarbon development in the Beaufort Sea is expected to have NEGLIGIBLE to MINOR impacts on fish. Alterations in water quality resulting from the discharge of most wastes will be limited to waters close to exploration and production platforms and vessels, therefore, few fish are likely to be killed or be otherwise affected by waste discharges. Similarly, disturbances from dredging, vessel traffic and icebreaking will be temporary and only evident close to the sources of disturbance and are not expected to have regionally significant effects on offshore fish populations. Near the shore, however, development-related activities and disturbances may have a greater degree of impact in some instances, since large numbers of important fish species are found in nearshore habitats, particularly during the summer months. Marine species such as herring spawn in nearshore areas, and large numbers of anadromous fish also feed and rear in these locations. Dredging activities are a source of disturbance to fish, and in some coastal habitats it is possible that MINOR to MODERATE impacts could occur if large numbers of fish or fish eggs were entrained in dredges. However, on the basis of previous studies of the effects of dredging in both temperate and Arctic waters, the impacts of dredging on fish will probably range from NEGLIGIBLE to MINOR when known spawning areas or particularly rich feeding and rearing areas are avoided. Other nearshore disturbances, including vessel traffic and sewage, are expected to have NEGLIGIBLE impacts on coastal fish populations.

Synergistic effects from some combinations of wastes and the physical presence of offshore platforms may occur for some species of fish, such as Arctic cod, because several types of wastes may be continuously or intermittently released to the sea surrounding offshore exploration or production islands and drillships. Although such effects are largely speculative, several cumulative but localized effects are considered possible. For example, some trace metal uptake from formation water, and to a lesser extent from drilling fluids, may occur and may be greater where thermal effluents are discharged. Also, the effects of low concentrations (approximately 50 ppm) of emulsified oil from both oily wastes and formation water may be enhanced when there are either higher background concentrations of dissolved trace metals or higher ambient water temperatures. Similarly, organisms in ballast water may survive longer when the ballast water is discharged along with heated water used for ice management purposes. Nevertheless, impacts from possible synergistic effects of multiple wastes are expected to be NEGLIGIBLE on regional populations of marine fish because of the relative inertness and/or biodegradability of most wastes, and the rapid dilution expected in offshore waters of the Beaufort Sea. This is also supported by the fact that there is little evidence to suggest that multiple wastes discharged from production facilities elsewhere in the world have caused observable effects on fish populations.

2.5.6 BENTHIC COMMUNITIES

Populations of benthic organisms will be directly disturbed by dredging activities during offshore island construction and pipeline installations. They will also be exposed to various discharges from exploration or production platforms. Dredging will result in localized direct mortality of benthic organisms as well as alteration of benthic habitats. However, in a regional context, the seabottom area disturbed by all combined dredging activities would be small. Also, in many areas selected for dredging, some of the effects are similar to those associated with naturally occurring ice scour, to which benthic organisms on the Beaufort Shelf are subjected regularly. Nevertheless, the impacts of dredging on benthic populations may range from MINOR to MODERATE in some areas, with the degree of impact depending largely on the number of generations necessary for specific benthic communities to recover. Available data on the recovery of benthic populations following past dredging on the Beaufort Shelf suggest that following disturbances from suction hopper dredges, recovery of disturbed sites begins quickly and should take about 2 to 3 years. In these situations, only a MINOR degree of impact would be expected. Nevertheless, even when MODERATE local impacts occur, the proposed dredging requirements are unlikely to disturb a regionally significant fraction of the benthic habitat or have significant indirect impacts on higher trophic levels.

The discharge of wastes into the sea are not expected to cause significant regional impacts on benthic populations. Wastes would include treated sewage, BOP fluids, drill muds, heated water, drill cuttings, cements and barites, and possibly formation water. All of these wastes will only affect the local areas surrounding drilling platforms and are not expected to cause significant losses of benthic populations in the region. The cumulative effects of all of these discharges, however, may contribute to the slower recovery of benthic communities in small areas such as around artificial islands and within dredged glory holes. Overall, the cumulative impacts from all of these disturbances may be MODERATE in localized areas, but will not affect a regionally significant portion of the existing benthic habitat.

2.5.7 PLANKTON AND EPONTIC COMMUNITIES

Disturbances and wastes from the development of offshore hydrocarbon resources are not expected to result in more than MINOR impacts on planktonic and epontic communities (Matrix 2.5-1). Phytoplankton and zooplankton are widely distributed throughout the region, and although dredging activities and discharges of oily wastes, formation water, and ballast water may affect local areas, the recovery time will be rapid due to reproduction and the natural transport of organisms from the surrounding sea. Nutrients in sewage discharges, formation waters, and warmed water are not expected to cause more than local increases in primary production or organic loading.

Epontic organisms will be mainly affected by icebreaking in the landfast ice and by possible ice management programs using heated water at offshore islands. Nevertheless, only small areas will be affected in relation to the extent of undisturbed habitat available throughout the region, and impacts in these areas will generally range from NEGLIGIBLE to MINOR.

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CHAPTER 3

ONSHORE MACKENZIE DELTA PRODUCTION REGION

Chapter 3 examines the possible environmental implications of the range of activities which may take place in the onshore Mackenzie Delta production region (Figure 3.1-1). The chapter begins with a brief review of the existing communities, the onshore petroleum exploration experience to date, and present transportation systems operating in the region (Section 3.1). This is followed by descriptions of the industry's existing and proposed shorebase needs (Section 3.2) and projected onshore oil and gas production facilities (Section 3.3).

Section 3.4 examines the effects of common disturbances associated with onshore oil or gas production facilities and onshore gathering systems and shorebases. Section 3.5 describes the possible effects of development or expansion at specific shorebases. The chapter ends with a review of the effects specifically related to onshore production and gathering systems in the region (Section 3.6).

3.1 EXISTING ACTIVITIES AND FACILITIES

The following is a brief description of the communities and existing water, ground and air transportation systems in the coastal Beaufort Sea region. Past petroleum exploration activities in this region are summarized to place in context the "Development Plan" described in Volume 2. More detailed descriptions of coastal communities, their fishing, hunting and trapping activities, and special areas such as migratory bird sanctuaries, land settlement areas and proposed National Parks in this region are provided in Volumes 3A and 5.

3.1.1 COMMUNITIES

Communities near future offshore Beaufort Sea development include Aklavik and Inuvik in the Mackenzie Delta, Tuktoyaktuk on Kugmallit Bay to the east of the Delta, Paulatuk on Darnley Bay off Amundsen Gulf, Holman Island at the tip of the Diamond Jenness Peninsula of Victoria Island, and Sachs Harbour on the south coast of Banks Island (Figure 3.1-1). Their combined population is about 5,300, compared with the N.W.T. population of about 46,000, and the total Canadian population north of 60° N latitude of approximately 68,000.

Inuvik, with a population of about 3,000, is the largest community in this region and north of the Arctic Circle. It is largely non-native, and was established by the Federal Government in 1957 as an administrative and commercial centre. Inuvik currently functions as a centre for business, transportation, government services and administration in the region.

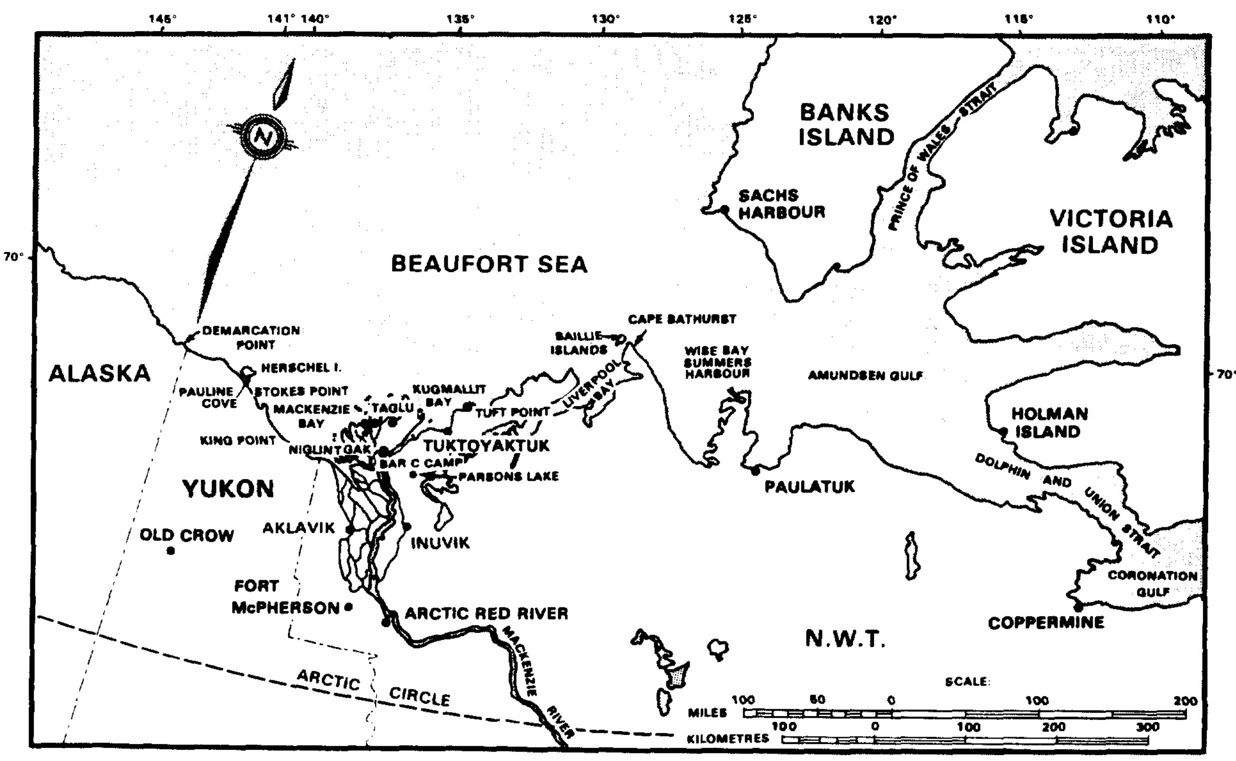


FIGURE 3.1-1 *Communities and other sites in the Beaufort Sea-Mackenzie Delta region.*

Tuktoyaktuk has a population of about 800, over 85% of which is Inuvialuit, and began as a modern community during the trapping era of the 1920's and 1930's. It has one of the few good natural harbours in the western Arctic, and is currently the principal support base for oil and gas industry operations. Future development plans include the continued expansion and improvement of facilities at Tuktoyaktuk to support offshore and onshore exploration and production.

Aklavik has not experienced as much industrial activity as Tuktoyaktuk, although it has also been influenced by the oil and gas industry. It has a population of approximately 800 and originated in the early twentieth century as a centre of missionary activity and fur trading. The population of Aklavik is about evenly divided between people of Dene and Inuit origin. They still pursue traditional hunting and fishing activities, and many have been employed at some time in various sectors of the oil and gas industry.

Paulatuk, with fewer than 200 people, mostly of Inuit origin, is located on the southern shore of Darnley Bay. Hunting, sealing, fishing and native hand crafts form the main economic base. Community services are limited and there is no scheduled commercial air service to Paulatuk.

Holman Island, on the western shore of Victoria Island, has a population of about 300. It has a scheduled air service, a volunteer fire department and nursing station. Hunting, fishing and native crafts are its main economic base.

Sachs Harbour on Banks Island has a population of less than 200. This community intensively traps Arctic fox which are abundant on Banks Island (Volume 3A). This resource is carefully managed by local trappers.

3.1.2 ONSHORE PETROLEUM EXPLORATION

Hydrocarbon exploration in northern Canada started in 1920 and about 100 wells were drilled over the next 30 years, most near Norman Wells in the Mackenzie River Valley. Exploration activity increased in the 1950's when 70 wells were drilled, followed by an additional 260 wells in the 1960's. Renewed interest in petroleum resources of the Canadian Arctic began in the 1970's, following the first major oil discovery.

In the Mackenzie Delta, hydrocarbon exploration began in 1956 and the first well was drilled north of Inuvik by Gulf in 1965. The first oil discoveries were made by Esso at Atkinson in 1970 and at Mayogiak in 1971. Major gas fields were discovered at Parsons Lake (Gulf), Taglu (Esso) and Niglintgak (Shell). Total gas reserves have been estimated at 6 trillion cubic feet (16.9×10^9 m^3).

3.1.3 TRANSPORTATION

3.1.3.1 Ground Transportation

Road construction on the sensitive terrain of the Arctic is a special area of concern and only a few all-weather roads have been built. Winter roads are commonly used, although their locations change almost every year depending on the logistical requirements of the private interests that build and use them. The use of winter roads depends on ice bridges over rivers, and before travel on the roads is approved, inspection of the ice bridges is required to ensure adequate bearing capacity.

Construction of the Dempster Highway began in 1959. It is 670 km long and connects Inuvik, Arctic Red River and Fort McPherson to Dawson City. The highway was completed in 1979, and is open from June to September in summer and from mid December to mid April in winter. The Dempster has a gravel surface, and ferries are used at crossings of the Peel and Arctic Red rivers during summer. In winter, ice bridges replace the ferries, and an ice road extension links the highway to Aklavik and Tuktoyaktuk. At present, the Dempster Highway is unusable during freeze-up and thaw of the river crossings, which coincides with the main caribou migration period.

With the opening of the Dempster Highway and the use of winter roads, freight now moves by trucks during winter to industry's Tuktoyaktuk base camps and the overwintering facilities at McKinley Bay. During the summer, trucks can travel as far as Inuvik and then freight is barged or flown to Tuktoyaktuk and McKinley Bay.

3.1.3.2 Water Transportation

Marine access to the Beaufort Sea is possible through two sea routes: a western route through the Bering Strait and the Chukchi Sea, and an eastern route through the Northwest Passage and Baffin Bay. Sea ice prevents shipping by conventional vessels from about November to June, depending on annual variations in ice conditions. The western route through the Bering Sea is used for most Canadian Beaufort Sea operations. Three general groups of marine vessels use this route: those associated with the offshore drilling fleet, scientific surveys, and ships used for supplying Arctic communities.

The Mackenzie River is a vital transportation link between southern Canada and the communities and industrial sites in the Beaufort Sea and Mackenzie

Delta. A major transport operation is undertaken on the river each year between May and early October. Supplies and heavy equipment move by road and rail to a terminal at Hay River, and then are barged to communities in the Delta and along the coast. Two companies handle freight on the Mackenzie River route. The largest is a crown corporation called Northern Transportation Company Ltd. (NTCL). This company services the Delta, Banks Island, Victoria Island and points along the coast from Colville River in Alaska to Spence Bay in the east. NTCL is licensed to transport supplies to the communities, but is also a major carrier for the oil companies. It operates 176 barges and 33 powered vessels. Arctic Transportation Ltd. (ATL) has a small operation on the Mackenzie River and a major operation offshore in the Beaufort Sea. It is not licensed to serve the northern communities, and all of its contracts are with the oil industry.

ATL's offshore operations in the Beaufort region usually extend from mid June to the end of October. These are based at Tuktoyaktuk where ATL is constructing a new base. A four year construction program began in 1981 with the installation of a 200 m wharf for the use of both river and offshore vessels. Landfill is expected to provide 8 hectares for warehouses and ancillary facilities. ATL will have the largest dock facility at Tuktoyaktuk at the end of the four years of construction. In 1981, ATL operated two seismic survey ships, three vessels for offshore supply services, eight tugs and twenty barges.

Transport Canada has public wharf facilities at Tuktoyaktuk, and NTCL also has wharves and facilities near this community. In addition, Dome and Esso have dock and marine support bases along Tuktoyaktuk harbour and a Gulf base is under construction.

3.1.3.3 Air Transportation

Air transport is the only transportation system that currently operates year-round in the Canadian Arctic. Pacific Western Airlines (PWA) and Trans North Turbo Air are the major commercial air carriers operating regularly in this region. PWA operates a daily service from Calgary and Edmonton to Inuvik using Boeing 737's. These can be be configured to fly a full passenger complement of 117 passengers or to fly cargo and up to 34 passengers. Trans North Turbo Air has scheduled flights between Inuvik and other centres in the Yukon and Northwest Territories, including Norman Wells, Yellowknife and Whitehorse.

Small local companies such as Northwest Territorial Airways Ltd. provide scheduled air services to the larger communities, while charter companies provide services to the smaller communities. Most air charter companies are based in Inuvik and are used to transport northerners from local communities to Tuktoyaktuk for work with the oil and gas industry. They also ferry personnel to and from Inuvik to connect with PWA commercial flights. The runway at Tuktoyaktuk has recently been lengthened to accommodate larger jet aircraft. It is used mostly by Dome which operates a regular Boeing 737 service.

Table 3.1-1 lists airstrip lengths, classification, associated equipment and services for communities in this region. DEW line airstrips at Komakuk Beach and Cape Parry have also occasionally been used to service drilling operations and overwintering facilities.

3.2 OIL INDUSTRY SHOREBASES - EXISTING AND PROPOSED

Logistics support for offshore exploration and production activities will be provided by shorebases at locations along the Beaufort Sea coast. This support comprises storage and distribution services for equipment and materials, marine dockage, dry docks, machine shops, and accommodation for support base, service company and construction personnel. Shorebases will also function as major fueling depots,

TABLE 3.1-1

AIRFIELDS IN THE BEAUFORT SEA REGION

Location	Length (m)	Class	Services
Fort McPherson	1,070	B	snow clearance; weather radio
Inuvik	1,830	A	all services except control tower
Tuktoyaktuk	1,500	B	weather radio
Aklavik	915	C	weather radio
Sachs Harbour	1,220	B	
Holman	1,300	B	

All airfields have landing lights and an Air Terminal Building airports and communications centres (Volume 2, Chapter 5). At present, the major base for Beaufort operations is at Tuktoyaktuk, while McKinley Bay functions as a winter mooring basin for the drilling fleet and support vessels. Future development plans include:

1. the establishment of major base camps at McKinley Bay and possibly a site on the Yukon coast in the near-term;

2. establishment or further development of a site on the Yukon coast in the long-term;

3. possible construction of a fuel storage facility at Wise Bay;

4. Caisson assembly and winter mooring sites at Tuft Point and in Pauline Cove; and

5. the possible re-opening of the Esso "Bar C" camp as a temporary staging area to transport materials to the Adgo area.

The existing and proposed facilities at the various marine shorebase locations are described in more detail in the following sections.

3.2.1 TUKTOYAKTUK

Tuktoyaktuk will continue to function as an important support base for all exploration drilling in the Beaufort Sea, and as the main transfer centre for all incoming and departing personnel. Dome and Esso already have accommodation, office, storage, dock and airstrip facilities at Tuktoyaktuk. Transport Canada, NTCL and ATL also have facilities in Tuktoyaktuk harbour. In addition, Gulf is presently building a base at Tuktoyaktuk.

3.2.1.1 Dome's Tuktoyaktuk Base

Dome's Tuk Base (Plate 3.2-1) is located 2 km southeast of the community of Tuktoyaktuk, and occupies 47 acres (19 ha) (Figure 3.2-1). This base was expanded in 1981, and includes an 8 ha storage area, a dock and staging area, and accommodation for 360 people. Facilities include light steel fabrication and machine shops, warehouses and storage for equipment and materials, yard storage for consumable drilling supplies and chemicals (Plate 3.2-2), a utility building including a secondary sewage treatment plant, an oil spill clean-up centre, fire hall and an oxygen acetylene plant. Fuel is presently stored in a 1 ha tank farm and is supplemented with fuel barges

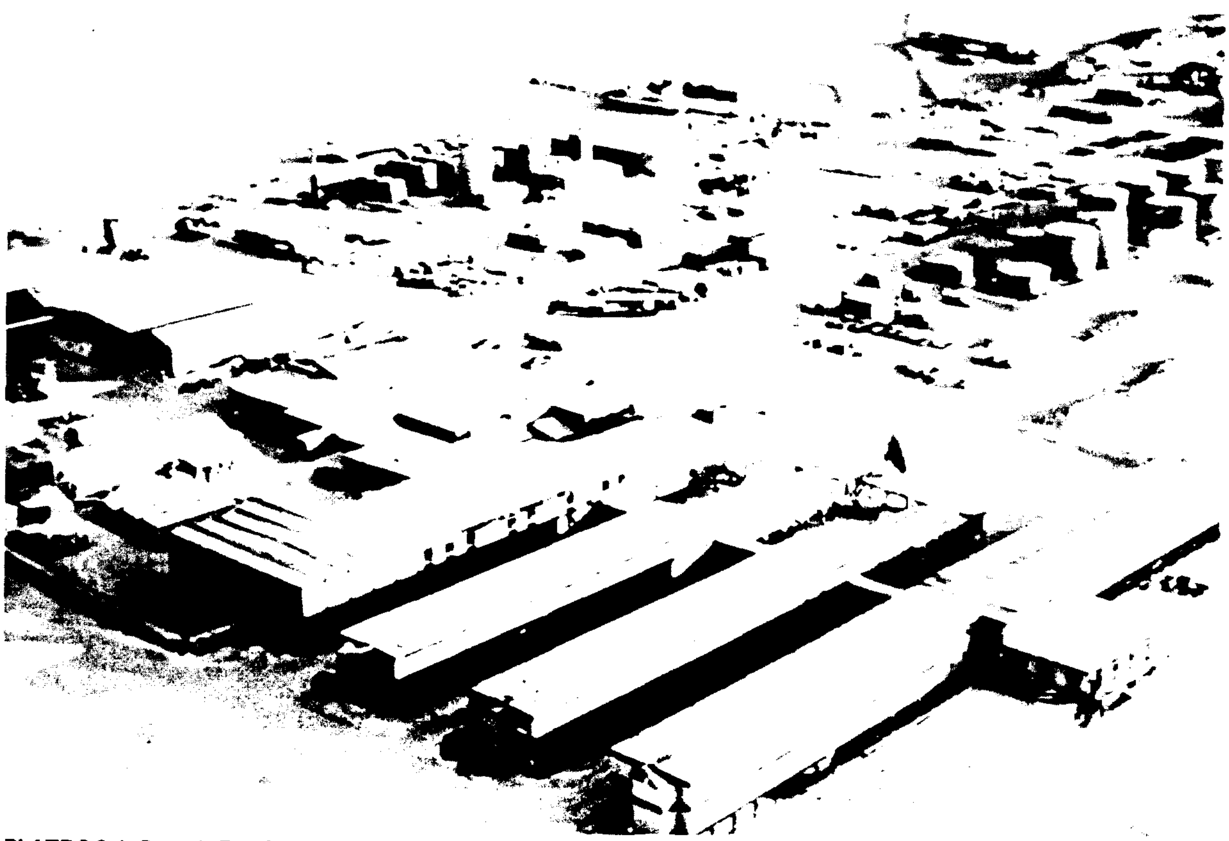


PLATE 3.2-1 *Dome's Tuk Base is located 2 km southeast of the community of Tuktoyaktuk. The base was expanded in 1981 and now provides accommodation for roughly 360 people.*

located at winter anchorage sites within Tuktoyaktuk Harbour. Personnel numbers at Dome's Tuktoyaktuk base are not expected to increase much from present levels, however it is expected that the storage area, roads, access allowance, air and dock facilities will be expanded, to encompass about 100 acres (40 ha) by 1986.

The Transport Canada airport at Tuktoyaktuk will continue to be the major airport supporting Dome's offshore activities. The gravel runway at Tuktoyaktuk was lengthened by Dome to 1,500 m in 1980. Facilities built by Dome include an aircraft parking ramp and an aircraft hanger (Plate 3.2-3). Land is being acquired near the airstrip for a larger terminal, additional navigational facilities, offices and maintenance shops. Eventually, the airstrip will likely be lengthened further to accommodate larger aircraft. Aircraft presently using the Tuktoyaktuk airport include STOL aircraft, executive jets, a Boeing 737, Hercules transports and helicopters. Table 3.2-1 shows a projection of future aircraft requirements for industrial operations in the Beaufort. It suggests a steady increase in air support requirements at Tuktoyaktuk and other bases as development proceeds. It is anticipated that most aircraft will continue to use Tuktoyaktuk as a primary airport along the Beaufort Sea coast. If another major base is to be developed in the future at a site along the Yukon North Slope, then large aircraft would also begin to travel there.

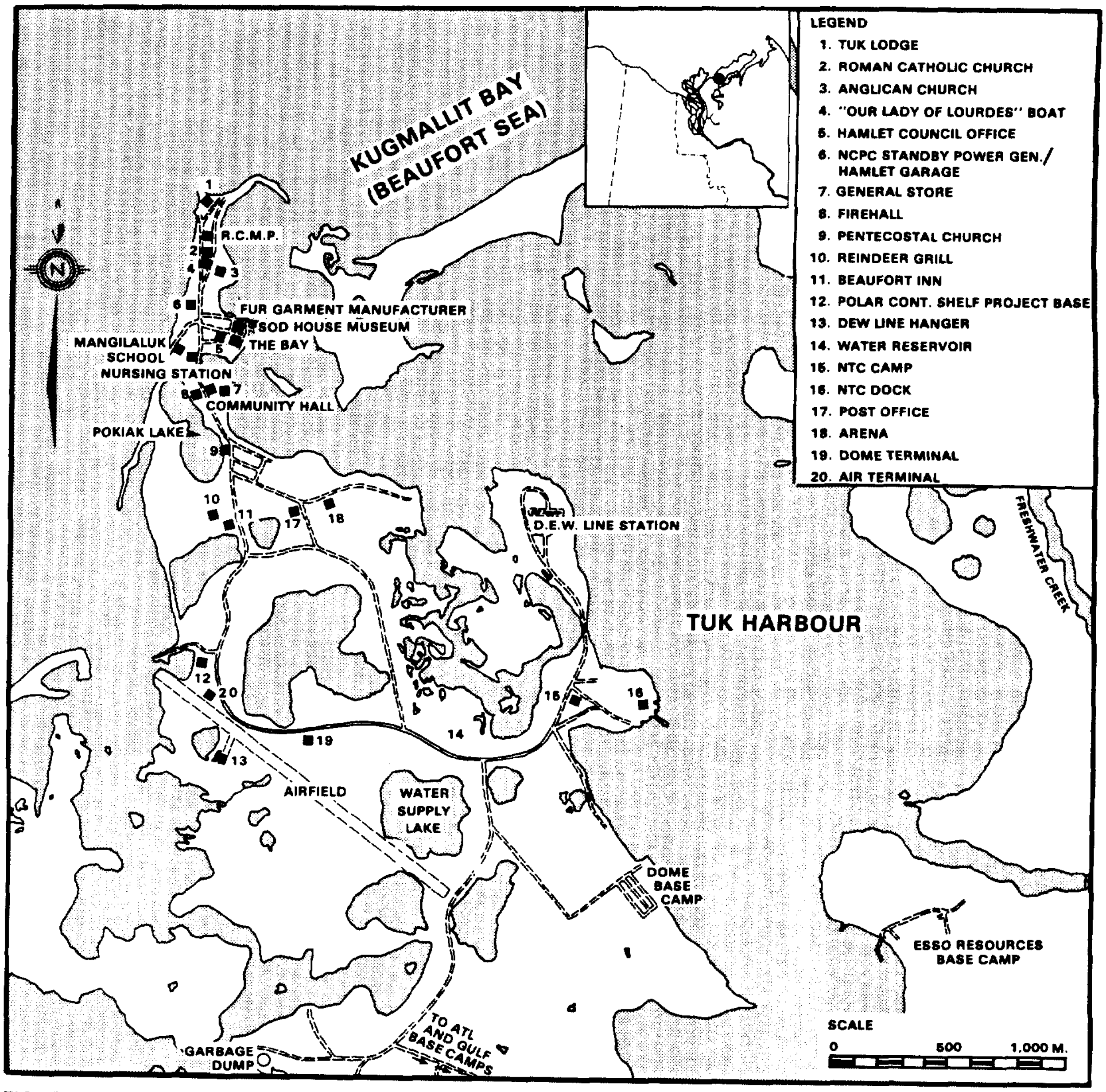


FIGURE 3.2-1 *Tuktoyaktuk, showing the location of various buildings and facilities.*

PLATE 3.2-2 *The base provides many services in support of exploration activities. It has light steel fabrication and machine shops, warehouses and a large storage yard for drilling supplies.*

PLATE 3.2-3 *In 1980 the gravel runway at Tuktoyaktuk was lengthened to accommodate Boeing 737 jets. Dome has also built an aircraft hangar and an aircraft parking ramp to service its needs.*

TABLE 3.2-1

APPROXIMATE NUMBER OF SUPPORT AIRCRAFT PROJECTED FOR OPERATIONS IN THE BEAUFORT SEA DEVELOPMENT ZONE*

Year**	Helicopters e.g. (Bell 206, 212 and Sikorsky S-76 and S-61)	STOL Aircraft (Twin Otter, Hercules, Cessnas)	Executive Jets (Cessna Citation, Lear Jet)	Passenger and Cargo Jets (Boeing 737 and 767)
1981 (existing)	6	3	2	1 (737)
1982	8	4	3	2 (737)
1983	9	5	4	2
1984	10	6	5	3 (737 or 767)
1985	12	7	6	4 (737 or 767)
1990	18	12	8	5 (737 or 767)
1995	23	17	11	5
2000	28	22	13	5

* Cumulative totals
** Year of delivery, does not consider replacement

At present, STOL aircraft are used to carry personnel mainly between Tuktoyaktuk, Inuvik and McKinley Bay. They are also used for offshore ice reconnaissance missions. The Boeing 737 Dome uses for crew changes travels daily to Tuktoyaktuk during peak activities in the summer. In the summer of 1982, a second 737 was added to the fleet and assuming Beaufort development proceeds, more 737's, or more likely the larger Boeing 767-type aircraft, will be added (see Table 3.2-1). Executive jets operate irregularly, but their flights would be expected to increase in number. Helicopters will continue to be used for transferring personnel between shorebases and offshore platforms and for completion of various aerial surveys. In the future, larger, longer range helicopters such as the new Super Puma (already in service) or Chinooks will likely be added to the present fleet.

Tuktoyaktuk harbour presently has an entrance draft of 4.3 m, which limits the draft of vessels entering the area to about 4 metres. Dome's base has a dredged docking area of 120 m × 55 m which allows two supply vessels to be directly loaded at one time. River barges can be handled adjacent to the dock. In the future, harbour and docking facilities could be expanded to accommodate more 4 m draft vessels. Minor maintenance dredging will be required around docks as in the past. There are no current plans to dredge the entrance to Tuktoyaktuk Harbour to accommodate deeper draft vessels. Access to the harbour is generally confined within the months of June through December. Icebreaking will continue to be limited to late spring and early fall and generally occurs along the navigation channel and in the vicinity of the docks.

3.2.1.2 Esso's Tuktoyaktuk Base

Esso's Tuk Base camp, with a lease area of 42 ha, is located on the east side of Tuktoyaktuk Harbour (Figure 3.2-1). Currently, 11 ha are used for staging and storage areas for rigs, offshore camps, seismic equipment, tubular goods, mud products, fuels, lumber, and oil spill cleanup equipment. There is one dock with a draft of 2.5 m, a barge off-loading area, garages, warehousing, helicopter pads and a STOL airstrip 650 m long. A new 75 man camp complete with offices, dining, and recreational facilities was built in 1981.

Esso Resources is planning to upgrade and expand its Tuk Base. In 1982, the camp will be able to accommodate 50 more people, and new dock facilities with a draft of 4.5 m will be added. Improvements to maintenance and warehouse facilities are planned for 1983. The camp area used is anticipated to expand to 19 ha by 1985, mainly to provide more storage and rig staging areas.

3.2.1.3 Gulf's Tuktoyaktuk Base

Gulf's base at Tuktoyaktuk, which is presently under construction, will provide services similar to those existing at the Esso and Dome bases, including: an administrative centre for offshore operations; a transfer station for personnel who are rotating between offshore facilities and their home communities; an equipment and fuel storage site; and a communications and weather monitoring station.

The base is being built on ATL property, and is illustrated in Figure 3.2-2. It will initially accommodate 100 people, 50 of these being permanent core staff, but may eventually support up to 200 personnel. The base will generate its own power, although commercial power backup is anticipated. The shop and warehousing land requirements will be approximately 0.16 ha, and current plans include construction of three buildings. Fresh water would be supplied from Tuktoyaktuk, and some water conserving facilities may be included in future designs to reduce water demand. The fuel storage volume, mainly for aircraft fuel, will probably total 3,000 to 4,500 m^3.

3.2.2 McKINLEY BAY

McKinley Bay is currently used as a medium draft winter mooring basin for Dome's drilling fleet and support vessels. In 1981, 4 drillships, 4 dredges, 3 crane barges, 2 floating barge camps, 13 supply boats and tugs, 9 barges and a dry dock were overwintered in McKinley Bay (Plate 3.2-4). Dredging operations in McKinley Bay began in September 1979 when a 35 ha mooring basin and 7 km access channel, both 10 m deep, were excavated (Figure 3.2-3).

A major storm in December 1979 shifted overwintering ships and barges within the basin, and demonstrated the need for a more protected mooring basin within the bay. As a result, a new 51 ha mooring basin and a 3 km access channel were dredged in McKinley Bay during the summer of 1980 (Figure 3.2-3). Sand dredged from the basin was used to build a 43 ha artificial island for protecting the moorage. It is located north of the basin and 2.5 km from the nearest natural shoreline.

During the summer of 1981, the mooring basin and artificial island areas were expanded to 100 ha and 63 ha, respectively. Geotechnical studies have shown the island to be satisfactory as a foundation for a future support base (Plate 3.2-5). Up to the end of

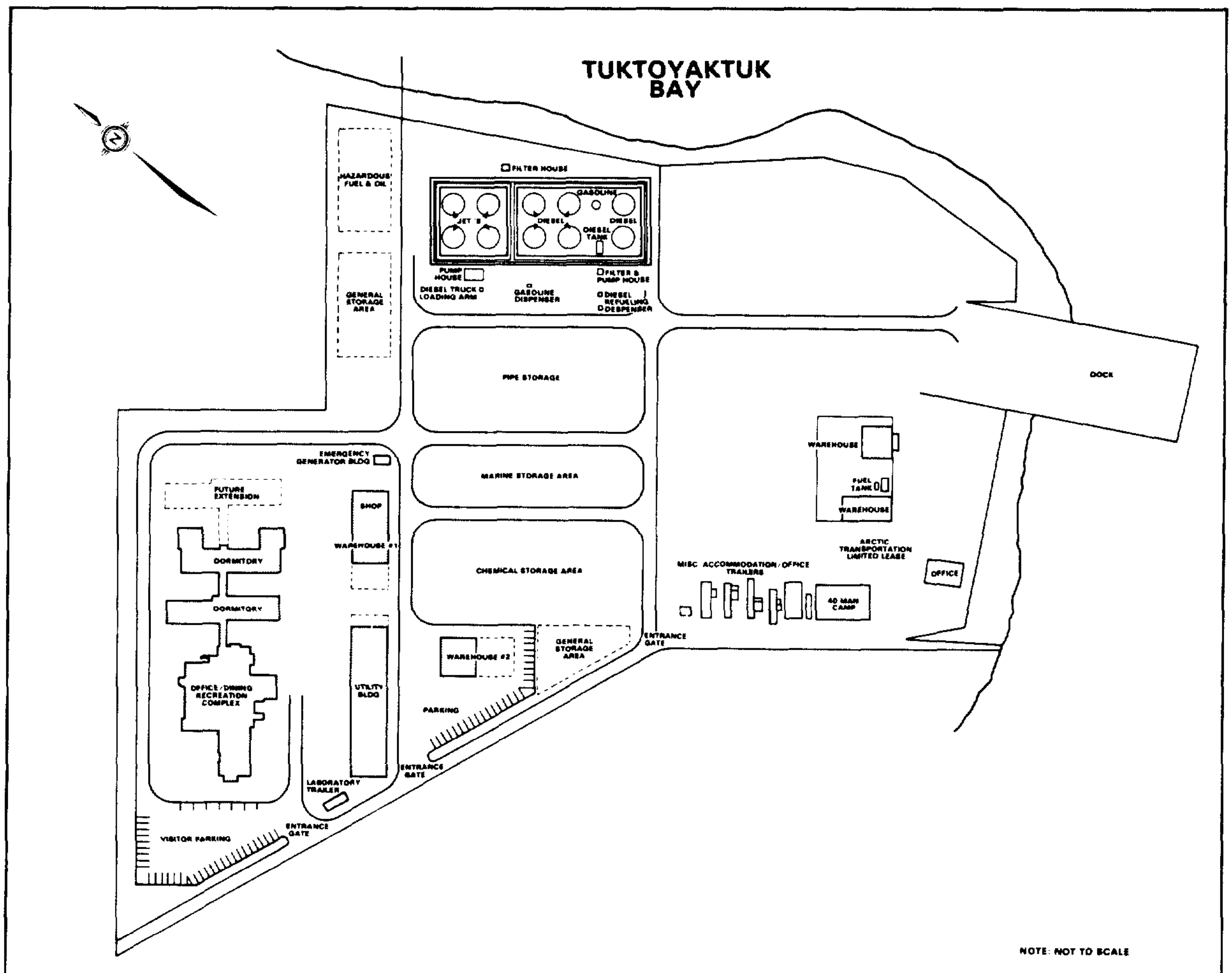


FIGURE 3.2-2 *Gulf's base, shown here in schematic form, is presently under construction. It will provide services similar to those existing at the Esso and Dome bases.*

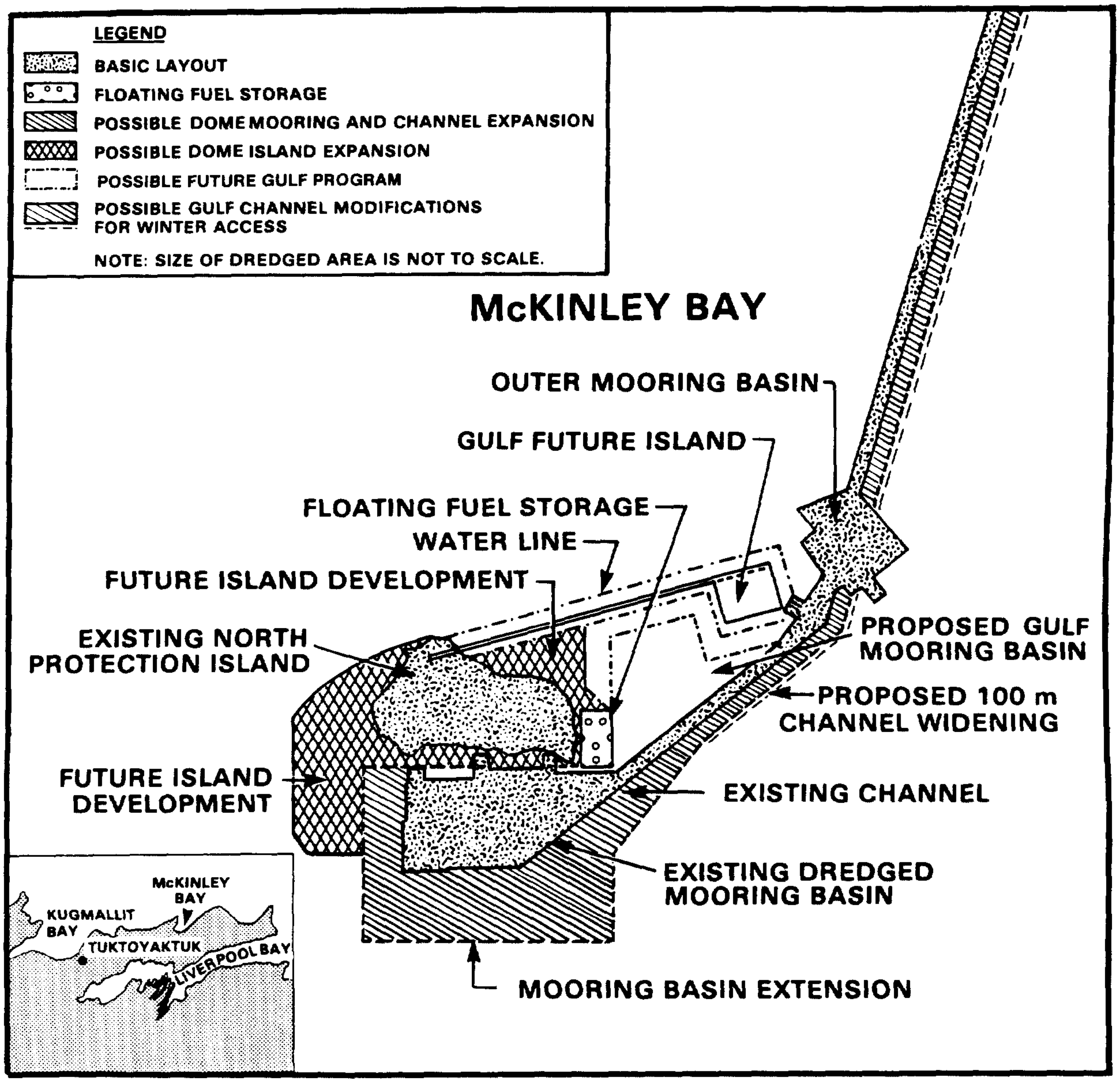


FIGURE 3.2-3 *The McKinley Bay support base will function as a supply and refueling centre for drillships, a marine maintenance and repair facility, a winter mooring basin and accommodation centre. The proposed expansion of the base up to 1986 is shown here.*

1981, about a 5 ha area of the island has been used for the storage of offshore drilling consumables and a further 5 ha are being considered for development during 1982. A temporary STOL airstrip was constructed on the island during the winter of 1980-81, although it no longer exists.

Up to the present time, about 60,000 m^3 of fuel, mostly diesel, has been stored in large barges at McKinley Bay. In 1982, Dome is planning to bring in a large fuel storage vessel which will be anchored at Summers Harbour. The arrival of this vessel will reduce the present fuel storage requirements at McKinley Bay. For the longer term, consideration continues to be given to the use of a small floating topping plant at McKinley Bay. Currently, accommodation for personnel is provided by floating camps and other vessels in the harbour.

Currently, Dome and Gulf plan to expand their presence at McKinley Bay in the future. Details of possible expansion are not known now since they will be influenced by the results of ongoing drilling, particularly at Tarsiut in the near-term. For example, in 1981, Dome had planned to expand the existing island, build a permanent dock, establish a base camp and carry out other activities. However, these plans have been scaled down and activities now

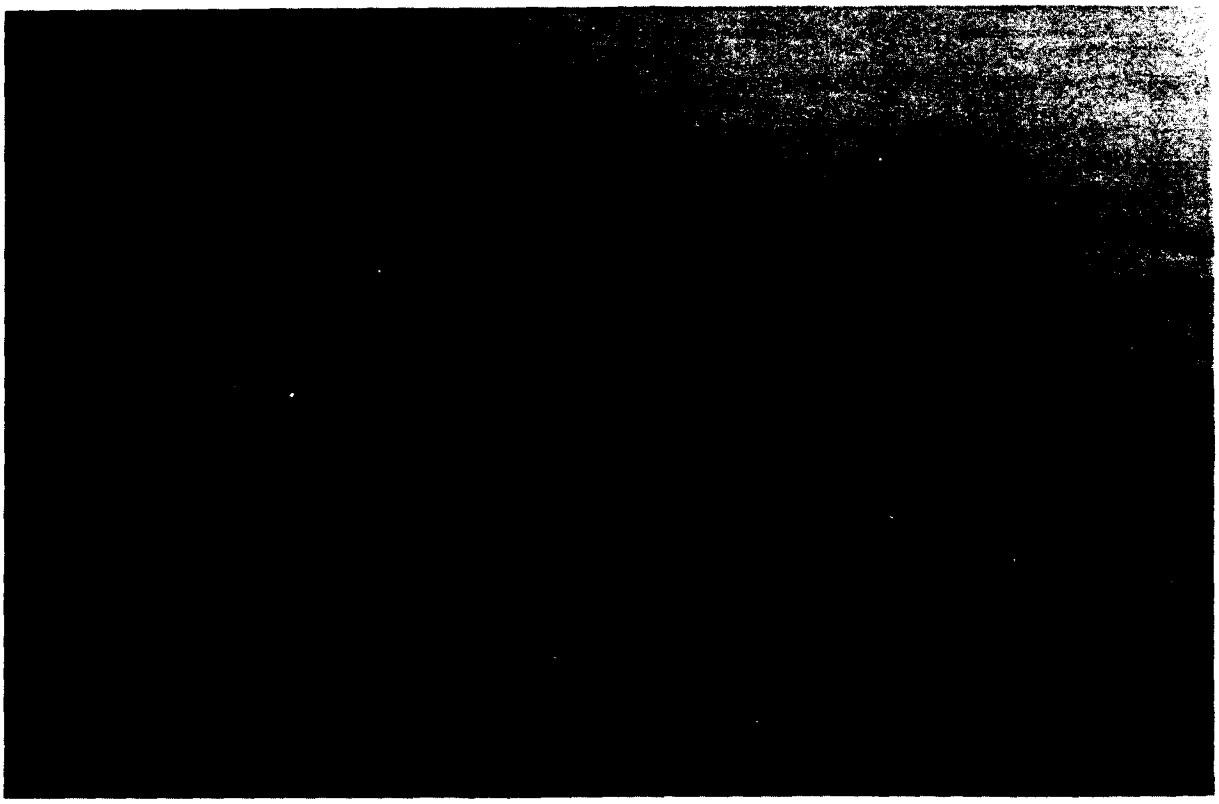


PLATE 3.2-4 *Aerial photo showing most of the 1981 offshore drilling fleet moored at McKinley Bay during the winter of 1981. The fleet includes 4 drillships, 4 dredges, 13 supply boats and tugs, an assortment of barges and a large floating drydock.*

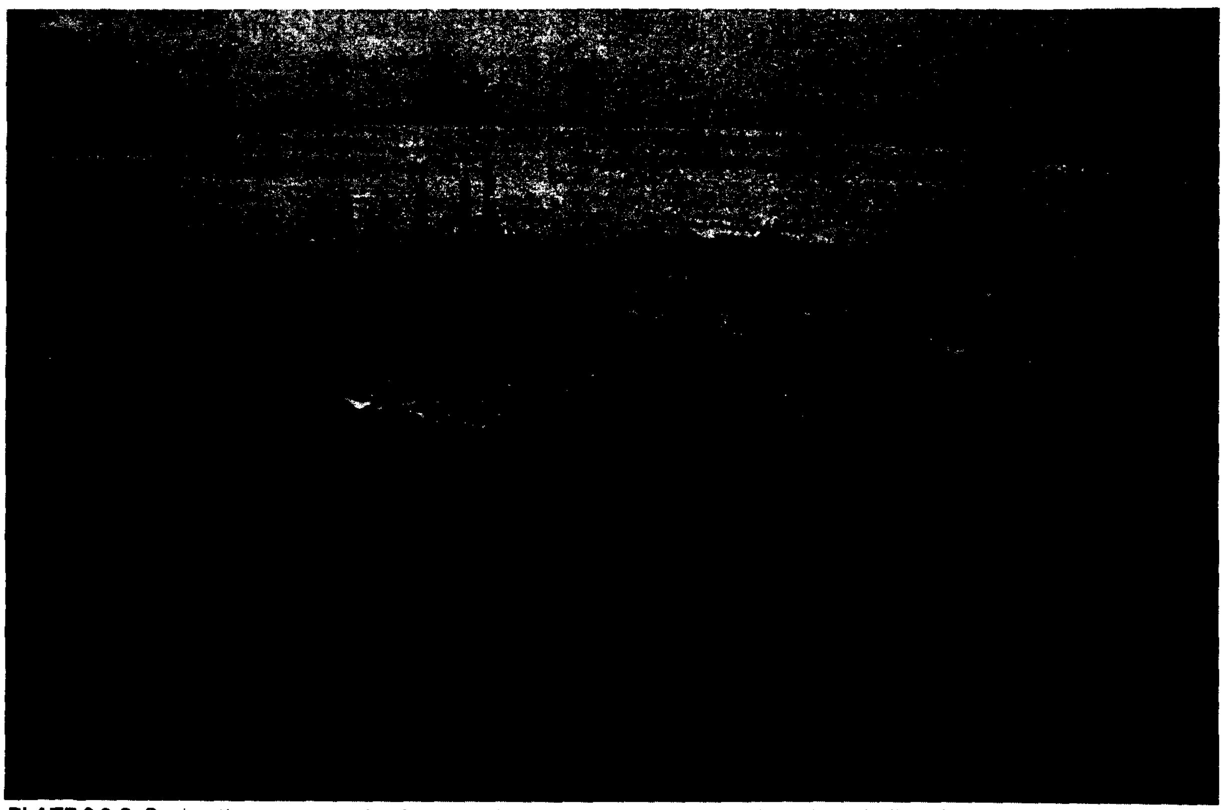


PLATE 3.2-5 *During the summers of 1980 and 1981, a large ice "protection" island was built with dredged material removed from the mooring basin. Geotechnical studies have shown the island to be satisfactory as a foundation for a future support base.*

under consideration for 1982 include: the installation of two temporary warehouses, one for oil spill equipment and a second for dredging equipment maintenance; and the possible establishment of a STOL airstrip along the beach of the island.

Assuming production proceeds in the future, the temporary barge dock at the McKinley Bay island would be replaced by a permanent dock. Construction of this dock could begin in 1983 and it could eventually be 400 m long. It would likely be fronted by cylindrical sheet metal piling, much of which could be installed during winter.

As development proceeds, the existing island and harbour would be enlarged to keep pace with expanding requirements. These requirements, however, will be affected by the type of harbour facilities provided offshore, such as at an APLA, and elsewhere. Expansion of the artificial island would most likely occur to the west and east, and may reach an area of 150 ha by 1987; with 25 ha of it supporting permanent facilities (Figure 3.2-3).

Permanent facilities which may be established in McKinley Bay by 1987 include: accommodation for up to 500 personnel, additional warehouses and yard space for drilling consumables and oil spill equipment, a desalination plant, power generators and a secondary sewage treatment plant. Combustible solid wastes will be incinerated on the island, while non-combustibles would be buried in a suitable and approved landfill site on the coast or could be barged to Tuktoyaktuk for disposal.

Present access to McKinley Bay is mainly by STOL aircraft, helicopters and vessels from Tuktoyaktuk. During winter (February, March) Boeing 737 jets and Hercules aircraft land on the sea ice in McKinley Bay and this practice will continue in the future. Fuel and drilling supplies will continue to be transported in barges from Tuktoyaktuk or directly from the south by the western marine route during the open water season. Other supplies will continue to be transported from Tuktoyaktuk to McKinley Bay on a winter ice road. Most of the barge and construction-related ship traffic to McKinley Bay would travel from July until freeze-up. Movement of drillships and icebreaker supply boats between their winter moorage and offshore development sites will occur mainly during the spring break-out in June and shortly after fall freeze-up in October and November. These movements will occur along a single 100 to 150 m wide corridor through the landfast ice zone. However, as more ice-strengthened vessels are added to the fleet, traffic between offshore development sites and McKinley Bay will increase and will eventually occur throughout the winter.

3.2.3 YUKON NORTH SLOPE

Sites along the Yukon North Slope have long been considered among the best available in the Beaufort region for possible shorebase development. Presently under active consideration by the oil industry are King Point and Stokes Point (Figure 3.2-4). The following describes possible plans for both of these sites although it is assumed that, in the long run, likely only one of the sites would develop into a major shorebase.

3.2.3.1 King Point

King Point is one of the few areas along the Beaufort Sea coast which is close to deep water. It is also close to a major source of quarry rock, the area has excellent civil engineering site conditions and it is relatively close to offshore areas of proposed short and long term development (Volume 2, Chapter 5). However, King Point is also located within the large area designated as a Northern Yukon Wilderness Park Area, which includes the Yukon coast and regions to the south and west (Volume 3A).

Assuming approvals, possible development for the King Point area between the present and 1985 could include: quarrying of rock at Mount Sedgewick which is located 40 km inland from King Point; construction of an all-weather haul road from the quarry to King Point; building of a camp for 50 people at the quarry; building of a camp for 140 people at King Point; construction of a STOL airstrip, construction of a ship or barge loading facility in 10 m water depth, and development of a rock stockpile area at King Point. The rock stockpile would be needed to accommodate periods when the haul road may be closed (e.g. for caribou migration); up to 250,000 tonnes of rock may be stockpiled at the base.

Assuming that development proceeds, major expansion at King Point is required, and that further approvals are given, construction of a major shorebase at King Point could begin between 1985 and 1987. The base could grow as required and could eventually look like the base concept shown in Figure 3.2-5. The proposed STOL airstrip could be upgraded and lengthened to 2,100 m to accommodate Boeing 737 or 767 jets, while a 220 km all-weather road could be constructed to connect King Point to the Dempster Highway near Fort McPherson (Figure 3.2-4). Development at the major shorebase could require a surface area of about 90 ha, and a deep water port including causeway and breakwater could require an additional 10 ha. The base would include support facilities for an estimated 500 personnel, a secondary sewage treatment plant, possibly a desalination plant (if no potable water is present), warehousing and storage yards, and a fuel storage area. With some

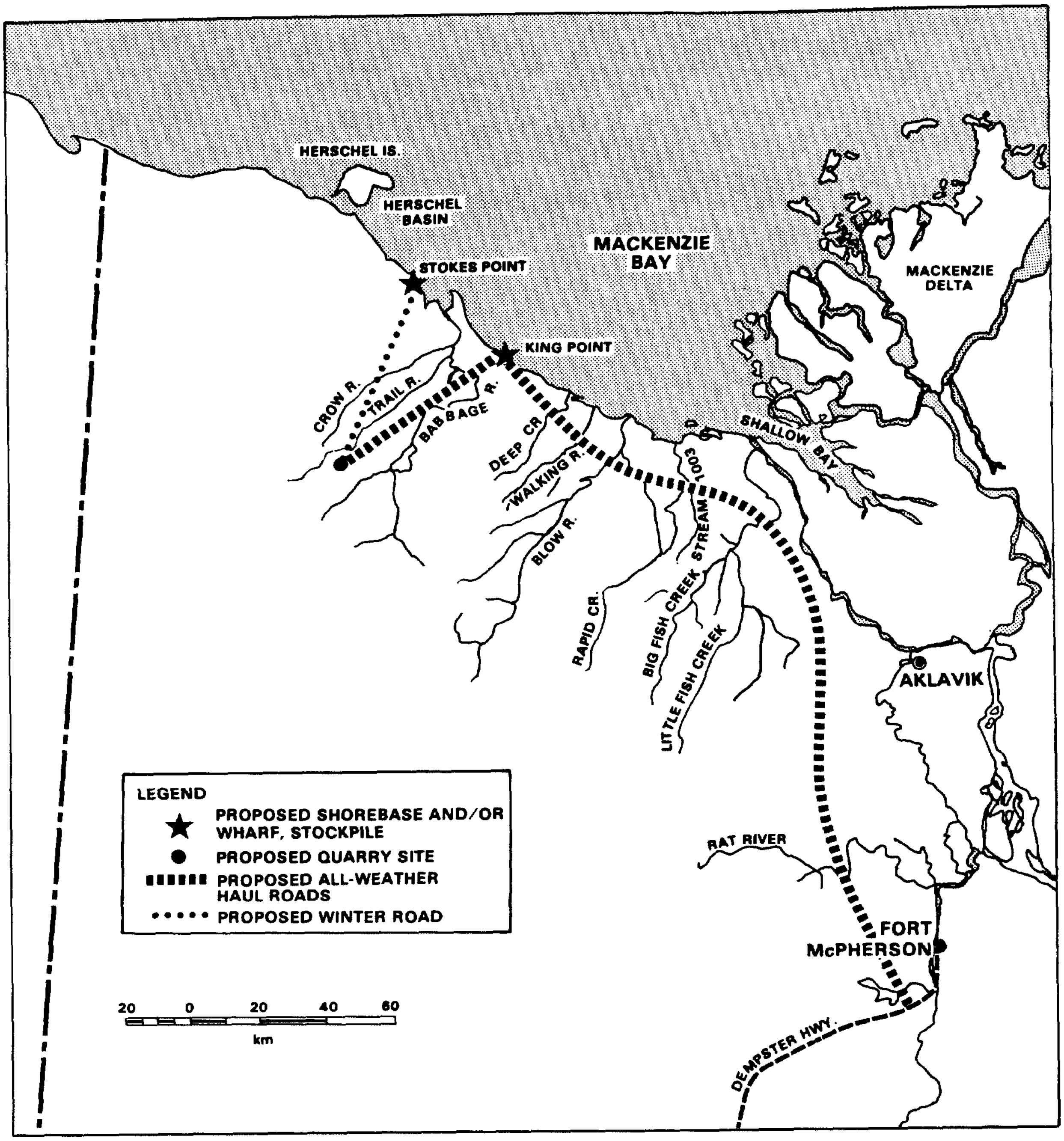


FIGURE 3.2-4 *Sites along the Yukon North Slope have long been considered among the best available in the Beaufort region for possible shorebase development. King Point and Stokes Point are the two areas under active consideration at this time.*

dredging and causeway construction, a harbour could be built to accommodate ships up to 25 m draft with all necessary docking, fueling, and maintenance facilities.

During later stages of oil production in the Beaufort region, it is possible that producible oil reserves may be found in the western Beaufort Sea. King Point could then become a site for supporting the additional onshore development which may be required for oil storage and the pipeline transport of oil. It could also be the location of an LNG terminal. Such future possible requirements at or near King Point are speculative at this time. Plans will naturally evolve as hydrocarbon development plans evolve in the future.

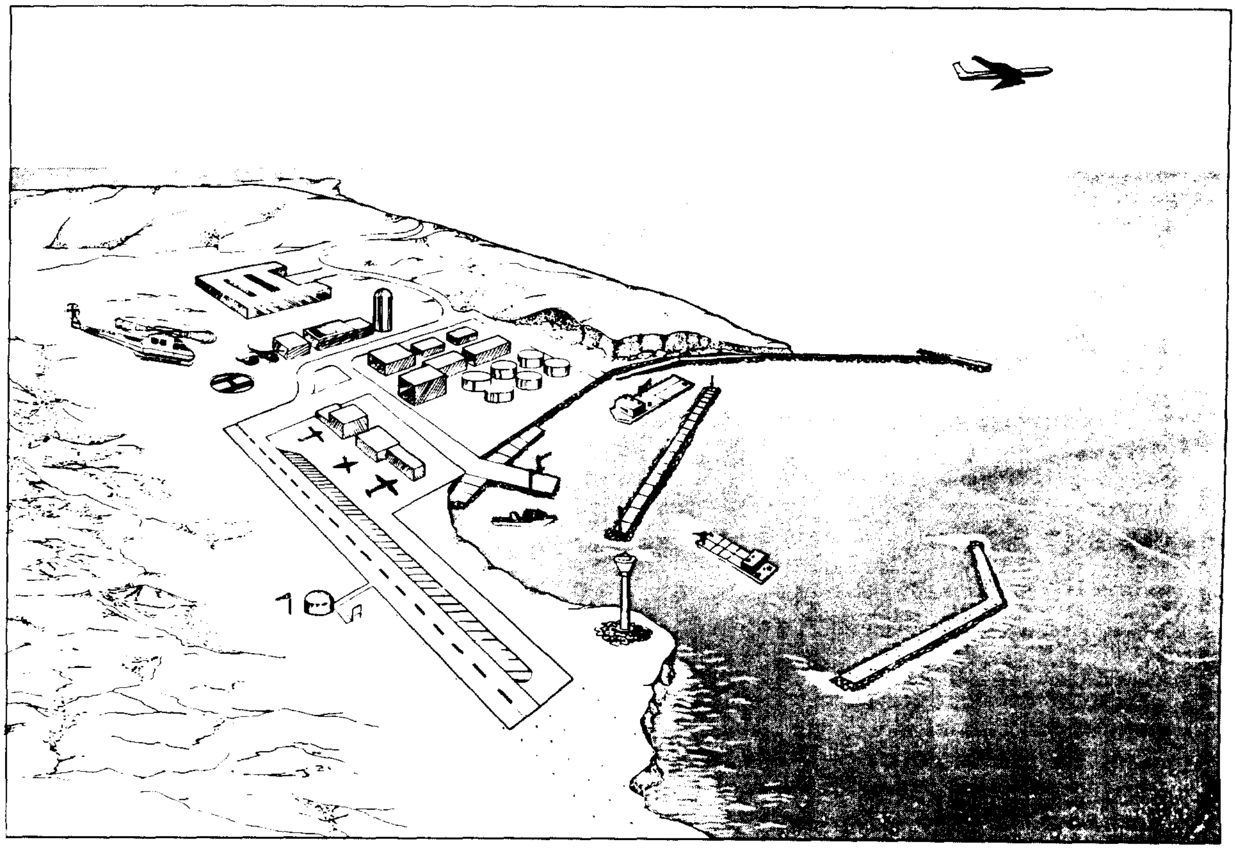


FIGURE 3.2-5 *If further expansion is required for support facilities, King Point is proposed as one of the preferred sites. It has potential for development as a deep water year-round port and is close to the offshore development sites. Shown here is an artist's rendering of the King Point support base as it may look by the late 1980's.*

3.2.3.2 Stokes Point

Stokes Point is the site of an abandoned DEW line installation southwest of Herschel Island on the Yukon Coast (Figure 3.2-4). It is being considered by Gulf as a potential site for a marine supply base. It would support Gulf's Beaufort Sea Drilling System, which will include the Conical Drilling Unit and the Mobile Arctic Caisson, supported by a fleet of ice-breakers and supply vessels (See Volume 2).

The Stokes Point location has several advantages as a supply base for Gulf's Beaufort Sea activities. It provides easy access to Herschel Basin (Figure 3.2-4), a natural deepwater mooring basin which is well protected from ice movements and which could be used to safely moor the Conical Drilling Unit for supply and maintenance activities during the winter. As with other potential base locations along the Yukon Coast, Stokes Point would require considerable work to develop a harbour capable of accommodating both incoming supply carriers and the drilling fleet. However, the bathymetric configuration at Stokes Point allows for a cost-effective harbour development design.

Onshore characteristics at Stokes Point are also favourable for supply base development. The terrain has been previously disturbed by construction of the DEW line station. The station site, an airstrip and an access road leading to a fresh water supply, are still intact, and could be restored for use with relatively little work. The extent of terrain suitable for development at Stokes Point ensures that both present needs and future expansion can be accommodated.

Like King Point, Stokes Point is located within the designated Wilderness Park area. If the location were to be developed as a supply base, activities would be designed to ensure minimal use and disruption of sensitive areas.

Development of a marine supply base at Stokes Point would be staged to meet increasing demands. Initial development would support exploratory and possibly development drilling programs. The site may or may not be a suitable candidate for a production terminal, depending on where oil is found and the production method selected.

If approvals are received, development of a minimal base would begin in 1983 to meet immediate support requirements of the Beaufort Sea Drilling System. The first stage of development would entail both the construction of a causeway and the dredging of an access channel to provide an inner harbour of 10 m depth. Approximately 10 to 25 ha of land would be required for this phase to accommodate buildings, storage and a STOL airstrip. Figure 3.2-6a indicates a conceptual design of this development phase which would undoubtedly change as more site specific data become available.

The second phase of base development would include construction of an extended causeway to provide a deepwater wharf for winter use. The causeway would be constructed of dredged and placed granular fill, and could be protected from wave erosion and longshore transport by armour material. A modified VLCC tanker could be grounded on-site to provide a breakwater and deepwater wharf.

The final base development phase would include extension of the harbour to accommodate vessels with drafts up to 12 m. Increased facility development may be required to support a wide range of activities and up to 100 ha of land could eventually be occupied.

Facilities could include storage and staging areas, warehouses, accommodation for approximately 150 personnel, offices, a landing strip for larger aircraft, fabrication and mooring facilities, a communication centre and a medical centre. The extent of development will depend on the success and nature of hydrocarbon development and production. Figure 3.2-6b illustrates one conceptual design of base facilities after the third phase of development.

Initially, the majority of supplies would be transported to Stokes Point by river barges using the Mackenzie River transportation route. As the need for greater quantities develops, the major supply emphasis would shift to oceangoing bulk carriers from the Canadian west coast.

The Stokes Point area does not have a connection to an existing road system, and links to the Dempster Highway would occur only by ice road or cat train during the winter.

Aircraft flying to the Stokes Point base would primarily be used to transport personnel. During early development phases the existing airstrip could be used. Eventually, an airport capable of handling larger aircraft such as the Boeing 767 could be required.

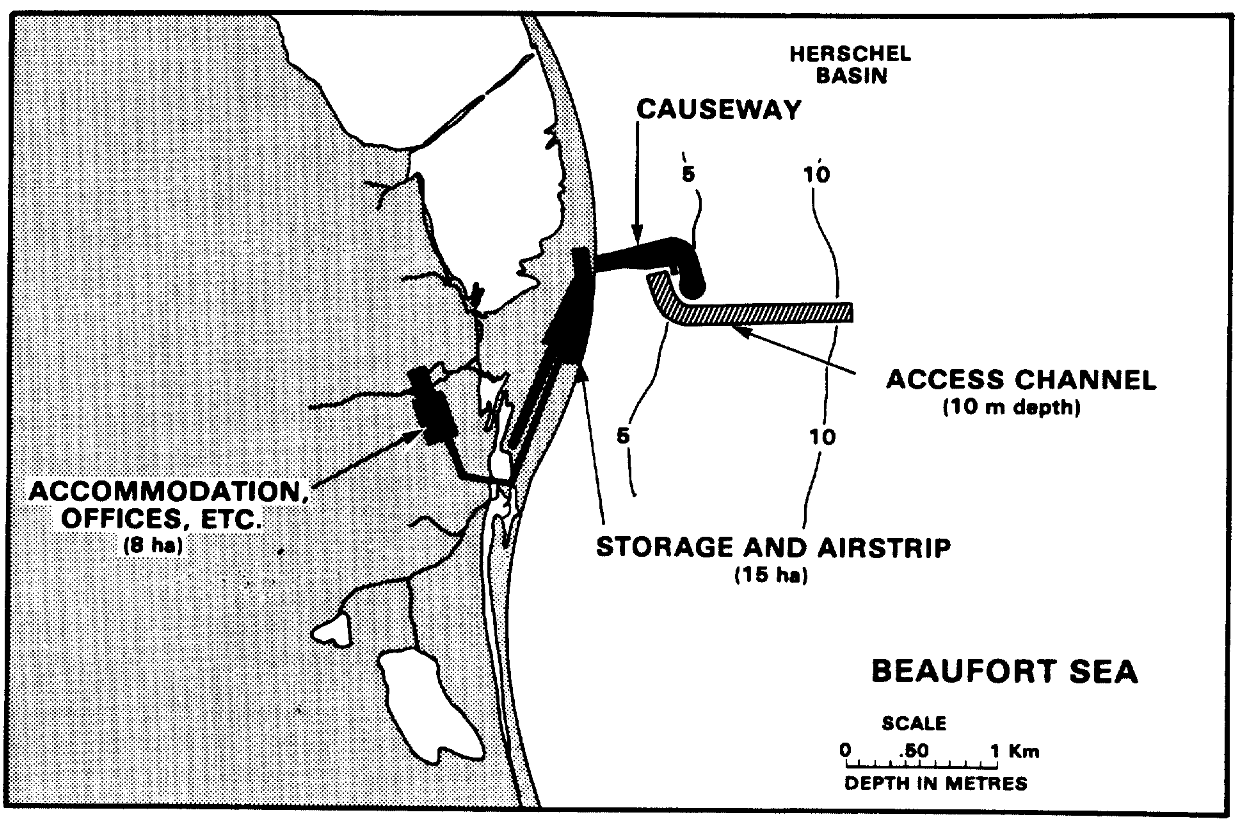


FIGURE 3.2-6a *Gulf may develop a marine supply base at Stokes Point. If approvals are received, phase 1 of the proposed development, shown here, could begin in 1983.*

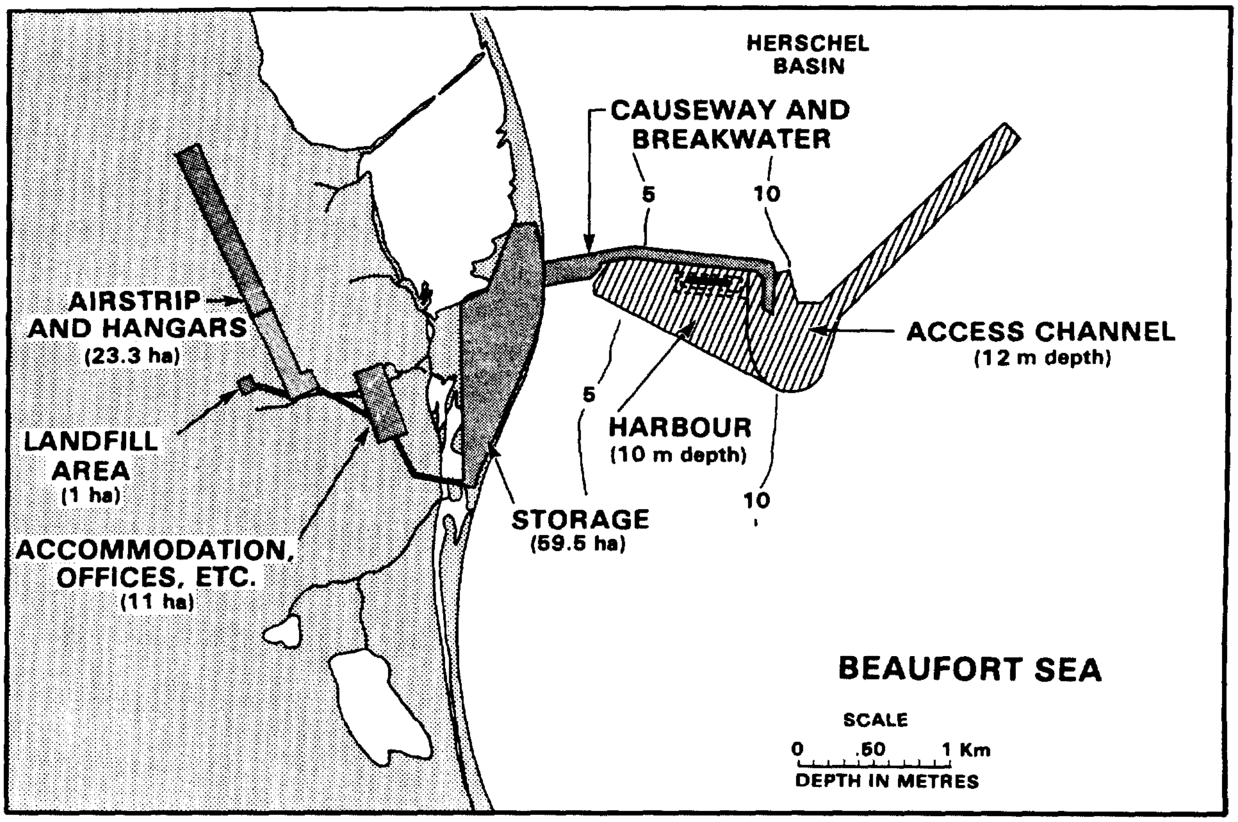


FIGURE 3.2-6b *One concept for longer term development at Stokes Point is illustrated in this schematic.*

3.2.4 WISE BAY-SUMMERS HARBOUR

The Wise Bay-Summers Harbour area on Cape Parry (Figure 3.1-1) has the best natural harbours along the Beaufort Sea coast for vessels with drafts of up to 25 metres. However, Cape Parry is far removed from sites proposed for hydrocarbon exploration or production (e.g. 415 km from the Kopanoar discovery). Therefore, development of a major shorebase at Wise Bay is not considered practical. During the early years of Dome's Beaufort operations, some vessels of the drilling fleet were moored at Summers Harbour (Plate 3.2-6), and deeper draft vessels such as the KIGORIAK have used the harbour for underwater repairs which could be best carried out in its protected, deep clear waters. In 1982, Dome is planning to moor a large fuel storage vessel in Summers Harbour. This ship has too deep a draft to allow it into McKinley Bay. In the longer term, Wise Bay may be used as a contingency diesel fuel storage area. Development of Wise Bay as a major deep draft harbour and marine marshalling area would be considered if oil and gas production activities extend into the eastern Beaufort Sea or Amundsen Gulf.

The only facility usable by industry at Wise Bay is the Cape Parry DEW line airstrip. Dome has government approval to install a 50,000 barrel fuel tank farm on land adjacent to Wise Bay but has no present plans to do so. The tank farm site proposed for Wise Bay would be located 7 km south of the DEW line airstrip. Basic facilities at the site, if built, could include ten 5,000-barrel fuel storage tanks surrounded by lined earthen berms with impervious liners, a temporary 24 man camp with a sewage disposal system, an access road connecting the tank farm with the DEW line airstrip, and an access road to a site of potable water. The natural harbour may also be used by deep draft vessels.

Combustible solid wastes would be incinerated on site, while incombustible wastes would be disposed of in an approved landfill site. A fuel tank farm at Wise Bay could be constructed in about 3 to 5 weeks and construction would likely take place in late summer or fall. The site for the proposed tank farm has been selected in accordance with Environmental Protection Service guidelines, and would be situated roughly 450 m from the shore at an elevation of 40 m asl. According to the proposal, a steel pipe would extend from the tank farm to the shore where it would be connected to a floating pipeline for refuel-

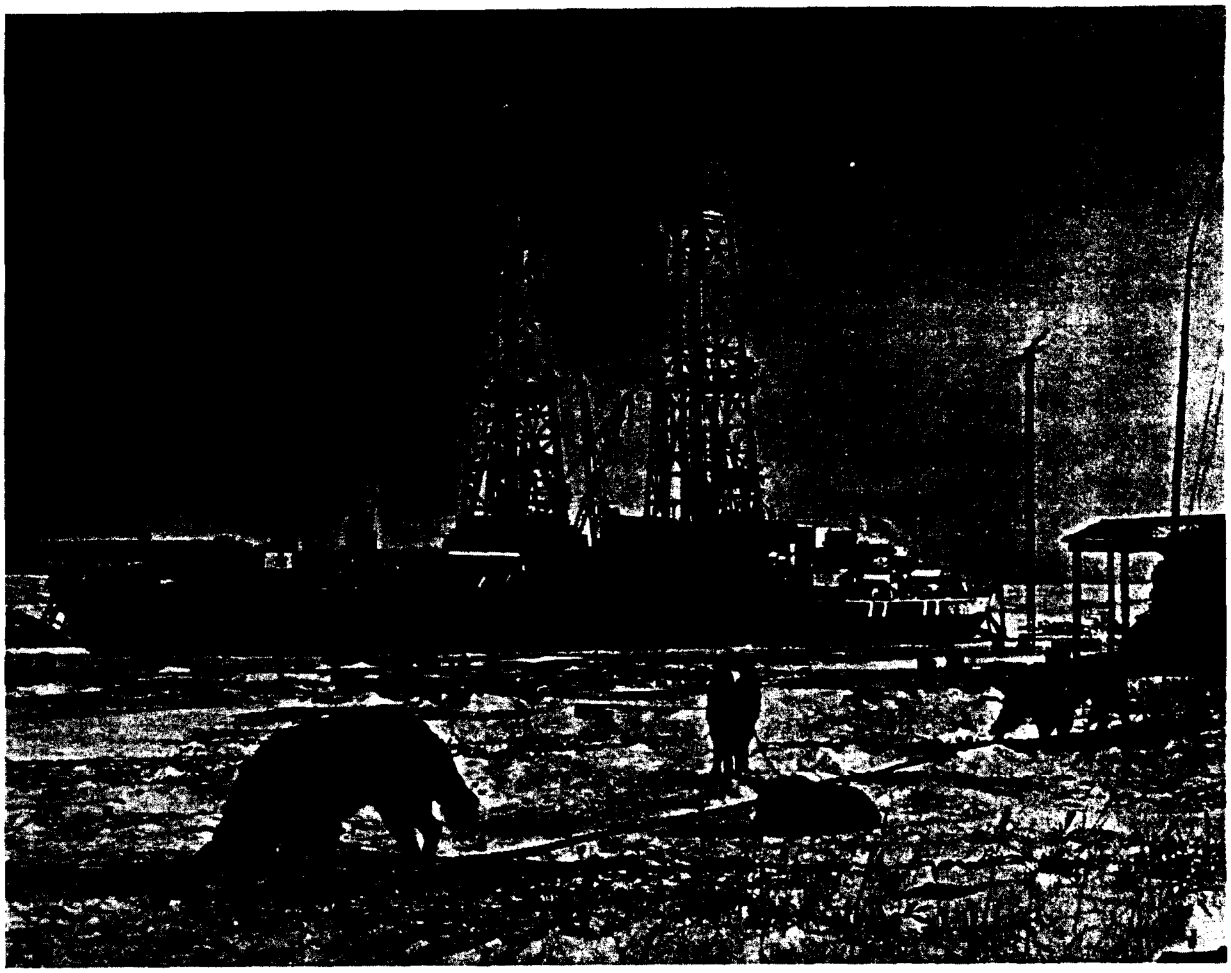


PLATE 3.2-6 *The Wise Bay-Summers Harbour area at Cape Parry has the best natural harbours along the sea coast but is far removed from present drilling operations. In 1979 part of the drilling fleet moored here.*

ling ships and offloading fuel brought in by supply barges. Dome's plan for 1982 is to moor the fuel tanker, containing approximately 70,000 m^3 of diesel fuel in inner compartments, at Summers Harbour and to transfer fuel as required to barges such as the CANMAR SHUTTLE for use in the operations area.

3.2.5 PAULINE COVE (HERSCHEL ISLAND)

Pauline Cove at Herschel Island (Figure 3.1-1) has been used in the past to winter some of the offshore drilling fleet. More recently it has served as a marine staging area for the caissons brought in from the west coast for construction of the Tarsiut exploration island (Plate 3.2-7). It is likely to continue to be used for staging and as a winter mooring area for deeper draft vessels.

3.2.6 TUFT POINT

Tuft Point on the Tuktoyaktuk Peninsula (Figure 3.1-1) has been proposed as a caisson assembly and winter mooring site for marine vessels involved with Esso Resources' caisson construction project. This area has been used as a source of borrow materials for offshore island construction from 1976 to 1979; also a breakwater and barge camp have been located near Tuft Point at various times in support of dredging and sand-hauling operations.

3.2.7 BAR C

Bar C is located on Richards Island at an abandoned DEW line site on Tununuk Point at the junction of East Channel and Middle Channel (Plate 3.2-8). It functioned as a main staging area for exploratory drilling in the northern Mackenzie Delta and shallow offshore area of Mackenzie Bay between 1968 and 1979. The camp was closed when Esso's operations were consolidated at Tuktoyaktuk but the storage area, 670 m long gravel airstrip, and tank farm remain at the site. If development proceeds at Adgo, Bar C would likely be reactivated and become a temporary staging area.

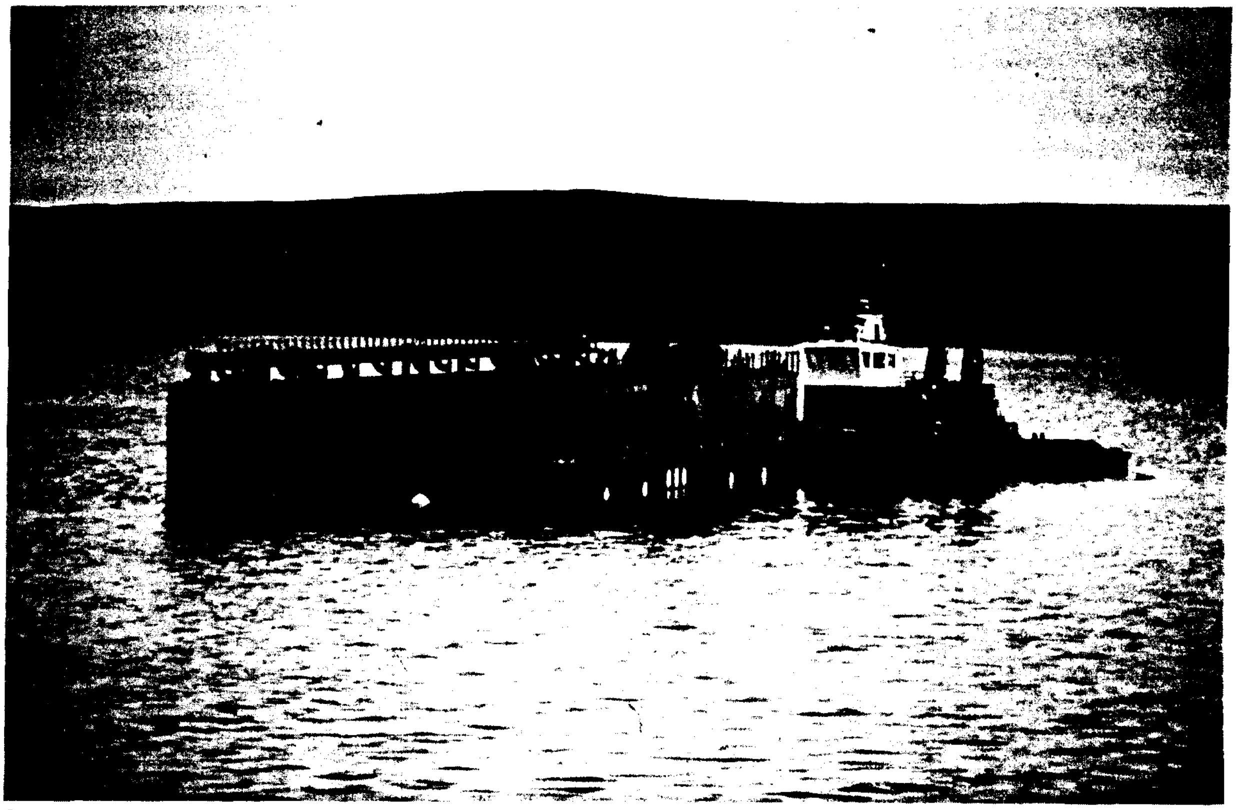


PLATE 3.2-7 *In the past, Pauline Cove, near Herschel Island, has been used to winter some of the drilling fleet, and more recently, has been used as a staging area for the Tarsiut Island caissons. These kinds of activities can be expected to continue to occur here in the future.*

PLATE 3.2-8 *Bar C located on Richards Island at an abandoned DEW line site, has functioned as a staging area in the recent past. If development proceeds at Adgo, it would likely be reactivated as a staging area.*

3.3 PROJECTED OIL AND GAS PRODUCTION FACILITIES

Onshore hydrocarbon exploration has resulted in discoveries of oil or gas at several Delta sites including: oil at Atkinson and Adgo in shallow water, and gas at Parsons Lake, Taglu and Niglintgak. The oil from these fields will be shipped to either an overland oil pipeline system or to a central terminal for delivery to a subsea pipeline and offshore tanker loading facility. Descriptions of both oil and gas production drilling, gathering, and processing facilities in the Beaufort Sea-Mackenzie Delta regions are provided in Volume 2. A description of gas production facilities is provided in the Mackenzie Delta Gas Development System (1974). An impact assessment of gas production and gathering lines at Taglu in the Mackenzie Delta was provided by Imperial Oil Limited (1975). The following is a brief summary of the five major components of oil production in the Beaufort Sea-Mackenzie Delta region.

3.3.1 WELL CLUSTER ON PRODUCTION ISLANDS OR PADS

At each producing oilfield, a number of directionally drilled wells, known as a "cluster," would be located on gravel-fill pads or islands (Figure 3.3-1). Production pads or islands would be similar in design and construction to those used in exploration drilling but with greater freeboard and permanent erosion protection. Each pad, depending on the number of wells, could be approximately 150 m wide by 600 m long. When completed, cluster-pad equipment will include wellheads, flowlines, manifolds, test modules, control units, and a flare stack.

3.3.2 DRILLSITE FLOWLINES

Oil well fluids will be transmitted through short flowlines, constructed above grade on piles frozen into the permafrost, to central processing facilities.

3.3.3 CENTRAL PROCESSING FACILITIES

Each larger onshore oilfield will have its own central plant to treat the well fluids (i.e. separate gas, water,

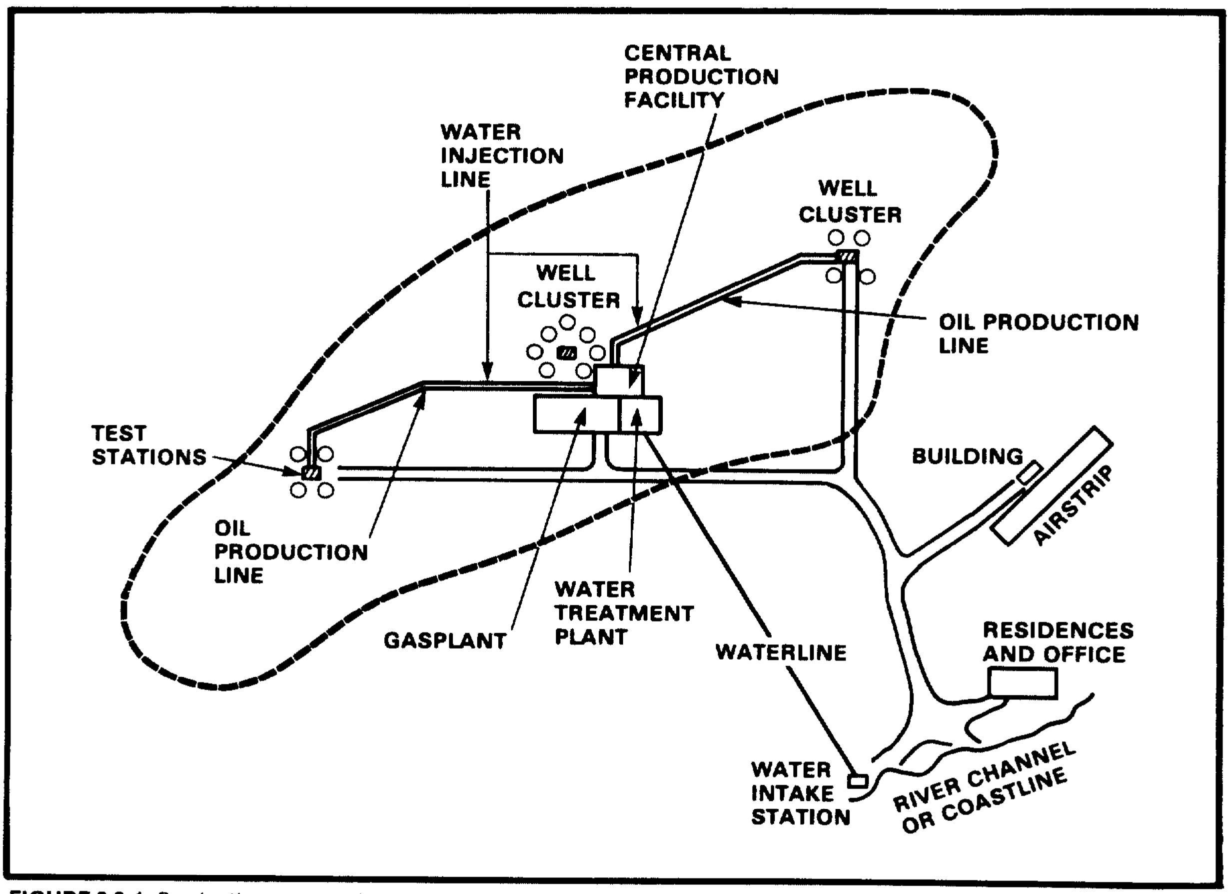


FIGURE 3.3-1 *Production systems include wellheads, production flow lines, oil and gas processing systems, water injection lines, and support facilities.*

and sand from the crude oil) (Plate 3.3-1). There are a number of options for using the associated gas. It might be treated for use as a fuel for the processing facility, compressed for reinjection to the reservoir or for injection into a gas gathering line, or flared. Produced water will be treated and reinjected into the reservoir. Smaller oil fields which are close enough together might share a central processing plant. In addition to the separators, each processing facility would have an airstrip, helicopter pads, utility and maintenance shops, water-treatment and waste-disposal units, river docks, communication systems, management offices, and staff accommodation and recreation quarters.

3.3.4 GATHERING SYSTEM

Crude oil leaving the process facilities at various locations in the Mackenzie Delta and Tuktoyaktuk Peninsula will be shipped via gathering lines to a terminal (Figure 3.3-2). Based on existing discoveries, it is estimated that approximately 300 km of small diameter pipelines, buried under 1 m of fill would be required in the Mackenzie Delta and Tuktoyaktuk Peninsula regions. Pipeline diameters are estimated to range from 219 to 508 mm. The crude oil can be pumped at or below the ambient ground temperatures of this continuous permafrost region. This will allow for flexibility in selection of the specific routes. The gathering line could be provided with thermal insulation to prevent excess heat loss from pipe to soils in winter and prevent excessive heat gain from soils to pipe in summer. Leak detection systems will be included as part of the control system and will be able to detect and identify the location of a leak in the order of 0.25 to 0.50% of gathering line flow. Flow valves will be spaced at regular intervals to isolate segments of the line in the event of leak. In addition, isolating valves will be located at junction points and at selected locations on both sides of major river and channel crossings.

3.3.5 GATHERING SYSTEM TERMINAL

The terminal would include a tank farm and a pump station for transportation of oil to market by overland pipeline or through an offshore tanker loading terminal.

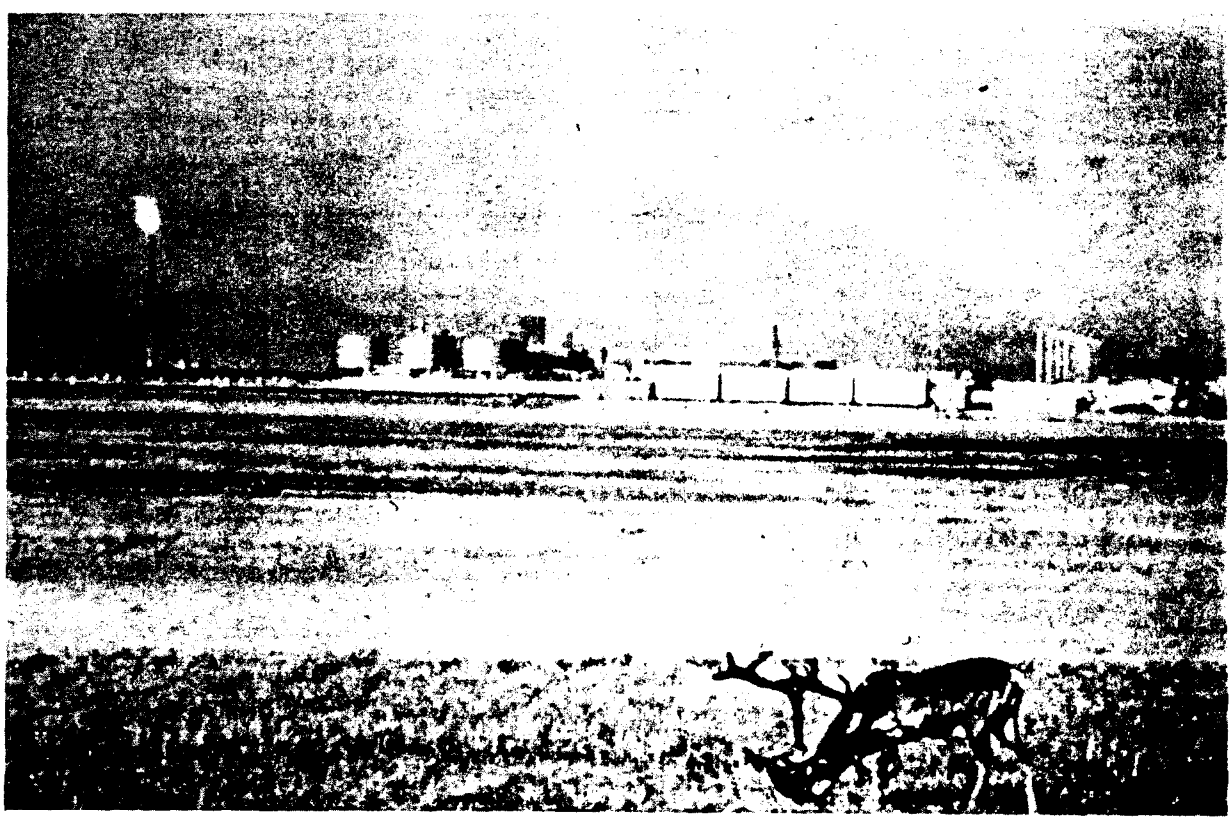
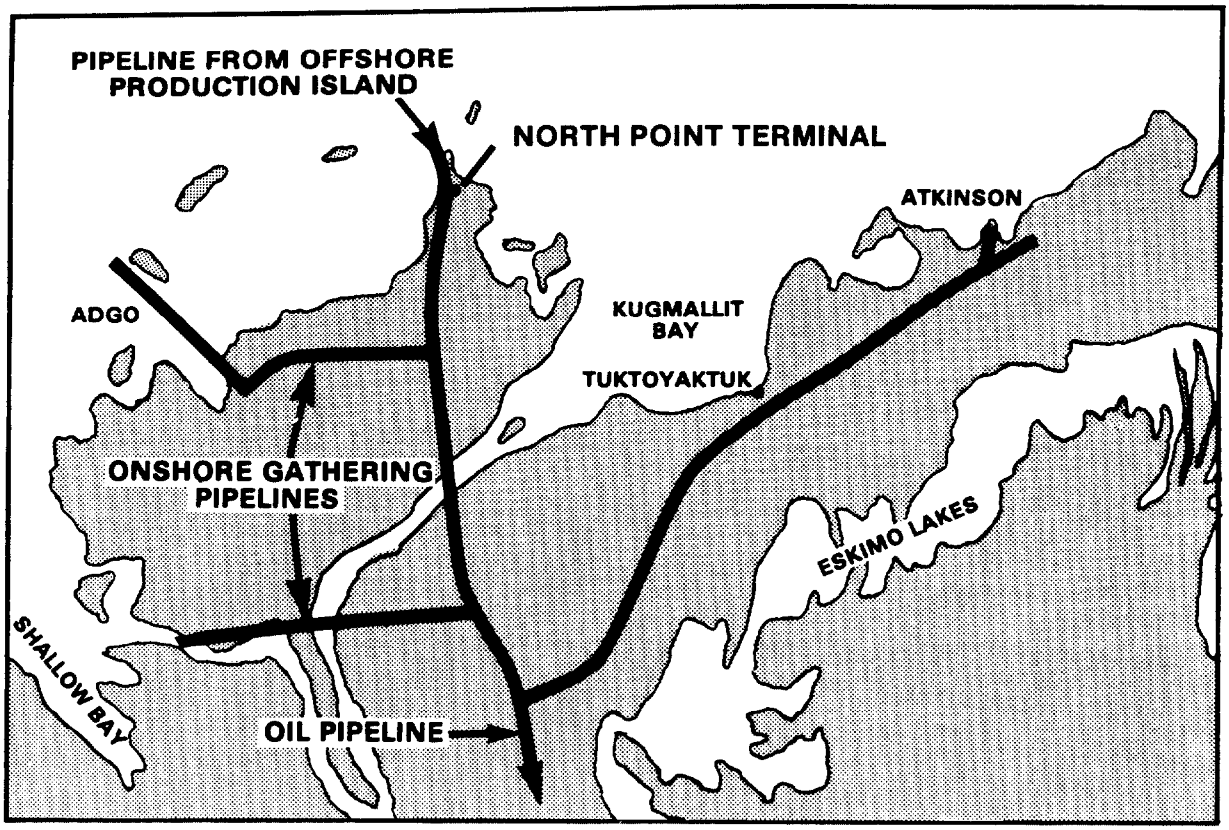


PLATE 3.3-1 *Each larger onshore oilfield will have its own central plant to treat the well fluids. They will be similar in appearance to this one at the Prudhoe Bay oilfield in Alaska. (Courtesy: Alyeska Pipeline Service Co.).*



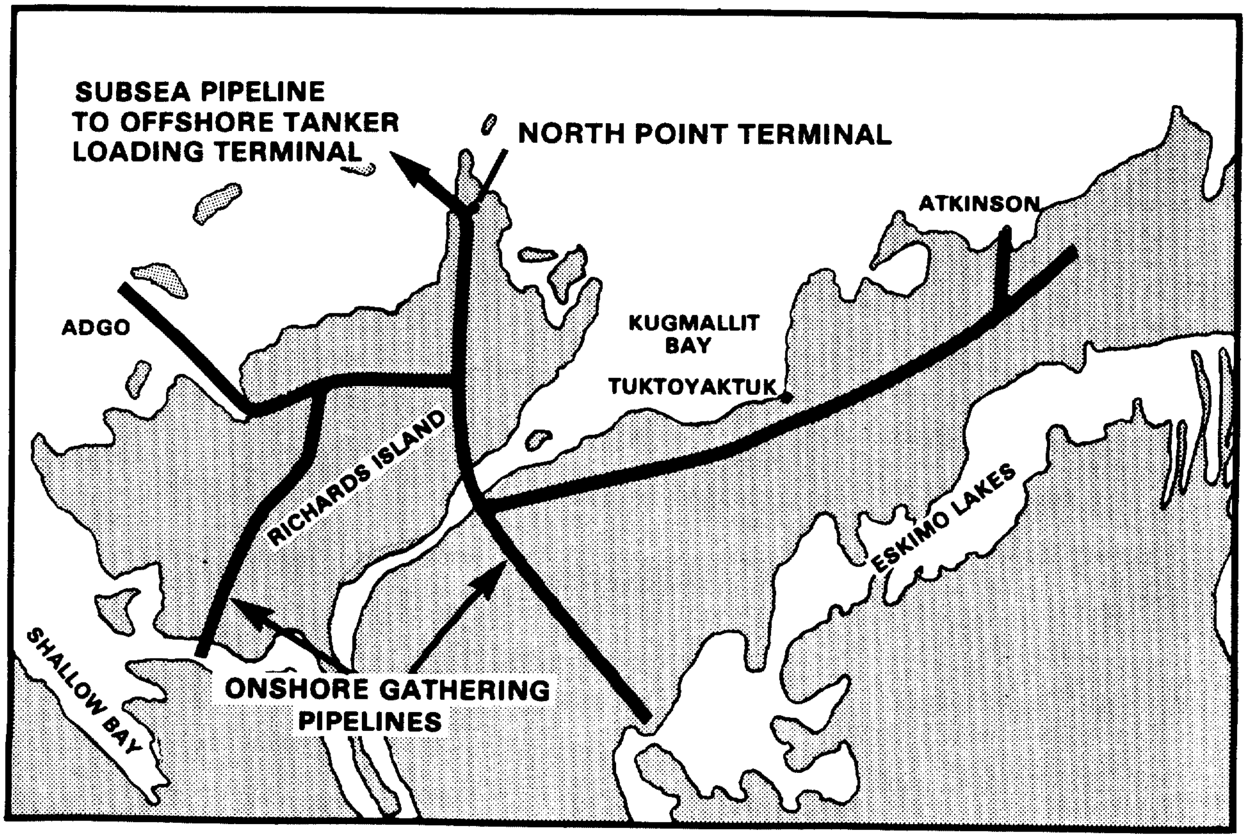


FIGURE 3.3-2 *Crude oil leaving the processing facilities at various locations in the Delta will be shipped via gathering lines to a terminal. From here it will be directed into the transportation system (tankers or pipeline) being used to carry the oil to market.*

3.4 COMMON DISTURBANCES OF SHOREBASES, ONSHORE PRODUCTION FACILITIES AND ONSHORE GATHERING SYSTEMS

The following sections deal with the possible effects of common disturbances related to onshore oil or gas production and shorebase-related activities. These activities include site preparation and construction, granular borrow, blasting, abandonment and reclamation. It is recognized that not all possible impacts or problems raised are expected to develop at each shorebase or onshore facility. The possible impacts associated with common disturbances are summarized in Matrix 3.6-1.

3.4.1 SITE PREPARATION AND CONSTRUCTION

When a shorebase or onshore production facility site has been selected, or an existing facility is to be expanded, it becomes necessary to prepare the site. Preconstruction activities would include surveying and soil sampling of the job site and remote aggregate sources and measurement and testing of any river courses. In all cases this work would require only a few personnel who would commute from existing camps in the Delta or operate from one camp at the site. The work would be done during summer and winter and would require very little equipment. Transportation would be by fixed wing aircraft, helicopter, boat and ground vehicles. Site construction includes: clearing, gravel hauling and grading, erection of temporary construction camps and support facilities, and foundation preparation by the use of gravel pads and timber or steel pilings. Rights-of-way would also be prepared by surveying, clearing, brush-burning, and hauling of gravel for road foundations.

For onshore oil production, equipment and facilities would be prefabricated and shipped to the site in large modules. These modules, some possibly weighing up to a thousand tonnes each, would be sized to fit the transportation units available. The modules would be transported to their site by barge and moved from the dock to their final location by crawler transporters. Installation would include interfacing, testing and commissioning of the prefabricated modules, erecting buildings, and installing the interconnecting piping controls and instrumentation from the wells to the plant itself.

Modular construction is a concept now commonly used in offshore projects which had not been extensively used on land prior to Prudhoe Bay. Once the modules are placed on their piles and enclosed, most of the hookup and commissioning would be done indoors where heat and light are available. Based on maximum use of modules, site construction should require approximately 300 to 500 specialized tradesmen for a typical oil production facility.

3.4.1.1 Geology and Soils

Site preparation and construction activities have been known to cause problems related to surface stability (permafrost integrity, thaw settlement, frost heave, and thermal erosion) and others related to slope stability (permafrost integrity, slumping, and shallow hydraulic erosion).

Thaw settlement and thermal erosion can occur where there are ice-rich soils and where site preparation and construction activities remove above-ground vegetation and at least a portion of the insulative organic layer. Where some of the organic layer remains and mineral soils are not exposed, thaw settlement will likely be shallow and thermal erosion will be very localized. Deeper thaw settlement and thermal erosion could occur where construction exposes ice-rich mineral soils. However, the use of Arctic construction techniques, including winter scheduling where appropriate, the use of protective gravel or sand pads, snow and ice roads, and packed snow will minimize the exposure of mineral soils. Preventative or remedial measures, including the use of fill, drainage control structures and revegetation, will be applied to stabilize areas where necessary. In general, the impacts on surface stability as a result of site preparation and construction are considered LOCALIZED and SHORT-TERM.

Construction of field gathering and processing facilities may interrupt and redirect or channelize surface runoff, especially in areas where pipelines cross small or diffuse drainage ways. On slopes with grades greater than 5%, these drainage alterations may result in shallow hydraulic erosion and possible gullying at stream crossings and slope breaks. If hydraulic erosion exposes ice-rich permafrost, it may be accompanied and accelerated by thermal erosion. Drainage and erosion control measures, including culverts, diversion berms, berm breaks and dispersion structures, will be employed to minimize drainage alterations and prevent hydraulic erosion on rights-of-way and other disturbed surfaces. Special attention will be given to drainage and erosion control measures at stream crossings. All exposed mineral soils will be revegetated to encourage stabilization. Shrub planting may be used at stream crossings.

Construction of local roads and pipeline rights-of-way may initiate slope instabilities by altering surface and subsurface drainage patterns and thermal regimes. However, careful route selection will avoid potentially unstable slopes. Drainage and erosion control measures will be designed to further minimize potential effects on slope stability. Gravel blankets may be used as necessary to protect slopes. The effects of site preparation and construction on slope stability are considered to be LOCALIZED and SHORT-TERM.

3.4.1.2 Hydrology and Water Quality

In some areas, surface disturbance may interrupt the surface and subsurface drainage, resulting in localized surface ponding, channelization and blockage of subsurface flow. Disruption of the surface may also cause increased surface erosion and sedimentation. Measures to minimize erosion and siltation will be specified in project-specific drainage and erosion control plans. Specific procedures will include breaching of temporary water crossings, such as ice bridges and fill, prior to the spring freshet. Most right-of-way clearing for onshore gathering lines will take place during winter to minimize the potential for hydraulic erosion. Buffer strips of undisturbed land will be maintained where feasible between all waterbodies and a given route. As a result, the likely impacts of surface disturbances on water quality, the discharge of surface waters and groundwaters from site preparation and construction will be LOCALIZED and SHORT-TERM.

3.4.1.3 Vegetation

Site preparation will disturb vegetation by clearing or by burial with gravel or sand pads and permanent roads. Also secondary disturbances may result from drainage alterations and localized erosion. All shrubs more than about 50 cm tall will be cleared from the facility sites and rights-of-way prior to construction. Almost no clearing will be required on the herbaceous tundra. Insulation of permafrost by vegetation will be maintained by gravel or sand pads at shorebase sites, onshore production well clusters, processing plant sites, and oil storage sites. Vegetation will also be destroyed during construction of permanent roads and airstrips.

Prior to any site preparation or construction, the vegetation of areas under consideration will be surveyed in order to document the possible presence of unique plants or communities. Impacts of clearing will be minimized by limiting the size of clearing to that essential for the operation of construction equipment. All exposed soils, including those along gathering line rights-of-way, will be revegetated with species proven successful in long-term, northern field trials (Hardy Associates, 1980). Erosion control techniques will be employed as required to maintain surface stability and thus, revegetation success.

The alteration of surface drainage patterns may contribute to ponding. Ponding could result in localized mortality of species intolerant of flooding but may improve the growth of certain sedges and other semi-aquatic plants. However, ponding will be minimized by installing drainage control structures such as culverts, pipeline berm breaks and diversion berms, to re-establish the natural drainage.

Localized hydraulic and thermal erosion along roads and pipeline rights-of-way could cause small losses of vegetation, especially on steep, ice-rich slopes and at river and stream crossings. However, erosion will be minimized by installation of drainage and erosion control structures and by surveillance for and reclamation of exposed soils. The revegetation techniques discussed in Hardy Associates (1980) will be employed where appropriate; in addition, shrub cuttings may be utilized to revegetate slopes at river crossings. In general the impacts on vegetation are expected to be LOCALIZED and LONG-TERM.

3.4.1.4 Mammals

Site preparation and construction activities may impact mammal populations mainly through direct disturbance but also presence of facilities, and localized habitat disruption. The amount of wildlife habitat altered as a result of site preparation will be very small in relation to the total available habitat. Revegetation will be successful at replacing the vegetation of affected areas.

Construction vehicles such as trucks and all-terrain vehicles can cause sensory disturbances and, less likely, can kill mammals. Disturbances have the potential to divert or prevent the movement of ungulates. Caribou observed by Surrendi and DeBock (1976) approached the Dempster Highway cautiously and movements were often interrupted or deflected. Slow-moving vehicles caused caribou to avoid the road, while faster movements produced a panic reaction and retreat. Horejsi's (1981) observations of the response of caribou to traffic on the Dempster Highway led to the conclusion that how caribou react to a vehicle depended on its rate of approach. In most cases caribou would flee for a short time.

Specific mitigative measures provided as follows are designed to protect mammal habitat used for feeding, birthing, nursery and overwintering areas. Careful site selection of production, shorebase, borrow sites, pump stations, airstrips, and access roads will be carried out so that critical habitat for wildlife will not be destroyed. Existing cleared areas will be used for the location of facilities where possible. Minimum necessary clearing will be done along access routes and at facility sites. Inspections will ensure that unnecessary habitat alteration is avoided. Reclamation where appropriate will ensure rapid revegetation. Drainage control measures will be carefully designed to reduce alteration of habitat in the vicinity of pipelines and other facilities. Movements of vehicles will be limited to designated access roads, rights-of-way boundaries, and facility sites. Wildlife harassment will be prohibited. The site-specific nature of possible disturbances together with the mitigative measures to be employed will ensure that impacts on reindeer and other mammals will be NEGLIGIBLE.

3.4.1.5 Birds

Winter activities, from mid October to mid April, will not affect birds with the possible exception of ptarmigan. Any gyrfalcon eyries found in the area will be avoided by ensuring that activities occur beyond the distances recommended by Roseneau *et al.* (1981) after February 15. If, for geotechnical or engineering reasons, it may not be reasonable or possible to avoid nests by recommended distances, each case will be reviewed with appropriate regulatory agencies.

Summer on-site construction activities, from mid April to mid October, are expected to have a NEGLIGIBLE effect on birds except in the low-lying western areas where impacts may be MINOR. It will be necessary for survey crews to avoid portions of the western lowlands at various times during the summer. Timing and location of area restrictions will vary from year to year and will be determined in consultation with appropriate government agencies.

3.4.1.6 Aquatic Resources

The main concern to aquatic resources related to site preparation and construction is the possibility of erosion and sedimentation of lakes and streams. During the open water season, some sedimentation can be anticipated in all water bodies adjacent to disturbed sites which have not been adequately stabilized.

The effects of suspended sediment on aquatic organisms have been studied extensively and are summarized by Cordone and Kelly (1961), Cairns (1971), Phillips (1971), Hynes (1973), and Brown (1975). In response to the proposed Mackenzie Valley Gas Pipeline application, sedimentation effects were also reviewed by the Mackenzie Valley Pipeline Inquiry (Berger, 1977). Other studies have dealt specifically with the Beaufort Sea onshore region, including Brunskill *et al.* (1973), McCart and deGraaf (1974), Porter *et al.* (1974), Rosenberg and Snow (1975), and McCart *et al.* (1979). The major effects of suspended sediments reported in these studies include: reduced primary production resulting from lower light penetration; reduced overall density of invertebrates; replacement of sensitive invertebrate species by more tolerant ones; reduced invertebrate species diversity; mortality of juvenile fish from clogging of gill membranes; reduced spawning success caused by declines in intergravel flow, smothering of eggs, or coating of gravel substrates; reduced emergence of fry as a result of blocked intergravel spaces; reduced escape habitat for fry in spaces between stones; and in extreme cases, interference with normal migratory activity of adult fish. With respect to the last point, such interference is considered extremely unlikely. Ambient suspended sediment loads in the Mackenzie mainstream commonly exceed 2,000 mg/L without adversely affecting migration.

Of greatest concern are sediment introductions which can affect the spawning, incubation, and emergence of fish, particularly the domestic, commercial, and sports species described in Volume 3A. Though spring spawners (e.g. grayling, pike, walleye) are important to the fishery of the region, these species are less sensitive to the effects of sediment than the fall spawning species (e.g. whitefish, ciscoes, char, lake trout). Spring spawners commonly spawn during spring discharge when ambient sediment loads are high; however, eggs of these species mature and emerge without the hazards of dewatering, low oxygen levels, or freezing. Eggs of fall spawners, on the other hand, are deposited at low water prior to freeze-up when ambient sediment loads are low, but the eggs remain in the gravel through winter, and dewatering, low dissolved oxygen, and freezing take a heavy toll on egg survival. For fall spawners, sedimentation can further reduce egg survival, and may significantly affect local populations.

Adult fish have been shown to tolerate suspended sediment concentrations in excess of 20,000 mg/L. A sediment concentration consistently lethal to adult fish has not yet been determined (Phillips, 1971). Rearing juveniles, however, particularly when they are newly emerged, may be more sensitive to suspended sediment levels than adult fish. A smaller gill size and a limited ability to avoid areas of high suspended sediment concentrations play an important role in this sensitivity.

The lower trophic levels are extremely sensitive to increases in suspended sediment concentrations. However, they display high recovery rates once concentrations decline and freshet conditions scour the substrate clean. Because of restocking from unaffected areas and high reproductive potential, these trophic levels recover rapidly from localized population reductions caused by sedimentation.

Most northern fish are slow growing, late maturing, and long lived (Volume 3A). Since numbers will quickly be restored to original levels through recruitment from subsequent year classes, a reduction in a single year class will have little overall effect on population levels. Unless wide-scale sedimentation of a major spawning area continues through a full generation, recovery from the effects of sedimentation will be rapid, requiring less than a single generation to restore the original population structure.

Areas used as spawning, rearing, and overwintering habitat are considered the most sensitive to suspended sediments. Sediments with high organic concentrations during winter would probably result in oxygen depletions sufficient to reduce the survival rates of overwintering eggs and fish. As a consequence, waterbodies supporting both spring and fall spawning species and providing overwintering habitat for fish may remain sensitive to sediment introductions during all but summer months.

Since high suspended sediment loads in the Mackenzie River Delta occur during the summer months (Campbell *et al.*, 1975), sediments are unlikely to have a measurable effect on either fish or lower trophic levels. Sedimentation during the winter months, when the river is relatively clear, could affect major concentrations of overwintering fish; however, the area will be frozen during site preparation and stabilization, making the introduction of sediment unlikely. Except for a few lakes, major spawning areas have not yet been documented in the lower Mackenzie Delta.

The effects of sediment in this region will be greatest in clear streams, lakes, and springs providing spawning, rearing, or overwintering habitat. Streams and lakes along the Yukon coast and the Tuktoyaktuk Peninsula support large numbers of fish during the winter months (Craig and McCart, 1974; DFO unpublished data). These waterbodies provide spawning habitat for both spring and fall spawners (Volume 3A). With the exception of a brief period at breakup, most streams and deep lakes in these areas are relatively clear year round. Although data are limited for waterbodies in the easternmost portion of the Beaufort Sea region, many sensitive habitats have been documented for both spring and fall spawning species. Most lakes and streams in this zone support overwintering fish (Volume 3A).

Except where slope stabilization difficulties are encountered, the duration of effects resulting from site preparation and construction will usually be limited to a single open water season. Some localized sedimentation, with a potential for lasting several years, may occur near bank failures or where revegetation and mechanical slope stabilization techniques are not wholly effective. These effects should, however, be promptly corrected once the problem areas are identified. Routine surveillance and inspection of project facilities will locate erosion problems and identify areas requiring further maintenance work.

A number of mitigative measures will ensure that sediment introductions during site preparation and construction are kept to a minimum. Facilities located adjacent to waterbodies will generally be prepared and stabilized during the winter months. Areas of sensitive terrain will be avoided during the final site selection. Except at stream crossings, direct deposition of soil material either in streams or on the ice will be avoided. Effective measures will be developed to stabilize actively eroding terrain, and to identify and repair these areas promptly, if required. The size of areas disturbed during site preparation and construction will be kept to a minimum.

Assuming the generally localized and brief nature of most sediment introductions, the rapid recovery of lower trophic levels and their widespread cosmopolitan distribution, and the use of the proposed mitigative measures, the effects of sedimentation resulting from site preparation on regional fish populations would be MINOR.

3.4.2 GRANULAR BORROW

Granular borrow material will be required for both shorebases and onshore oil production facilities. Activities associated with granular borrow include gravel deposit survey, extraction, crushing, and washing prior to stockpiling or transport (Plate 3.4-1). Several recognized problems associated with granular borrow will be mitigated by temporal or technological measures which include scheduling of operations during winter, use of Arctic construction procedures, using existing borrow sites, avoidance of stream channels, and minimizing granular fill requirements. Most gravel hauling and stockpiling will be performed during the winter months on winter roads. This would allow for summertime dewatering prior to gravel spreading the subsequent winter. Gravel hauling might continue by barge through the summer. In any case, hauling, stockpiling, and gravel spreading would probably continue through a number of construction seasons. The gathering lines will not require gravel work pads or year-round roads. Only permanent facilities (i.e. shorebases, production facilities, airstrips, and a few all-weather access roads) will require gravel. Viability of borrow sites will be viewed within the context of overall development and the needs of local communities.

3.4.2.1 Geology and Soils

Borrow pit construction may have LOCALIZED and SHORT-TERM effects caused by reduced soil

a

b

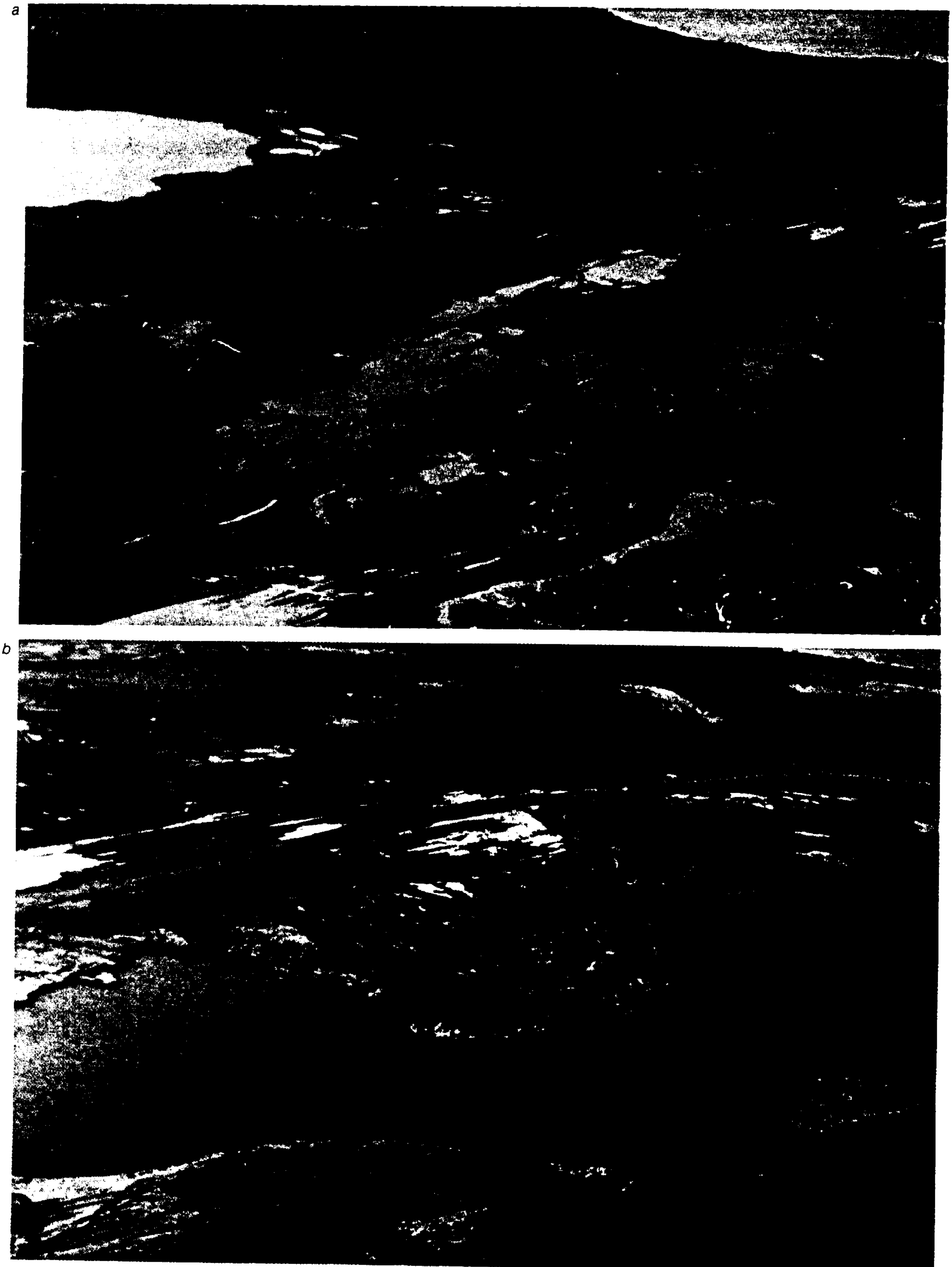


PLATE 3.4-1 *Summer extraction operations at YA YA gravel esker. (a) Separation process of sand and gravel (b) Stockpile of gravel.*

productivity, and possible hydraulic and thermal erosion. The latter two effects could result from drainage alterations and the exposure of ice-rich strata. However, these effects would be local and mitigated by standard Arctic construction practices. Mitigation measures would include recontouring of slopes, replacement of topsoil on recontoured slopes, mulch application where topsoil is not available, and fertilizing and seeding. Drainage and erosion control measures will be applied as necessary. The spread of granular material at various sites and on roads will provide mechanical and thermal protection of underlying soils. If gravel materials are salvaged at project abandonment, some thaw settlement and thermal erosion of underlying soils may occur.

3.4.2.2 Hydrology and Water Quality

It is possible that the extraction of granular material may result in some LOCALIZED and SHORT-TERM thermal degradation, erosion and siltation in adjacent waterbodies. Erosion will be minimized by selecting stable borrow sites and by applying standard engineering drainage and erosion control measures (Canuck Engineering Ltd., 1981). These include recontouring of pit slopes to stable angles and surface reclamation. Buffer zones of 100 m minimum will be left between waterbodies and gravel extraction areas, and buffer zones will be left between public roads and pits and quarries.

3.4.2.3 Vegetation

Borrow pit construction will result in the direct LOCAL but MEDIUM-TERM removal of all vegetation from the site and possible alteration of drainage patterns which may affect surrounding vegetation. Where feasible, borrow sites will be reclaimed according to standard procedures. Specific measures will include recontouring of slopes, replacement of topsoil on recontoured slopes, mulch application where topsoil is not available, fertilizing and seeding with species proven successful in Arctic field trials (Hardy Associates, 1980).

3.4.2.4 Mammals

Gravel borrow pits and associated activities will generally have a MINOR effect on most wildlife because of the small area involved relative to available habitat. The destruction of den sites of grizzly bears, foxes, and wolves will be avoided by ensuring that sites selected for borrow operations do not contain dens of these animals. Some reindeer, grizzly bears and other wildlife may be temporarily disturbed by vehicles and humans at borrow operations. However, because encounters will likely be infrequent, the consequences are considered to be NEGLIGIBLE.

3.4.2.5 Birds

Surveys for raptor nests will be undertaken in the vicinity of prospective granular borrow sites. Winter operations are generally considered to have a NEGLIGIBLE impact on these birds provided raptor nest-sites are avoided. Summer transport of material by barge or vehicles in the Delta area is expected to have a MINOR impact on waterfowl.

3.4.2.6 Aquatic Resources

Extraction of granular material from inland sites is expected to have little effect on aquatic resources, unless these sites are close to streams or modify hydraulic regimes. Gravel washing will be conducted either on a system with no outlet to waters supporting fish, or with adequate settling ponds to reduce sediment concentration before effluents enter natural waters. Using these measures the impacts of granular borrow extraction activities on the fisheries resources should be NEGLIGIBLE.

3.4.3 BLASTING

Blasting includes any detonation of explosives, either during the construction of facilities or during seismic exploration. While constructing a shorebase or installing an onshore gathering system, blasting may be required to remove unrippable rock or frozen material. Most blasting will take place during winter. Judicious choice of explosive type together with optimal timing, will mitigate most potential impacts to both fish and wildlife populations.

3.4.3.1 Hydrology and Water Quality

Blasting in streams or other waterbodies, if required, may cause a LOCALIZED, generally SHORT-TERM increase in siltation which could affect aquatic habitat. However, siltation can be minimized by selectively blasting to avoid sensitive aquatic habitat.

3.4.3.2 Atmospheric Environment

Blasting of a pipeline trench or in borrow pits, for example, will result in LOCALIZED and SHORT-TERM increased noise levels. Near settlements or wildlife concentrations, blasting would be scheduled to minimize noise disturbances.

3.4.3.3 Mammals

Several authors have reported on the reactions of ungulates to sudden loud noises such as blasting and sonic booms (Espmark, 1972; Gray, 1972; Lent and Summerfield, 1973; Reynolds, 1974; Slaney, 1975). They indicate that while mammals may show initial adverse responses to blasting, these reactions are seldom extreme and the mammals appear to habituate relatively rapidly to this form of disturbance. Bergerud (1974b) observed no visible reaction by caribou to the sound of dynamite explosions and suggested that noise disturbances in the absence of sight or scent stimuli usually have little impact. The behavior of a small herd of reindeer was not seriously affected by sonic booms, regardless of boom intensity, however Epsmark (1972) stated that the Lapps avoid keeping large herds in corrals during thunderstorms since such herds may panic at sudden and intense disturbances.

Loud sounds generally appear to have little effect on moose behavior, although Law *et al.* (1972) noted that moose treat diesel airhorns as a threat and cannon blasts have been effectively employed to keep moose away from particular areas.

Hill (1978) concluded that marine mammals are probably less vulnerable to underwater shock waves than are terrestrial mammals of similar size. Westworth (1977) found seismic blasting in the Mackenzie Delta to cause minor pathological effects on muskrats within a distance of 30 m and no increase in pushup abandonment beyond a distance of 180 metres. Westworth recommended that the regulation prohibiting blasting within 12 m of waterbodies be maintained.

A policy and guidelines for the use of explosives in waters of the Northwest Territories is provided by Wright (1982). With adherence to guidelines and optimal timing, the impacts of blasting on mammals are expected to be NEGLIGIBLE.

3.4.3.4 Birds

The effects of blasting on birds will be NEGLIGIBLE during winter when most blasting is likely to occur providing it does not impinge on known raptor nest-sites. Blasting, if necessary between April 16 and October 15, will avoid disturbances to raptor nest-sites by ensuring that recommended distances from these sites are maintained (Roseneau *et al.*, 1981). Likewise, disturbances to concentrations of nesting, molting or staging geese and swans will be avoided by ensuring that at least 8 km (5 mi) distance exists between these concentrations and any blasting (Barry and Spencer, 1976). With these mitigative measures, effects on birds will not likely exceed the MINOR category.

3.4.3.5 Aquatic Resources

For pipeline installations, blasting in some streams may be required. Although blasting that results in a fish kill is not a serious problem, blasting in areas with large concentrations of fish, particularly during migration, spawning, and overwintering, is a matter of concern. Studies of the effects of underwater blasting in standing water indicate that it causes a rapid change from high water pressure to negative pressure (rarefaction) which can cause fish kills (Hubbs *et al.*, 1960). Kills have been recorded at distances greater than 900 m from single explosions (Muth, 1966). Typical injuries attributable to underwater blasting include severe tearing of muscle tissue, rupture of the internal organs or the coelomic cavity, rupture of blood vessels, and damage to the nervous system.

Blast effects have been observed on the kidney, ear, cerebral cavity, liver, spleen, gills, and gonads, however, the swim bladder is generally the most sensitive internal organ. Aplin (1947) indicated that fish with swim bladders are much more sensitive to the effect of blasting than fish without swim bladders. Salmonid eggs are sensitive to agitation up until the 18th or 19th day after fertilization. After this time, they are relatively insensitive until fry are three to six months of age, when the swim bladder begins to develop (Rasmussen, 1967; Falk and Lawrence, 1973).

Many variables affect the killing radius of underwater blasting: the type of explosive, the size and pattern of charges, the intervals between blasts, the depth of burial of the charge, the depth of water and speed of water flow, the presence of ice cover (Roguski and Nagata, 1970), and the species of fish present.

Available data suggest the killing radius is least in shallow, rapidly-flowing water, and greatest in deep, stationary water. In the Canyon Slough study conducted by the Alaska Department of Fish and Game (1976), smolt-sized sockeye salmon fry were subjected to a blast created by 200 kg of 40% special Gel used to loosen bedrock in the pipeline trench of the Alyeska Pipeline. The fry were placed in test cages 17 m to 167 m from the blast centreline in 2 to 3 metres of water. They were not affected by the blast.

On the Bow River crossing of the Alaska Highway Gas Pipeline Prebuild, an unpublished study examined the effects of a blast created by 1,760 kg of Geogel at 15 ms intervals on 100 to 200 mm rainbow trout. The trout were placed in cages 10 m to 50 m upstream and downstream of the blast in 1 to 2 m of water. The only recorded kills occurred 10 m downstream from the blast in 2 m of water. Fish 10 m upstream of the blast and 15 m downstream, in 1 m of moving water (1.5 to 2.0 m/sec) were not affected and showed no signs of distress (Aquatic Environments Limited, unpublished data).

Fish are often attracted to a detonation site to feed on benthic organisms which have been disturbed and on fish which have been killed in a previous blast.

Observers report this attraction can result in subsequent kills if repeated blasts occur in the same location (Fitch and Young, 1948). Observations by divers along the Alaska Highway Gas Pipeline Prebuild indicate that fish are attracted to low current areas in the pipeline trench where overburden has been removed, particularly when suitable low-current habitat in the area is limited. Since large concentrations of fish may be present in the immediate vicinity of the disturbance and may not be readily moved out of the area by frequent blasts, blasting during migration is of special concern.

With the exception of major river crossings such as the channels of the Mackenzie River, gathering system stream crossings will usually be constructed during the winter months when most small streams are frozen to the bottom. However, there are concerns for: streams with sufficient winter discharge to support overwintering fish; lakes which may be crossed by gathering lines; and summer crossings where there are aggregations of either migrating or spawning fish.

The Mackenzie Delta supports large fish concentrations during most of the year, but given the nature of the underlying materials, instream blasting is unlikely to be needed. Of greater concern would be blasting in streams along the Yukon coast, the Tuktoyaktuk Peninsula, and along the eastern edge of the Beaufort Sea coast where unrippable rock may occur. In streams of these areas, anadromous fish use restricted spawning and overwintering habitat.

Although blasting is not expected to be needed in fish bearing lakes, the density and species composition of fish in lakes will be assessed prior to blasting. Where it is apparent that high densities of important species may be adversely affected by blasting, alternate routing will be considered. Although some local sedimentation will occur after an underwater detonation, a blast will generally be an isolated local event, hence the effects of sedimentation are expected to be insignificant. Recovery after an inadvertent fish kill depends on recruitment, but complete recovery of local populations will occur within a single generation even with the largest conceivable kill.

The following mitigative measures will greatly reduce the effects of underwater blasting on fisheries resources. Most blasting at stream crossings can be conducted during the winter months when smaller streams are frozen to the bottom. When feasible, blasting will be conducted to avoid large concentrations of fall spawners and over-wintering fish. Blasting in lakes and streams can be done using a series of small charges, connected by delays, and detonated as a single shot to minimize the area affected and avoid repeated kills at the same location. If necessary, to avoid large aggregations of migrating fish, blasting can be delayed until the fish move elsewhere. Should blasting in a known overwintering area be necessary, it can be conducted either in open water or as soon after freeze-up as possible to avoid large concentrations of fish that often occur in later winter.

To minimize fish kills when pipeline crossings are constructed in summer, blasting will typically have the least effect if done in early summer. At this time, concentrations of fall spawners and large concentrations of migrating fish can be avoided. During the winter, concentrations of overwintering fish are often confined to relatively small sections of streams for six to eight months. Where such concentrations are known to exist, winter blasting will have the least effect early in winter when the ice is thinnest and the available habitat least confined.

It is conceivable that fish kills will occur as a result of underwater blasting, but the areas affected will be small and the numbers of fish affected are likely to be few assuming the mitigative measures described are adhered to. Thus, the effects of underwater blasting on aquatic resources are considered to be MINOR.

3.4.4 ABANDONMENT AND RECLAMATION

Once the production life of an onshore oil or gas field or other facilities has expired, the following abandonment procedures would be undertaken. All wells would be plugged and abandoned in accordance with existing regulations. Pipe would be cut off below ground level and capped. Gravel may be salvaged and transported to other construction locations. Any not required would be left in place. All elevated pipelines or electrical transmission lines would be removed. Pile supports would be cut off at ground level and rights-of-way restored as nearly as possible to their original condition. Buried pipelines or electrical transmission lines would be removed or abandoned in place with approval of the regulatory body. All equipment and buildings located at the plant site, well locations, or docks would be salvaged.

Reclamation programs include recontouring, terrain stabilization to ensure integrity of surface and subsurface drainage, surface preparation, mulch application, fertilizing, and seeding/revegetation. This post-construction phase of development will require implementation of measures designed to avoid subsidence and slumping, particularly in areas containing fine-textured, ice-rich soils. Protection against these impacts will provide similar protection against altered drainage patterns, silted watercourses, and undue loss of wildlife habitat. General impacts due to reclamation and abandonment will be minimized by those mitigative measures (e.g. terrain stabilization and revegetation) discussed previously under Site Preparation (Section 3.4.1). Specific measures designed to mitigate particular resource impacts follow.

3.4.4.1 Geology and Soils

The removal of buildings and recontouring of industrial sites may initiate disturbances such as local thaw settlement and shallow hydraulic erosion. If gravel is salvaged from pads, roads and airstrips on ice-rich soils, the thermal regime of underlying soils could be altered. This would result in deepening of the active layer, thaw settlement and possibly local thermal erosion. To minimize such disturbances, drainage and erosion control measures will be established during project abandonment to ensure that newly disturbed areas stabilize quickly. These measures may include grading to stabilize slope angles and construction of diversion berms, ditches, and berm banks. Surface reclamation may include erosion control mats, mulches, shrub plantings and application of seed mixes and fertilizers. Natural drainage patterns will be reestablished or in some cases improved. Special attention will be given to stabilizing slopes which have grades greater than 5% and have ice-rich soils.

Following abandonment of the facility sites, all exposed mineral soils will be revegetated as described in the vegetation section. Impacts of reclamation and abandonment on geology and soils are considered LOCALIZED and SHORT-TERM.

3.4.4.2 Hydrology and Water Quality

Given the protection measures described in Sections 3.4.4.1 and 3.4.4.3, drainage patterns will remain generally unaltered and siltation will be controlled. Impacts will be minimal.

3.4.4.3 Vegetation

During abandonment of a facility or site, most above-ground equipment and structures, and possibly some buried sections of pipe, will be removed. In addition, gravel may be salvaged from pads, roads and airstrips. The land will be recontoured and drainage and erosion control measures will be established to encourage the return of vegetation similar to that in surrounding areas. These activities could disturb some previously revegetated areas and may result in local losses of existing natural vegetation. Drainage and erosion control measures will be established during abandonment to ensure that newly disturbed areas become revegetated. Physical erosion control measures will include grading to stable slope angles and the construction of berms, berm breaks and water diversion ditches. Surface reclamation may include the use of erosion control mats, mulches, shrub plantings and the application of seed mixes and fertilizers.

Following both construction and abandonment, assisted revegetation techniques will be applied to all exposed soils. The goal will be to return disturbed areas to their original productivity (Plates 3.4-2 and 3.4-3). The immediate objectives will be to promote soil stability and encourage the reestablishment of natural plant communities. It is expected that natural revegetation will continue and, except on sites where gravel is not removed, natural vegetation cover will be reestablished within 10 to 15 years (How and Hernandez, 1975).

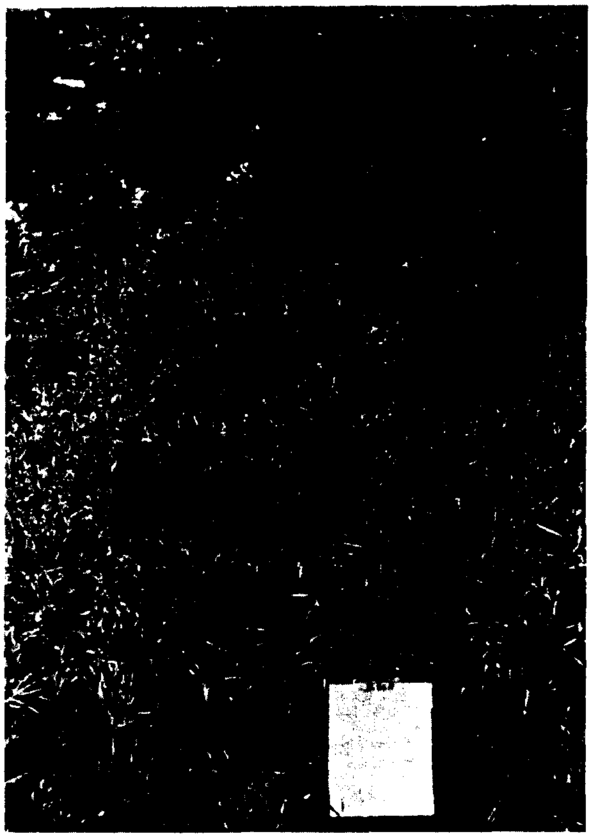
Many species of grasses and legumes have been studied for use in reclamation projects in the Mackenzie Valley and Delta area since 1970. Information gained from species and seed mix trials (Dabbs *et al.*, 1974; Younkin, 1976; Hardy Associates, 1980) suggest that two to three seed mixtures combining adapted grasses and legumes would provide an adequate protective cover. The rate of application would be approximately 50 kg/ha for broadcast methods. However, this may be altered if other application methods are employed or as site conditions prescribe. Aerial broadcasting may be the best method of applying both seed and fertilizer where there is limited access to some areas, particularly along pipeline rights-of-way.

Studies of the soils in the area and similar studies elsewhere have shown that nutrients are generally low over the coastal Beaufort Sea region (Younkin, 1972, 1976; Janz, 1974; Mitchell and McKendrick, 1974). Therefore, fertilizer will be required to assist seedlings to grow. A complete fertilizer containing nitrogen, phosphorus, potassium and micronutrients, in a formulation determined by standard agronomic analysis of soils collected from the sites prior to construction, will be applied at rates appropriate to the locale.

Planting of cuttings of suitable, locally available shrub species to enhance desirable wildlife habitat may be feasible where important habitat has been disturbed. Species of willow have been successfully established from cuttings in northern areas (Younkin, 1976).

It is possible that some disturbed surfaces will require more intensive reclamation measures to ensure protection from erosion. These surfaces could include slopes at major stream and river crossings and most mineral soil surfaces with slopes greater than 3°. A suitable combination of seeding, fertilizing, shrub planting, mulch materials and erosion control mats may be applied to such surfaces. The rate of application of mulch would be from 1,000 to 1,500 kg/ha of woodfibre or 2,000 to 4,000 kg/ha of straw, depending on the slope and degree of protection required. Tackifiers will be used to hold the mulch in place. Suitable types include polymer binders, plant gum binders, and netting.

a



b

c

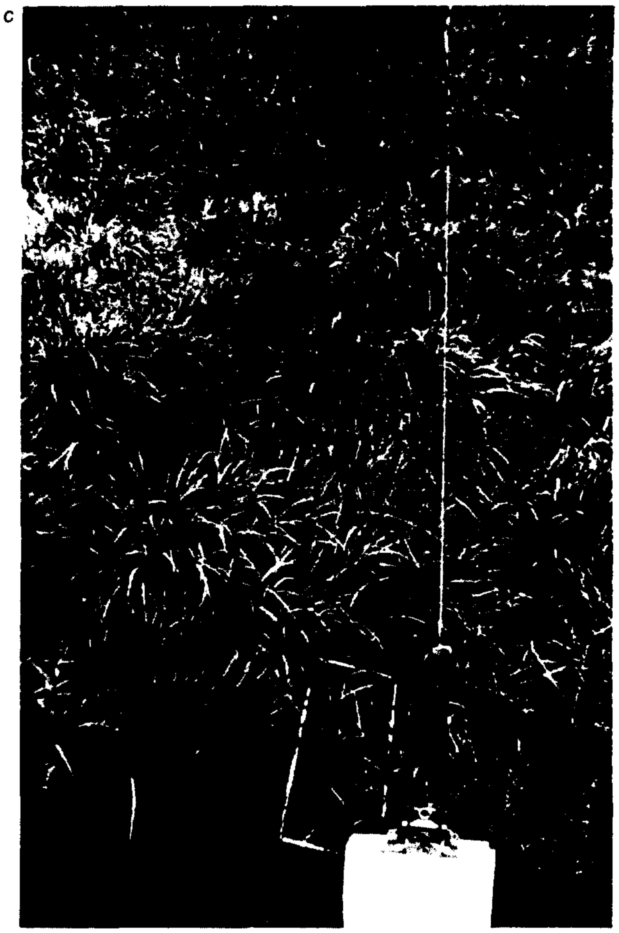


PLATE 3.4-2 *A seed mixture study at Site A-01 an abandoned drill rig site in the Caribou Hills area of the Beaufort Sea-Mackenzie Delta region. (a) Plant cover in year one, (b) year three, and (c) year seven. The plots were seeded with a seed mixture at 28 kg/ha. Cover is dominated by climax timothy in year 1 and by a mixture of nugget Kentucky bluegrass, boreal creeping red fescue and native species in years 3 and 7. (Source: Hardy Associates, 1980).*

a

b

PLATE 3.4-3 *Revegetation by sod replacement. This study was conducted at Tuktoyaktuk. The objective was to encourage the reestablishment of natural plant communities on disturbed areas where conditions may limit plant establishment from seed. (a) Twenty to forty cm of shrub-heath tundra sod have been stripped and stored to one side. (b) Regrowth from replaced sod in shrub-heath tundra one year and (c) four years following replacement. (Source: Hardy Associates, 1980).*

PLATE 3.4-3 *Continued (c).*

3.4.4.4 Mammals

Reclamation and abandonment will tend to reverse the minimal habitat lost during site preparation and construction. Some mammals, including meadow voles and reindeer, may be attracted to the initially luxurient vegetation which often grows on re-seeded and fertilized areas. As native vegetation communities gradually become reestablished, the native mammalian fauna will also become reestablished. The area involved in reclamation will be small so that the benefits to wildlife will be correspondingly limited and the overall impact NEGLIGIBLE.

3.4.4.5 Birds

Possible effects on birds resulting from reclamation and abandonment are expected to be NEGLIGIBLE since the mitigation measures employed in initial site selections would minimize disturbances to birds. For example, the loss of raptor nests will be avoided by routing choice, habitat loss due to clearing will be minimized, and major abandonment activities will take place during winter.

3.4.4.6 Aquatic Resources

Surface disturbances from the recontouring of sites, the stabilization of stream banks, and the removal of bridges and culverts will result in incidental sedimentation of adjacent waterbodies. Those facilities that would be constructed using winter roads would likely be abandoned and reclaimed during the winter so that stream sedimentation is unlikely. Where slope failures occur, erosion may begin after break-up.

All sediment introductions are anticipated to be both local and short-term and, once disturbed areas are stabilized, recovery is expected to be rapid. Experience with the Alyeska Pipeline indicates that, using state-of-the-art technology and an aggressive prevention program, most areas of active erosion can be stabilized within one to three years (Aquatic Environments Ltd., unpubl. data).

Most erosion resulting from reclamation and abandonment will occur during the open water period, particularly during spring freshet and storms. Measures to minimize sedimentation of aquatic habitats are similar to those described for site preparation and construction (Section 3.4.1.6). Assuming that these measures are applied during reclamation and abandonment, and an aggressive program of erosion prevention is in place, effects on benthic aquatic resources are expected to be NEGLIGIBLE.

Fish, in contrast to benthic organisms, display a somewhat slower recovery rate, are more restricted in their distribution, and are dependent on sensitive habitats subject to short-term damage. Assuming, however, the application of proposed mitigation measures and the localized nature of sediment introductions, the possible effects of sedimentation resulting from site reclamation on regional fish populations should range from NEGLIGIBLE to MINOR.

3.5 POSSIBLE IMPACTS AT EXISTING AND PROPOSED SHOREBASES

This section describes possible effects from the development or expansion of shorebase activities at Tuktoyaktuk, McKinley Bay, King Point, Stokes Point and Wise Bay. Concepts for future shorebase developments are generally described in Volume 2 and are reviewed in Section 3.2 of this chapter. In order to assess the possible impacts of such developments, they are assumed to occur. However, whether they will occur will depend on many factors including drilling success, government approvals, and rate of development. All of the bases to be examined will, to varying degrees, accommodate personnel, store and ship supplies, and maintain and repair vessels and equipment. All will harbour various types of vessels and handle different types and volumes of air traffic. Although each shorebase will be different, each development will contribute common wastes and disturbances to their local environments, and each base will employ a number of common mitigative measures aimed at reducing or eliminating potential impacts. Common wastes and disturbances are discussed in Chapter 2, Section 2.3 and in Section 3.4.

Unlike the assessment approach used in other chapters of this volume, the assessment of shorebase effects assumes that local rather than regional effects are generally of concern. Consequently, the definitions for degree of impact provided in Chapter 1 of this volume have been modified to apply to local populations where appropriate.

3.5.1 TUKTOYAKTUK

Proposed development for Tuktoyaktuk indicates that there will be a limited increase in the number of base personnel, and limited expansion of the main airport, storage and dock facilities. Consequently, most future expansion of the Tuktoyaktuk bases are not expected to result in more than minor incremental increases in impacts on biological resources. The potential impacts from activities and facilities at Tuktoyaktuk are identified in Matrix 3.5-1.

Human presence, the disposal of sewage, solid wastes and wastewater, air emissions, artificial illumination and icebreaking activities at Tuktoyaktuk are expected to cause NEGLIGIBLE impacts on most terrestrial and marine biota. The effects of human presence, such as on-foot encroachment into environmentally

MATRIX 3.5-1

POTENTIAL LOCAL IMPACTS* OF ACTIVITIES AT THE TUKTOYAKTUK SHOREBASES AND A SHALLOW DRAFT HARBOUR

	MARINE MAMMALS				TERRESTRIAL MAMMALS									BIRDS							FISH				LOWER TROPHIC LEVELS			
	WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	GRIZZLY BEAR	TUNDRA WOLF	RED FOX	OTHER FURBEARERS	CARIBOU	REINDEER	OTHER UNGULATES	LOONS	WHISTLING SWANS	GEESE	DUCKS	RAPTORS	SHOREBIRDS	GULLS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	FRESHWATER	EPONTIC ORGANISMS	PLANKTON	EPIBENTHIC INVERT.	INFAUNA INVERT.
HUMAN PRESENCE					○	○	○	○	○	○	○	○	○	◊	◊	○	○	○	○	○								
SOLID WASTES					○	○	○	○	○	○								○		○								
TREATED SEWAGE			○	○										○			○			○	○	○	○	○	○	○	○	○
WASTE WATER DISCHARGE			○	○										○			○			○	○	○	○	○	○	○	○	○
AIR EMISSIONS					○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○								
AIRBORNE NOISE: AIRCRAFT	○	○	○	○	○	◊	○	○	◊	○	◊	○	○	◊	◊	◊	◊	○	○	○								
AIRBORNE NOISE: OTHER SOURCES					○	○	○	○	○	○																		
ARTIFICIAL ILLUMINATION					○	○	○	○	○	○				○	○	○	○	○	○	○								
DREDGING	○	○	○	○										○			○		○	○	◊	●	●			◊	●	●
ICE BREAKING	○	○	○	○		○											○			○	◊				◊			
UNDERWATER SOUND	○	○	○	○																	◊	◊	◊		○	○	○	○

LEGEND
○ NEGLIGIBLE ● MODERATE
◊ MINOR ■ MAJOR

*POTENTIAL IMPACTS (ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT) sensitive areas, or increased hunting and fishing in the vicinity of the Tuktoyaktuk shorebases will be minimal. As is currently the case, base personnel will not be permitted to have privately owned firearms at project facilities. Hunting, trapping and fishing by project personnel will not be permitted on shorebase sites. Specific regulations will be implemented in consultation with government agencies, if necessary.

Domestic sewage will continue to be treated before discharge at Tuktoyaktuk now and in the future. This will ensure that the potential impacts on local flora and fauna will continue to be NEGLIGIBLE. Solid wastes will continue to be incinerated and buried in accordance with regulatory guidelines. This should continue to minimize its attraction for bears and foxes in the Tuktoyaktuk area. The levels of artificial illumination, human presence, presence of artificial structures and stationary airborne noise, which contribute to the attraction of these species, are not expected to increase beyond present levels. Icebreaking in Tuktoyaktuk harbour is also expected to have NEGLIGIBLE impacts on local marine fauna because activities of the shallow draft icebreaking vessels will be restricted to the single navigation corridor during brief periods in the fall before thick ice forms.

Disturbances at the Tuktoyaktuk shorebases which could result in impacts on some marine resources greater than NEGLIGIBLE include underwater sound, dredging and increasing levels of airborne noise from aircraft. Aircraft presently using the main Tuktoyaktuk airstrip include Boeing 737 jets, Hercules aircraft, STOL aircraft, helicopters, and executive jets. In the future, the airstrip will become busier as more aircraft, such as those projected in Table 3.2-1, begin to land at Tuktoyaktuk.

Increasing air traffic may affect a small number of Arctic and red foxes that den in the vicinity of Tuktoyaktuk from May to October. Potential impacts on these animals would probably not exceed the impacts of current noise levels which are considered NEGLIGIBLE to MINOR. The semi-domesticated reindeer herd that inhabits the Reindeer Grazing Reserve usually calves south of Tuktoyaktuk near Parsons Lake during April and early May. By June, the animals are at their summer range on the eastern half of the Tuktoyaktuk Peninsula. Air traffic between Tuktoyaktuk and Inuvik could disturb reindeer during the calving period, although maintenance of minimum altitudes of 600 m asl (2,000 ft) will maintain possible effects on the herd during calving at a NEGLIGIBLE level. In this regard, the proponents will maintain regular contact with the principals of Canadian Reindeer (1978) Ltd., to ensure that no significant problems develop.

Disturbance of nesting loons and whistling swans by air traffic in the Tuktoyaktuk area will continue to have MINOR impacts on local populations, while other species will probably not be adversely affected during nesting. During late summer, diving ducks that moult and stage along the Tuktoyaktuk Peninsula may be disturbed by increasing traffic originating or destined for Tuktoyaktuk. However, Tuktoyaktuk harbour has not been identified as an area of particular importance to moulting ducks (Barry *et al.*, 1981) and effects of disturbance would probably be MINOR and local.

Future dredging operations in Tuktoyaktuk harbour will be limited to the borrowing of sand for onshore expansion and maintenance dredging. Large dredging programs have occurred within the harbour during previous years, including the removal of 750,000 m^3 of material in 1981 for construction of a water supply reservoir for the community of Tuktoyaktuk. The results of studies conducted during dredging programs within Tuktoyaktuk harbour, were reviewed in Chapter 2. In general, disturbances associated with noise, vessel movements and changes in water quality during dredging are expected to result in NEGLIGIBLE impacts on all resources in the harbour because of the relatively local and short duration of most dredging-related disturbances.

The potential impacts of dredging on marine mammals and birds in Tuktoyaktuk harbour are also expected to be NEGLIGIBLE. Dredging may have small positive effects on some surface-feeding bird species if food organisms are brought to the surface, although increased turbidity may reduce feeding efficiency of species that dive for food. The potential impacts of dredging on benthic populations may be MODERATE due to the direct but local disturbance of fauna in excavated areas, and the fact that complete recovery of affected communities may require several generations for some species. Depending on the locations of dredging, some fish habitat could also be lost, including spawning areas for marine species such as four-horned sculpin (bullhead). In addition, some fish will be killed when entrained in the dredges. If spawning habitats are affected by dredging, impacts could be considered MODERATE since significant loss of a year class of fish would require several generations for recovery. On the other hand, if only a few fish are lost through entrainment, the impacts of dredging on local populations will probably be MINOR.

Although a small number of seals occur in Tuktoyaktuk harbour, underwater industrial noise from vessels is expected to have NEGLIGIBLE impacts on the local population since only a few individuals would be affected and any disturbance would be short-term and infrequent. Seals also appear to tolerate and in some instances are attracted to sites of industrial activity, irrespective of the presence of unusual underwater noise in the area (ESL, 1982).

Vessel traffic originating from Tuktoyaktuk has occasionally disturbed white whales in the Kugmallit

Bay concentration area near Hendrickson Island during July. However, the proponents have and will continue to sponsor regular aerial monitoring programs, the objective being to mitigate possible impacts by controlling vessel traffic in the area frequented by white whales. Largely because of this program, the industry has been successful in limiting its impacts on the whales of the area to a NEGLIGIBLE level so far. It is expected that this record can be maintained in the future.

3.5.2 McKINLEY BAY

As described earlier (Section 3.2.2) continued construction and operations at McKinley Bay will require a steady increase in personnel, logistics support and harbour activities. The biological resources and physical environment of the McKinley Bay region, and the possible impacts of earlier operations in the area on local biota are described in detail by Dome (1979), Ward (1981), Dome (1981) and Boothroyd and Karasiuk (1981). The potential future impacts at the McKinley Bay marine base are summarized in Matrix 3.5-2.

The possible impacts of human presence, disposal of treated sewage, solid wastes and wastewater, air emissions, artificial illumination, and the physical presence of artificial structures on most marine resources in McKinley Bay are expected to be NEGLIGIBLE. Treated sewage and solid wastes will be disposed of in accordance with regulatory guidelines, while off-shift activities of personnel will be restricted by industry and confined to the artificial island located 2.5 km from the nearest natural shoreline.

Polar bears and Arctic foxes are occasionally attracted to the McKinley Bay marine base during periods of ice cover due to numerous factors including human presence, solid waste disposal, cookhouse odours, airborne noise, artificial illumination and the physical presence of artificial structures. Arctic foxes are unlikely to be killed when attracted to the base so that the potential impacts on the local fox population are expected to be MINOR. Polar bears have only rarely been observed in McKinley Bay because they are normally further offshore near the transition ice zone. However, they do occasionally frequent coastal areas, and the polar bear monitoring program will be continued for protection of industry personnel. The occasional removal of problem bears may have a MINOR impact on the local population, although the regional effect of this program would be considered NEGLIGIBLE.

Other common wastes and disturbances from operations at McKinley Bay that may have more than NEGLIGIBLE effects on local marine resources

MATRIX 3.5-2

POTENTIAL LOCAL IMPACTS* OF THE McKINLEY BAY SHOREBASE FACILITY AND MEDIUM DRAFT HARBOUR

	MARINE MAMMALS						TERRESTRIAL MAMMALS							BIRDS							FISH				LOWER TROPHIC LEVELS			
	WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	GRIZZLY BEAR	TUNDRA WOLF	RED FOX	OTHER FURBEARERS	CARIBOU	REINDEER	OTHER UNGULATES	LOONS	WHISTLING SWANS	GEESE	DUCKS	RAPTORS	SHOREBIRDS	GULLS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	FRESHWATER	EPONTIC ORGANISMS	PLANKTON	EPIBENTHIC INVERT.	INFAUNA INVERT.
HUMAN PRESENCE					◊	◊								O	O	O	O	O	O	O								
SOLID WASTES					◊	◊														O								
TREATED SEWAGE			O	O										O			O		O	O	O	O	O	O	O	O	O	O
WASTE WATER DISCHARGE			O	O										O			O			O	O	O	O			O	O	O
AIR EMISSIONS					O	O	O	O	O	O		O	O	O	O	O	O	O	O	O								
AIRBORNE NOISE: AIRCRAFT	O	O	O	O	◊	◊	O	O	◊	O		◊		◊	◊	O	◊	O	O	O								
AIRBORNE NOISE: OTHER SOURCES					◊	◊								O	O	O	O		O	O								
ARTIFICIAL ILLUMINATION					◊	◊								O	O	O	O	O	O	O								
DREDGING	O	O	O	O										O			O			O	●	●	●			◊	◊	●
ICE BREAKING	O	O	◊	O		O											O			O					O			
UNDERWATER SOUND	O	◊	◊	◊																	◊	◊	◊		O	O	O	O

LEGEND
O NEGLIGIBLE ● MODERATE
◊ MINOR ■ MAJOR

***POTENTIAL WORST CASE IMPACTS (ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT)**

include airborne noise, underwater sound, icebreaking and dredging. Helicopters land at McKinley Bay throughout the year, while STOL aircraft land on the sea ice during much of the winter and Boeing 737 jets and other large aircraft land on the sea ice during February and March. Aircraft support logistics in the Beaufort region will increase in air traffic at McKinley Bay is also anticipated, particularly once the base becomes fully operational in support of offshore production activities. During spring breakout activities in 1980, an average of 17 helicopter trips were required per day, while 9 trips per day were required during summer dredging activities (J. Ward, pers. comm., cited in Boothroyd and Karasiuk, 1981). Use of the island or adjacent sea ice as a landing strip has not had any detectable adverse effects on local bird and mammal populations to date, partly due to the distance of the island from shore (Dome, 1981). Except during take-off and landing, aircraft are at relatively high altitudes (greater than 305 m asl) during flights over coastal areas. A small proportion of hauled-out seals within a few kilometres of McKinley Bay may dive in response to aircraft overflights in June, but the potential impacts on the local populations of birds and seals are expected to be NEGLIGIBLE.

Other concerns related to aircraft logistics traffic at McKinley Bay are possible effects on the local reindeer herd, denning Arctic and red foxes, and birds. The potential impacts of airborne noise at McKinley Bay on the local Arctic and red fox populations would probably be NEGLIGIBLE to MINOR since only a few individuals could be temporarily affected. The McKinley Bay area is not a primary denning location, and as indicated earlier, most aircraft will be at altitudes greater than 305 m asl during flights over the Tuktoyaktuk Peninsula.

During a two week period each June, the domestic reindeer herd on the Tuktoyaktuk Peninsula is rounded-up at the DEW line site near Atkinson Point using helicopters. Conflicts between reindeer herding operations and industry logistic flights have not resulted to date, and the existing impacts of airborne noise on this herd are considered NEGLIGIBLE to MINOR (Dome, 1981). Nevertheless, communication between industry personnel and the principals of Canadian Reindeer (1978) Ltd. will be maintained to ensure that conflicts do not develop.

Potential impacts on nesting birds are likely to remain NEGLIGIBLE due to aircraft activity at McKinley Bay because the aircraft will generally fly at high altitudes except during landing or take-off. However, aircraft activity may temporarily disturb ducks during July and August since McKinley Bay has been identified as an important moulting area (Barry *et al.*, 1981). The maximum number of ducks estimated to be in the bay was about 18,600 on July 21, 1981 (Scott-Brown and Allen, 1981), although 9,000 were reported on July 31, 1977 in Louth Bay alone (Sharp, 1978). The birds tend to concentrate along the shoreline (Boothroyd and Karasiuk, 1981; Scott-Brown and Allen, 1981), but they are occasionally widely distributed throughout the bay (Scott-Brown and Allen, 1981; Ward, 1981).

The biological effects of aircraft disturbance on birds were reviewed in Chapter 2, Section 2.3.5. Although no detailed studies have been done in areas experiencing large numbers of aircraft overflights, diving ducks during moult appear to be relatively tolerant of aircraft disturbance. For example, Ward (1981) reported that about 400 overflights of McKinley Bay from July 3 to August 31, 1980 (maximum of 25 on July 29) did not appear to prevent moulting ducks from using McKinley Bay since an estimated 5,800 were present on August 11, 1980 (Boothroyd and Karasiuk, 1981), and over 18,000 were present on July 21, 1981 (Scott-Brown and Allen, 1981). The potential long-term effects of air traffic in McKinley Bay on local bird populations are unknown, although altitude regulations can mitigate potential impacts with the exception of possible disturbance in the immediate vicinity of the artificial island and future airstrip. Nevertheless, because much of the coast of the Tuktoyaktuk Peninsula is used by moulting ducks and there is some evidence of as great or greater densities of moulting ducks in these adjacent areas (Barry *et al.*, 1981), possible impacts from aircraft disturbance on the local populations will probably be MINOR, while regional impacts would be considered NEGLIGIBLE.

Future development plans indicate that further dredging will be carried out in the McKinley Bay mooring basin and channel to accommodate the expanding base and harbour operations. During previous years, extensive dredging has occurred in conjunction with construction of the mooring basin and artificial island, with the removal of 5 x 10^6 m^3 of material in 1980, and about 3 x 10^6 m^3 in 1981. Expansion of the mooring basin and island in the future (e.g. 1986) to at least twice their current size will also require similar dredging over one or two seasons. The potential effects of dredging activities on water quality and marine biota were discussed in Chapter 2, Section 2.4.2. Past dredging activity in McKinley Bay has had no detectable effects on local marine mammal and bird populations (Ward, 1981). The only species of marine mammal that may be affected by dredging is the bearded seal, which may be indirectly affected through a local loss of benthic feeding habitat. Nevertheless, the possible impacts on this species are expected to be NEGLIGIBLE since bearded seals are not common in McKinley Bay and alternative feeding areas are available.

Ward (1981) noted that most ducks remained more than 1 km from active dredging operations in McKinley Bay, although a few birds were observed feeding within 300 m of the dredge. However, even total exclusion from the area within 1 km of the island, mooring basin and channel would have a NEGLIGIBLE impact on the local duck populations.

Shorebirds and, particularly, gulls were observed feeding on invertebrates brought to the surface during dredging (Plate 3.5-1) in McKinley Bay in August, 1980, and Ward (1981) reported groups of up to 700 oldsquaw in the dredge plume. Some of the birds were observed diving, and were believed to be feeding within the plume.

The potential local impacts of dredging on benthic infauna may be MODERATE due to the mortality of organisms in borrow and spoil deposition areas, and since recovery of some populations may require several generations. On the other hand, only MINOR impacts on benthic epifauna are expected because these species will recolonize dredged habitats soon after the dredging programs are complete (Thomas, 1982). Past attempts to monitor fish entrainment by dredges at McKinley Bay found that the fish drawn in were primarily four-horned sculpins (bullheads) and small cod. Future dredging is expected to entrain small numbers of the local population of these species. The effects on a local basis, would be considered to range from MINOR to MODERATE.

Icebreaking in McKinley Bay will be required within the mooring basin and in a 100 to 150 m wide channel leading from the marine base to the transition ice zone. In the near term, most icebreaking along this corridor will occur during late fall and in June, although as development proceeds, icebreaking will extend throughout the winter. The potential effects of fall and spring icebreaking in McKinley Bay on seals are expected to be NEGLIGIBLE because the activities will be spatially and temporally restricted (Plate 3.5-2) and seal mortality is considered unlikely. However, the potential impacts on ringed seals could approach MINOR once icebreakers operate in the landfast ice throughout the winter since some seals may breed on the ice within the corridor. Mortality of fish and epontic flora and fauna may occur on overturned or rafted ice in the vessel tracks, particularly during icebreaking excursions in spring. However, these effects will be local, and the potential impact on the populations is expected to be NEGLIGIBLE.

Underwater noise effects in McKinley Bay are of concern relative to possible masking of whale and seal vocalizations. Few if any bowhead and white whales typically occur within McKinley Bay, although bowheads off the Tuktoyaktuk Peninsula may detect low frequency sounds originating from the shorebase

PLATE 3.5-1 *Shorebirds and gulls, as shown here, have been observed feeding on invertebrates brought to the surface during dredging in McKinley Bay.*

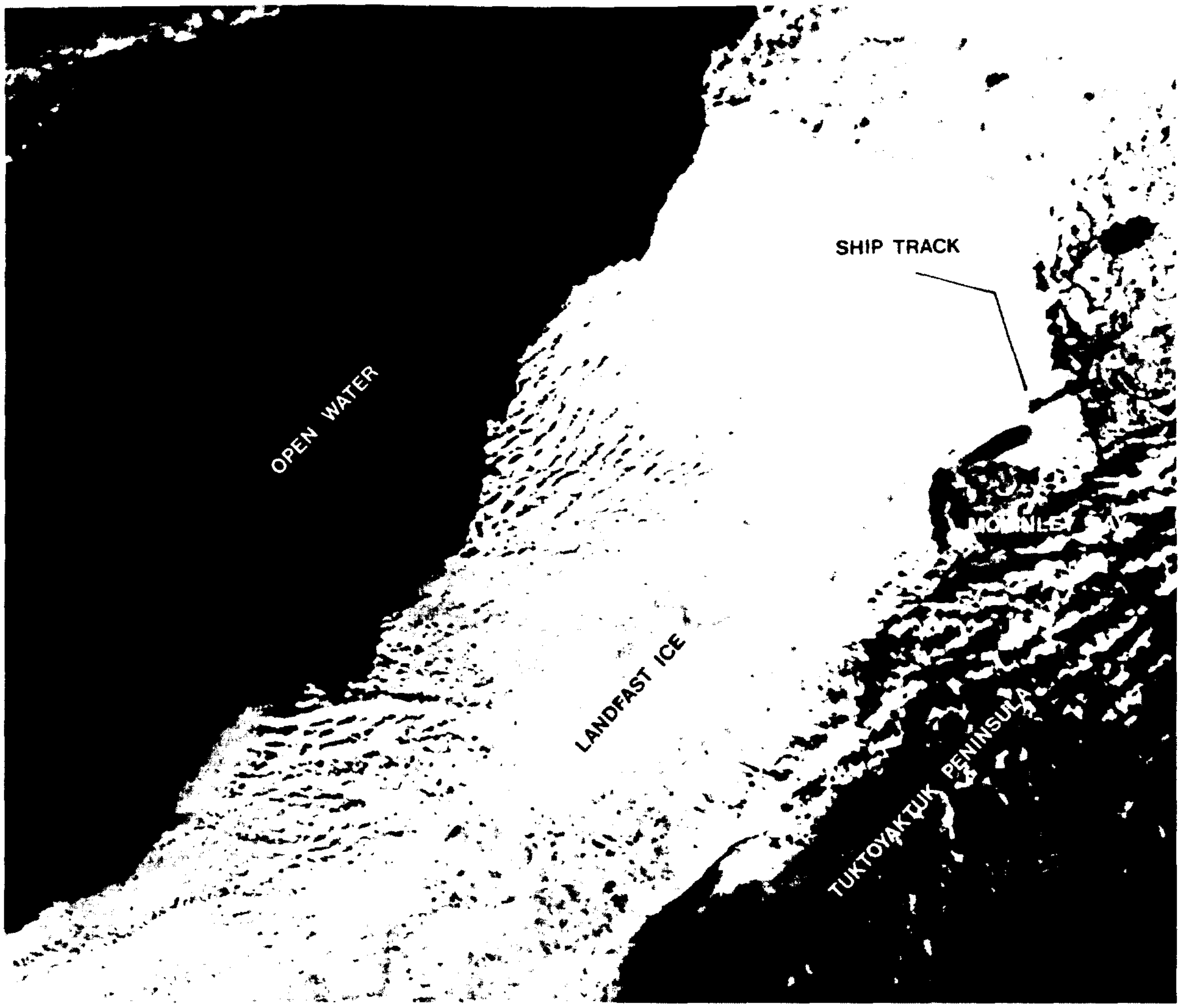


PLATE 3.5-2 *This satellite photo, taken on June 9, 1982, shows the track created by icebreaking ships through the landfast ice outside McKinley Bay.*

under some circumstances. Possible effects of this underwater noise on bowheads could include a reduction in conspecific communication distances, although the biological significance of masking in bowheads remains unknown. The impacts of underwater noise originating from McKinley Bay would probably be indistinguishable from impacts of underwater noise from other offshore operations. The impacts of existing noise levels on the bowhead whale are probably NEGLIGIBLE, while impacts associated with noise from composite future operations could range from NEGLIGIBLE to MINOR. On the other hand, since white whales are less likely to detect underwater noise originating from McKinley Bay, impacts on this species are expected to be NEGLIGIBLE.

Ringed and bearded seals in McKinley Bay may also detect underwater noise from harbour operations. The potential biological significance of masking in these species is also not known. However, ringed seals have frequently been observed near dredging operations, accommodation barges and the existing island in McKinley Bay with no detectable adverse effects. Consequently, the potential impacts of underwater sound in McKinley Bay on the local seal populations would probably range from NEGLIGIBLE to MINOR, depending on source levels, the abundance and distribution of seals in the area, and the biological significance of masking.

3.5.3 YUKON NORTH SLOPE

Areas such as King Point and Stokes Point along the Yukon coast are under active consideration as sites for future shorebases. Although firm plans have not yet been made, for assessment purposes it is necessary to make some assumptions about future shorebase development. Thus the following view of the future will form the basis for the subsequent assessment. Further information is provided in Section 3.2.3 of this chapter.

Operations along the Yukon coast could begin as early as 1983 with the establishment of a harbour for overwintering of vessels and a supply base camp and STOL airstrip adjacent to the harbour. Assuming that granular material would be required for offshore construction purposes, preparations may eventually be undertaken to develop a quarry and gravel pits with support camps, and haul roads to the marine base on the coast. Initial development at Stokes Point would only require use of on-site granular materials. Rock quarrying and gravel pit operations and shore-based actvities would grow and evolve over time to accomodate the rate of development, and would presumably continue well beyond the year 2000 time-frame examined in this EIS.

It is assumed that major shorebase construction activities will take place during the period 1983 to 1987, and after that time, the level of activity will remain relatively constant. The development scenario currrently envisioned by Dome includes the construction of an all-weather road between the shorebase and the Dempster Highway and between the shorebase and a quarry at Mount Sedgewick. The possible impacts of these roads are discussed in this section. Shorebase development currently envisioned by Gulf does not require a road to the Dempster as base resupply would be accomplished by water transportation. Figures 3.2-5 and 3.2-6 illustrate how development at either King Point or Stokes Point may appear by the early 1990's. Using this information as a basis, Matrix 3.5-3 summarizes the projected impacts of proposed shorebase development along the Yukon coast on the marine and terrestrial biological resources of the area.

MATRIX 3.5-3

POTENTIAL LOCAL IMPACTS* OF THE YUKON COAST DEVELOPMENTS

SHOREBASE ON THE YUKON COAST	MARINE MAMMALS				TERRESTRIAL MAMMALS									BIRDS							FISH				LOWER TROPHIC LEVELS			
	WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	GRIZZLY BEAR	TUNDRA WOLF	RED FOX	OTHER FURBEARERS	CARIBOU	REINDEER	OTHER UNGULATES	LOONS	SNOW GEESE	OTHER GEESE	DUCKS	RAPTORS	SHOREBIRDS	GULLS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	FRESHWATER	EPONTIC ORGANISMS	PLANKTON	EPIBENTHIC INVERT.	INFAUNA INVERT.
HUMAN PRESENCE					●	◊	●	◊	◊	◊	◊		◊	○	◊	○	◊	◊	◊	◊								
SOLID WASTES					●	◊	●	◊	◊	◊										◊								
TREATED SEWAGE			○	○																	○	○	○	○	○	○	○	○
WASTE WATER DISCHARGE			○	○																	○	○	○	○	○	○	○	○
AIR EMISSIONS					○	○	○	○	○	○	○		○	○	○	○	○	○	○	○								
AIRBORNE NOISE: AIRCRAFT	○	○	○	○	◊	◊	◊	◊	◊	◊	◊		◊	◊	◊	◊	◊	◊	◊	◊								
AIRBORNE NOISE: OTHER SOURCES					◊	◊	◊	◊	◊	◊	◊		◊	○	○	○	○	○	○	○								
ARTIFICIAL ILLUMINATION					◊	◊	◊	◊	◊	◊	○			○	○	○	○	○	○	○								
DREDGING	○	○	○	○										○			○			○	◊	●	●			◊	◊	●
ICE BREAKING	○	○	◊	○	○	○											○			○	○				○			
UNDERWATER SOUND	○	◊	○	○																	◊	◊	◊		○	○	○	○

LEGEND

○ NEGLIGIBLE ● MODERATE

◊ MINOR ■ MAJOR

***POTENTIAL IMPACTS (ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT)**

MATRIX 3.5-3 (Cont'd) POTENTIAL LOCAL IMPACTS* OF THE YUKON COAST DEVELOPMENTS	MARINE MAMMALS					TERRESTRIAL MAMMALS							BIRDS								FISH				LOWER TROPHIC LEVELS			
	WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	GRIZZLY BEAR	TUNDRA WOLF	RED FOX	OTHER FURBEARERS	CARIBOU	REINDEER	OTHER UNGULATES	LOONS	SNOW GEESE	OTHER GEESE	DUCKS	RAPTORS	SHOREBIRDS	GULLS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	FRESHWATER	EPONTIC ORGANISMS	PLANKTON	EPIBENTHIC INVERT.	INFAUNA INVERT.
ROCK QUARRIES AND CAMPS ACCESS/HUMAN PRESENCE GRAVEL PITS						◊	●	◊	◊	◊	◊				◊	O	O	●		O			◊	◊				
SOLID WASTES						◊	●	◊	◊	◊										O								
SEWAGE																												
AIR EMISSIONS						O	O	O	O	O	O		O	O	O	O	O	O		O								
AIRBORNE NOISE						◊	●	◊	◊	◊	◊		O	◊	◊	◊	O	◊		O								
PHYSICAL PRESENCE/ ARTIFICIAL ILLUM.						◊	●	◊	◊	◊	◊		◊	O	O	O	O	◊		O								
ROAD - QUARRY OR GRAVEL PIT TO SHOREBASE HABITAT LOSS						◊	O	O	O	O	O			◊	◊	O	O	◊					◊	◊			◊	◊
DISTURBANCE						O	◊	O	O	O	◊			◊	◊	O	◊	●		O								
ACCESS						O	O	O	O		◊				O	O	O	O					O	O				
ROAD-YUKON COAST - DEMPSTER HIGHWAY HABITAT LOSS						◊	O	O	O	O	O		◊	◊	O	O	◊	◊					◊	◊			◊	◊
DISTURBANCE						O	◊	O	O	◊	◊		◊	●	O	O	●	◊										
ACCESS						O	O	O	O	O	O		O		O	O	O	O					O	O				

LEGEND
O NEGLIGIBLE ● MODERATE
◊ MINOR ■ MAJOR

*POTENTIAL IMPACTS
(ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT)

3.5.3.1 Impacts on Marine Resources

Possible impacts on the marine environment could occur from treated sewage, solid waste and wastewater disposal, air emissions, artificial illumination, physical presence of artificial structures, human presence, and icebreaking. However, these possible impacts on most marine resources at the Yukon coast shorebase are expected to be NEGLIGIBLE when appropriate mitigative measures are followed. Disposal of sewage and solid wastes, and air emissions will conform to regulatory guidelines, while industry will encourage personnel to adhere to government regulations to minimize the potential for impact on sensitive coastal marine habitats.

Human presence, landfill sites, airborne noise and artificial illumination at the Yukon coast base may attract polar bears, Arctic foxes and terrestrial mammals to the base throughout the development period despite the implementation of mitigative measures (Section 3.5.3.2). The combination of these sources of attraction may have a MINOR impact on local fox populations if some animals are destroyed. Polar bears may be attracted to the base, particularly during the winter months. Although mitigative measures include monitoring of bears and sedation and live removal of problem animals (LGL, 1982), some problem animals may have to be destroyed for reasons of human safety. If all mitigative measures are strictly adhered to, few polar bears should have to be destroyed. Consequently, on a regional basis, impacts on polar bears from development on the Yukon coast are expected to be MINOR, while local impacts could increase to MODERATE.

Before 1985 when there is little activity at the Yukon coast shorebase, mainly STOL aircraft and helicopters would use the airstrip. Assuming major development proceeds, the airstrip would be lengthened for use by larger aircraft including Boeing 737 and 767 jets. Airborne noise from aircraft operations may temporarily disturb certain marine mammals, such as breeding ringed seals, possibly hauled-out ringed seals and bearded seals, and denning Arctic foxes. However, the potential impacts of overflights on breeding and hauled-out seals would probably be NEGLIGIBLE since STOL aircraft and helicopters would usually fly at altitudes greater than 305 m (1,000 ft), and because the turbojets would be at even higher altitudes within a few kilometres of the airport. On the other hand, disturbance of denning Arctic foxes could result in a MINOR impact on the local population because this area is an important denning location for this species. As discussed earlier, airborne noise from the base operations and air traffic may also contribute to the potential attraction of polar bears, Arctic foxes and other mammals to the Yukon coast shorebase.

The potential for significant aircraft disturbance on birds is much greater over land than over the sea (see Section 3.5.3.2). Over the sea, the species most likely to be affected by airborne noise are moulting and staging ducks. Although present evidence indicates that ducks in marine areas are not particularly sensitive to aircraft disturbance (Gollop *et al.*, 1974a), studies have not been conducted in areas subject to heavy air traffic. However, since the potential shorebase sites have not been identified as important areas for moulting ducks (Barry *et al.*, 1981), the potential impacts of regulated air traffic on ducks along the coast are expected to be MINOR.

Assuming a protected harbour is built at the Yukon coast shorebase, there will be a need for dredging of a basin, and the dredge spoils would likely be used for constructing a breakwater-causeway. Dome (1979) has estimated that between 2.8 and 6.2 million cubic metres of material might eventually be dredged to create either a 10 m or 17 m anchorage, respectively. At Stokes Point, Gulf has estimated that approximately 655,000 cubic metres of material would be dredged for initial development and 2.3 million cubic metres for ultimate development.

The documented effects of dredging activities on marine flora and fauna were described in detail in Section 2.4.2. In general, the potential impacts of dredging at a Yukon coast shorebase on water quality and most resources are expected to be NEGLIGIBLE because the activities and subsequent effects will be local and of short duration. Possible impacts of dredging on local benthic infauna may approach MODERATE due to direct mortality of organisms in the borrow areas and the fact that recovery of some populations in excavated sites may require several generations over a period of one to three years. On the other hand, recolonization of the basin, causeway and breakwater by epibenthic species would likely occur quickly, and rock, if used for construction of parts of these structures, may provide a hard substrate for colonization by additional species which are not common to the area. Nevertheless, potential impacts of dredging on local epibenthic invertebrate populations are expected to be MINOR.

Possible effects of dredging on fish may include a local alteration of marine spawning habitat and removal or burial of benthic food sources. Disturbance of feeding habitats may result in NEGLIGIBLE to MINOR impacts on local fish populations, while disturbance or loss of spawning areas may cause MINOR to MODERATE impacts on some species of the local marine fish population, particularly sculpins and possibly flounder. The potential impact of fish entrainment in dredges is likely to be NEGLIGIBLE based on experience elsewhere in the Beaufort Sea, due to the small percentage of the local populations which could be affected.

Assuming that granular materials are required for the construction of offshore platforms, up to three icebreaking barges may be required to transfer these materials to offshore sites throughout the year. In winter and spring, these vessels would follow a 100 to 150 m wide corridor through the landfast ice, and are unlikely to deviate much from this track until they reach the transition zone. The number of ice-strengthened vessels operating between the Yukon coast shorebase and the offshore production zone is projected to increase with time, however, all vessels are likely to follow the designated icebreaking corridor. The potential effects of icebreaking on marine resources of the Beaufort region were described in Section 2.4.4. In general, icebreaking in the area will probably have NEGLIGIBLE impacts on local populations of polar bears, Arctic foxes, bearded seals, white whales, bowhead whales, pelagic fish and epontic flora and fauna. On the other hand, the potential impacts of icebreaking on ringed seals in the region may approach the MINOR rating since a small number of seals probably breed on the landfast ice off the Yukon coast, and some pups may be killed during the 6 week pupping period in the spring. The proposed icebreaking corridor also crosses through documented ringed and bearded seal haul-out areas (Volume 3A, Section 3.2), although the potential impacts on seals during June would probably be NEGLIGIBLE, since only a few individuals would be temporarily disturbed and mortality is unlikely.

In general, underwater industrial noise along the Yukon coast is expected to leave most local marine mammal populations unaffected, hence impacts are expected to be NEGLIGIBLE. The number of seals and white whales which may be able to detect underwater sound from operations at the base would be relatively small because of their low hearing sensitivities and widespread distribution. Although conspecific communication between some individuals may be temporarily interrupted, the potential impacts of this form of disturbance would probably not be more than NEGLIGIBLE.

Underwater noise originating from the shorebase area may have some effect on bowhead whales, particularly during late summer and fall before and during their autumn migration (Volume 3A, Section 3.2). Unfamiliar sounds may temporarily disturb whales, while increased ambient noise levels may reduce their communication distances. There have been a relatively large number of bowheads observed along the Yukon coast between Herschel Island and Shingle Point during August and September. From 1 to 7 whales are usually sighted with most individuals being seen within 3.2 km of the shore (Fraker and Bockstoce, 1980). Consequently, a large fraction of the fall migrant bowheads may detect low frequency underwater sounds produced in the vicinity of a shorebase by vessels and aircraft approaching or leaving the area. Bowhead whales appear to be tolerant of a certain level of industrial noise. They have been observed in large numbers near operating machinery in the Beaufort Sea (ESL, 1982). There is evidence to suggest that bowheads may be less sensitive to underwater noise disturbances created by Alaskan Inuit whalers during fall than in spring. Ambient noise levels are usually greater in fall and may account for the apparent decrease in sensitivity of bowheads to underwater noise at this time. The potential impacts of the levels of underwater noise created at a Yukon coast shorebase to 1987 on the bowhead population would probably be NEGLIGIBLE, while increased activities after that time could result in NEGLIGIBLE to MINOR local disturbance effects. However, industry-sponsored whale monitoring programs will be continued. From these, mitigative measures will be derived and implemented as development of the Beaufort region progresses. Consequently, potential adverse impacts of shore-based or offshore activities on whales will be minimized. Such a program has proved to be very successful at Tuktoyaktuk (Fraker and Fraker, 1982).

3.5.3.2 Impacts on Terrestrial and Freshwater Resources

Assumed developments along the Yukon coast are described in Section 3.2.3, and include a shorebase at King Point or Stokes Point, a rock quarry at Mount Sedgewick, gravel pits and perhaps eventually an all-weather road connecting King Point and the Dempster Highway at Fort McPherson. In addition, either an all-weather road, or a winter road could be built between the proposed quarry and a shorebase site. Since impacts from an all-weather road could be expected to be greater than those associated with a winter road only, the more permanent roads will be dealt with in some detail.

It is recognized that certain land areas associated with and adjacent to potential Yukon coast shorebase sites are biologically important. Hence, mitigative measures need to be identified to ensure that possible impacts of this development scenario are minimized. A more detailed discussion of biological concerns, potential impacts and mitigative measures which may be necessary for development at King Point can be found in a supporting document to this EIS (LGL, 1982). Matrix 3.5-3 summarizes the potential residual impacts of shorebase development and associated activities on the Yukon North Slope on terrestrial resources after various mitigative measures have been applied.

(a) Common Wastes and Disturbances

Human presence, air emissions, sewage and solid waste disposal, artificial illumination, and stationary airborne noise at a King Point or Stokes Point base or a rock quarry site such as Mount Sedgewick are not expected to result in impacts greater than NEGLIGIBLE or MINOR on most terrestrial resources (Plate 3.5-3). Some species of mammals and birds including grizzly bears, red foxes, tundra wolves, wolverines, ravens and gulls may be attracted to the Yukon coast base and to quarry or gravel pit camps. This attraction may result from human presence, solid waste disposal practices, or airborne noise, despite the application of mitigative measures and the implementation of a carnivore control program (LGL, 1982). (The potential for attraction of polar bears and Arctic foxes was previously discussed in Section 3.5.3.1). Also, some northern grizzlies may be attracted to these developments during the summer. Although mitigative measures include monitoring of bears and sedation and removal of problem animals, some individuals may have to be destroyed for reasons of human safety. Possible effects of Yukon coast shorebase development on grizzly bears will depend on the numbers of bears in the area and the effectiveness of mitigative measures (LGL, 1982). If the proposed mitigative measures are largely successful, the regional impacts on grizzly bears would likely be MINOR although the local impact on this population could approach MODERATE.

The attraction of other scavengers, both bird and mammal, to shorebase development should be minimized by careful handling of food and incineration of wastes. In general, there should be little direct

PLATE 3.5-3 *This photograph shows a herd of caribou in the vicinity of a compressor station at the Prudhoe Bay complex in Alaska. (Courtesy: Alyeska Pipeline Service Co.).*

mortality of other mammal and bird species as a result of activities at a Yukon coast shorebase or associated rock quarry or gravel pits. Some mammals such as foxes, wolves and wolverines, may have to be destroyed if they become a nuisance or exhibit the behavioural traits of rabid animals. Some birds may be killed in collisions with structures at these sites. However, impacts on the regional populations of these species should be NEGLIGIBLE to MINOR.

Some terrestrial species may be affected by increasing levels of airborne noise from aircraft landing at the Yukon coast shorebase, operating in the area, or travelling between the airport and other locations in the Beaufort region. These include: caribou during spring migration, calving and post-calving; moose; nesting raptors; staging geese; moulting ducks and ground nesting birds.

To reduce or avoid adverse air traffic effects on the Porcupine caribou herd, overflights of spring migrating, calving and post-calving caribou will be prohibited whenever possible between early May and early August. If such overflights are considered essential, altitudes greater than 600 m asl would be maintained as recommended by Miller and Gunn (1979) unless there is a risk to human safety. Between August 15 and September 30, all overflights of traditional staging areas of snow geese and white-fronted geese, for example, on the North Slope and parts of the Mackenzie Delta, will be avoided to the extent possible. In addition, aircraft flights over active raptor nest sites would be at altitudes of 300 to 500 m above nest sites (see Roseneau *et al.*, 1981; LGL, 1982) whenever possible during the nesting period from February 15 to August 31, the timing depending on species. If these mitigative measures are followed, potential impacts of aircraft disturbance on terrestrial birds and mammals will be confined to the immediate vicinity of the Yukon coast shorebase and should vary from NEGLIGIBLE TO MINOR.

(b) All-Weather Haul Roads, Rock Quarries and Gravel Pits

Birds and mammals may be affected by the construction and operation of roads, quarries and gravel pits. Impacts may result from direct disturbance, habitat reduction or loss through increased public access, or interactions with vehicles or facilities. Disturbance may cause: increased energy expenditures which may affect the bioenergetics of certain species; behaviour that may result in increased mortality of adults and juveniles; and exclusion of some species from important habitats. Habitat reductions could result from industrial land use, change in water levels, and the dusting of local vegetation. There could also be reduced access by animals to some habitats. Some birds and mammals could be killed by industrial activities such as moving vehicles, but most losses would occur through increased access to areas by hunters and trappers. Direct mortality due to industry activities is expected to have a NEGLIGIBLE impact rating for all mammal or bird species, while potential cumulative impacts from disturbance, habitat loss and increased human access could range from NEGLIGIBLE to MODERATE, depending on species and mitigative measures employed.

Disturbance: The species most likely to be affected by disturbances are caribou, raptors and waterfowl. Effects of disturbances on other mammals and birds are discussed in LGL (1982) and are expected to be NEGLIGIBLE.

During some springs, portions of the Porcupine caribou herd migrate into and through potential Yukon coast shorebase sites such as Stokes Point and King Point (Figure 3.5-2). Migration routes are generally parallel to and south of the route between King Point and the Dempster Highway, and in most years only a few of the animals that migrate via the Richardson route would likely encounter the proposed haul road. On the other hand, many of those following the Richardson route and a few of those using the Old Crow route would encounter the Mount Sedgewick quarry and the all-weather haul road between the quarry and King Point. The portion of the Porcupine herd that uses the Richardson route can vary markedly from year to year. For example, in 1978, less than 5% of the herd followed this route, compared to more than 50% in 1974 (LGL, 1982). Within the proposed Yukon coast shorebase area, spring migration generally begins in late April and continues until late July. Early migrants (April-May) are mainly females, while bulls follow at a more leisurely pace in mid June to July.

Calving generally occurs between the last week of May and mid June. In most years, the eastern extremity of the calving grounds would include the Mount Sedgewick quarry site, the haul road route and the proposed shorebase sites, although only scattered calving activity generally occurs in the vicinity of the latter area (Figure 3.5-3). In late June and early July, large post-calving groups begin an eastward movement from Alaska across the northern Yukon to the Richardson Mountains. The Mount Sedgewick quarry site and the routes (one all-weather, one winter-only) connecting the quarry with proposed shorebase sites are almost directly perpendicular to the primary movement corridor used during these eastward post-calving movements, but few caribou are expected to encounter the shorebase facilities. Later movements of the caribou herd are generally south of the proposed facilities, while scattered groups usually remain in the northern Yukon during August.

The physical presence of a road and quarry are not expected to be a major source of disturbance to the caribou (Plate 3.5-4), however, the activities of personnel and vehicles are of potential concern (LGL, 1982). In order to avoid disturbing caribou during their spring migration and while calving and during post-calving, construction and quarrying at Mount Sedgewick and the use of the all-weather haul road may have to be restricted from time to time between early May and early August. These times would be determined by aerial monitoring of the movements of the Porcupine herd. To ensure a constant supply of rock, it will be stockpiled at the Yukon coast shorebase during winter for use when the quarry and haul road may be closed or activity reduced. Blasting at the quarry site will be carried out at times and under conditions that will minimize disturbance to the caribou.

Although hauling on the road from the Yukon coast shorebase to the Dempster Highway would not interfere with spring migration of the herd in most years, aerial monitoring of the road will be conducted during the migratory period. If large numbers of caribou are observed in the vicinity of the road, construction near the animals would be halted and traffic restricted until caribou moved away. Disturbance to caribou will be reduced further by use of an education program for all industry personnel and by employing restrictions on vehicle operations. Successful implementation of these mitigative measures should reduce the potential degree of impact of disturbance from industry activities on the roads and at the quarry on caribou to a MINOR level.

Regarding birds, high densities of raptors are found in the upland and foothill portions of the Buckland Mountains along the Trail and Babbage rivers, particularly in the area adjacent to Mount Sedgewick. Dominant species include the peregrine falcon, gyrfalcon, rough-legged hawk and golden eagle (Volume 3A; LGL, 1982).

Disturbance of raptors is only likely if activities such as aircraft traffic, heavy construction, or blasting occur near nest sites during the pre-nesting and nesting period, or if personnel approach nest sites. Blasting and human on-foot encroachment are the activities most likely to disturb these species since there is evidence that many raptors can tolerate modest levels of traffic activity when it is distant from nest sites (see LGL, 1982).

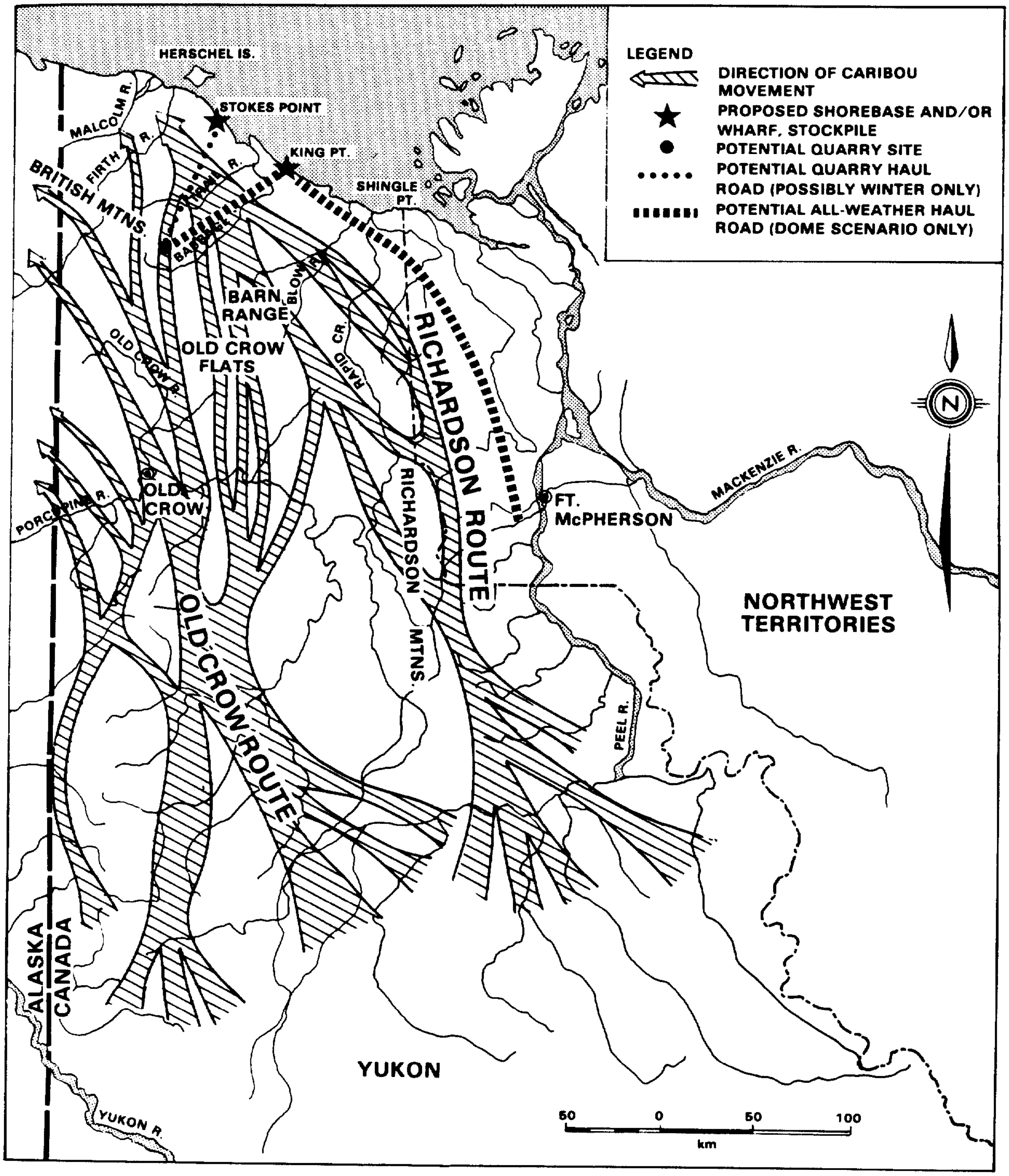


FIGURE 3.5-2 *Spring migration routes of the Porcupine caribou herd relative to proposed onshore developments along the Yukon coast. (Source: LGL, 1982).*

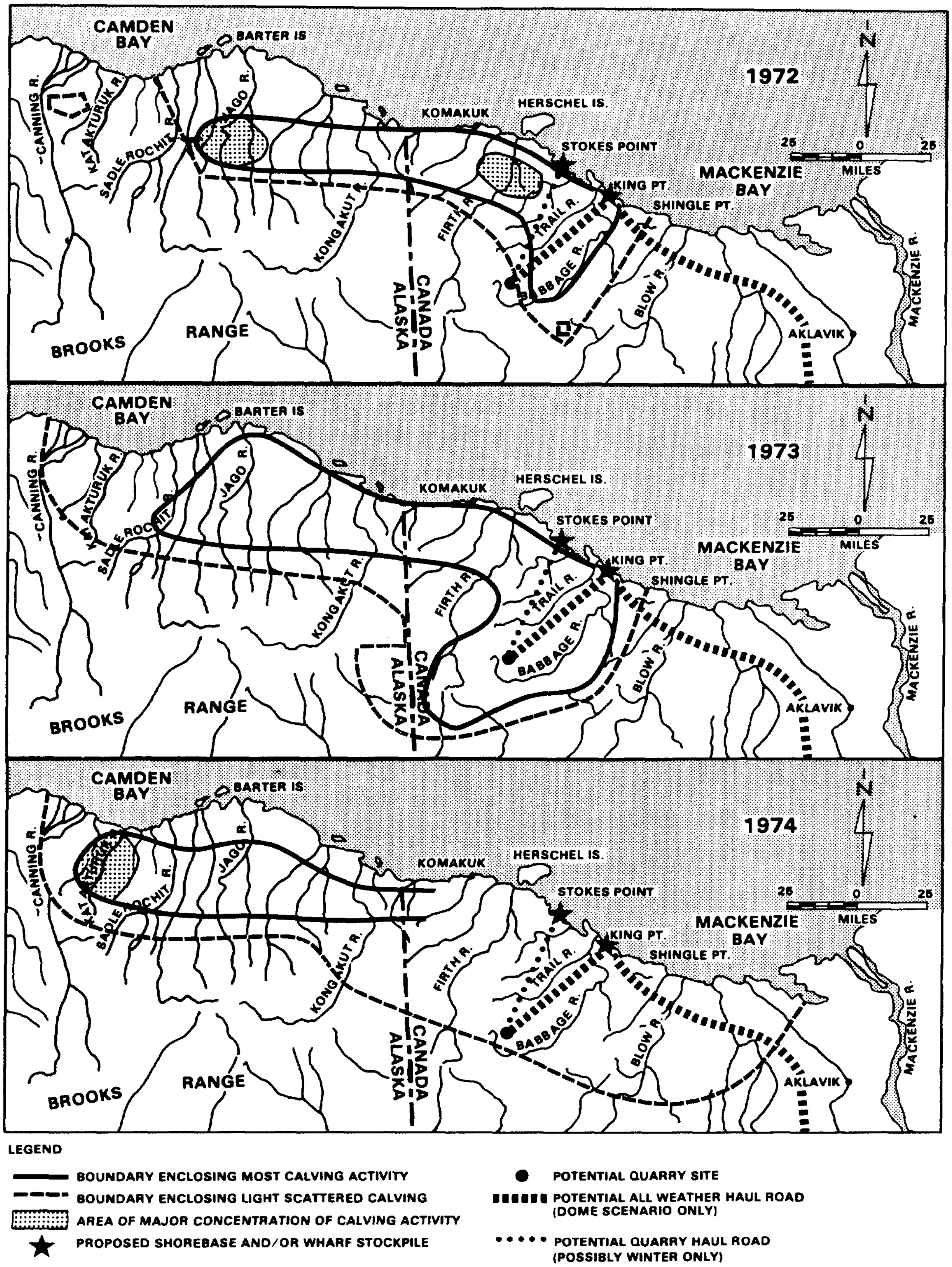
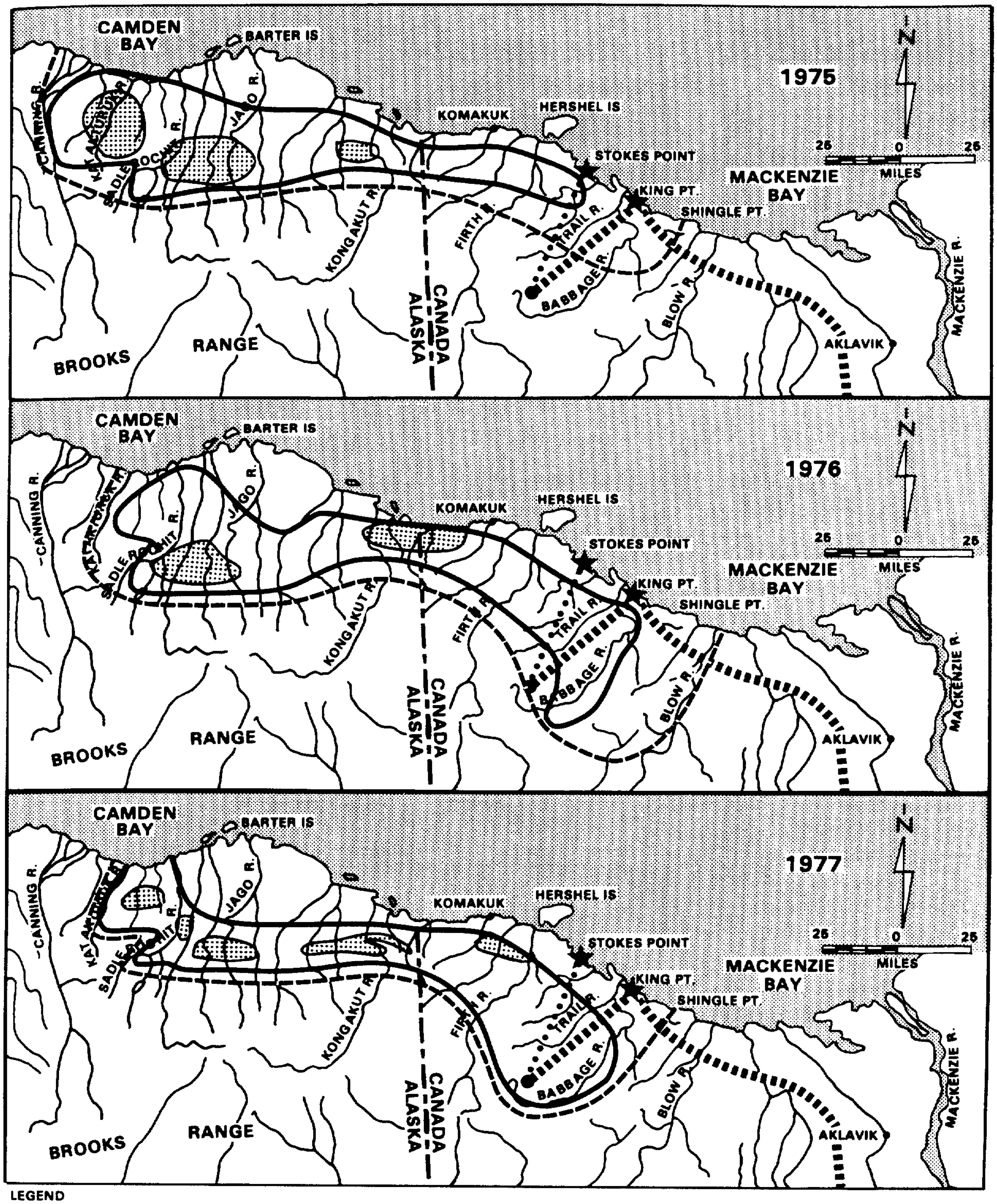


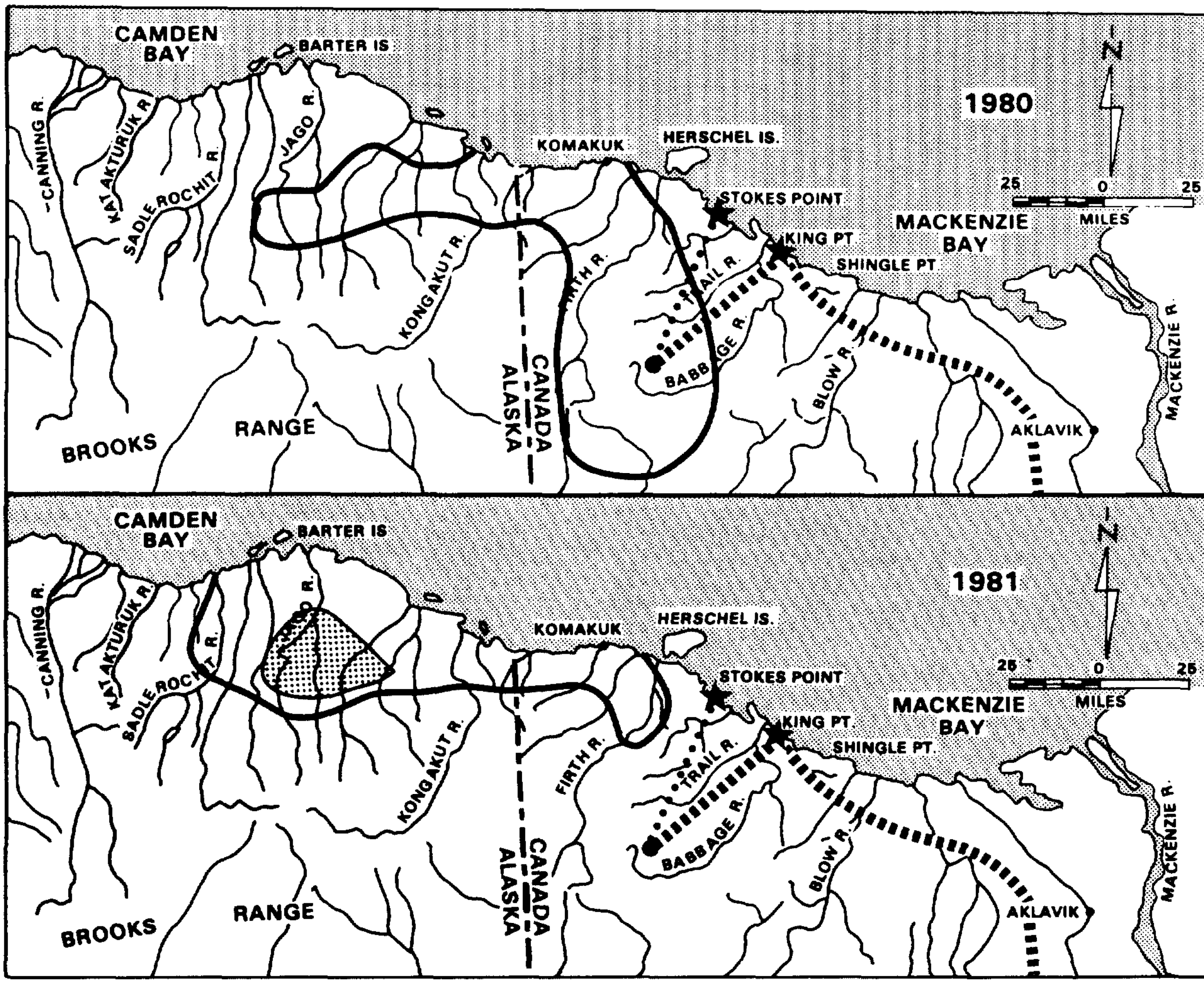
FIGURE 3.5-3 *Calving areas used by the Porcupine caribou herd during the years 1972 to 1981 in relation to proposed onshore development along the Yukon coast (Source: LGL, 1982).*



LEGEND

- BOUNDARY ENCLOSING MOST CALVING ACTIVITY
- BOUNDARY ENCLOSING LIGHT SCATTERED CALVING
- AREA OF MAJOR CONCENTRATION OF CALVING ACTIVITY
- PROPOSED SHOREBASE AND/OR WHARF STOCKPILE
- POTENTIAL QUARRY SITE
- POTENTIAL ALL WEATHER HAUL ROAD (DOME SCENARIO ONLY)
- POTENTIAL QUARRY HAUL ROAD (POSSIBLY WINTER ONLY)

FIGURE 3.5-3 *(cont'd)*



LEGEND

- BOUNDARY ENCLOSING MOST CALVING ACTIVITY
- AREA OF MAJOR CONCENTRATION OF CALVING ACTIVITY
- ★ PROPOSED SHOREBASE AND/OR WHARF STOCKPILE
- ● POTENTIAL QUARRY SITE
- ▪▪▪▪▪▪ POTENTIAL ALL WEATHER HAUL ROAD (DOME SCENARIO ONLY)
- • • • • • POTENTIAL QUARRY HAUL ROAD (POSSIBLY WINTER ONLY)

FIGURE 3.5-3 *(cont'd)*

Mitigative measures that will be implemented to reduce disturbance to nesting raptors will include identifying active and historic raptor nest and perch sites before development and facility plans are finalized. The final planning will account for the spatial and temporal constraints recommended by Roseneau *et al.* (1981). These include placing facilities beyond certain distances from nest sites and restricting ground-based activities and overflights during the nesting period. If for engineering reasons, facility placement restrictions cannot be met in some instances, alternative solutions will be sought through consultation with appropriate government regulatory agencies.

Some raptors may be disturbed by quarrying and road construction activities despite the successful implementation of mitigative measures. Although activities of the Mount Sedgewick quarry and its haul road may be restricted from May to August to reduce disturbance of caribou, gyrfalcons and golden eagles may be disturbed because they nest earlier. Raptor species nesting near the road right-of-way between Fort McPherson and the Yukon coast shorebase could be disturbed during road construction, but will probably become habituated to the lower intensities of activity once the road is in use. Overall, the impacts of activities along the route on regional populations of raptors would likely be MINOR. The disturbance

PLATE 3.5-4 *In general, caribou appear to habituate to northern roads and have little difficulty crossing them. These caribou were photographed next to a road in the Prudhoe Bay development area (Courtesy: Alyeska Pipeline Service Co.).*

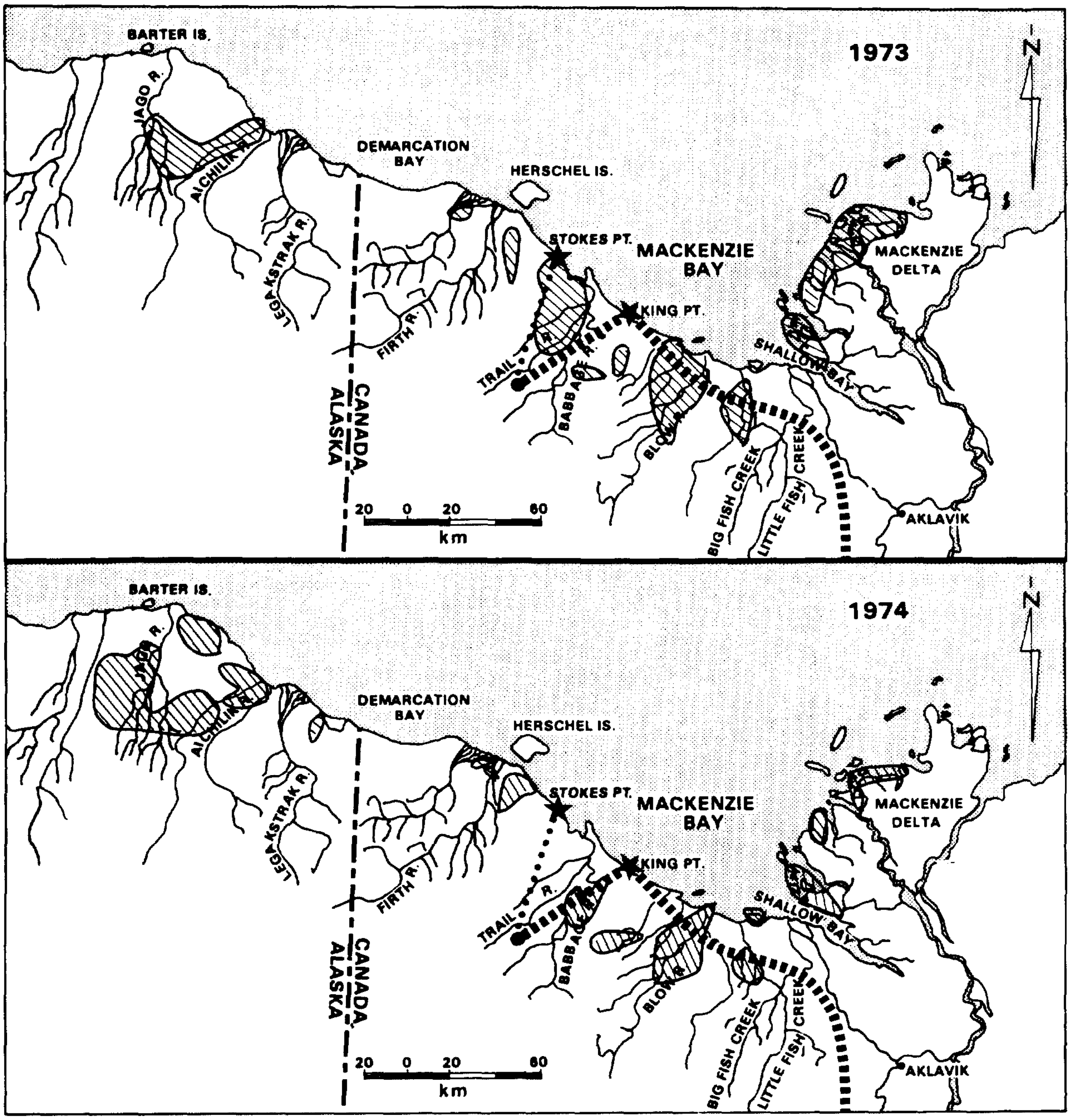
caused by quarrying and the quarry haul road could result in MINOR to perhaps MODERATE local impacts on nesting peregrine falcons, gyrfalcons and golden eagles, depending on their abundance and distribution where activity is most intense.

Possible disturbance of autumn staging geese is of concern with respect to a Yukon coast shorebase. Also, nesting and moulting ducks, as well as nesting loons, shorebirds and passerines may be disturbed by air traffic and activities associated with road construction and operation.

From mid August until early October in most years, 200,000 to 500,000 lesser snow geese (the entire western Canadian population) stage on the Yukon and Alaskan north slopes and along the coast of the Northwest Territories (Figure 3.5-4; Campbell and Weber, 1973; Koski and Gollop, 1974; Koski, 1975, 1977b). Although they generally stage in the Mackenzie Delta, Koski (1977b) has observed an estimated 18,000 white-fronted geese in association with snow geese along the North Slope between Shallow Bay and King Point. A few Canada geese also stage along this part of the North Slope (Koski, 1977b), while black brant stage and rest at coastal lagoons and river deltas along the Yukon coast during their westward fall migration (Koski, 1977a).

Most studies of disturbance on autumn staging geese have dealt with disturbance by aircraft. These show that white-fronted geese and particularly snow geese are very sensitive to this form of disturbance (LGL, 1982). There are no comparable data on the effects of construction and operation of roads, borrow sites and camps on autumn staging geese. The results of experiments using gas compressor noise simulators suggest that snow geese may be sensitive to these ground-based sources of disturbance and would stay away from these activities (ESL, 1982).

To ensure that autumn staging geese are not disturbed and excluded from traditional feeding areas by use of a route from the Yukon coast to the Dempster Highway, road use can be restricted between roughly August 15 to September 30 if necessary. This restriction, along with measures designed to limit aircraft disturbance, are expected to reduce the degree of impact of disturbance on autumn staging snow geese and other geese to MINOR. Although construction and operations on the quarry haul road could disturb and displace staging snow geese, this



LEGEND

- • • • • • POTENTIAL QUARRY HAUL ROAD (POSSIBLY WINTER ONLY)
- ▮▮▮▮▮▮ POTENTIAL ALL-WEATHER HAUL ROAD (DOME SCENARIO ONLY)
- ★ PROPOSED SHOREBASE AND/OR WHARF, STOCKPILE
- ● POTENTIAL QUARRY SITE
- ▨ SNOW GOOSE STAGING AREA

FIGURE 3.5-4 *Areas in the Mackenzie Delta-North Slope used by autumn staging snow geese; 1973 through 1976. (Source: LGL, 1982).*

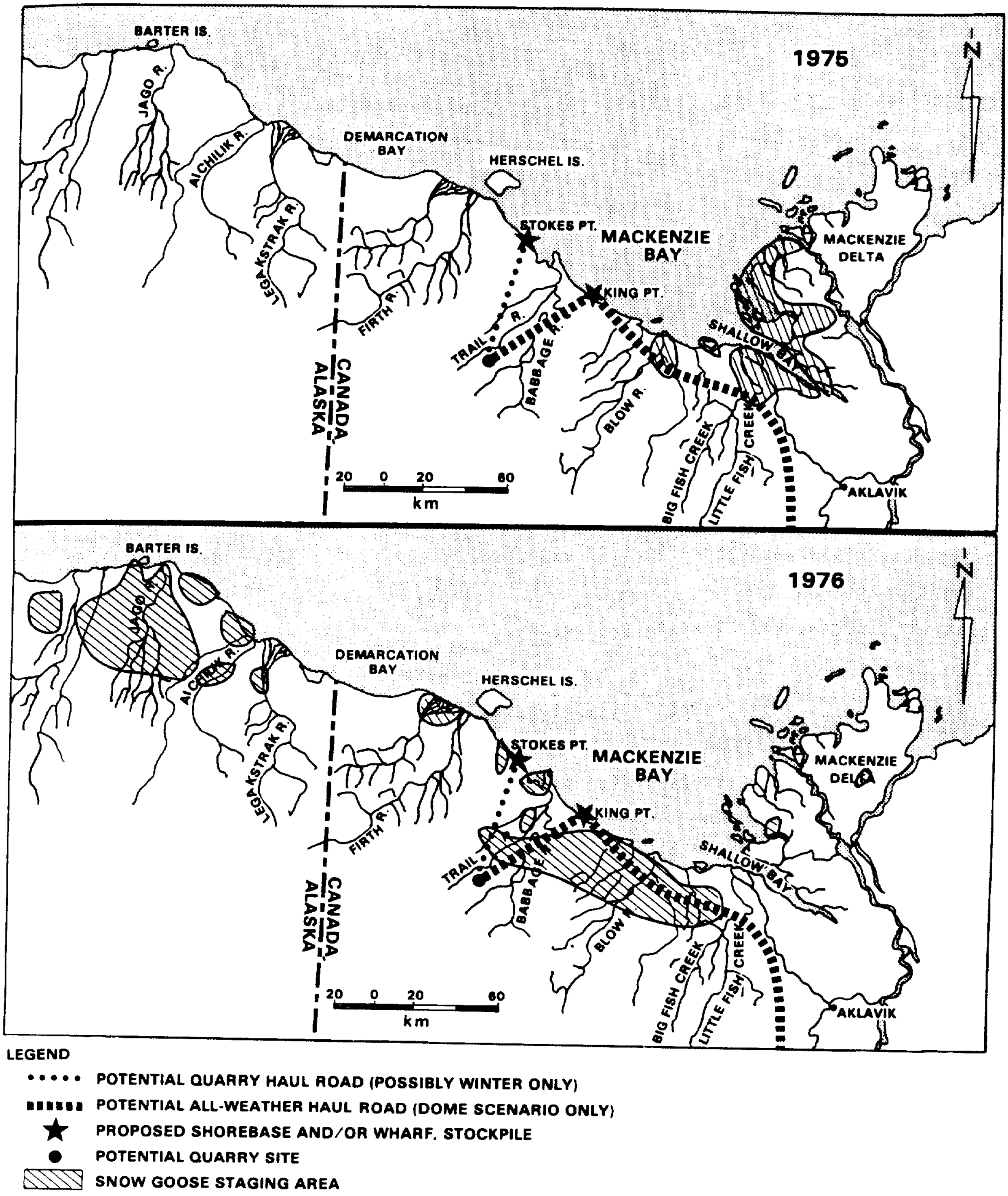


FIGURE 3.5-4 *(cont'd)*

area does not appear to be particularly important to staging snow geese in most years (Figure 3.5-4; LGL, 1982).

Birds, particularly loons and waterfowl, that attempt to nest or moult along the road and adjacent to shorebase facilities may be displaced or experience decreased productivity as a result of disturbance. Although the potential local impacts of the road from the Yukon coast to the Dempster Highway on nesting loons and waterfowl and on moulting waterfowl could approach MODERATE, potential regional impacts would probably be MINOR.

Habitat Reduction: Reduction or loss of habitat for birds, mammals and fish may occur directly by destruction or modification of habitats, or indirectly by exclusion as a result of disturbance. Direct habitat loss could occur when roads and facilities are constructed, and from alterations in surrounding habitats if drainage patterns are changed, or if dusting of habitats occurs.

Roads could produce the most extensive direct and indirect losses of habitat, while comparatively little habitat loss would result from Yukon coast shorebase development and a rock quarry at Mount Sedgewick. Mitigative measures for roads would include the design and routing of roads to minimize changes in water levels and drainage patterns. This would protect muskrat and beaver habitat, breeding habitat for waterfowl and shorebirds, and the hunting habitats of raptors. In addition, road dust could be prevented from dusting adjacent habitats, by wetting down the road as required.

There would be an insignificant direct loss of caribou habitat due to project activities, but indirect loss by the possible blocking of migration routes either by disturbance or physical or psychological barriers presented by roads is of potential concern. The road from the Yukon coast to the Dempster Highway would be essentially parallel to the direction of migration, and therefore not likely to interfere with caribou movements. On the other hand, the all-weather quarry haul road would be perpendicular to migration routes. However, recent data on the effects of the Dempster Highway on the Porcupine caribou herd, derived from a joint three year project between the Yukon Government and the Canadian Wildlife Service, indicated that caribou had little difficulty crossing the highway, even at steep gravel banks (Russell, 1982). In fact, two of the major crossing sites documented during their study had the highest, steepest berms. Russell (1982) concluded that for the years of their study, the road environment did not appear to impede caribou movements, although he cautioned that they had not had the opportunity to measure crossing characteristics under deep snow conditions. On this basis, it is assumed that caribou would have little difficulty crossing these future proposed roads and possible exclusions from preferred habitat due to barrier effects should have no more than a MINOR impact on the herd.

Direct habitat loss could also result from road construction if fox, wolf, wolverine and grizzly bear dens were destroyed. Den sites are often traditional, and suitable denning sites are few in some areas. To minimize this potential habitat loss, surveys of proposed road alignments would be made in order to avoid important denning areas. The final alignment will be decided in consultation with government agencies and the local people. Assuming successful implementation of mitigative measures, the potential impacts of habitat loss on these and other mammal species are expected to be NEGLIGIBLE.

Where possible, the proposed roads will avoid low-lying wet areas which are preferred habitat of loons, most ducks and shorebirds, and will avoid rock outcrops and cliffs favoured by nesting raptors. The quarrying activity is the only operation likely to represent a direct threat to some raptor habitat. Mitigative measures designed to minimize direct habitat loss to ground-nesting birds (such as the prevention of dusting and changes to drainage patterns) and cliff-nesting and tree-nesting raptors have been discussed previously. Successful implementation of these measures will reduce potential impacts of direct habitat loss on birds to NEGLIGIBLE or MINOR levels. Indirect habitat loss could occur in the vicinity of project activities as a result of disturbance. This may have a greater effect on nesting and moulting birds than direct habitat loss.

Sedimentation in stream beds, mechanical disruption of stream beds and banks, and improperly placed culverts may result in habitat loss for freshwater fish (Section 3.4; LGL, 1982), while water withdrawal from streams with low flows could cause fish losses. Consequently, fish habitat will have to be protected using various means, such as: using bridges instead of culverts to cross rivers and large streams (e.g. Babbage River, Big Fish River) which have upstream fish overwintering or spawning areas; adhering to guidelines provided in Dane (1978) and Dryden and Stein (1975) for placement of culverts in smaller streams; and scheduling construction for mid summer or winter to avoid conflicts with fish migration and spawning. These and other potential mitigative measures may be necessary to avoid adverse impacts of Yukon coast shorebase development on fish resources (LGL, 1982). Successful implementation of these mitigative measures should reduce potential impacts of the development on important fish habitats to NEGLIGIBLE or MINOR.

Increased Access: The Yukon North Slope is presently relatively inaccessible to people, especially during the spring and summer, the times of particular importance to mammal and bird populations. All-weather roads from the area to the Dempster Highway, and from the Yukon coast shorebase to Mount Sedgewick could lead to increased hunting, trapping and recreational fishing, as well as the illegal collection of raptor eggs and young for sale to falconers. Harvesting and disturbance from increased access could result in a marked increase in potential impacts on some terrestrial mammals (particularly caribou), waterfowl, raptors and freshwater and anadromous fish. It is recognized that governments have the ultimate responsibility for the management of natural resources. The increased access to this region may require new regulations and an effective enforcement program to minimize adverse impacts of increased harvesting pressure.

3.5.4 WISE BAY

Dome Petroleum Limited obtained approval in 1979 to construct a 50,000 barrel fuel tank farm and construction camp on the land adjacent to Wise Bay on the Parry Peninsula, but there are currently no firm plans to use Wise Bay land. The general area, including Summers Harbour, has been used as a winter anchorage for ships of the drilling fleet in past years, and in 1982, Dome is planning to moor a large, 130,000 DWT fuel storage vessel at Summers Harbour.

The following discussion deals with the possible impacts of construction and operation of the fuel tank farm. The information used is drawn largely from a previous environmental assessment of the project (Canmar, 1979). Matrix 3.5-4 summarizes the potential impacts of the proposed activities on the local marine and terrestrial resources of the Wise Bay area.

Treated sewage, solid wastes, treated oily wastewater, air emissions, dredging, and underwater industrial sound in Wise Bay are expected to have NEGLIGIBLE impacts on most marine or terrestrial biota in the Cape Parry region. Although some dredging may be required during initial construction of the Wise Bay facility, it would be done in a small area in a short time so that potential impacts on most resources would be NEGLIGIBLE. Since underwater sound

MATRIX 3.5-4

POTENTIAL LOCAL IMPACTS* OF THE WISE BAY CONTINGENCY FUEL STORAGE FACILITY

		MARINE MAMMALS				TERRESTRIAL MAMMALS									BIRDS							FISH				LOWER TROPHIC LEVELS			
		WHITE WHALE	BOWHEAD WHALE	RINGED SEAL	BEARDED SEAL	POLAR BEAR	ARCTIC FOX	GRIZZLY BEAR	TUNDRA WOLF	RED FOX	OTHER FURBEARERS	CARIBOU	REINDEER	OTHER UNGULATES	LOONS	GEESE	THICK-BILLED MURRE	DUCKS	RAPTORS	SHOREBIRDS	GULLS	PELAGIC MARINE	DEMERSAL MARINE	ANADROMOUS	FRESHWATER	EPONTIC ORGANISMS	PLANKTON	EPIBENTHIC INVERT.	INFAUNA INVERT.
HUMAN PRESENCE				O	O	◊	◊	◊	O	◊	O			O	◊	O	O	◊	O	O	◊								
SOLID WASTES						◊	◊	◊	O	◊	O									O									
TREATED SEWAGE				O	O																	O	O	O		O	O	O	O
WASTE WATER DISCHARGE				O	O										O			O		O		O	O	O		O	O	O	O
AIR EMISSIONS		O	O			O	O	O	O	O	O			O	O	O	O	O	O	O	O								
AIRBORNE NOISE:	AIRCRAFT			◊	◊	◊	◊	◊	O	◊	O			◊	O	O	◊	◊	O	O	O								
	OTHER SOURCES					◊	◊	◊	O	◊	O				O	O	O	O	O	O	O								
ARTIFICIAL ILLUMINATION						◊	◊	◊	O	◊	O				O	O	O	O	O	O	O								
DREDGING				O	O										O			O		O	O		O	O	O		O	O	◊
ICE BREAKING		O	O	◊	◊		O								O			O		O	O	O				O			
UNDERWATER SOUND		O	O	O	O																	O	O	O		O	O	O	O

LEGEND
O NEGLIGIBLE
◊ MINOR
● MODERATE
■ MAJOR

*POTENTIAL WORST CASE IMPACTS (ASSUMING SUCCESSFUL IMPLEMENTATION OF MITIGATIVE MEASURES DESCRIBED IN TEXT) would be generated infrequently by vessels and operations in Wise Bay and would be rapidly attenuated, adverse impacts on local marine mammal or fish populations are not anticipated. The discharge of sewage, solid wastes, and air emissions will conform with regulatory guidelines and are not expected to have more than NEGLIGIBLE impacts on local resources.

Polar bears, grizzly bears, and Arctic and red foxes may be attracted to the Wise Bay site by the presence of people, artificial illumination, the presence of artificial structures, solid waste and airborne noise, despite the application of mitigative measures. The Cape Parry area is located at the perimeter of important polar bear wintering habitat, while Arctic foxes are apparently common on the peninsula in some years (Volume 3A; Canmar, 1979). However, few polar bear dens have been reported on the Parry Peninsula (Stirling *et al.*, 1981), and suitable denning areas for Arctic and red foxes do not occur on the northern portions of the Parry Peninsula near Wise Bay. Grizzly bears probably occur over most of the peninsula from April to September, but few are likely to den in the area during winter. Consequently, grizzlies and foxes could be attracted to the Wise Bay facilities during the spring and summer, while polar bears and foxes may be attracted in winter. The potential impacts of attraction of Arctic and red foxes are likely to be NEGLIGIBLE because the number of affected individuals would be small and no mortality is anticipated. On the other hand, the attraction of polar and grizzly bears to the Wise Bay facility may result in MINOR local impacts if nuisance animals had to be removed.

Increased human activities and encroachment in the Wise Bay area could result in reduced nesting success of birds in the immediate vicinity of the storage facility. However, this area is not known to be an important nesting area for any species, and potential impacts on birds will probably be MINOR and highly localized. Since the thick-billed murre colony at Police Point is located 10 km from the proposed Wise Bay facilities, potential impacts on murres from human disturbance are expected to be NEGLIGIBLE.

3.6 ACTIVITIES AND FACILITIES RELATED TO ONSHORE PRODUCTION AND AN OIL GATHERING SYSTEM

The general nature of facilities and activities related to onshore production and gathering systems which could be employed in the region is described in Section 3.3 of this chapter and is reviewed in more detail in Volume 2. To summarize, it will consist of clusters of wells on shallow water production islands or gravel pads on the tundra, and central processing facilities at each larger oilfield. Crude oil leaving the process facilities will be shipped via gathering lines to a terminal for temporary storage and subsequent transportation to market via overland pipeline, or to an offshore tanker loading terminal for shipment by sea. The exact locations and production capacities of the oilfields and gathering lines cannot be accurately defined at this time, but it is assumed that prospective oil fields such as Atkinson on the Tuktoyaktuk Peninsula, and Adgo, in the shallow waters off the Mackenzie Delta are likely candidates for initial onshore oil production (Figure 3.3-2).

The following impact assessment includes both "linear" and "non-linear" aspects of gathering systems and production facilities. Linear aspects include: gathering line ditching and installation, gathering system testing and fluid disposal, stream crossings, access roads, and buried or elevated pipelines. Non-linear aspects include well cluster pads and physical presence, drilling fluid disposal and sumps, central processing facilities and flares, staging sites and stockpiles, wharves and barge traffic, aircraft and airstrips, camps, waste disposal, off-duty activities by personnel, and equipment removal and reclamation. Such activities as site preparation and construction, granular borrow, blasting, and reclamation are discussed in Section 3.4. The possible impacts associated with production facilities and an oil gathering system in the onshore Beaufort region are summarized in Matrix 3.6-1.

3.6.1 GATHERING LINE DITCHING, INSTALLATION, AND BACKFILLING

Construction of gathering lines will take place in winter and will include pipeline stringing, welding, wrapping, weighting, laying in and burying of pipe, plus machinery operation and maintenance. The selected right-of-way, approximately 20 m wide, will be cleared of trees and shrubs prior to the start of construction activities. The centreline of the pipeline will be located off the centre of the right-of-way and the wider portion of the right-of-way will be designated as the work area, while the narrower portion of the right-of-way will be designated as the spoil area. The work area of the right-of-way will be used for movement of construction equipment and inspection vehicles. In the case of winter construction in the continuous permafrost, preparation of the work area of the right-of-way will involve special techniques. Specifically, maintaining the integrity of the permafrost requires that the vegetation mat covering the permafrost not be removed. This requirement does not allow the use of the conventional southern

MATRIX 3.6-1

POTENTIAL ENVIRONMENTAL IMPACTS RESULTING FROM HYDROCARBON DEVELOPMENTS IN THE BEAUFORT SEA ONSHORE AND MACKENZIE DELTA REGION

		Geology and Soils				Hydrology and Water Quality			Air		Vegetation			Mammals								Birds					Aquatic Resources	
		SOIL CHEMISTRY	SURFACE STABILITY	SLOPE STABILITY	GENERAL TERRAIN	WATER QUALITY	SURFACE WATER	GROUNDWATER	AIR QUALITY	MICROCLIMATE	RIPARIAN	CONIFEROUS FOREST	TUNDRA	REINDEER	BARREN GROUND CARIBOU	MOOSE	GRIZZLY BEAR	BLACK BEAR	AQUATIC FURBEARERS	TERRESTRIAL FURBEARERS	GENERAL MAMMAL CONCERNS	RAPTORS	GEESE/SWANS	DUCKS	OTHER	GENERAL/AVIAN CONCERNS	LOWER TROPHIC LEVELS	FISH
COMMON WASTES AND DISTURBANCES 3.4	SITE PREPARATION & CONSTRUCTION		L-s	L-s	L-s	L-s	L-s	L-s			L-l	L-l	L-l	○	○		○			○			◊			○		◊
	GRANULAR BORROW		L-s	L-s		L-s	L-s					L-m	L-m	◊			◊			◊	◊	○	◊	◊	○			○
	BLASTING					L-s	L-s		L-s												○					◊	○	◊
	ABANDONMENT & RECLAMATION		L-s	L-s	L-s						L-s		L-s								○					○	○	◊
ACTIVITIES AND FACILITIES RELATED TO PRODUCTION AND AN ONSHORE GATHERING SYSTEM 3.6	1 DITCHING, INSTALLATION, BACKFILL		L-s	L-s	L-s	L-s	L-s		L-s		L-s		L-s								○						○	◊
	2 PIPELINE TESTING, FLUID DISPOSAL		L-s	L-s	L-s	L-s	L-s				L-s		L-s								○						○	◊
	3 STREAM & CHANNEL CROSSINGS		L-s	L-s	L-s	L-s	L-s				L-s		L-s						◊		○		◊	◊			◊	◊
	4 BURIED GATHERING LINES		L-s	L-s	L-s		L-s	L-s			L-s		L-s								○					◊		
	5 ELEVATED PIPELINES		L-s	L-s	L-s						L-s		L-s								○					◊		
	6 TEMPORARY ACCESS ROADS		L-s	L-s	L-s	L-s	L-s				L-s		L-s								◊					○	○	○
	7 PERMANENT ACCESS ROADS		L-s	L-s	L-s	L-s	L-s	L-s			L-l		L-l								◊					◊	○	○
	8 WELL CLUSTER, PHYSCIAL PRESENCE		L-s	L-s	L-s	L-s	L-s		L		L-l		L-l								◊		●			◊		
	9 DRILLING FLUID DISPOSAL, SUMP		L-s	L-s	L-s	L-s	L-s	L-s			L-s		L-s															
	10 PROCESSING FACILITY & FLARE								L	L	L		L								◊					◊		
	11 STAGING SITES & STOCKPILES		L-s		L-s	L-s	L-s	L-s			L-s		L-s								◊		●			◊		
	12 WHARVES & BARGE TRAFFIC																				○		◊	◊			○	○
	13 AIRCRAFT & AIRSTRIPS																				◊	◊	●	◊				
	14 CAMPS		L-s	L-s	L-s						L-s		L-s	◊	○	◊	●	◊	◊	◊			◊	◊		○	○	○
	15 WASTE DISPOSAL													○	○	○	●	○	○	◊						○		
	16 FUEL STORAGE																				○					■		
	17 OFF-DUTY ACTIVITIES																				◊					◊		○

LEVEL OF POTENTIAL IMPACT

BIOTIC

○ = NEGLIGIBLE ● = MODERATE

◊ = MINOR ■ = MAJOR

PHYSICAL

L = LOCALIZED m = MEDIUM-TERM s = SHORT-TERM

R = REGIONAL l = LONG-TERM

BLANKS INDICATE NON-APPLICABILITY OR ADDRESSED ELSEWHERE

method of right-of-way preparation which involves grading as a method of preparation of the travel or work area. Instead of grading, a fill method using snow or snow sprayed with water will be used for right-of-way preparation. Construction of snow roads for the work area of the right-of-way for the winter construction season in the north has been recognized as a technique causing limited environmental impact while at the same time offering good quality travel and work areas.

Two ditching techniques are considered for winter construction in permafrost. Trenchers are efficient and provide a smooth and even ditch bottom. Spoil from trenchers is well suited for backfilling of the ditch. The efficiency of trenchers decreases in cobbles, boulders and frozen abrasive (sand) soils. Therefore, in areas containing large boulders, drilling and blasting of the ditch will be required. Either a trencher or a backhoe can be used to remove the spoil from the ditch. This ditching technique is slower and leaves uneven ditch bottoms which require padding prior to pipe installation. The spoil from blasting operations contains large chunks of frozen soil which are less suited for use as a backfill. Both bedding and padding using selective borrow material might be required in the case of ditch blasting.

3.6.1.1 Geology and Soils

Construction of an onshore gathering system will likely initiate active layer deepening, thaw settlement and localized hydraulic erosion of the right-of-way and immediately adjacent areas. Active layer deepening will probably occur to some degree across the entire right-of-way but will be greatest in areas where the insulative organic cover is most disturbed, such as on pipeline working areas and in spoil placement areas. Where the pipeline right-of-way crosses areas of ground ice, active layer deepening will be accompanied by thaw settlement, especially adjacent to the ditchline. Channelization of runoff by thaw depressions and the ditch berm may result in localized hydraulic erosion especially on the banks of stream channels and at other slope breaks. The potential for hydraulic erosion will probably be greatest where the right-of-way crosses diffuse surface runoff or numerous small streams. On slopes, especially at stream crossings, increased thaw depths and changes in subsurface drainage due to pipeline construction may locally increase the occurrence of slope instabilities.

Surface disturbance to terrain and soil will be minimized by winter construction when surfaces are frozen. Snow roads and snow pads will be constructed to provide temporary right-of-way access and working surfaces, and will minimize disturbances to insulative organic layers. Areas of greatest potential for hydraulic erosion will be avoided where possible during route selection. The following protective and mitigative procedures are proposed for potentially erodible areas. Where cuts are required, measures will be implemented to direct surface water flow across the disturbed area in a controlled fashion, using techniques developed on a site-specific basis. Design specifications will allow for maintenance of natural drainage patterns. Since a low berm will be left over the pipeline to accommodate settlement of the backfill, breaks in the berm will be provided where necessary for drainage across the right-of-way. Portions of the berm and drainage breaks that are exposed to flowing water will be armoured with granular blankets and erosion mats in conjunction with reclamation measures including shrub planting as necessary. The use of dikes, ditches, rock aprons, or settlement ponds will be considered in areas susceptible to excessive erosion. With the application of these mitigative measures, the impacts of thaw settlement and hydraulic erosion are considered LOCALIZED and SHORT-TERM.

Maintenance of slope stability is a major concern, therefore, detailed stability analyses will be conducted prior to construction along all major slopes. Several methods to avoid creating unstable slopes will be implemented as necessary and may include the following: relocation and minor rerouting to avoid potentially unstable slopes; placement of drain pipes and granular filters at the toes of unfrozen slopes to relieve internal pore pressures and increase shearing resistance; slope stabilization by construction of toe berms or buttresses; use of rip-rap or other protective material to protect river and stream banks subject to erosion; deep pipe burial and replacement of weaker soil with granular fill on some slopes; and special designs involving back fill replacement or gravel buttresses to ensure the stability of cuts in ice-rich soils. As a result, slope failures are expected to be small and LOCALIZED and will represent a SHORT-TERM impact.

3.6.1.2 Hydrology and Water Quality

Ditching and construction of a berm over the ditch will interrupt minor surface drainage patterns, especially diffuse runoff and small streams, and may redirect these waters along the right-of-way, with some ponding in level areas. In areas of ice-rich permafrost, thaw settlement along the ditch may locally create shallow, long depressions which would further contribute to channelization along the right-of-way. Subsurface flow may be interrupted and redirected by the trench or the pipe (Owen and Van Eyk, 1975). Hydraulic erosion of the berm materials and of other surfaces as a result of thermal degradation of ice-rich soils may result in increased silt loading of nearby waterbodies. This would occur primarily during periods of high runoff, thus coinciding with normally high sediment loads.

The major factor reducing potential drainage and erosion problems will be winter construction. A drainage and erosion control and reclamation plan will be implemented to minimize potential problems. Other safeguards will include berm breaks and diversion berms to maintain natural drainage patterns and direct runoff away from the right-of-way. Temporary water crossing structures such as ice-bridges and fill will be removed prior to spring freshet. Where necessary, impermeable plugs will be installed to prevent drainage along the trench. A buffer strip of undisturbed land will be maintained, where feasible, along all aquatic systems parallel to the right-of-way. Settling ponds and basins will be used, where feasible, in areas susceptible to excessive erosion. On this basis, the impacts should be LOCALIZED and SHORT-TERM.

3.6.1.3 Atmospheric Environment

Construction equipment used for gathering line ditching, installation, and backfilling will produce low level noise and release small quantities of gaseous and particulate emissions. However, because of the isolated and temporary nature of these activities, effects on air quality will be LOCALIZED and SHORT-TERM.

3.6.1.4 Vegetation

Ditching and backfilling operations will remove vegetation and organic cover from the ditchline and immediately adjacent areas. The total affected area is calculated to be less than 3 km^2 (gathering system is 300 km long and 10 m of the right-of-way is affected) and will be surveyed prior to construction to document the possible presence of any unique or sensitive vegetation communities.

Pipeline construction will interrupt certain surface and subsurface drainage patterns adjacent to the right-of-way, especially in lowland areas with slow, diffuse flow and seepage. These lowland areas are common in the Mackenzie Delta and occur locally within the Tuktoyaktuk Peninsula and Yukon North Slope. Upslope ponding in these areas may cause very localized mortality of shrubs and improved growth of semi-aquatic species, while drying within a downslope shadow zone may result in localized mortality of mosses and sedges.

Ditching and pipe installation will be conducted on a surface of packed snow (known as a 'work pad') in order to reduce disruption of vegetation and organic layers. Some injury of above ground vegetation will likely occur but plant roots and organic layers should only be affected very locally. Above ground vegetation recovery is expected to be rapid. Shallow hydraulic and thermal erosion, which may result from ditching operations, may locally disrupt vegetation on the right-of-way and immediately adjacent areas.

All gathering line construction activities, with the exception of major river and channel crossings, will be conducted in winter when the ground is frozen. This will minimize effects on vegetation. Following construction, the exposed soils will be stabilized to control erosion, and will be fertilized and seeded with species successful in northern revegetation trials (Hardy Associates, 1980). Mulches, erosion control mats, and shrub plantings may be applied as necessary to aid surface stabilization, especially at river and stream crossings. A drainage and erosion control program will be developed which will include designs for water crossing structures, diversion berms, and berm breaks to minimize drainage interruptions. As a result of these and other standard mitigative measures, the impacts of ditching, gathering line installation, and backfilling on vegetation should be LOCALIZED and SHORT-TERM.

3.6.1.5 Mammals

Several aspects of the impacts of gathering line ditching, installation, and backfilling on mammals will be similar to the impacts of site preparation and construction (Section 3.4.1.4). Some wildlife habitat will be altered although it will not be significant in relation to the amount available. Some beaver ponds may be drained if ditching proceeds through beaver dams. Water flow may be obstructed by backfill material, possibly resulting in ponding or channelization of water. Resulting changes in vegetation communities may, in turn, lead to alterations in the associated mammal community. Disturbance from machinery and human activity associated with pipelining will cause short-term avoidance of an area surrounding the site of the activity, if the area is being used by animals at that time. The open ditch and strung pipe may result in a temporary barrier to movements of reindeer and moose. Smaller mammals may fall into the open ditch and be unable to escape.

Mitigative measures designed to minimize these impacts include the following. Drainage control measures will be carefully designed to reduce alteration of habitat in the vicinity of the right-of-way. Care will be exercised to avoid destruction of beaver dams and to avoid drainage of ponds used by overwintering beaver and muskrat. The excavated trench at any particular location will normally not remain open for more than a few days to minimize disruption of wildlife movements. Strung pipe will be placed at an angle to allow passage of wildlife between pipe sections. Overall, the impact of gathering line ditching and installation on mammals is considered to be NEGLIGIBLE.

3.6.1.6 Aquatic Resources

All pipeline installations are scheduled for winter completion and the associated surface disturbance may result in localized soil erosion in the ensuing open water period before reclamation and re-seeding procedures become effective. In the vicinity of stream crossings, this erosion may result in sedimentation of downstream areas. A discussion of the effects of sediments on aquatic organisms and their recovery is provided in Section 3.4.1.6.

Pipeline ditching will involve excavation of a ditch 0.5 to 1 m wide. Except on slopes beside water courses, erosion from the ditchline will normally be filtered through vegetation before entering a watercourse. Effective slope stabilization, ditch plugs, reseeding, and berms to divert surface runoff into adjacent vegetation, will greatly reduce the amount of sediment reaching waterbodies.

Any sedimentation resulting from erosion along gathering system rights-of-way is anticipated to be both local and short-term. Sedimentation of waterbodies will be greatest immediately following breakup in the first year after pipeline burial. With an effective revegetation plan and an aggressive program to repair or stabilize areas of active erosion, little sedimentation should occur after the first one or two open water seasons. After sediment introductions cease, the recovery of lower trophic levels will be rapid. Adult fish will not be affected by local sediment introductions but, in areas where sediments enter water used as spawning habitat, spawning success may be reduced for one to two seasons. Because gathering line ditching, installation, and backfilling are scheduled for the winter months, no specific measures other than general erosion control measures are required. The effects of sediment introduction resulting from ditching, installation, and backfilling on all aquatic trophic levels are anticipated to range from NEGLIGIBLE to MINOR.

3.6.2 GATHERING SYSTEM TESTING AND FLUID DISPOSAL

Once a gathering system is installed, sections of the line will be individually pressure tested to verify their integrity. A mixture of warm water and water with an addition of freezing-point depressant will be used as a testing solution. Water withdrawal will be regulated so as not to affect other industrial, domestic or recreational interests, nor fishing, trapping, or wildlife resources. A water withdrawal plan will be designed and discussed with the appropriate government agencies prior to final application. The test solution containing freezing point depressant will be collected, reused, and disposed of at approved disposal wells. Following the completion of testing, each section will be tied in.

3.6.2.1 Geology and Soils

Spills of the testing fluid (usually water-methanol) could occur during handling or pressure testing. Previous studies (Hardy Associates, 1980) have shown that small spills (less than 9 L/m^2 of 20% methanol) had no detectable effect on permafrost and that larger spills, which may kill vegetation, cause increases in the active layer thickness. A contingency plan will be developed during the final design stage to deal with methanol spills. The plan will consist of personnel education and awareness programs; and surveillance, detection, containment, clean-up, and reclamation procedures. The impact of testing is considered LOCALIZED and SHORT-TERM.

3.6.2.2 Hydrology and Water Quality

Accidental spills of the test fluid may pollute waterbodies to levels which are toxic to aquatic organisms (McMahon and Cartier, 1974). Toxic liquid spill contingency measures will be implemented to minimize the effects of any spills, particularly if testing fluids contain methanol. Hydrostatic testing procedures and disposal of the testing fluids will be done in accordance with existing regulations and in consultation with appropriate government agencies. The potential impacts of testing are considered LOCALIZED and SHORT-TERM.

3.6.2.3 Vegetation

Spills of a water-methanol solution could occur during handling or pressure testing. Previous studies (Hardy Associates, 1980) have shown that small spills (less than 9 L/m^2 of 20% methanol) had little effect, However, larger spills may kill vegetation, and result in affected areas showing little vegetation recovery within five years (Plate 3.6-1). Spills of warm water testing fluid may affect soil and water microflora due to the presence of chemical agents to control pipeline corrosion. In the event of a spill, the potential impacts on vegetation will be minimized by measures to detect and contain the spill and reclaim the affected area. Overall, the potential impact of water-methanol spills is considered LOCALIZED and SHORT-TERM.

3.6.2.4 Mammals

Disposal of water may have local adverse effects on small mammals if large quantities are spilled on the ground. This may cause the death of some small mammals by drowning or exposure if their subnivean (under-snow) habitat is flooded in winter. Water for testing will be withdrawn from ponds in quantities that will not adversely affect overwintering beaver and muskrat, and non-toxic testing fluid will be directed to ponds or streams, thus the potential impacts will be NEGLIGIBLE.

3.6.2.5 Aquatic Resources

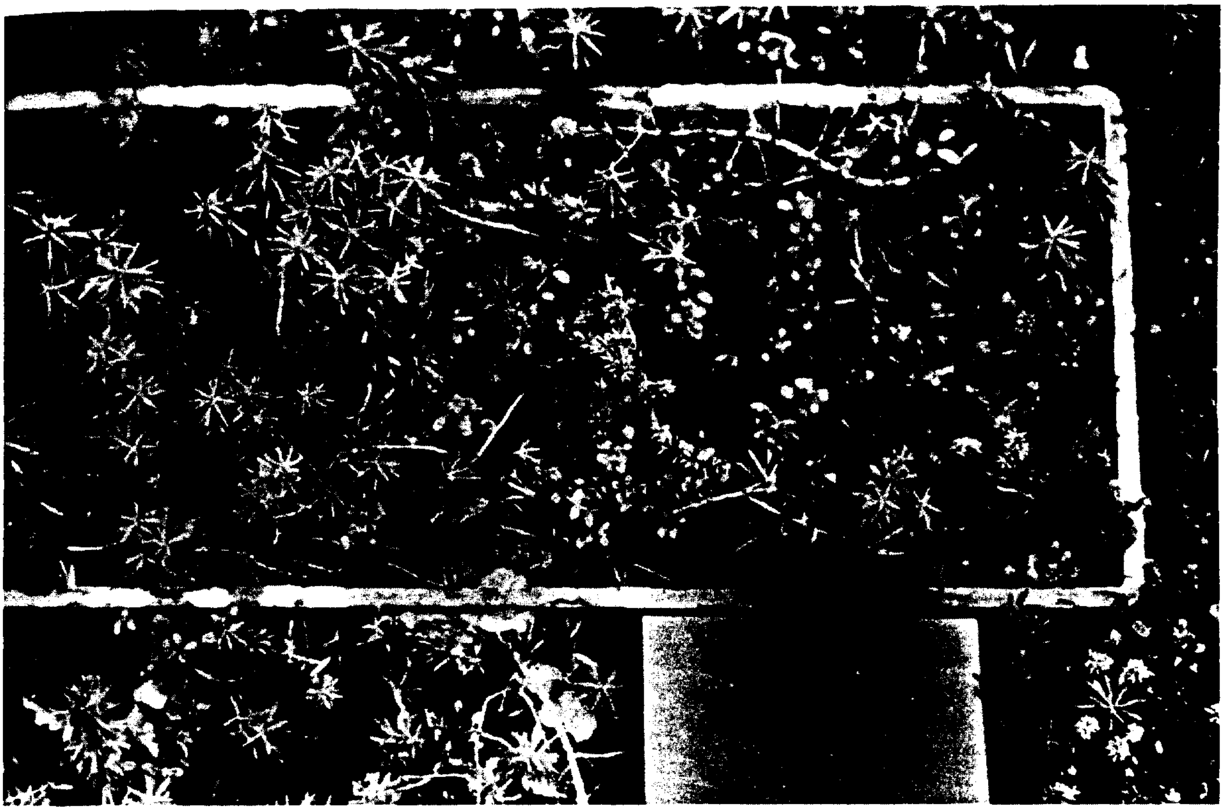
Because the use of methanol was proposed for hydrostatic testing in the Canadian Arctic Gas Pipeline, studies were conducted to determine the potential toxicity of methanol to aquatic resources (McMahon and Cartier, 1974; Craig, 1977; McCart *et al.*, 1977). Methanol is now known to have toxic effects on all stages in the life history of fish and, in sufficient concentrations, on many species of benthic invertebrates. Concentrations of 2.5% methanol are lethal to both Arctic char and grayling fry, and concentrations of only 1.0% delay or prevent hatching of fish eggs.

The concentration of methanol required for hydrostatic testing has not yet been determined but it will be necessary to transport the undiluted product to the pipeline injection point and the concentration used for actual testing will certainly exceed the 2.5% known to be toxic to char and grayling fry. Because methanol is highly soluble in water, any spill entering a major waterbody will be quickly diluted. Spills reaching smaller streams or lakes are of greater concern since dilution rates will be much slower and toxic effects more pronounced.

Methanol spills into important fish habitat, or into areas where concentrations of migrating fish are present, could result in some localized, short-term mortality. Feeding adults and juveniles are usually widely dispersed, making it unlikely a spill would affect more than incidental numbers; however, large concentrations of fish, either migrating toward or gathered within spawning, rearing, and overwintering habitats, may be adversely affected in some instances.

Methanol spills will have the greatest effect if released into spring-fed streams or lakes supporting isolated populations of Arctic char, whitefish, ciscoes, gray-

a



b

PLATE 3.6-1 *Methanol spill study, Inuvik. A comparison of vegetation in a control plot (a) and (b) a plot treated with 36 L of fluid/m², 6 years after treatment. Source: Hardy Associates (1980).*

ling, and lake trout. However, in natural environments, methanol dilutes, degrades, and evaporates rapidly, and its effects will be short-term. Even in the most confined spill site, toxic effects would not be expected to last longer than a few weeks. Recovery will depend on the numbers of fish affected, the species involved, and the location and timing of the spill. Lower trophic levels will recover within a single generation as will most fish populations. If severely depleted, these populations will not restock rapidly from outside areas and may required several generations to recover.

Several mitigative measures will contribute to greatly reducing the effects of methanol spills on aquatic resources. Since methanol testing will only occur during the winter months when most streams are frozen, the risk of a major spill entering water with major concentrations of overwintering fish is low. Should such a spill occur, a substantial fish kill could result, requiring up to an entire generation for recovery through recruitment and reinvasion. In most areas, the frozen surface of receiving waters will permit cleanup of spilled methanol and both lower trophic levels and fish will remain unaffected. The impacts of testing fluid spills is considered to be NEGLIGIBLE on lower trophic levels (because of their rapid recovery rate and cosmopolitan distribution) and MINOR on fish populations (because of their sensitivity in certain habitats).

Hydrostatic testing of the gathering line will require water withdrawals from sources approved by regulatory agencies. Where water availability is low, special measures, including shunting water ahead to the next test section for re-use, may be necessary. Testing is scheduled for winter months when water availability in many Tuktoyaktuk Peninsula streams is low. Overwintering habitat for fish in many of these waterbodies is generally limited, and fish are often concentrated in a few areas. Since water withdrawals from overwintering areas that already have low water availability could result in high mortalities of fish and their eggs, these areas should be avoided. Assuming that adequate controls are placed on sources and rates of winter water withdrawals and disposal methods, the impacts of water use will be NEGLIGIBLE.

3.6.3 STREAM AND CHANNEL CROSSINGS

Oil and gas gathering lines inland from the Beaufort Sea coast will cross intermittent waterways, streams, and major channels in the Mackenzie Delta and Tuktoyaktuk Peninsula. The bottoms of rivers and channels in the region remain unfrozen throughout the year and the gathering system will operate at temperatures at or below the freezing point of water. To prevent the formation of a frozen "bulb" around the pipe, and frost heave of silt/clay river sediments, the pipe will be provided with thermal insulation. Negative buoyancy and mechanical protection will be provided by a coating of concrete and wire mesh. Deep-burial of the pipe in the stream bottom will be extended into either bank to ensure that it does not become exposed due to lateral bank erosion. Decisions regarding the location of all river crossings will not be made until site specific field evaluations have been made. Major crossings will take place in summer. Most smaller or intermittent streams which are generally frozen to the bottom will be crossed in winter using standard crossing design; hence many terrain and habitat impacts can be avoided.

3.6.3.1 Geology and Soils

The most erodible terrain along gathering line rights-of-way will commonly be found at those crossings where approach slopes are relatively steep. Construction may cause hydraulic erosion and slope instabilities, especially where cut grading is necessary. Summer construction at crossings of the Mackenzie River channels presents the greatest potential for erosion. Erosion at stream crossings will be minimized by careful route selection to avoid steep slopes and by minimizing grading. Mitigative measures will be developed on a site specific basis to control surface water flow across all cuts. Normal drainage patterns through fills will be maintained and drainage and erosion control measures, including installation of ditch plugs, select backfill, diversion berms, berm breaks, and dikes, will be used as necessary to ensure slope stability. Appropriate structures such as rip-rap and gabions will be installed where necessary to stabilize and protect banks from river and ice erosion. The impact of stream crossings on terrain and soils is expected to be LOCALIZED and SHORT-TERM.

3.6.3.2 Hydrology and Water Quality

During construction, small streams may be blocked by ice bridges or other debris. In-stream construction activities, particularly on the major crossings, may result in temporary erosion and downstream siltation. Winter construction at most crossings, plus judicious route selection to avoid unstable slopes, will minimize effects on streams. The pipeline will be buried in the stream bed so that stream scour or changes in the river course cannot affect the integrity of the pipeline. A drainage and erosion control plan, including reclamation, will be applied following construction activities. These plans will include measures to maintain downstream flow at water crossing structures. In-stream construction activities will be minimized as much as possible. Ice bridges, as well as fill, will be breached prior to the spring freshet. Natural drainage will be maintained across the right-of-way with berm breaks and diversion ditches. Stream banks will be stabilized, and where feasible, toes of potentially unstable banks will be armored to prevent water and ice erosion. Water crossings will be monitored on a regular basis following the construction phase and a preventative maintenance program will be implemented. The impact of stream crossings on hydrology and water quality is considered LOCALIZED AND SHORT-TERM.

3.6.3.3 Vegetation

Impacts on vegetation will likely result from clearing of shrubs, loss of vegetation through excavation of banks and, at major river and channel crossings, winter placement of granular fill over herbaceous vegetation. Excavation of banks may initiate localized hydraulic and thermal erosion which would disturb vegetation and affect revegetation success.

Drainage and erosion control measures for stream crossings will include special measures, such as hand clearing, use of special backfill material, ditch plugs, pipe insulation, berms, and berm breaks to stabilize slopes and minimize erosion and thermal degradation. These measures will be augmented by surface reclamation measures such as topsoil salvage, and use of erosion control mats, mulches, tree and shrub plantings, fertilizers and seed mixes. Stream crossings will be monitored continually following construction, and will be maintained as necessary. These stabilization measures are expected to encourage a return of natural vegetation. Overall, the impact of stream crossings on vegetation is considered LOCALIZED and SHORT-TERM.

3.6.3.4 Mammals

Stream crossings will cause some local habitat alteration and disturbance from construction equipment and human activity. Habitat in the vicinity of streams is often of greater value to wildlife than is adjacent upland habitat. Semi-aquatic furbearers such as beaver and muskrat live in slow moving waterbodies and feed on plants bordering them, while ungulates may depend on browse which is, characteristically, of better quality near streams. Stream crossing construction practices are designed to minimize changes to drainage patterns and habitat. Hence loss of habitat for furbearers, moose, and reindeer will be NEGLIGIBLE.

Disturbance in river valleys may also temporarily disrupt local movements of animals along the valley. Reclamation by shrub planting to replace riparian vegetation removed during construction will enhance habitat. Impacts on local aquatic furbearers may approach MINOR while impacts on other mammals will likely be NEGLIGIBLE.

3.6.3.5 Birds

In the western outer Mackenzie Delta, the construction of a channel crossing to the Adgo area in the summer months could cause a local, MINOR disturbance to waterfowl flocks.

3.6.3.6 Aquatic Resources

Stream crossings will cause some sedimentation, may trap some fish or cause temporary migration barriers and will modify local aquatic habitats.

(a) Sedimentation

Installation of gathering lines at stream crossings will result in some sedimentation. Installation at the Mackenzie River and other major channels will occur during summer when natural suspended sediment concentrations are already extremely high. A summary of the effects of suspended sediments on aquatic resources is provided in Section 3.4.1.6.

Since most other streams will be frozen to the bottom during installation, sedimentation in these streams will occur only as a result of incidental erosion from disturbed substrates and adjacent stream banks. Sedimentation will occur during spring freshet when natural sediment loads are high and many streams are subject to considerable scour. Properly stabilized stream crossings will clear up shortly after breakup and crossings will contribute little to the sediment load thereafter. During the second and third breakup seasons following construction, the banks of some stream crossings may have a tendency to erode. These problem areas will be identified during routine inspections of the pipeline, and measures will be taken to stabilize the eroding surfaces with rip-rap or surface and subsurface drainage control. With an effective erosion control program, however, little stream sedimentation is anticipated after the first two to three years of operation.

Sedimentation will have its greatest effect on streams which normally remain clear at breakup. Examples of such streams are spring-fed tributaries, lake-fed systems, or small tundra streams crossing relatively stable terrain. These habitats, which may be affected in the immediate vicinity of newly installed crossings, often serve as spawning areas for spring spawning species such as Arctic grayling and northern pike. The widespread distribution of these species, however, and the ready availability of alternate spawning habitat considerably reduces the possibility of adverse effects. Since most substrates will be scoured clean of deposited sediments and will not be subject to further erosion during the fall and winter months, fall-spawning species are unlikely to be affected.

Sedimentation from stream crossings may result in local reductions in the reproductive success of fish species and in decreased productivity of certain lower trophic levels, particularly algae and benthic invertebrates. Because of recruitment and restocking from unaffected areas, recovery will be short-term, requiring less that a single generation for all trophic levels.

In addition to the mitigative measures detailed in Seciton 3.4.1.5, the effects of sedimentation due to stream crossing installation will be minimized in the following ways. Prior to breakup, stream substrates and banks will be returned to their original configuration and measures taken to ensure substrate and bank stability. Spoils will not be left piled on the ice cover of streams. In consultation with the Department of Fisheries and Oceans, streams and channels capable of supporting overwintering fish will be identified. Streams will be crossed at times and using techniques to minimize impacts on fish resources. Stream crossings will be monitored after installation to identify those crossings which require additional stabilization and maintenance. Sedimentation at stream crossings will have local short-term effects on all aquatic trophic levels. Although recovery will be short-term, stream crossings will affect a large number of watercourses over a broad geographic area. Considering the widespread distribution of local effects and assuming proposed mitigative measures are adhered to, the impact of sedimentation at stream crossings on all aquatic trophic levels will be MINOR.

(b) Entrapment and Migration Barriers

Experience with the Alyeska Pipeline system suggests that installation of stream crossings during the winter months may result in problems with fish entrapment and migratory barriers after breakup. Under winter conditions, locating very small stream channels and restoring their original hydraulic configuration after construction is often a difficult task. Failure to achieve these objectives may lead to restriction in the free movements of fish, particularly during low river flows.

Blockages may be created by leaving deep ruts through stream channels, by depositing coarse material in streams which may cause them to dry up during low flows, by re-routing streams through impassable barriers, or by creating impassable water currents for fish. Along the Alyeska Pipeline, all of these effects have been observed in areas constructed during the winter months (Gustafson, 1977). On major streams, the creation of obstructions to fish passage are considered unlikely since no documentation of such an obstruction resulting from pipeline installation exists.

In the Beaufort Sea onshore region, blockages in small tundra streams, at the inlets and outlets of lakes, and in spring-fed streams may prevent access to spawning and overwintering habitat. Also, blockages may interfere with the downstream movement of young-of-year, restrict access to important summer feeding habitat, or prevent fish from escaping small streams as flows reduce in late summer or at freeze-up. Two common phenomena may result from the creation of barriers: prevention of access to important habitat; and entrapment and mortality of fish unable to escape declining discharges. Most sensitive are: small streams and those used by large numbers of whitefish and ciscoes as access routes to feeding and overwintering habitats (e.g. Parlaiyut Creek on the Tuktoyaktuk Peninsula), and areas of restricted spawning and overwintering habitat in the vicinity of groundwater sources used by Arctic char, broad whitefish, and round whitefish (e.g. Fish Creek) (Volume 3A).

Blockages resulting from interference with natural hydraulic regimes may create barriers to fish migration ranging from "fish traps" which may kill only a small number of fish during unusual low water years, to complete year-round barriers which eliminate large areas of upstream habitat. Such blockages, if they occur, will be removed. Recovery of local populations will depend on the duration of the blockage, its location, and the species affected. For example, if a stream along the Tuktoyaktuk Peninsula was blocked for several years, access to upstream habitats might be restricted for as many as a million or more fish. The consequence could be a considerable depletion of local fish stocks, requiring several generations for restocking and recruitment to completely restore the run. If a blockage occurred near the mouth of a small spring-fed tributary serving as a spawning and overwintering area for anadromous Arctic char, substantial numbers of spawners might be lost. Recovery in such a case might take one or more generations. However, a blockage on a small tundra stream serving only as a feeding area for Arctic grayling would, as a result of rapid restocking from outside areas, recover in a much shorter time.

Blockage and entrapment effects will be greatly reduced or eliminated through the use of the following mitigative measures: small stream channels scheduled for winter construction will be accurately located prior to freeze-up; the Department of Fisheries and Oceans will be consulted regarding streams which require fish passage; to ensure the original stream configuration is maintained, stream channels will be reconstructed prior to breakup; during operations, regular inspections will be made to ensure continuous fish passage is possible throughout the open water season; extremely sensitive habitats will be avoided where feasible. The effects of stream crossing installation on fish movements in the region will be MINOR.

(c) Habitat Modification

Buried pipeline installation at stream crossings will result in localized changes in stream configuration and stream substrates. Such changes will include removal of boulders in the stream, sedimentation of downstream areas, removal of bank vegetation, and modification of bank configuration, all of which will affect fish habitat. In many instances, the effects will be detrimental to fish but in some instances, the effects may prove beneficial. Generally, the area disturbed by installation of a buried stream crossing is small, representing a very low percentage of total available habitat. In addition, careful route selection for gathering lines will direct stream crossings to less sensitive habitats where the effect of habitat modification will be reduced.

In most areas, natural hydraulic forces will return stream substrates and banks to their original configuration within a few years. As a result, the effects of most habitat modification will be relatively short-term, with recovery of local fish populations within a single generation. Where permanent stream training structures are necessary, habitat modification will be permanent, as will any effects on fish distribution. In all cases, the area affected by permanent stream modifications will represent a small percentage of the total available habitat.

Mitigative measures designed to minimize habitat modifications will include: minimizing the size of the disturbed area within streams (e.g., crossing streams at right angles); avoiding areas of sensitive fish habitat wherever feasible; restoration of stream channels and stream banks to a condition as close as possible to the original configuration. Given these mitigative measures, and the relatively small amount of habitat affected by stream crossing installation, the effects of habitat modification on fish are anticipated to be NEGLIGIBLE.

3.6.4 BURIED GATHERING LINES

Oil gathering lines used to transport processed hydrocarbons to major transportation systems will usually be buried. Using conventional pipeline construction techniques, the lines will be buried with a minimum of one metre of overburden, and will have weights attached to keep them negatively buoyant in high water-table areas. An anti-corrosive coating will be applied to protect pipeline integrity. In some sections, strips of metal acting as sacrificial anodes will be laid parallel to the line to protect it from electrolytic corrosion caused by electric currents between the gathering line and the soil.

Discussions of impacts from buried pipelines on geology and soils, hydrology and water quality, vegetation, and mammals are provided in Section 5.2.7. In the Beaufort Sea-Mackenzie Delta region, the right-of-way of buried gathering lines will probably not be detectable by wildlife except in areas where vegetation cover is sufficiently high to result in a visible corridor along the right-of-way. For this reason, buried pipelines are expected to have a NEGLIGIBLE impact on wildlife in this area. Summer monitoring and required maintenance of the buried pipeline may have a MINOR impact on birds, depending on the timing, frequency, and duration of activities.

3.6.5 ELEVATED PIPELINES

Flowlines and reinjection lines will be confined to production and processing areas and will likely be elevated for geotechnical reasons. Impacts to wildlife populations are considered NEGLIGIBLE. A discussion of the impacts of elevated pipelines on geology and soils, vegetation, and mammals is provided in Section 5.2.6. Air and ground monitoring and required maintenance of elevated lines during summer could have a MINOR impact on birds, depending on the frequency and duration of activities.

3.6.6 TEMPORARY ACCESS ROADS

Temporary access roads include those facilities constructed from snow and ice, together with interim bridges, all of which are generally used only in winter (Plate 3.6-2). Snow and ice roads will be constructed to provide access to construction sites, and to minimize effects of construction or maintenance traffic on permafrost. Snow will be collected by snow fences, mined from nearby drifts, or manufactured from water drawn from approved sources. In the event that compaction does not produce a sufficiently hard surface, the roads will be strengthened by the addition of water.

3.6.6.1 Geology and Soils

Previous studies (Adam and Hernandez, 1977; Hardy Associates, 1980) indicate that snow and ice roads

PLATE 3.6-2 *Winter ice roads provide ready access to production or exploration locations, granular borrow, or other sites throughout the Mackenzie Delta and nearshore Beaufort Sea.*

cause relatively little permafrost degradation provided they are properly constructed and maintained. Small increases in active layer depths and some localized thaw settlement may occur, but considering that Arctic engineering practices will be used, impacts of temporary access roads on geology and soils are considered LOCALIZED and SHORT-TERM.

3.6.6.2 Hydrology and Water Quality

Because temporary roads will be constructed with snow and/or water drawn from approved sites and because these sources will have sufficient volume that aquatic habitat will not be affected, the impacts are considered LOCALIZED and SHORT-TERM.

3.6.6.3 Vegetation

Snow and ice roads will be used for temporary access along the field gathering pipeline system. Previous studies (Hernandez, 1973; Adam and Hernandez, 1977; Hardy Associates, 1980) indicate that use of snow and ice roads results in no long-term impacts on vegetation provided they are properly built and maintained (Plate 3.6-3). Short-term effects include initial loss of above ground vegetation cover, but roots are not damaged and mineral soils are rarely exposed. As a result, above ground vegetation recovers quickly. Impacts of snow and ice roads on vegetation will be LOCALIZED and SHORT-TERM.

3.6.6.4 Mammals

The following provides a general discussion of the possible impacts of roads on mammals. Roads, whether permanent or temporary, may affect wildlife populations through habitat alteration, disturbance from traffic, and the provision of increased access for hunters and trappers. Habitat alteration by snow and ice roads for most wildlife is negligible. Since the local subnivean (under-snow) environment used by small mammals is destroyed, there is some temporary habitat loss. Habitat alteration is considered to be of little consequence because of widespread distribution of small mammals and the limited area utilized by temporary access roads.

Traffic on roads may affect ungulate populations as a result of disturbance or collisions. Disturbance may in turn cause displacement of ungulates or act as a barrier to their movements. Caribou observed by Surrendi and DeBock (1976) approached the Dempster Highway cautiously and movements were often interrupted or deflected. Slow-moving vehicles caused

a

b

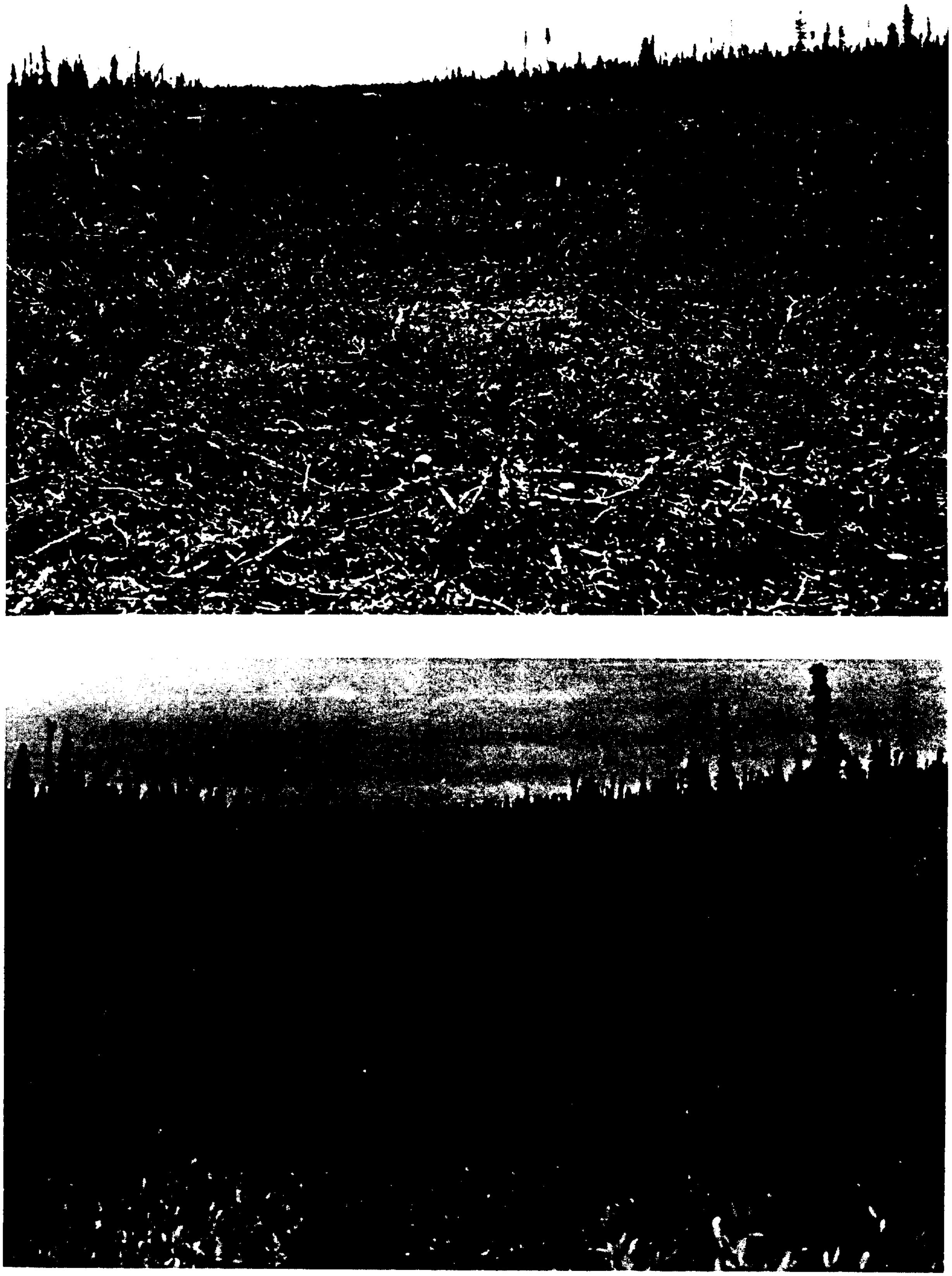


PLATE 3.6-3 *Snow road study, Inuvik. Snow road right-of-way in open black spruce-heath vegetation the first year (a) and sixth year (b) following use. Source: Hardy Associates (1980).*

caribou to avoid the road, while faster movements produced a panic reaction and retreat. Horejsi (1981) observed that caribou reacted to the rate of approach of vehicles, thus reacting to looming, rather than to the movement itself. In most cases caribou were seen to flee for a short time. One of the preliminary conclusions of a three-year study on caribou and the Dempster Highway, conducted by the Yukon Government and the Canadian Wildlife Service, was that there was little evidence to indicate that the movement of the herd itself was affected by the road (Russell, 1982). The study showed that caribou crossed the road, even where banks are steep; in fact, the caribou have been observed loafing on the road and sometimes travelling along it. The study also concluded that the greatest concern related to the highway was the access it provided to hunters. Studies of the Central Arctic caribou herd near the Alyeska Pipeline showed a progressive avoidance of the haul road by cow-calf groups from 1975 to 1978 with some apparent recovery beginning to occur in 1979 (Cameron and Whitten, 1976, 1977, 1978, 1979, 1980). Further evidence that accommodation does occur can be seen in the National Parks where, in the absence of harassment or hunting, large ungulates generally pay little attention to vehicular traffic.

With regard to the impact of traffic on ungulates other than caribou, some information is available on deer but there is very little on moose. In some areas, deer have been displaced by snowmobile activity (Baldwin and Stoddard, 1973; Dorrance *et al.*, 1975) and by highway traffic (Smith, 1973; Reilly and Green, 1974).

Contrasting the displacement effect of roads, there is also evidence that ungulates may be attracted to roads during the winter because of favourable snow conditions and increased forage availability. McCourt *et al.* (1974) noted that caribou of the Porcupine herd appear to make concentrated use of cutlines and winter roads, where vehicular use had resulted in shallower, more compacted snow. Similarly, Klein (1971) stated that reindeer appeared to be attracted to roads and railway clearings in Scandinavia. In British Columbia, moose showed a strong preference in late winter for forest edge habitats created by an extensive network of seismic lines, roads, pipeline rights-of-way, and agricultural clearings in river valleys (Silver, 1976).

This attraction of ungulates to roads contributes to a second possible impact of the operation, namely vehicle-mammal collisions. Studies of deer mortality in the United States have shown that the number of collisions with ungulates tends to increase with traffic volume, traffic speed (Hancock, 1963; Allen and McCullough, 1976; Goodwin and Ward, 1976), and the number of ungulates along the road (Bellis and Graves, 1971; Carbaugh *et al.*, 1975; Allen and McCullough, 1976). Substantial numbers of deer, elk, moose, and bighorn sheep are killed each year by vehicles and trains in Banff National Park (Parks Canada, 1982). Road kills were, however, relatively infrequent during construction of the Alyeska Pipeline.

Little information is available on the impact of roads and associated traffic on mammals other than ungulates. In one study which examined the distribution of furbearers adjacent to an interstate highway in Maine (Ferris *et al.*, 1978), the distribution of red squirrel, snowshoe hare, and weasel did not differ significantly in relation to the distance from the highway. The evidence indicated that fishers may avoid the area within 200 m of the highway, while red foxes and coyotes appeared to be more common near the highway. Like ungulates, bears, furbearers, and small mammals are often killed by vehicles on roads. In Banff National Park, there are records of considerable numbers of these animals being killed on the highway (Parks Canada, 1982).

Providing access into previously inaccessible areas creates possible impacts related to increased harvest of wildlife, mainly ungulates and furbearing mammals. Past history has shown that the completion of a development, such as a pipeline gathering system or shorebase, may result in improved access to the area. Facilities such as access roads and rights-of-way, together with increased public awareness of the area, may encourage tourism and outdoor recreational activities. This may cause reduced control on the number of hunters within an area or increased disturbance caused by encroachment of recreational activities into once far-removed habitat. In many areas where a road has been opened up into caribou range, population declines due to hunting have resulted (Skoog, 1956; Cowan, 1972; Lent, 1975a, b; Scott, 1975; Weeden, 1975; Mossop, 1976).

Caribou are extremely vulnerable to hunting: they live in the open, have traditional and generally predictable movements, do not perceive danger at great distances, and, even under continual harassment, do not appear to become more wary towards man. The decline in caribou numbers in North America has been attributed to increased human hunting coupled with increased natural predation (Bergerud, 1974a). It has been suggested that the total disappearance of caribou from the Seward Peninsula and Lower Yukon in the 19th century was due to heavy human hunting (Lent, 1966; Skoog, 1968).

Increased access will also increase hunting pressures on other ungulates such as moose. Lynch (1973) reported 80% of hunter effort and 23% of total moose kills occurred within 1.6 km of a road in northern Alberta. In British Columbia, ranges previously inaccessible experienced declines in moose population after road construction into the area (Murray, 1974). The problem of over-harvest is compounded for populations subjected to wolf predation (Haber *et al.*, 1976; Gasaway *et al.*, 1977). As with ungulates, grizzly bears can also be expected to receive greater hunting pressure due to increased access. Kucera (1974) suggested that grizzlies would eventually be exterminated from any area that became populated by people as a result of any type of development. In the case of the Mackenzie Delta area, this has already occurred to some extent, due to local hunting and efforts to protect the reindeer herds.

Roads may also result in changes in the traditional fur harvesting pattern of the area. Because of their high reproductive capability, however, muskrat and Arctic fox are not particularly vulnerable to over-harvesting. Provision of increased access will be minimized by the use of existing rights-of-way wherever possible, by the use of existing transportation routes including Mackenzie River channels, and by the fact that many roads (snow and ice roads) will be temporary. The effects of increased access on patterns of harvest of big game and furbearing mammals can be controlled with proper management of these resources.

To reduce impacts of the roads themselves, routes will be planned to minimize the crossing of critical wildlife habitat. Movements of ground vehicles will be limited to designated access roads, ancillary facility sites, and right-of-way boundaries. When mammals are encountered by vehicles, drivers will allow animals to move off the road. Existing access roads will be used wherever possible to minimize access into previously inaccessible areas. No privately owned firearms will be permitted at project facilities. Sealed firearms may be issued to work party heads when operations are being conducted in areas where dangers such as bear problems exist. Use of firearms will be permitted only in cases of direct risk to human life. A report to the appropriate government and/or company authority will be required in all cases where the seal on a firearm is broken. Development facilities will not be permitted to be used as a base of operation for hunting or trapping. With the application of appropriate mitigative measures and government wildlife management and regulatory controls, the impacts to mammals resulting from roads, in general, and in this case, access roads, can be maintained to a MINOR level.

3.6.6.5 Birds

NEGLIGIBLE impacts on birds are to be expected if the use of temporary access roads is limited to the winter period, which will normally be the case.

3.6.6.6 Aquatic Resources

Construction of temporary winter roads involves compaction of snow to the density required to support vehicles, and, where the proper densities cannot be achieved, by increasing road strength by applying water. Assuming that adequate controls are placed on sources and withdrawal rates, the impact of water use for temporary roads on aquatic resources will be NEGLIGIBLE.

3.6.7 PERMANENT ACCESS ROADS

In the Beaufort Sea onshore region, permanent roads may eventually connect Inuvik to Tuktoyaktuk or Fort McPherson to the Yukon North Slope. Industry-only permanent access roads would be located at production fields to link well clusters with process plants, stockpiles, airstrips, and docks. No permanent access roads would parallel onshore oil or gas gathering lines. Permanent roads will be built in accordance with standard Arctic construction procedures which are intended, amongst other things, to maintain terrain stability and drainage patterns wherever possible. The successful use of these procedures will avoid secondary environmental effects such as stream siltation and unnecessary habitat or vegetation disruption. Guidelines for the construction of northern roads to minimize disturbances to permafrost, terrain, vegetation, and fisheries are provided by Curran and Etter (1976). The effects of permanent roads on the environment will in some ways be similar to those discussed previously for temporary access roads. Section 3.5.3.2 examines the possible impacts of the proposed all-weather roads from a proposed quarry at Mount Sedgewick to the Yukon coast, and from there to the Dempster Highway.

3.6.7.1 Geology and Soils

Permanent access roads may cause LOCALIZED and SHORT-TERM alterations to surface and subsurface drainage patterns resulting in shallow thaw settlement and surface erosion. The extent and magnitude of these impacts are expected to be minimal due to the short distances involved and the flexibility in route location. In addition, these impacts will be reduced by implementation of drainage and erosion control and surface reclamation measures.

3.6.7.2 Hydrology and Water Quality

Permanent access roads may interrupt minor drainage systems, including unchannelized flow and very small streams, resulting in localized upslope ponding. Roads may block or interrupt small streams due to inadequate placement of crossing structures or accumulation of debris. However, the appropriate spacing of bridges or culverts will limit areas and volumes of ponding and therefore permanent road-related impacts on the hydrology of the region will be generally LOCALIZED and SHORT-TERM.

3.6.7.3 Vegetation

Aside from the permanent removal of vegetation, roads can alter surface and subsurface drainage patterns. Where roads cross marshy lowland or tundra, localized upslope ponding may cause drowning of shrubs and improved growth of semi-aquatic species. Likewise, downslope drying may result in improved growth of shrubs. After construction, the exposed soils and ground surfaces not required for traffic will be stabilized and revegetated to control erosion. Drainage and erosion control measures, including culverts, berms and berm breaks, will be used to stabilize road surfaces and reestablish major drainage courses. Reclamation procedures including the use of seed, fertilizer, shrub plantings, mulches and erosion control mats, will be applied as necessary to help stabilize surfaces not receiving traffic. The overall effects of permanent roads on roadside vegetation will generally be LOCALIZED and LONG-TERM.

3.6.7.4 Mammals

Possible impacts of permanent access roads on wildlife are similar to those discussed for temporary access roads (Section 3.6.6.4). Mitigative measures applied to reduce impacts of temporary access roads will also be applied to permanent access roads. With appropriate regulatory controls on hunting, it should be possible to maintain impacts on all mammals in the area at the MINOR level.

3.6.7.5 Birds

Impacts from activities along roads on birds will result mainly from the movement of vehicles and people and the accompanying noise levels. Some temporary avoidance of habitats along road margins by birds can be expected between May 1 to Sept. 30. There will be some effect from increased access provided for hunters. The locations of waterfowl staging, nesting, and molting areas and raptor nest-sites will be considered in the final siting of permanent access roads and the facilities they connect. Monitoring will establish the need for traffic limitations on a site-specific basis. With appropriate restrictions, impacts from permanent access roads on birds can generally be maintained to the MINOR level.

3.6.7.6 Aquatic Resources

Impacts from permanent access roads on aquatic resources include fish passage obstruction and sedimentation (discussed as follows) and increased recreational fishing (discussed in Section 5.3.10.2).

(a) Fish Passage

Whenever fish-bearing streams are encountered, permanent access roads will require provision for fish movements. Depending on the timing and location, blocking watercourses that support fish could result in a wide range of effects, including entrapment, loss of feeding habitat, loss of spawning and overwintering areas, and concentration of fish in less desirable habitats. Morehouse *et al.* (1978) reported that fish passage barriers were one of the most common problems associated with construction of the Alyeska Pipeline. For this reason, all roads through fishbearing streams must include provision for fish passage through either culverts or bridges. Low water crossings (a type of stream ford) in conjunction with the Alyeska Pipeline caused a number of problems (outwashes, siltation) for fish passage (Gustafson, 1977).

Any stream supporting fish is sensitive to damage resulting from restricted fish passage. Of primary concern are those streams serving as migratory routes or utilized for spawning, rearing, or overwintering. Such streams must remain accessible or local fish populations will be rapidly depleted. The examples cited in Section 3.6.3.6 for stream crossings are also applicable to fish passage through access roads.

Criteria for prevention of fish passage problems during highway construction in the Northwest Territories have been developed by Dryden and Stein (1974). Specifications for fish passage structures are presented by Metsker (1970), USDA (1972), McCart (1975), and Dane (1978). Information on the swimming performance of fish is presented by Jones *et al.* (1974), who detailed critical stream flow speeds for 17 species in the Mackenzie River drainage. Fry and Cox (1970) describe the relationship between size and swimming performance in rainbow trout. MacPhee and Watts (1976) describe the swimming performance of grayling in highway culverts.

While there appears to be considerable variability in swimming performance among species, researchers have recommended that current speeds not exceed 0.9 m/sec without installation of structures that provide for fish passage. In short bursts, adult fish can swim at speeds exceeding 1.5 m/sec; however, the evidence indicates they cannot move at this speed for more than a few metres.

Dryden and Stein (1974) and Dane (1978) provided standards for the installation of structures which will ensure adequate fish passage. In practice, bridges have proved to be the most effective structures, because they ensure fish passage without meeting the strict standards governing culvert installation. As a rule, bridges do not require annual de-icing or the high maintenance typically required for culverts;

however, the initial cost of a bridge is often prohibitive, compared with culvert installation, when small numbers of fish are using a particular stream. With respect to culverts, Doran (1974) recommends that "culverts should be designed to pass the kinds of and sizes of fish known to utilize specific watercourses."

With adequate inspection, few problems with fish passage through bridge and culvert installations on access roads are anticipated. As a result, the duration of any blockage should not exceed one year, and recovery of local populations affected by a blockage will occur in less than one generation.

There are a number of other mitigative measures to ensure that access roads do not unduly restrict fish passage. Fish passage structures and installation specifications will conform to approved standards of regulatory agencies. Sensitive fish areas (e.g., spawning, overwintering, or rearing habitats and major migratory routes) will be avoided in access road routing wherever feasible. Where sensitive fish habitats cannot be avoided, bridges will be considered the preferred crossing method. All fish passage structures will be regularly inspected and maintained to specifications. Inadequate structures will be replaced as a component of routine inspection. Assuming that mitigative measures are adhered to and given the relatively small number of permanent roads required for access to production and support facilities, impacts on fish passage should be NEGLIGIBLE.

(b) Sedimentation

The installation, maintenance, and removal of culverts, bridges, or other instream structures will result in localized short term sedimentation of downstream areas. Common effects of stream sedimentation on aquatic resources are described in Section 3.4.1.6.

Generally, sedimentation resulting from access road construction will be less than that produced by pipeline stream crossings. In the unlikely event that both occur together, the effect on lower trophic levels and fish populations will be cumulative. Deposition of sediment downstream of a crossing will occur during actual installation, but will cease once instream activity is complete.

In high energy systems, deposited sediments will be scoured out by ice and the spring freshet, often in the first year. Low energy streams and lakes will not be scoured out quickly but, since these systems are less important as spawning areas, and their invertebrate communities are adapted to mud substrates, the effects of sedimentation will be less. In either case, recovery of lower trophic levels and fish populations from the effects of road construction will be short-term, generally requiring less than one generation.

The following mitigative measures will reduce the effects of sedimentation associated with permanent access road construction and operation. The duration and extent of instream activities during the open water period will be minimized. The best times for carrying out the work will be established prior to construction and adhered to during installation. Culverts, bridges, and other fish passage structures will be inspected regularly and maintained to prevent flooding and erosion. Overall, sedimentation resulting from access roads is anticipated to have NEGLIGIBLE effects on aquatic resources.

3.6.8 WELL CLUSTER PAD AND PHYSICAL PRESENCE

A well cluster is a series of wells drilled directionally from a single surface gravel pad to a subsurface target (Plate 3.6-4). Metering and test facilities will be provided at each well cluster. An example of the numbers and kinds of wells on 3 connected clusters might be the following: 11 active production wells, 2 standby production wells, 2 water injection wells, and 1 gas injection well. Problems associated with production wells in permafrost regions are caused by thawing when heat is transmitted through the casing to the permafrost from the warm drilling fluid, crude oil, or natural gas. Wells will normally be drilled through the permafrost interval with chilled drilling fluids and will be completed with insulated casing and/or tubing strings to limit thermal disturbance. In addition, special techniques and mechanical equipment will be used to ensure that the wells will be adequately protected against potential collapse, and against downdrag forces caused by freezing and thawing during long term production operations. Oil well fluid will be transported through short flowlines, constructed above grade on piles frozen into the permafrost, to central processing facilities. Similarly, injection lines will run from the processing facility to the injection wells at the clusters for the injection of water or gas.

3.6.8.1 Geology and Soils

Principal impacts on geology and soils resulting from well clusters will include localized thaw settlement and shallow hydraulic erosion. These effects will be caused mainly by construction of the well cluster, and during abandonment, if gravel is salvaged from pads. The mitigative measures proposed to maintain impacts to a LOCALIZED and SHORT-TERM level are described in Sections 3.4.1 and 3.4.4.

3.6.8.2 Hydrology and Water Quality

The construction of well cluster pads may alter surface drainage patterns resulting in localized surface ponding and possible channelization or temporary

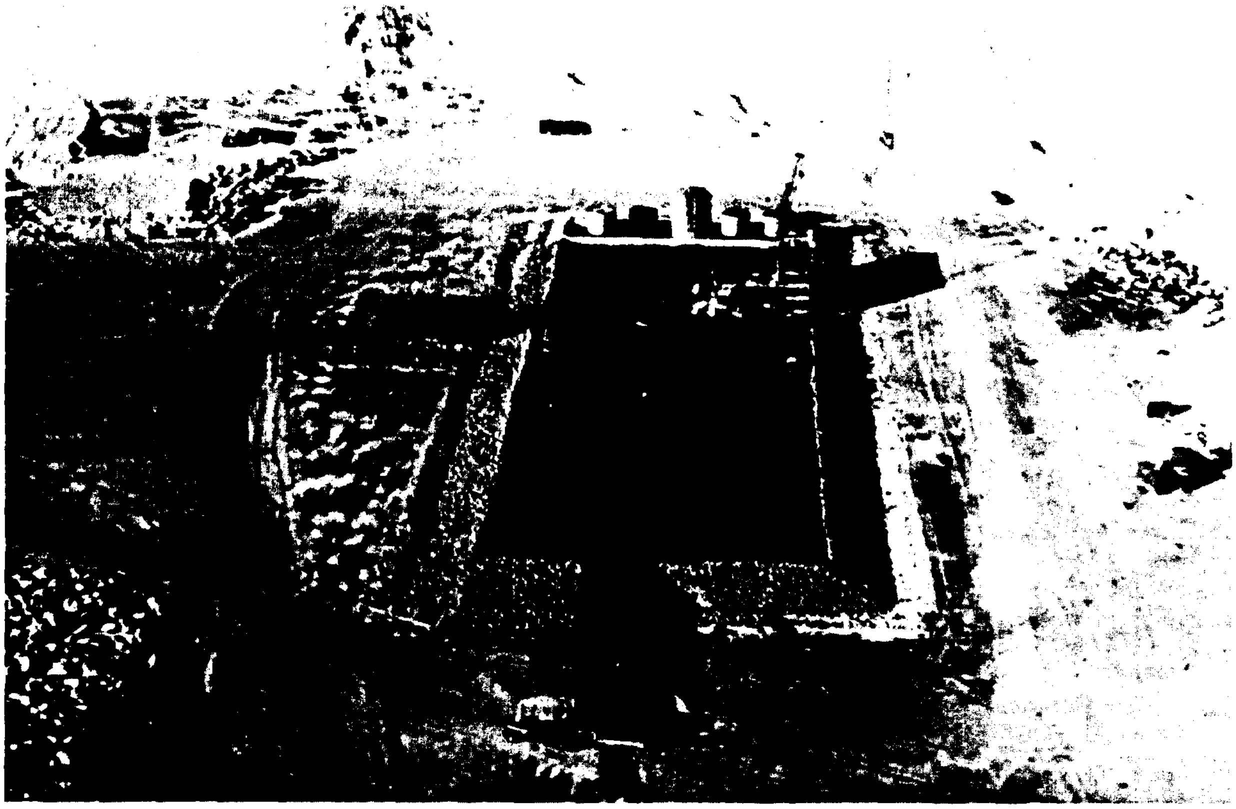


PLATE 3.6-4 *In shallow waters of the Beaufort Sea well clusters will be located on production islands similar to this exploration island at Adgo.*

blockage of subsurface flow. Construction near waterbodies may cause a temporary increase in siltation which will temporarily affect aquatic habitat. Drainage control measures will be installed to reestablish natural drainage patterns and to minimize erosion. In this manner, the impact of well cluster pads will be LOCALIZED and SHORT-TERM.

3.6.8.3 Atmospheric Environment

Atmospheric emissions from the plant and equipment such as drilling rigs during the operations phase would consist primarily of those associated with the plant flare, gas turbines, direct fired heaters, and noise. These parameters are examined in Section 3.6.10.1 related to emissions from a central processing facility.

3.6.8.4 Vegetation

The construction and operation of well clusters will result in the LOCALIZED but LONG-TERM clearing of shrubs and the placement of gravel pads and permanent roads over herbaceous vegetation. These activities may also cause changes in vegetation composition due to drainage interruptions, hydraulic or thermal erosion, and spills of fuels or lubricants. Discussions of these impacts and mitigative measures are provided in Section 3.4.1.

3.6.8.5 Mammals and Birds

Wildlife in the vicinity of well clusters will be subject to possible impacts including the localized loss or avoidance of habitat, and disturbance as a result of the physical and human presence at well clusters.

Observations of the reactions of ungulates to man-made facilities indicate that noise rather than physical presence is the major factor influencing response (Kelsall, 1968; Bergerud, 1974b; McCourt *et al.*, 1974). This is probably the case for other mammal species also. Several authors have noted the minimal level of response of caribou to stationary man-made structures (Urquhart, 1973; Jakimchuk *et al.*, 1974; McCourt *et al.*, 1974; Roby, 1978; Cameron and Whitten, 1979). Disturbance at well clusters will be most intensive during construction. Because of the limited land surface occupied by facilities at well sites and the low level of response of wildlife to constructed features and to human activity, the amount of habitat made unavailable will be negligible in relation to that available. Some deflections of movement of reindeer and other wildlife as a result of facilities at well sites may occur but will be minimal.

Studies have been conducted in northern Alaska and the Northwest Territories on the responses of wildlife to both small scale isolated exploration drilling operations (Barry and Spencer, 1976; Wright and Fancy, 1980) as well as large scale petroleum development (Cameron and Whitten, 1979; Hanson and Eberhardt, 1979; Gavin, 1980).

At an exploration drilling site in the Mackenzie Delta, Barry and Spencer (1976) found that, within 2.5 km of the rig, 43% of the more abundant bird species were noticeably less numerous. Fifty-two percent of the species were not affected, and 5% (two species) were more abundant. Geese and swans, especially moulting individuals and family groups, stayed more than 2.5 km from the rig. Helicopters at low levels were the most disturbing factor. In a followup study, Barry (1976) reported that larger water birds such as white-fronted geese, whistling swans, and sandhill cranes reoccupied the area; other bird species still occurred in fewer numbers. At an isolated summertime drilling site on the Alaskan Coastal Plain, Wright and Fancy (1980) found bird species composition, community structure, abundance, and nest density were similar at both drilling and control sites. The movement of large water birds along the shore (750 m away) was not altered by the drilling operation. In contrast, caribou remained beyond 1.2 km of the drilling site. The approach of drilling personnel towards each group of caribou was considered to be the most important disturbance.

The Prudhoe Bay, Alaska, oilfield is a large scale operation which includes numerous wells, base camps, flow stations, process facilities, injection plants, road networks, airstrips, and a series of gathering lines. After ten years of surveys and study at Prudhoe Bay, Gavin (1980) concluded while some of the activities may have disrupted the overall environment, the effects have not been of a drastic or permanent nature (Plate 3.6-5). Most of the effects occurred during heavy construction of the development and operating facilities. The development and operation of an oil field has not caused major changes in the wildlife populations. Natural population trends and normal population cycles continue. The population of the caribou herd using the Prudhoe Bay area has remained stable. Although some of the original nesting sites of whistling swans have been abandoned due to encroachment, a number of these swans still continue to nest within sight of drilling rigs, camp sites, and other facilities. The high level of human activities near some black brant colonies caused some shifting in nesting densities from one local area to another, the overall black brant population has remained stable. The white-fronted goose and the lesser Canada goose have shown adaptability to the various oilfield activities by increasing their numbers considerably over the past several years. The snow goose population has exhibited the largest population fluctuations for a variety of reasons. Overall, the productivity of ducks and geese in the Prudhoe Bay area continues to be excellent.

Oilfield production facilities such as well clusters and process plants should have only MINOR impacts on mammals of the Mackenzie Delta region. The impact on birds will be a function of the location and number of well clusters and other facilities. In the Mackenzie Delta region, the impact is generally considered MINOR although it could become MODERATE in the western Mackenzie Delta flatlands.

3.6.9 DRILLING FLUID DISPOSAL AND SUMPS

As a consequence of production drilling, two types of drilling fluid disposal are envisaged. Liquid drilling fluid wastes from the water-based clay and polymer system would be disposed of directly into nearshore Beaufort Sea waters, either discharging from shallow water production islands such as those envisaged for Adgo, or by trucking from inland drilling pads (such as Atkinson) to a suitable point prior to disposal to the sea. Liquid drilling wastes, to which a lubricating agent has been added, will be temporarily stored in a land sump. Incinerators will evaporate the liquid component of the wastes. Formation cuttings which are not oil stained will be discharged directly to nearshore waters. Oil stained cuttings will be washed and discharged or disposed of into land sumps. The sumps will be lined with impermeable membranes and bermed to prevent seepage. After completion of production well drilling, non-combustible materials in the sumps will be allowed to freeze before back filling.

Drilling fluid disposal from production wells in the onshore Beaufort Sea-Mackenzie Delta region will recognize research conducted by two industry/government working groups in Canada; the Industry/Government Working Group on the Disposal of Waste Fluids in the Canadian North (APOA Project 73, 1974); and the Offshore Drilling Fluid Disposal Industry/Government Working Group (1982), as well as other drilling fluid research.

3.6.9.1 Geology and Soils

Excavation of sumps may cause localized thaw settlement and shallow hydraulic erosion. However, the use of below-ground sumps to contain waste drilling fluids does not lead to permafrost degradation below the sumps (French and Smith, 1980). Persistent problems with some abandoned sumps include thawing of sump walls, subsidence, leakage of sump infill and mud wastes, sheet and gully erosion, and subsequent terrain disturbance adjacent to the sump. The use of

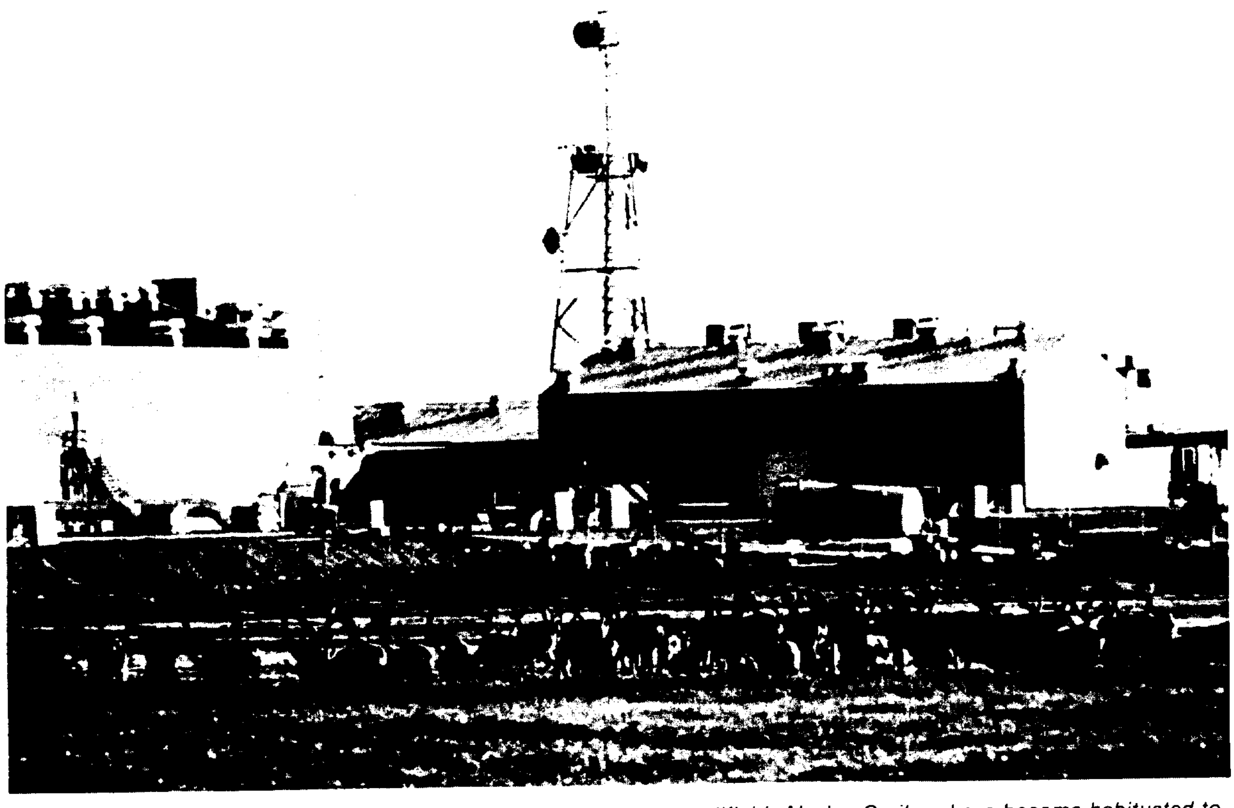


PLATE 3.6-5 *Processing facilities and gas flare at the Prudhoe Bay oilfield, Alaska. Caribou have become habituated to hydrocarbon production and ancillary facilities in the Prudhoe Bay area.*

proper techniques when abandoning sumps will minimize erosion problems, thereby maintaining impacts to a LOCALIZED and SHORT-TERM level.

3.6.9.2 Hydrology and Water Quality

The surface disturbance resulting from the excavation of a sump may alter surface drainage patterns, resulting in localized stream ponding and possible channelization or temporary blockage of subsurface flow. Hrudey (1980) found that surface waters (and subsurface waters, to a lesser extent) in the vicinity of abandoned sumps were often contaminated by sump fluids. However, no evidence of leaching was found. Flooding of abandoned sumps in areas like the Mackenzie Delta can cause contact with surface waters. Pollution of surface and subsurface waters by abandoned drilling sumps can be minimized by ensuring complete freezing of the sump prior to burial with a minimum of 1.5 m of overburden. Accordingly, impacts on surface and subsurface waters are considered LOCALIZED and SHORT-TERM. A discussion of the effects of marine disposal of drilling fluids is provided in Chapter 2, and in ESL (1982), a support document to the Environmental Impact Statement.

3.6.9.3 Vegetation

The excavation of sumps will result in shrub clearing, as well as drainage alteration, and hydraulic or thermal erosion. Smith and James (1980) found a local reduction in plant cover and in species numbers due to the combined effects of chemical uptake by vegetation and physical disturbance at abandoned sumps. Effects can be minimized as mentioned in Section 3.6.9.2., and accordingly, impacts on vegetation should be LOCALIZED and SHORT-TERM.

3.6.10 CENTRAL PROCESSING FACILITIES

Oil processing facilities are described in Volume 2 and briefly summarized in Section 3.3.3. Each larger field, such as Atkinson, will have its own central plant to treat the well fluids. Prior to construction of the facilities, surveying and soil sampling of the job site and remote aggregate sources would be required. Preconstruction would require small numbers of personnel who would commute from existing camps in the Mackenzie Delta or operate from one camp at the site. The work would be done during summer and winter and would require very little equipment. Transportation would be by fixed wing aircraft, helicopter, boat, and ground vehicles. Site construction would begin with gravel hauling and spreading, erection of temporary construction camps, and support facilities. Equipment and facilities would be prefabricated and shipped to the site in large modules. The modules would be transported to their site by barge and moved from the dock to their final location by crawler transporters. Installation would include interfacing, testing and commissioning of the prefabricated modules, erecting buildings, and installing the interconnecting piping controls and instrumentation from the wells to the plant itself. Modules would be placed on piles and enclosed. Approximately 300 to 500 specialized tradesmen would be required to construct and assemble a typical processing facility.

The following is a general discussion of impacts related primarily to the operation of a central processing facility and accompanying activities. Many possible impacts can be avoided by careful site selection. The effects of various activities such as site and road preparation and construction on the geology and soils, hydrology and vegetation of the area are discussed in Section 3.4-1.

3.6.10.1 Atmospheric Environment

Primary sources of atmospheric emissions during construction and drilling phases would be from the engine sets, drilling rigs, construction equipment, furnaces and other heat generating equipment, and living accommodations. The emissions would be primarily water and the various products of combustion. Quantities of emissions from drilling rigs and associated camp facilities would be similar to what is currently experienced on exploratory rigs. Atmospheric emissions from plant and field equipment during the operations phase would originate from the plant flare, gas turbines, direct fired plant heaters, oil or gas fired incinerators, and non-routine flaring of well effluents at well sites or the central processing plant.

Noise emissions from the production facilities will normally be less than the criteria established in AR/71 of the Alberta Noise Protection regulations. Since all major equipment will be installed in insulated buildings, the noise levels on the outside will be further reduced. Noise attenuation devices will be employed as necessary.

Crude oils and natural gases in the Beaufort Sea-Mackenzie Delta region are "sweet," that is, the hydrogen sulphide content is almost nil. Hence, the concern for sulphur emissions is minimized. Other gaseous emissions include oxides of nitrogen, unburned hydrocarbons, carbon monoxide and water vapour. However, effects of these emissions on air quality will be minimal and very localized, since concentrations are expected to remain well below Federal air quality guidelines, with the possible exception of brief periods of strong inversion conditions.

Ice fog may be formed when moist exhaust gases containing water vapor are vented into air colder than -30 °C. If the fog accumulates and persists, reduced visibility may affect traffic safety for both aircraft and ground vehicles; however, the possibility of ground level ice fog is low, since the high exhaust velocity will carry the vapors to elevations well above ground level, where they will be dispersed by air currents at high elevations.

Central processing facilities will be well removed from present communities or recreation areas. Emission stacks will be of sufficient height to ensure dispersion of gases under normal atmospheric conditions and emissions will comply with government guidelines. In this manner, impacts of central processing facilities on air quality should be minimal and LOCALIZED.

3.6.10.2 Vegetation

The operation of a processing plant, especially the gas turbines, flare, and direct fixed heaters, will produce atmospheric emissions such as sulphur dioxide and nitrogen oxides which may cause minor changes in lichen and moss communities in the immediate vicinity of the plant site.

Effects of processing plant construction and operation on vegetation will be minimized by limiting the size of clearings and gravel placement to that necessary for safe and efficient operation of the facility. All exposed soils not utilized for plant operations will be stabilized and revegetated. Drainage control structures will restore, to the extent feasible, natural drainage patterns beyond the plant site. Careful attention will be given to protecting any unstable or highly erodible slopes. Processing plants will be located on topography with relatively low inversion potentials, and the regulated air emission levels will ensure that ground level concentrations of pollutants will meet air quality guidelines. Therefore, the impacts of processing plants and their activities on vegetation are anticipated to be LOCALIZED.

3.6.10.3 Mammals and Birds

The siting and activities associated with processing plants will cause some loss of habitat, both as a result of the ground surface occupied, as well as localized areas which some wildlife may avoid because of the disturbance from human activity and noise. The total area made unavailable to wildlife will, however, be very small in relation to the habitat available. Plant sites may also influence local animal movements. A discussion of impacts of facilities on mammals and birds is provided in Section 3.6.8.5.

Where feasible the plant site will be located away from critical mammal and bird habitat. Assuming oil spills are prevented, the anticipated levels of impact on mammals and birds are considered to be MINOR.

3.6.11 STAGING SITES AND STOCKPILES

Materials, fuel, camps and equipment required for construction will be transported by barges to stockpile sites in the Mackenzie Delta and Tuktoyaktuk Peninsula. Where serviced by temporary wharves, staging sites and stockpiles will generally be located in the immediate vicinity of the off-loading area. To minimize surface disruption, stockpiles for the gathering system will be located, where possible, on well cluster or processing facility pads. Winter snow roads will be used to move pipeline materials, consumables, and petroleum products and equipment from stockpile sites to gathering line rights-of-way.

The construction of staging areas, will cause generally LOCALIZED and SHORT-TERM impacts on geology, soils, water quality, hydrology and vegetation. Discussions of impacts on these resources are provided in Section 3.4.1.

3.6.11.1 Mammals

The construction and operation of staging areas will result in localized temporary losses of habitat. In addition, some wildlife will avoid small areas surrounding staging sites because of disturbance and human activity. However, the impact on mammals should be MINOR.

3.6.11.2 Birds

Once the general location for a staging area has been established, detailed examination of the use of the area by birds will be an important factor in determining the precise staging locations. Particular attention will be given to waterfowl concentrations (swans, geese, and ducks), and the presence of raptors and other birds such as sandhill cranes. If a staging area is constructed at North Point, the impact is expected to be NEGLIGIBLE because the habitat lost is probably of importance only to a small number of birds in any season. At Atkinson, the site will be chosen in consultation with the regulatory agencies with the intent of avoiding areas traditionally used by concentrations of birds for staging, nesting, brood-rearing, and molting. Assuming these measures are employed, the impact on birds here would be expected to be MINOR. Almost any staging area set up in the western flatlands of the Mackenzie Delta can be expected to conflict with some waterfowl and other waterbird or shorebird concentrations at various times in the summer season. Sites will again be selected in consultation with the appropriate regulatory agencies. The most effective mitigative measure may be to reduce or suspend construction activities during prescribed time periods. Impact on birds should not generally exceed MINOR but may approach the MODERATE rating, depending on site and degree of summer activity.

3.6.12 WHARVES AND BARGE TRAFFIC

Wharf construction includes the erection of pilings, bank preparation, and construction of access to wharf sites. The navigation season for barge traffic in the Mackenzie Delta lasts approximately 13 weeks, from mid June to mid September. Docks would be built close to any central processing facility and virtually all plant materials will be imported via these docks (Plate 3.6-6). Staging areas would be built alongside the dock in order that unloaded materials could be stored as required for subsequent activities such as construction or operations resupply.

Ocean-going barges carrying the larger, heavier modules would travel from the west coast around Point Barrow to Mackenzie Delta plant sites. At the mouth of the Mackenzie River in Kugmallit Bay, the barges would be lightered using river barges to reduce draft.

Bulk materials, equipment and small modules would be transported by existing rail and road networks to riverside staging areas such as Hay River. Here they would be loaded onto river barges and transported down the Mackenzie River directly to the processing facility site.

3.6.12.1 Mammals

Barges may occasionally encounter beaver, muskrat or mink, or more rarely, swimming moose or reindeer. Because of the infrequency of these encounters and because swimming mammals can easily avoid slow moving barges, the anticipated impact is NEGLIGIBLE.

3.6.12.2 Birds

Wharf construction and operations are likely to have only a local MINOR impact on birds, depending on locations and degree of use. Increased barge traffic and noise, particularly if associated with dredging, could be locally disturbing to birds feeding or nesting along the river (Barry, 1976). Moulting and staging waterfowl or waterfowl with young would be most affected. The siting of wharves and the routing of barge traffic, together with the development of fuel spill contingency plans, will take place in consultation with appropriate government agencies. Overall, impacts on birds are generally considered to be MINOR.

3.6.12.3 Aquatic Resources

Wharves will be located in the Mackenzie Delta and along the Tuktoyaktuk Peninsula. Piling installation and bank preparation will take place during open water when natural sediment loads are high. Given the limited number of wharf sites, their locations, the limited disturbance associated with their construction and the timing of their construction, impacts on all aquatic trophic levels are considered NEGLIGIBLE.

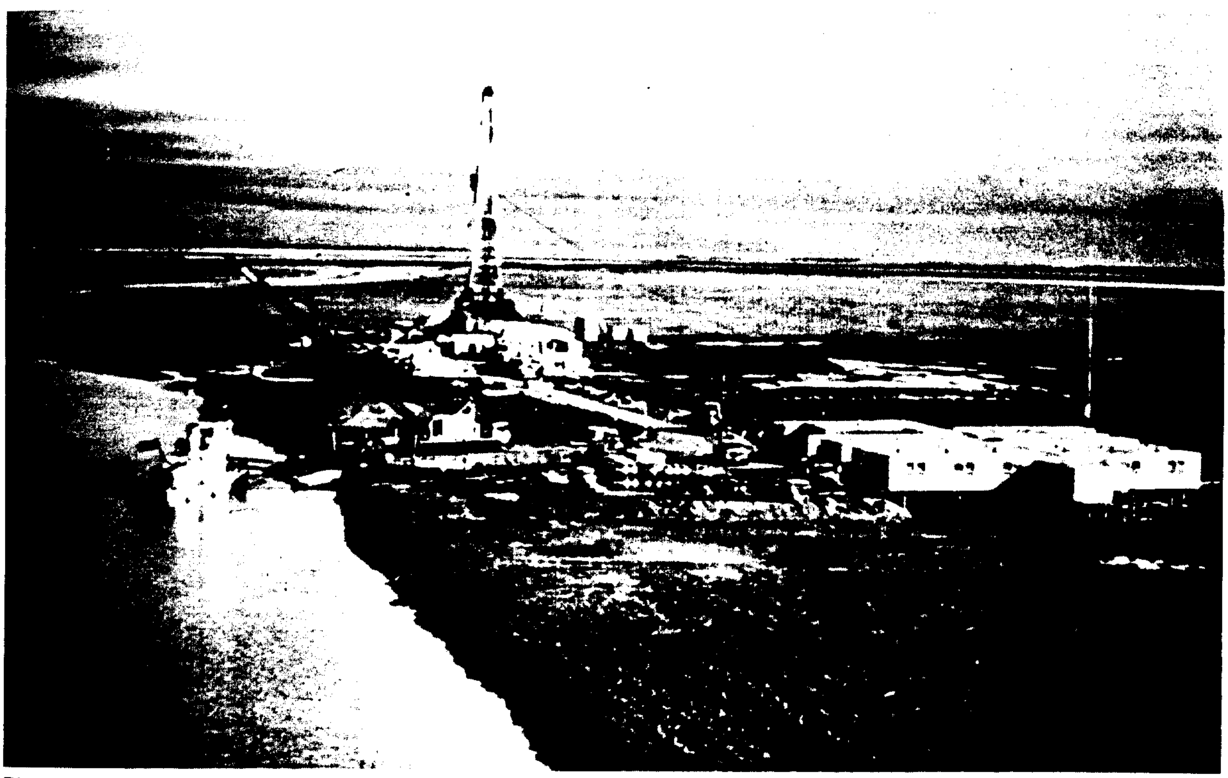


PLATE 3.6-6 *Barges will be used in summer to supply or stockpile materials for onshore production facilities.*

3.6.13 AIRCRAFT AND AIRSTRIPS

Both helicopter and fixed-wing aircraft will be used during all phases of the project to transport personnel and equipment (Plate 3.6-7). The overall frequency of aircraft use will be greatest during the construction phase, with the highest levels of activity being centred at the airstrips and construction camps.

3.6.13.1 Mammals

Discussions of impacts of aircraft on mammals are provided in Sections 2.3.5 and 5.4.8.1. A number of mitigative measures will be employed to minimize impacts on mammals. Aircraft flights with no specific requirements for low level flying will be required to maintain minimum flight altitudes of 600 m above ground level. Pilots will be informed of sensitive areas, minimum altitudes, and flight corridors. Harassment of mammals or the transport mammal carcasses, furs, or hides will be prohibited. In this manner, the impacts resulting from aircraft overflights on mammals will generally be MINOR.

3.6.13.2 Birds

Because helicopter and fixed-wing aircraft overflights are known to disturb some waterfowl species, for example snow and white-fronted geese, especially during nesting, there is a significant potential for impact, particularly in the lowland western Mackenzie Delta and Kittigazuit Bay area. A discussion of the impacts of aircraft on birds is provided in Sections 2.3.5 and 5.4.8.2. Mitigative measures such as aircraft routing, altitude restrictions, and avoidance of certain areas will be implemented in consultation with the appropriate government agency. Assuming compliance with restrictions, impacts on waterfowl should generally not exceed MINOR, although in specific areas, during key time periods, impacts could approach MODERATE. If raptor nest sites are avoided by the recommended distances during requisite periods as suggested by Roseneau *et al.* (1981), NEGLIGIBLE to MINOR impacts should occur.

3.6.14 CAMPS

Camps will be required in the preconstruction, construction, and operation of well clusters, processing facilities and gathering lines. There are several types and sizes of camps. Preconstruction crews of approximately 50 personnel would be required to prepare campsites, temporary wharves, and roads (Plate 3.6-8). By using one construction spread for each of two winter seasons, 300 personnel would be required for construction of the gathering lines. Some channel crossings of the Mackenzie Delta will be constructed during summer and would require a total work force

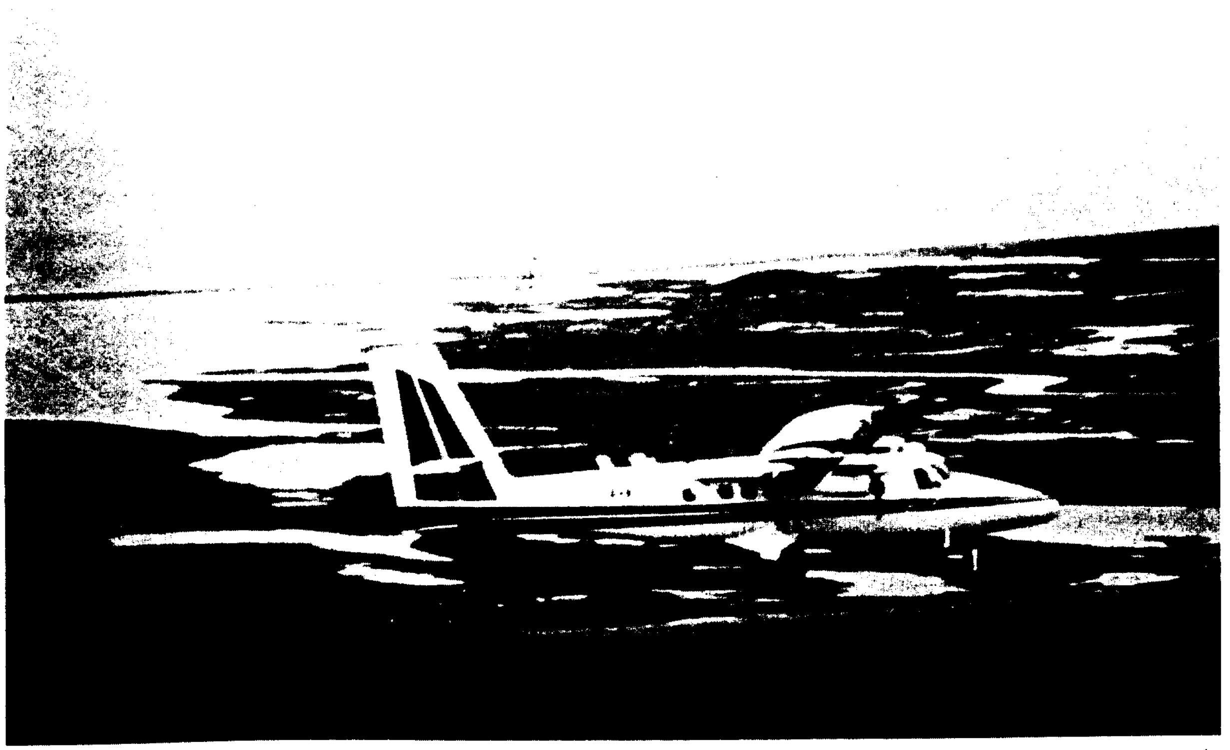


PLATE 3.6-7 *Short takeoff and landing (STOL) aircraft such as this Twin Otter will be used regularly to transport personnel, supplies, and equipment to facility sites in the Mackenzie Delta-Beaufort Sea region.*

PLATE 3.6-8 *A typical small scale seismic or construction camp. Note track vehicles, skid trailers, and Otter supply aircraft.*

of 50 to 70 personnel. Construction and assembly of central processing facilities would require 300 to 500 personnel, assuming modular construction. Approximately 50 personnel will be required to operate a processing facility.

Impacts from camp construction and use are similar to several other activities and facilities. Impacts on geology and soils are discussed in Section 3.4.1.1, hydrology and water quality in Section 5.3.9, and vegetation in Section 3.4.1.3. Impacts on mammals are discussed in Section 5.4.7.1 (short-term and local habitat loss), Section 5.3.9.1 (attraction to waste disposal sites), and 5.3.10.1 (recreational activities).

3.6.14.1 Birds

Camp sites in the western outer Mackenzie Delta, Atkinson, or North Point areas will be selected in consultation with the appropriate government agencies to avoid waterfowl concentration areas, nesting colonies, or raptor nest sites. Impacts on birds are considered to be NEGLIGIBLE in terms of habitat loss. The movement of aircraft, vehicles, and personnel in and out of the camp areas are considered to cause MINOR impacts in local areas.

3.6.14.2 Aquatic Resources

Concerns for potential impacts on aquatic resources arising from work camps are related to sewage disposal (Section 5.3.9.2), increased opportunity for recreational fishing (Section 5.3.10.2), and water use, discussed as follows.

In many areas on the North Slope of Alaska, meeting the water requirements of exploration, construction, and production personnel has proved to be a major problem particularly during the winter months. Obtaining water during late winter often requires such elaborate measures as use of desalinization equipment and construction of water storage reservoirs. In the Beaufort Sea-Mackenzie Delta region, however, an abundance of deep lakes and streams with perennial discharge ensures a supply of fresh water during winter months in most areas.

Daily water requirements are currently estimated at 318 L per capita, necessitating a daily withdrawal of approximately 32,000 L for an average camp size of 100 people. In the Mackenzie Delta region and along the Tuktoyaktuk Peninsula, water supply should pose little problem; however, along the Yukon coast and in the easternmost parts of the region, locations for camp facilities must be selected with care to ensure that water requirements do not conflict with fish requirements.

Overwintering fish and their eggs are subject to stress during late winter when ice thickness is greatest, water availability lowest, dissolved oxygen reduced, and energy reserves least. Water withdrawal from shallow lakes and streams with very limited discharge, or from pools fed by intergravel flow, can result in considerable mortality for both eggs and overwintering fish. If withdrawal sites are not located elsewhere, fish with extremely limited overwintering habitat in shallow lakes and near perennial groundwater sources will be seriously affected by camp water requirements. Of particular concern are Arctic char, round whitefish, and grayling spawning and overwintering along the Yukon coast; and cisco, whitefish, and char overwintering in the eastern portion of the Beaufort Sea region. Some of these areas are listed in Volume 3A.

If camp water supplies infringe on limited overwintering habitat, effects may continue for the duration of camp operation. Although recovery will depend on the extent of damage to local populations, most areas will be fully restocked through recruitment and reinvasion from outside areas within a single generation. Complete elimination of an isolated stream-resident Arctic char population will be a permanent effect, however, which can be avoided by limiting water withdrawal from streams where such populations occur. Protection of overwintering fish from the effects of camp water withdrawals is best accomplished through placement of camps near adequate year-round water supplies where water withdrawal will not interfere with overwintering fish. Also, where there is doubt regarding the adequacy of water in an area, water availability will be determined prior to facilities construction. Assuming these measures are adhered to, the effects of camp water use on aquatic resources are considered to be NEGLIGIBLE.

3.6.15 WASTE DISPOSAL

At all temporary work camps, construction sites and processing facilities, domestic sewage waste will be released to approved disposal sites after treatment to government waste water guidelines and standards. All combustible wastes (e.g., kitchen wastes) will be incinerated (Plate 3.6-9). Liquid and solid wastes and scrap metals will be disposed of in a manner approved by regulatory agencies. Techniques used may include incineration, burial in approved sites, injection into approved disposal wells, storage in designated impermeable sites, or shipping out to be recycled. Liq-

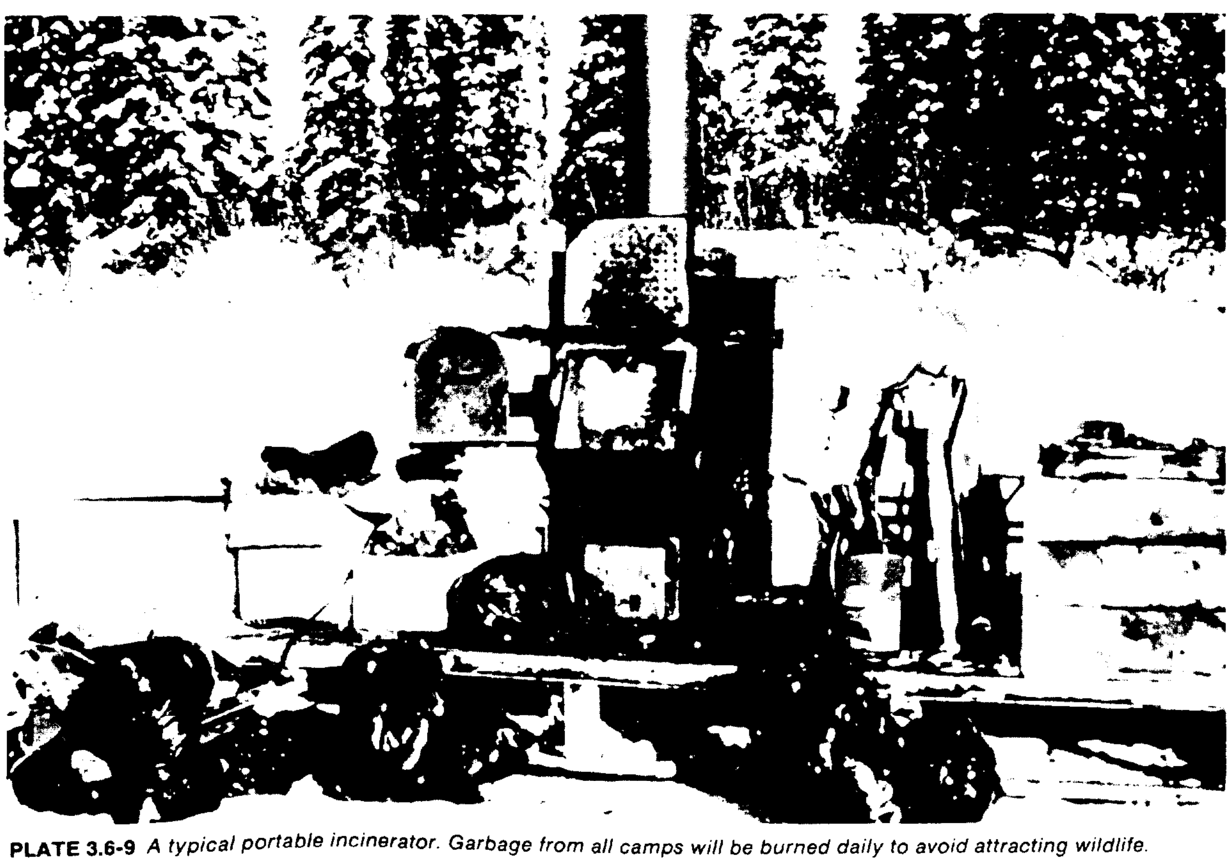


PLATE 3.6-9 *A typical portable incinerator. Garbage from all camps will be burned daily to avoid attracting wildlife.*

uid wastes such as produced waters, sump fluids, and surface waters accumulated in the tank storage areas would be re-injected into a disposal well. Discussions of the impacts of waste disposal on mammals, birds, and aquatic resources are provided in Sections 2.3 and 5.3.9.1.

3.6.16 FUEL STORAGE

Prior to processing facility startup, it would be necessary to operate the units and the emergency generating station on diesel fuel. When required, diesel and other fuels, will normally be stored in dyked tank storage areas (Plate 3.6-10). The dyked area would have sufficient capacity to contain at least 110% of the storage capacity of the tanks in compliance with Federal regulations. Impermeable liners would be employed and covered with overburden during construction of the dykes. After startup of processing facilities, the requirement for fuel storage will be considerably reduced. The treated gas would be used as the main source of fuel for utilities.

3.6.16.1 Mammals

Although habitat made unavailable to wildlife as a result of the area occupied by fuel storage facilities will be negligible, fuel storage is of concern because of the potential for tank rupture and/or leaks which allow fuel to enter aquatic environments. Semi-aquatic furbearers, especially muskrat which are the most numerous, would be vulnerable to oiling of their fur if fuel contaminated the water. Locating fuel storage areas away from important wildlife habitat, preventing potential leaks from entering waterbodies and the construction of impervious dykes around fuel storage areas will ensure that impacts on mammals will be NEGLIGIBLE.

3.6.16.2 Birds

The possibility of fuel leakage into water bodies is a concern which should be mitigated by measures similar to those described for mammals. Assuming no spills occur, impacts on birds would be NEGLIGIBLE. If spills were to occur, impacts on birds could range from NEGLIGIBLE to MAJOR, depending on the circumstances. However, these kinds of impacts would not be considered to be a "normal" event associated with onshore operations. Volume 6 of this Environmental Impact Statement examines oil spills and their possible environmental implications, and should be consulted for further information on this subject.

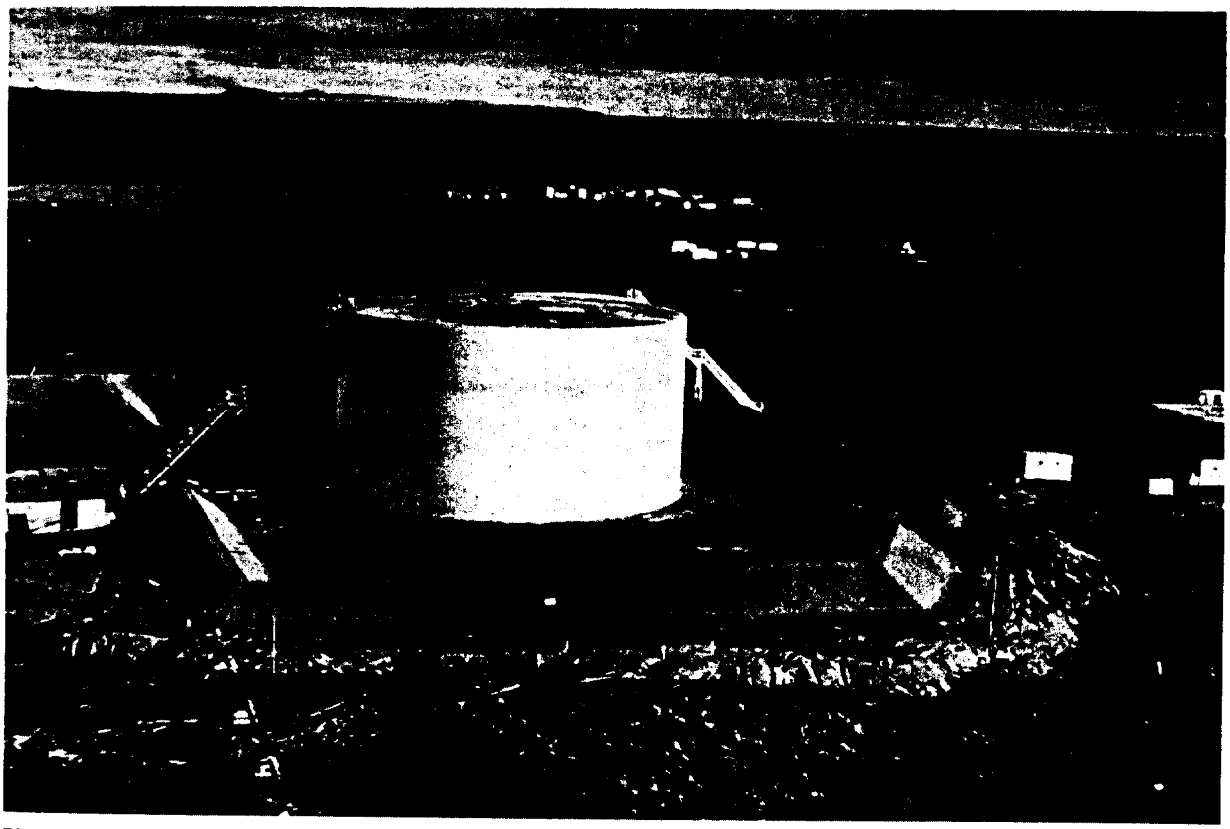


PLATE 3.6-10 *Fuel storage at Tununuk Point (Bar C) on Richards Island in the Mackenzie Delta. The berm surrounding the tank will confine possible leaks.*

3.6.17 OFF-DUTY ACTIVITIES OF PERSONNEL

Construction and production facility camps will greatly increase the opportunity for hunting and fishing. Increased access to remote areas will be facilitated by permanent and temporary access roads, aircraft, snowmobiles, and all-terrain vehicles. The activities of industry employees at worksites will be regulated by their employers and will be directed towards minimizing impacts of their presence on the natural resources of the area. Off-duty activities will be regulated by and conform with established government legislation. Discussions on the impacts of off-duty activities by construction or production personnel are provided in Section 5.3.10.

3.6.18 SUMMARY OF IMPACTS FROM ONSHORE PRODUCTION FACILITIES AND AN OIL GATHERING SYSTEM

This section provides an overall summary of anticipated impacts on the natural resources as a result of possible oil production facilities and an oil gathering system in the Beaufort onshore region.

3.6.18.1 Geology and Soils

Impacts of the proposed oil and gas gathering production facilities on geology and soils will include active layer deepening, localized thaw settlement, and shallow hydraulic erosion of rights-of-way, facility sites, and immediately adjacent areas. Thermal effects will be greatest where mineral soils are exposed, and where gravel may be salvaged from pads and roads. Shallow hydraulic erosion will likely occur where facilities redirect surface runoff or channelize diffuse flow. Potentials for erosion are probably greatest at stream banks and other slope breaks. However, these effects are considered manageable with the application of appropriate drainage and erosion control and reclamation measures. Other, localized effects may include creation of slope instabilities along sections of the field gathering system, especially at channel crossings of the Mackenzie River. In the unlikely event of a pipeline failure, emergency repair measures may cause additional terrain damage including hydraulic erosion, thaw settlement and slope instabilities. Overall impacts on geology and soils resulting from processing, gathering line, and support facilities should be LOCALIZED and SHORT-TERM.

3.6.18.2 Hydrology and Water Quality

Stream flow and water quality will be unavoidably affected by several onshore construction and operation activities such as ditching, stream crossing, and permanent access roads, which will cause drainage alterations and siltation. The mitigative measures outlined previously will minimize these effects. The impacts of oil and gas production facilities on drainage patterns should be LOCALIZED and SHORT-TERM.

3.6.18.3 Atmospheric Environment

The construction and operation of oil production and gathering systems will result in minor noise, particulate and gaseous emissions, and ice fog. Principal sources of noise will include wellsite machinery, processing plant machinery, and, for brief periods, blasting and aircraft. Gaseous and particulate emissions will be generated primarily by processing plants and associated flares. In the event of inversion conditions during plant upset, plant emissions as well as ice fog may be trapped near ground level for some period of time. The severity and extent of the effects will depend on emission levels, the duration of the inversion, prevailing winds and other factors. High exhaust temperature and velocity will cause ice fog primarily at higher elevations, where the possibility of dispersal by upper level winds is high. The overall impact of production and gathering facilities on air quality will be limited and LOCALIZED.

3.6.18.4 Vegetation

Vegetation will be removed or destroyed at well sites, processing plant sites, permanent roads, airstrips, shorebases and permanent camps during the lifetime of the development. The impact of this disturbance is considered LOCALIZED due to the small areas involved. Vegetation will be surveyed prior to construction in order to identify any unique or especially sensitive vegetation. If such vegetation exists, facility sites may be relocated. All exposed soils on temporary facility sites and the gathering system rights-of-way will be revegetated to restore plant cover within a short period of time. The overall impact of oil and gas development in the Beaufort Sea-Mackenzie Delta region on vegetation is considered to be LOCALIZED and SHORT-TERM.

The removal of the natural vegetation and surface organic layers may initiate localized hydraulic erosion, thaw settlement, drainage interruptions, and thermal erosion. The impact of these potential effects on vegetation will be LOCALIZED. The operation and construction of facilities will increase soil disturbance and instability, however, the overall impact is likely to be LOCALIZED and SHORT-TERM.

3.6.18.5 Mammals

Concerns for overall impacts on wildlife relate to possible habitat alteration, disruption of movements, general disturbance, and direct mortality. The following section discusses these issues under headings of particular species or herds which are deemed particularly relevant due to their economic, recreational, ecological, or aesthetic value.

(a) Reindeer

Interactions between reindeer and activities and facilities associated with onshore oil development will occur on the Tuktoyaktuk Peninsula and in the western portion of the Mackenzie Reindeer Grazing Reserve. Localized short-term habitat loss will result from the development of borrow pits, construction of field gathering pipelines and temporary access roads, and from the operation of construction camps. Longer term habitat loss will occur at well cluster sites, staging areas, processing plants, fuel storage areas, and along permanent access roads, both as a result of the land surface occupied by facilities and because of the possible displacement response of reindeer to activities of men and machines at these facilities. The total amount of habitat made unavailable will, however, be very small relative to the amount in the region and is not expected to measurably reduce the carrying capacity of the range for reindeer.

Reindeer movements may be disrupted to some extent during construction of field gathering pipelines because of the open pipeline ditch and intensive construction activity along sections of the pipeline routes. Because of the relatively short length and duration of these potential barriers in any particular area, they are not considered to be of great concern. In addition, herd movements can be controlled to avoid such areas if necessary. Other linear facilities such as roads and buried pipelines are not expected to present barriers to reindeer movements. Construction of non-linear facilities will probably result in small deflections in reindeer movements; however, no adverse consequences are expected.

Disturbances caused by human activity, noise, vehicles, aircraft, and blasting will be largely restricted to the facility sites and along corridors of linear facilities. Reindeer may be locally displaced near areas of activity, but should not significantly affect the reindeer herd because they are accustomed to human activity, skidoos, and helicopters used during herding operations. Potential displacement of reindeer can be minimized by planning the range use patterns in advance of gathering line construction.

Additional access provided by temporary and permanent roads, and the human population influx to the Mackenzie Delta as a result of the oil and gas development may result in increased poaching of reindeer. It may be necessary to increase the intensity of patrols of the herd if this becomes a problem. However, because the herd is managed more intensively than herds of wild caribou, potential impacts due to industry development can be minimized with herding and other management procedures, and the level of potential impacts should be MINOR.

(b) The Bluenose Caribou Herd

Because the western limit of the traditional winter range of the Bluenose herd is southeast of the gathering system and development area, few of these caribou will encounter the development. Although a western expansion of the winter range of the herd was discussed by Hawley *et al.* (1976), this extension did not subsequently continue in 1975-76 and 1976-77, when caribou ranged only as far west as the Kugaluk River (Wooley and Mair, 1977). The current distribution of the herd is east of the Tuktoyaktuk Peninsula and Eskimo Lakes (Volumes 3A and 3C). Although a few caribou may wander within the sphere of influence of the hydrocarbon development activities and some may be exposed to aircraft flights over the westernmost portion of their range, these potential isolated interactions are expected to have a NEGLIGIBLE impact on the herd.

(c) Moose

Interactions between moose and activities and facilities associated with onshore oil development are expected to be limited because of the low moose population in the Mackenzie Delta region. Nevertheless, the few moose which do inhabit the area will be subjected to some habitat loss, possible barriers to movement, disturbance, and possibly more intensive hunting pressure. Habitat loss will occur at linear and nonlinear facility sites, both as a result of the land surface occupied by facilities, and because of the displacement response of moose to human activity. The total amount of habitat made unavailable will, however, be very small relative to the amount available and is not expected to measurably reduce the carrying capacity of the range for moose.

Moose movements may be disrupted to some extent during construction of field gathering pipelines, because of the open pipeline ditch and intensive construction activity along sections of the pipeline routes. Because of the relatively short length and duration of these potential barriers in any particular area, they are not considered to be of particular concern. Other linear facilities such as roads and buried pipelines are not expected to be a barrier to moose movements. Non-linear facilities may result in small deflections of moose movements but are likely to be too small to have adverse consequences. Disturbance caused by human activity, noise, vehicles, aircraft, and blasting will be largely restricted to the facility sites and along corridors of linear facilities.

Although moose may be locally displaced near areas of activity, this is not expected to affect the population status. Additional access provided by temporary and permanent roads, and the human population influx to the Mackenzie Delta as a result of the development, may result in increased hunting of moose. It may be necessary to modify hunting regulations and intensify enforcement of these regulations to avoid a decline in the moose population in the area.

In general, facilities and activities involved in the development of petroleum reserves in the Mackenzie Delta region are expected to have a MINOR effect on the moose population; however, because the population is currently very low, it is particularly vulnerable to impact from increased hunting and therefore strict wildlife management procedures should be considered.

(d) Grizzly Bear

Interactions between grizzly bears and activities associated with onshore oil development may occur anywhere within the area where activities are proposed. Habitat loss will generally be insignificant in proportion to the habitat available. Loss of denning areas, the major concern with respect to habitat alteration, will be avoided by selecting borrow pits and facility sites in areas not used by grizzly bears for denning. Disturbance due to aircraft, machinery, and human activity along the pipeline route and at associated facilities will cause some local displacement and may result in some stress reactions by bears, but will not likely have measurable effects on the population. The greatest source of impact will be mortality of "problem bears" attracted to project facilities. Despite mitigative measures regarding waste disposal and handling of problem bears, some bears may have to be killed. In addition, improved access and the increased human population in the Mackenzie Delta region would tend to increase hunting pressure on grizzly bears. In view of current regulations governing the numbers of bears which may be harvested, increased hunting pressure will not increase the legal harvest of bears but may result in some illegal harvest. With the application and enforcement of strict wildlife management procedures, it should be possible to maintain impacts to the MINOR level.

(e) Aquatic Furbearers

Beaver: The distribution of beaver in the Mackenzie Delta region is restricted primarily to the active delta. Potential interactions between beaver, and oil and gas development activities are therefore of little concern.

The prime concern with beaver is the potential for widespread movement of oil through their habitat in the event of a spill or leak. The number of beaver which would be affected if such an event occurred would depend on a number of factors, including the extent of aquatic habitat downstream from the spill, the amount of oil spilled, the season of the spill, and the effectiveness of clean-up measures. A discussion of the effects of oil spills is contained in Volume 6. Despite the fact that a potential oil spill is a serious threat to beaver, the widespread distribution of this species ensures that a significant proportion of the population would not be affected even in the event of a spill. Therefore, the net effect of development on beaver is expected to be MINOR.

Muskrat: Muskrat are much more plentiful in the Mackenzie Delta region than beaver. However, since most oil and gas development activities will avoid direct contact with wetlands, interactions between onshore oil and gas development activities and muskrats will be limited. As with beaver, the potential for an oil spill is the greatest concern. However, because of the wide distribution of muskrats and their very high reproduction potential, there will be, at worst, a MINOR effect on the muskrat population.

(f) Terrestrial Furbearers

Arctic Fox: Arctic foxes are widely dispersed within the Mackenzie Delta region and are not particularly abundant. Interactions with oil and gas development activities will therefore likely be infrequent. Since few den sites occur within the area, chances of destruction of a den site are low. Some foxes may be attracted to construction camps and may be killed if they appear rabid. The possibility that foxes may become dependent on camp garbage or handouts and be unable to fend for themselves when the camp is abandoned is remote because of proposed methods of garbage disposal and regulations against feeding any wildlife. The increased human population during the construction period may result in some increased hunting and trapping of Arctic fox but is unlikely to significantly affect the population. The overall impact of oil and gas development activities on the Arctic fox population is expected to be MINOR.

Red Fox: Interactions with red fox will be more frequent than with Arctic fox because red fox are more common in the Mackenzie Delta region. As with Arctic fox, the most important potential impacts will include destruction of den sites, attraction to camps, and some increased hunting and trapping. Because of the widely dispersed nature and high reproductive potential of the red fox, industry-related effects on the population will be MINOR.

Wolf: Since wolves are uncommon in the Mackenzie Delta area, interactions with oil and gas development activities will be infrequent. Habitat alteration by development activities will have little impact on wolves, although some beneficial effects may result from construction of transportation rights-of-way which, Horejsi (1979) noted, are often used by wolves when hunting. Conversely, negative impacts may occur if their food supply is depleted in the Mackenzie Delta region as a result of overharvesting of moose by hunters. Wolves could also be adversely affected by disturbance of dens or rendezvous sites; however, the rarity of these sites together with surveillance for dens makes it unlikely that the project will disturb these habitat types. Improved access and the increased human population may result in a larger harvest of wolves, but this increased harvest is unlikely to have a significant effect on the wolf population. Overall, the anticipated effect of the development is expected to be MINOR.

(g) Other Furbearing Mammals

Mink, weasels, squirrels, wolverines and others are generally widely distributed in the Mackenzie Delta. As a result, few of these mammals are likely to be affected. Habitat alteration and disturbance will therefore have insignificant impacts, although increased trapping may result in local depletion of numbers of those species susceptible to over-harvesting. The effect on regional populations will range from NEGLIGIBLE to MINOR.

(h) Other Terrestrial Mammals

Populations of other mammals such as shrews, small rodents, and hares are widely distributed. Only insignificant proportions of the populations of these mammals are expected to interact with onshore oil and gas development and therefore impacts on populations of these species are anticipated to be NEGLIGIBLE.

3.6.18.6 Birds

Although the impacts of winter exploration and construction activities are expected to be negligible because so few birds are present during that period, some impacts during the remainder of the year may occur, as activities increase and spread over the area during the 10 to 20 year period.

In the eastern outer Delta and Tuktoyaktuk Peninsula, impacts may take the form of a general reduction of breeding range and decrease in productivity for a variety of species (waterbirds, waterfowl, shorebirds, gulls, terns, jaegers, cranes, and others). Impacts are likely to range from MINOR to perhaps MODERATE in some instances. The western outer Delta is of great importance to the annual sequence of spring staging, nesting, brood-rearing, molting, and fall staging of waterfowl and other birds. As a result, large numbers of birds are found in the area; in fact, as much as 85% of the regional population of a species may be present here at one time (Barry and Barry, 1982). In addition, flocks of non-breeding birds may summer here. This portion of the Delta includes one of the seven areas designated as key areas for coastal birds along the Beaufort Sea Coast (Barry and Barry, 1982).

Impacts on birds will be a function of the location and number of facilities, the types of activities involved and the intensity of disturbance associated with these activities. The overall impacts of normal activities should range from MINOR to perhaps MODERATE in some areas for snow geese, white-fronted geese, brant geese, whistling swans; other waterfowl and sandhill cranes; and generally MINOR for other species, including raptors. In the event of major oil spill in the Delta, MAJOR impacts on some species of birds could occur.

3.6.18.7 Aquatic Resources

(a) Sedimentation

Instream activities and all proposed activities involving disturbance of stream banks will contribute somewhat to stream sedimentation. In most streams sedimentation is also a natural phenomenon, and, depending on timing, concentration, and duration, sediment introductions may have few detrimental effects on aquatic biota. The Mackenzie Valley Pipeline Inquiry (Berger, 1977) developed standards for determining the effects of suspended sediments in northern waterbodies. These standards, while arbitrary, recognize the ability of aquatic organisms to tolerate longer term siltation when concentrations are low, and to tolerate short-term exposure to high sediment loads.

Even with an aggressive program of inspection, reclamation, and revegetation, failures in stream banks, slopes, and erosion control techniques will continue to add some suspended sediments throughout the life of a gathering line and production development. In general, sediment contributed by onshore development will be associated with acute erosion problems, which means that any effects will usually be both local and short-term. Unless sedimentation becomes generalized or chronic at a single location, recovery of both lower trophic levels and fish will also be short-term. Fish populations in the region are well-adapted to tolerating brief periods of extremely high sediment levels, and have developed strategies to avoid high sediment areas during sensitive periods of their life histories (Volume 3A). Because of the self-scouring action of high-energy systems, and the tendency of aquatic biota to recover rapidly from the effects of sediment introductions, no long term effects of sedimentation are anticipated.

Although a few localized reductions in fish populations are probable, the cumulative effect of all sediment introductions on fish populations in the region is projected to be MINOR.

(b) Habitat Modification

Stream crossings, access roads, stream training, spills of toxic material, sediment introductions, and other environmental modifications that accompany development will cause alteration or loss of aquatic habitat. Although a few of these modifications will be beneficial in their effects, the majority will reduce habitat quality. Most aquatic habitats in the region serve only as summer feeding areas and migratory corridors, and are thus not considered critical to fish populations. As a rule, large fish will readily seek alternate habitat if unsuitable conditions are encountered. However, in spawning, rearing, and overwintering areas, alternative habitat is often limited, and reductions of habitat quality in these areas may have a detrimental effect on regional populations.

Although most of the streams crossed by gathering lines serve as migratory routes for fish moving to and from sensitive habitats, habitat modifications associated with the onshore oil and gas development are not expected to interfere with these migrations. Since natural hydraulic processes will quickly return most habitats to almost their original configurations, many habitat modifications will be extremely short-term, often less than one year. Given the small amount of habitat affected, and the brief duration of most habitat modifications, the cumulative effect of proposed activities on fish habitat will be NEGLIGIBLE.

(c) Direct Mortality

In addition to the indirect effects of sediments on eggs and juvenile fish, the operation of machinery, spills of toxic materials, blasting in streams, entrapment and blocked passage to and from critical habitats will cause some direct mortality to fish. Were all these disturbances to occur at a single location, their collective effect would undoubtedly cause a considerable reduction in local populations; however, these disturbances are more likely to be dispersed throughout the Mackenzie Delta onshore region and will not all affect a single area at any one time.

Individually, construction activities causing direct mortality will result in local, short-term effects on fish populations. In each case, the duration of the effect is brief, and recovery will generally occur in a single generation or less. Collectively, these effects will also result in short-term localized declines in fish populations, and the effects are consequently rated as MINOR.

(d) Increased Angling Pressure

The increased number of both onshore oil and gas development personnel and residents, will create increasing angling pressure. Lake trout and Arctic char populations will be most sensitive to increased fishing and, without stringent measures to regulate angling, will suffer local declines. Increased recreational fishing is not expected to affect other species in the region because they are less vulnerable to overfishing.

Although all species, including lake trout, found in the area have demonstrated some ability to recover from the effect of heavy fishing , it is probable that, once access is provided to certain areas, angling pressure will remain heavy as long as fish are available. With appropriate regulatory controls, the overall effects attributable to increased angling will be NEGLIGIBLE.

(e) Water Requirements

Water withdrawals from areas providing overwintering habitat for fish can cause fish mortalities by dewatering habitat or reducing dissolved oxygen concentrations, however, this concern does not apply to the Mackenzie Delta region where there is an abundant year-round water supply.

Development plans call for selection of water withdrawal sites in consultation with regulatory agencies. Where water availability is in doubt, studies of water availability and the status of overwintering fish could be carried out prior to any water withdrawals. Assuming that proper consideration is given to overwintering fish, water requirements can be met without endangering local fish populations and the effect of water withdrawals will be NEGLIGIBLE.

(f) Reduced Productivity of Lower Trophic Levels

Sedimentation, nutrient enrichment, and spills of toxic materials can alter the productivity of lower trophic levels and have indirect effects on consumer organisms. With the exception of oil spills, which are discussed in Volume 6, however, such disturbances are only likely to affect lower trophic levels in the immediate vicinity of the release sites.

Limited nutrient enrichment from sewage discharges will increase productivity of certain lower trophic levels, and sedimentation and toxic spills may cause local reductions in numbers at most trophic levels. These disturbances may alter local community structure, an alteration which may affect the feeding distribution of local fish populations. Because they can quickly recolonize disturbed areas from nearby unaffected areas, lower trophic levels recover rapidly from disturbance, often in a single generation. Many species also display a high reproductive potential, often producing multiple generations in a single year, and are capable of repopulating a depleted area quickly once a disturbance has abated.

With the exception of large hydrocarbon spills, and sites of continuous long-term sewage introductions, disturbances affecting lower trophic levels will be short-term, generally affecting an area for less than one season. Until populations of prey organisms have recovered sufficiently to provide an adequate food supply, fish feeding in an affected area may temporarily seek alternative habitats. These local redistributions, however, have little significance, and fish will quickly return to disturbed areas once lower trophic levels are replenished.

In this region, communities of consumer organisms (algae, zooplankton, and zoobenthos) are cosmopolitan, so it is unlikely that disturbance will affect any unique feature of their distribution. Most disturbance will be both local in effect and brief in duration. Given the rapid recovery rate of the lower trophic levels and the limited effects on the distribution of consumer organisms, the overall effect will range from NEGLIGIBLE to MINOR.

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CHAPTER 4

NORTHWEST PASSAGE TRANSPORTATION REGION

This chapter discusses the possible effects of the normal operation of icebreaking tankers in the Northwest Passage and Davis Strait-Baffin Bay region. The possible physical and biological effects which may result from the operation of these vessels in the Beaufort Sea hydrocarbon production region were previously described in Chapter 2, while possible oil spills from tankers are described in Volume 6. The design of the proposed icebreaking tankers and frequency of operation necessary to meet expected daily production levels are discussed in Volume 2.

For this assessment, it is assumed that the safest, direct route with adequate water depths would be followed through the Northwest Passage (Figure 4-1). At the present time, only general transportation corridors have been defined for Amundsen Gulf, Prince of Wales Strait and Viscount Melville Sound. East of Viscount Melville Sound, the ships would follow the corridor proposed for Arctic Pilot Project liquid natural gas (LNG) ships (APP, 1981a). This corridor represents the best compromise in view of economic, physical and environmental concerns. This route includes use of any of the passages between Bathurst, Garrett, Lowther and Young islands, and then proceeds eastward along the approximate centre of Barrow Strait and Lancaster Sound. The ships would remain within a corridor approximately 8 km wide in these two channels.

The proposed transportation corridor would be centred in Baffin Bay and Davis Strait and is wider than the corridor in Lancaster Sound. The corridor does not approach the Greenland coast closer than 100 km or the Baffin Island coast closer than 150 km. Further details regarding the proposed transportation corridor are provided in Volume 2, Chapter 6.

For this assessment, it is assumed that the first icebreaking tanker is required by the end of 1985, after which time the fleet would increase gradually depending on production and transportation requirements (Figure 4-2). Depending on which development plan is envisaged (Volume 2, Chapter 3), there could be between 6 to 9 tankers required by 1990 and between 16 to 26 required in the year 2000. The lower numbers would apply to the intermediate development rate and the higher numbers to the technically achievable development rate. In each case, no overland pipeline construction is assumed. An average round trip between the Beaufort Sea loading terminal and the southern terminal is expected to require 28 to 30 days.

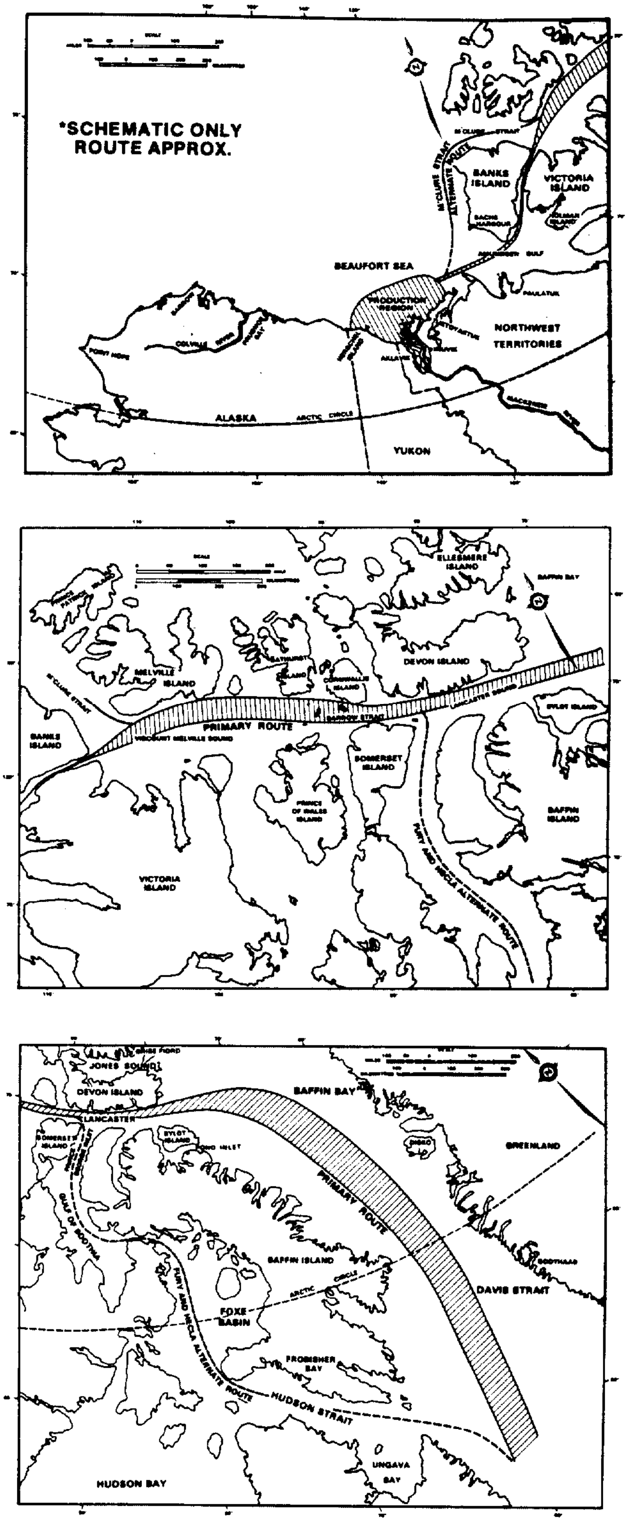

FIGURE 4-1 *The eastern shipping corridor and its possible alternate branches through M'Clure Strait and Fury and Hecla Strait. The alternate route west of Banks Island and through M'Clure Strait would add 150 km to the total route and in most years Arctic tankers would encounter high concentrations of multi-year ice in M'Clure Strait. At present, an alternate route through Fury and Hecla Strait, though no longer, is not viable for larger ships because of sparse soundings and possible insufficient water depths.*

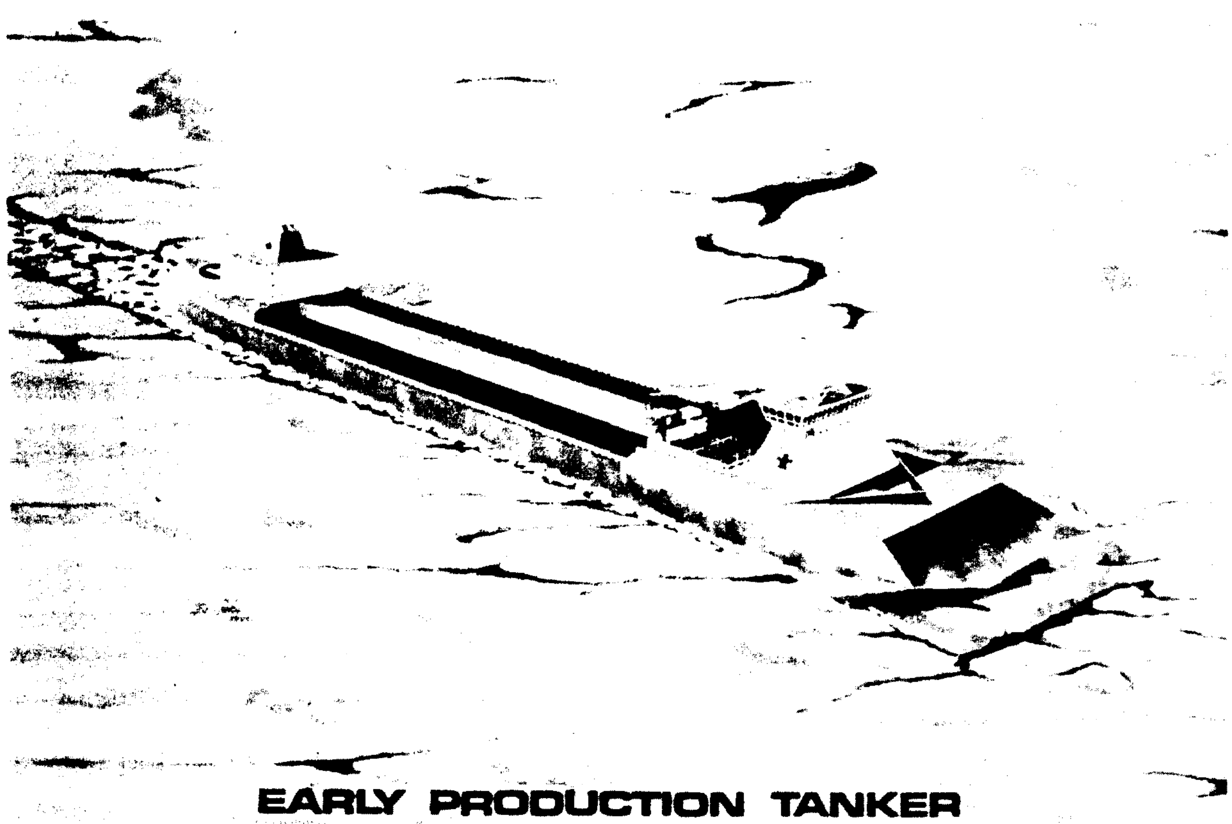

FIGURE 4-2 *Arctic Class 10 icebreaking tankers have been proposed to transport oil from the Beaufort Sea to southern markets. The first tanker could be an 80,000 DWT version of the full size 200,000 DWT vessels proposed over the longer term.*

The major concern with tanker transportation is the threat of a major oil spill. This Volume addresses only the normal activities associated with operations, hence oil spill impacts are not discussed here, but are covered in Volume 6, which is dedicated to the subject.

There is concern that icebreaking tankers in the Northwest Passage may create impassable artificial leads, cause changes in the stability of the ice regime, and alter the timing and patterns of local ice break-up. These physical effects could indirectly affect Inuit hunting patterns, and some species of marine mammals, terrestrial mammals, birds, fish, pelagic invertebrates and epontic organisms. Tankers may directly affect some marine biota, particularly seals through collisions, and epontic communities through the turning over of ice. A major concern is the generation of underwater noise, and effects it may have on marine mammals. Other concerns are related to the discharge of treated sewage, atmospheric emissions, and ice reconnaissance activities. The potential impacts of these activities are assessed in this chapter. The definitions used to assess the degree of potential impact are provided in Chapter 1, Table 1-1. Summaries of the potential impacts, in specific geographic areas and by major resource groups are provided at the end of this chapter.

4.1 POSSIBLE IMPACTS OF ICEBREAKING ON THE ICE REGIME

4.1.1 CREATION OF ARTIFICIAL LEADS

Observations from Canadian Coast Guard icebreakers and from the Class 4 icebreaker, MV CANMAR KIGORIAK provide a basis for assessment of artificial lead formation by icebreaking vessels. Icebreakers passing through loose pack ice usually leave an open water track that extends 1 to 2 km behind the vessel (Hatfield and Kanik, 1979; Kanik *et al.,* 1980). However, open water is naturally present in areas of loose pack ice and as a result, icebreaking under these conditions is expected to have little effect on marine biota. On the other hand, the passage through close pack and fast ice, where open water is not normally present is of greater concern. However, trials with the MV CANMAR KIGORIAK at various times throughout the winter and spring of 1981-82 indicated that in fast ice, the track behind the vessel was filled with ice rubble that quickly consolidated (B. Danielewicz, pers. comm.).

Ship track experiments were conducted in conjunction with the Hunters and Trappers associations of

Beaufort Sea communities. Observers from the Eastern Arctic were present during the June test period. The main purpose of the work was to determine how quickly the ice in the track consolidated and what problems might be encountered in crossing the ship track. During all test periods between early December and early June, the participants experienced little difficulty in crossing the track on foot, on skidoo, or on a skidoo with a laden komatik (Plate 4.1-1). A report on the work is presently being prepared. On the basis of these studies, terrestrial mammals such as Peary caribou and muskox, are not expected to encounter difficulties crossing ship tracks. When the first ships traverse the Northwest Passage, ship track crossing experiments will be repeated in the Eastern Arctic to determine whether any differences in results occur there (see Volume 7).

4.1.2 ICE EDGE BREAK-UP IN LANCASTER SOUND

The prospect of year-round tanker traffic in the Northwest Passage raises concerns about possible alterations of the landfast ice in Barrow Strait and resulting effects on local climate and wildlife. The concerns centre on the structural integrity of the landfast ice edge which forms each year in late winter across Lancaster Sound or Barrow Strait. It is thought that regular icebreaking tanker traffic through the landfast ice edge could delay its formation, cause its median location to be further west when it does form, and result in its earlier disintegration. MARTEC Ltd. was retained to address the structural integrity question. Their report is a support document to this volume (Lowings and Banke, 1982). Their main results are outlined below. (Volume 3B provides further information on the ice regimes of Barrow Strait and Lancaster Sound).

Figure 4.1-1 shows systems of major leads, cracks and open water in Lancaster Sound and northern Baffin Bay for selected months in late winter for various years. The position of the landfast ice edge in Lancaster Sound is seen to vary in different years, being well into Barrow Strait in April, 1976 and towards the eastern end of Lancaster Sound in February, 1979. Within the context of great natural variability, there remains the possibility in any year that the ice edge may stabilize further west due to icebreaking tankers than would occur naturally.

The consequences of ice edge locations being further west than normal were examined relative to ice cover variations in the region shown in Figure 4.1-1, which includes the North Water in northern Baffin Bay. From a regional climate point of view, any additional

PLATE 4.1-1 *During the winter of 1981-82, ship track crossing experiments were conducted near McKinley Bay, N.W.T. by the industry in conjunction with the hunters and trappers associations of Beaufort Sea communities. Based on the results obtained, there would appear to be few difficulties in crossing the ice under most conditions.*

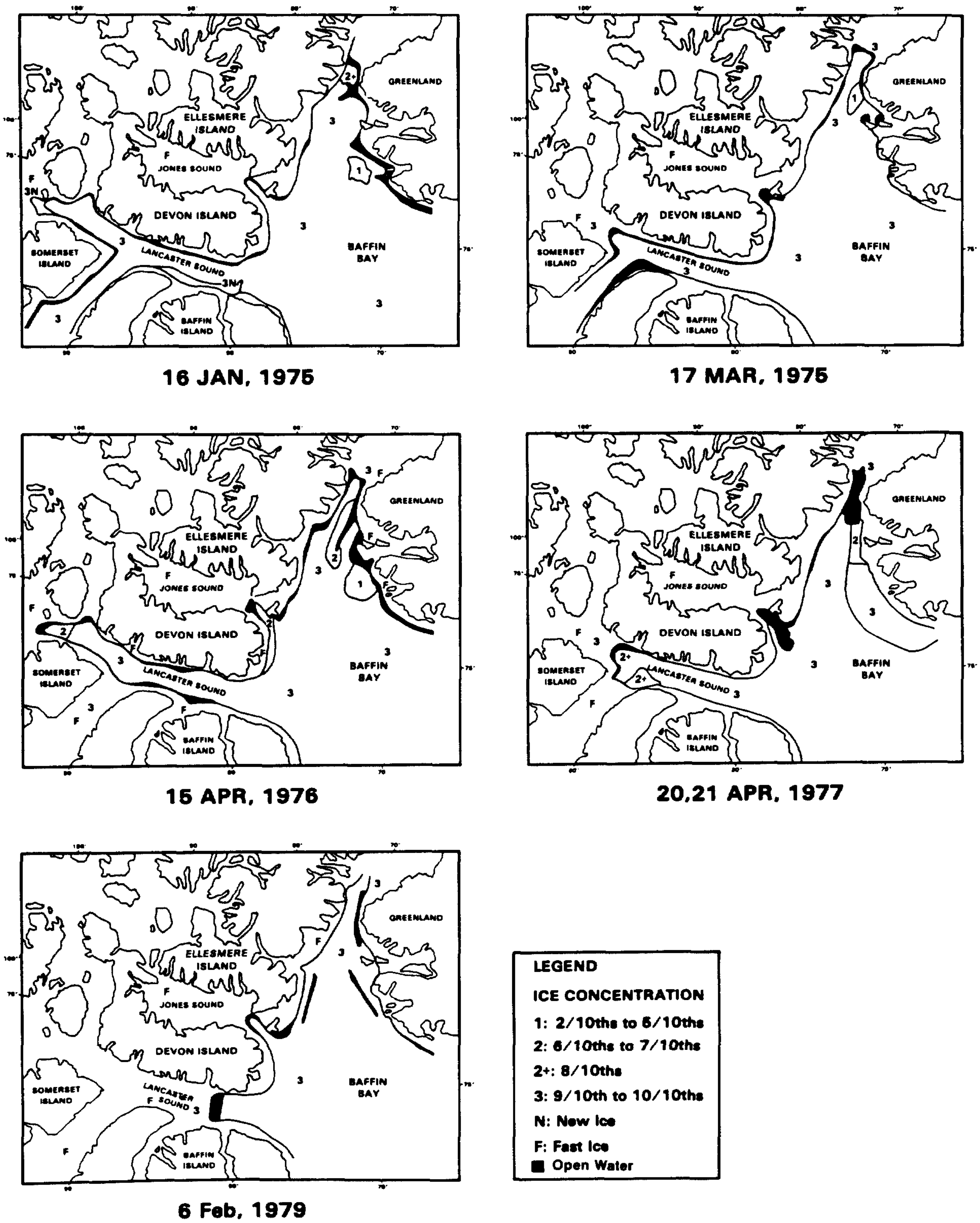

FIGURE 4.1-1 *Systems of leads and areas of open water in Lancaster Sound and northern Baffin Bay (source: Smith and Rigby, 1981). The position of the fast ice edge in Lancaster Sound changes considerably from year-to-year.*

mobilized ice and open water as a result of icebreaking needs to be compared with minimum and maximum coverage of landfast ice in Lancaster Sound and with the vast changes in ice cover in the North Water which occur from year to year.

Factors which control the location where the fast ice edge stabilizes include ocean currents, winds, air temperature, and the nature of the ice prior to stabilization. These factors operating in side channels also influence the ice edge position in Lancaster Sound. The ice edge is least stable during spring. In the fall, prevailing winds help maintain its integrity as it advances eastward. Therefore in spring there could occur a set of circumstances - winds, currents, crack patterns and icebreaking - which could precipitate a cascade-like removal of ice in a short time. However such a removal could occur without the aid of icebreaking tankers, making the effects of icebreaking indistinguishable from natural ice removal.

Lowings and Banke (1982) conclude that compared to the normal range of oceanographic and climate conditions expected for Lancaster Sound, and the large scale effects that these have, ship activity is probably of NEGLIGIBLE significance. Any ship-related effects, if they did occur, would be difficult to detect due to the masking effect resulting from wide natural variations in the location of the fast ice edge at the same dates in various years.

4.2 POSSIBLE IMPACTS OF ICEBREAKING ON BIOLOGICAL RESOURCES

4.2.1 MARINE MAMMALS

Two concerns have been raised about the potential direct effects of icebreaking on marine mammals. The first is the possible creation of open leads which could subsequently close and trap whales, and the second is the destruction or alteration of the physical platform provided by the ice and used by wintering and breeding seals.

4.2.1.1 Whales

Most whale species found along the primary eastern shipping corridor only occur there during spring and summer, and only as far north as southern and central Baffin Bay. Consequently, these species would not usually occur in areas affected by icebreaking activities. Species that migrate into the central High Arctic in spring and summer (white whales, narwhals and bowheads) may however be affected. White whales and bowhead whales also occur in leads and polynyas of Amundsen Gulf during spring, and may at that time be present in areas where tankers are operating in the icebreaking mode.

There is concern that white whales, narwhals, and possibly bowheads may follow artificial leads created by icebreaking vessels, and subsequently become entrapped if the leads refreeze or close. Although these species are well adapted to live in Arctic waters, they are known to occasionally become trapped by ice and die, usually from being hunted. Entrapment of white whales and narwhals has been recorded in West Greenland (Vibe, 1967; Kapel, 1977), in the Canadian High Arctic (Degerbøl and Freuchen, 1935; Freeman, 1968; Finley and Johnston, 1977), and in the Beaufort Sea area (Barry, 1967).

White whales that winter in the Baffin Bay North Water and that may be present along the southeast coast of Devon Island at the entrance to Lancaster Sound (Volume 3B) are the main species that may have opportunities to enter ship tracks. However, they are not expected to follow ship tracks since virtually no open water is created in the track behind a vessel under most conditions (Plates 4.2-1 and 4.2-2). In addition, noise from the moving ship will likely deter whales from following it. Fraker and Fraker (1982) observed that white whales avoided ships travelling in pan ice in the Beaufort Sea. Potential impacts on whales as a result of entrapment in icebreaker tracks are expected to be NEGLIGIBLE. If evidence of entrapment is found, opportunities for mitigation include routing the tankers farther south through Lancaster Sound to avoid interaction with the whales.

The possibility of entrapment during the fall is even more remote since most whales usually leave the Beaufort Sea and the central High Arctic in September and October before major ice formation begins.

4.2.1.2 Seals

The hooded seal and the ringed seal are considered particularly vulnerable to the potential physical impacts of icebreaking because they use the ice as a platform for breeding. During spring, a major concentration of hooded seals occurs in southern Davis Strait. The seals haul-out on the ice to give birth to their pups and to mate (Volume 3B), and the passage of tankers through the whelping patch could cause considerable mortality of hooded seal pups. However, this can and will be avoided by knowing where the main whelping areas are located. To mitigate possible impacts on hooded seal pups the proponents will use real-time data to establish the location of the whelping patch, and whenever possible, restrict the tankers from traversing these areas. Consequently, the potential impacts of icebreaking operations on the Davis Strait hooded seal population would be NEGLIGIBLE.

PLATE 4.2-1 *This photo, taken during the late spring in Baffin Bay shows several natural open water leads which are generally clear of ice, compared to the ice-filled "lead" or track created by a Canadian Coast Guard icebreaker, running from left to right across the top of the photo. Whales have been sighted in natural open water leads prevalent at this time, but not in icebreaker tracks (Courtesy: Hatfield Consultants Ltd.).*

PLATE 4.2-2 *This photograph taken in March, 1982 illustrates the condition of the track 20 minutes after the KIGORIAK had passed through the site. Conditions appeared similar to this even in June, although the ice did not refreeze as quickly.*

Ringed seals also give birth to their pups on the ice, but they do not occur in large aggregations during the whelping period. During winter, ringed seals are widely distributed in areas of fast ice and close pack ice where they maintain breathing holes. In late March and April, pregnant females give birth to pups in lairs hollowed out of snow drifts on the ice surface. The highest densities of birth lairs tend to be in areas of stable first year ice (McLaren, 1958; Smith *et al.*, 1979). It is generally agreed that newborn pups are unable to withstand exposure to cold water under the ice, but there is conflicting opinion about the age at which they can. The main insulative feature of pups up to three to four weeks old is a substantial layer of blubber. Pups moult their first (woolly) coat by three to four weeks of age (Chapskii, 1938), and could probably survive exposure then. It is assumed in this assessment that mortality would occur if pups are exposed to cold water before six weeks of age.

Mortality of some ringed seal pups is probable in the direct path of a tanker and in areas adjacent to the track where ice may be rafted. The number of seals that may be affected would depend on several factors including the number of tanker passages, the location and number of tracks used, and the density of birth lairs. Eight passages of an LNG carrier through Parry Channel (Viscount Melville Sound, Barrow Strait and Lancaster Sound) during the six-week pup rearing period could result in a maximum estimated loss of 1% of the newborn pups along the route (APP, 1981a). This estimate is based on worst case assumptions that eight separate tracks were created, all pups in a corridor 120 m wide along each track were lost, and that the ringed seal population was distributed relatively uniformly in areas affected by icebreaking. Impacts of this magnitude would be considered to be MINOR.

The number of tankers required to transport oil to the southern terminal is anticipated to increase gradually from one in 1985 to between 16 and 26 by the year 2000. At worst there could be about 80 passages per year within the six-week pup rearing period, or approximately 2 per day. The possible impacts from two tankers per day during the pupping season can be minimized by having the shipping corridor through fast ice as narrow as possible. Experience with the MV CANMAR KIGORIAK in the Beaufort Sea suggests that it will be possible for the tankers to use a narrow corridor through fast ice. In the following discussion it is assumed that the width of the corridor will be 2 km, including the requirements for separation of inbound and outbound ships. The average widths of the channels with fast ice along the shipping route and the percentages of first year ice in these channels are listed in Table 4.2-1.

A 2 km wide shipping corridor would use about 2 to 3% of the available first year ice habitat in Lancaster Sound, Barrow Strait and Viscount Melville Sound and about 7% of the habitat in Prince of Wales Strait. These percentages would be higher if the actual corridor is wider and lower if a narrower corridor could be used.

Two extreme reactions of ringed seals to shipping and icebreaking in the corridor may occur with gradations between the two also being possible. The first possibility is that seals will abandon the corridor during the 8 or 9 month period of fast ice cover due to frequent disturbance of the ice and noise from the ships. If abandonment occurs, then no seal pups would be killed by the ships. On the other hand, 2 to 7% of the available habitat in these channels would be lost to seals for the life of the full-scale production phase of the project. These seals may not be able to occupy and breed successfully in adjacent areas of fast ice because ringed seal numbers appear to be limited by winter food availability (McLaren, 1958; Finley, 1979) and their winter distribution is determined by territorial behaviour (Smith and Hamill, 1981). Thus, fast ice areas adjacent to the shipping corridors are expected to support the maximum number of seals possible so that displaced seals may be lost to the breeding population. According to the

TABLE 4.2-1

AVERAGE WIDTH OF CHANNELS WITH FAST ICE ALONG THE SHIPPING ROUTE AND PERCENT FIRST YEAR ICE

	Average Channel Width (km)	Average Width of First Year Ice (km)	% of First Year Ice Affected
Lancaster Sound	83	83	2
Barrow Strait	94	94	2
Viscount Melville Sound	175	75	3
Prince of Wales Strait	28	28	7

definitions of impact used in this statement, this loss could represent a MODERATE to MAJOR local impact. However, the integrity of the regional population would not likely be affected so the possible regional impact would likely range from MINOR to perhaps MODERATE.

The second possibility is that ringed seals will not be displaced between subsequent ship passages. Studies in the Beaufort Sea (Alliston, 1980) and Lake Melville, Labrador (Alliston, 1981) indicate that ringed seals do not abandon fast ice areas in response to small numbers of icebreaker passages in winter. In fact, there is evidence that seals may preferentially establish breathing holes in the rubble of a ship's track (Plate 4.2-3). These studies examined the effects of only two winter ship passages in the Beaufort Sea and one in Lake Melville. It is, therefore, not possible to predict how ringed seals would react to a "worst case" average of as many as two passages per day within a 2 km wide corridor.

If it is assumed that seals are territorial and that they exhibit site tenacity, then it is probable that at least some individuals will remain in the shipping corridor. A small proportion of these animals would be displaced during each ship passage but they presumably would re-establish breathing holes in the ship track. During the pupping season, the worst case is that all pups displaced at less than 6 weeks of age would die of exposure or crushing. A more realistic scenario is that only pups less than 3 to 4 weeks old would be lost. During this 3 to 4 week period there could be about 50 ship passages. The number of deaths caused by these passages could be quite high in the corridor although on a regional basis the potential impact is expected to range from MINOR to MODERATE. Unknown factors are the survival rates of pups less than 4 weeks of age; the proportion of the female population that would not abandon the shipping corridor prior to pupping; and the proportion of the width of the shipping corridor actually affected during the pup-rearing season.

Opportunities for mitigation of the potential impacts of icebreaking activities on ringed seal pups include: identification of high density pupping areas which would reduce impacts if these areas could be avoided by the tankers. However, there is no evidence to date that major concentrations of birth lairs occur. Therefore, the most effective mitigative measure would be to maintain the narrowest, most direct shipping corridor possible through areas of fast ice.

The largest area of stable first year ice along the proposed shipping corridor occurs in Barrow Strait. Lowings and Banke (1982) considered the probability that tanker traffic would result in early break-up of this ice sheet. They concluded that although unlikely, under certain circumstances this might occur. It was also considered unlikely that the icebreaking activities would affect the timing of break-up beyond the large range of natural variability. In some years (4 of 16) the ice in eastern Barrow Strait does not even consolidate into fast ice (APP, 1981a). Since most ringed seal pups are born before mid April and are probably weaned by late May, the potential for early break-up to affect substantial numbers of

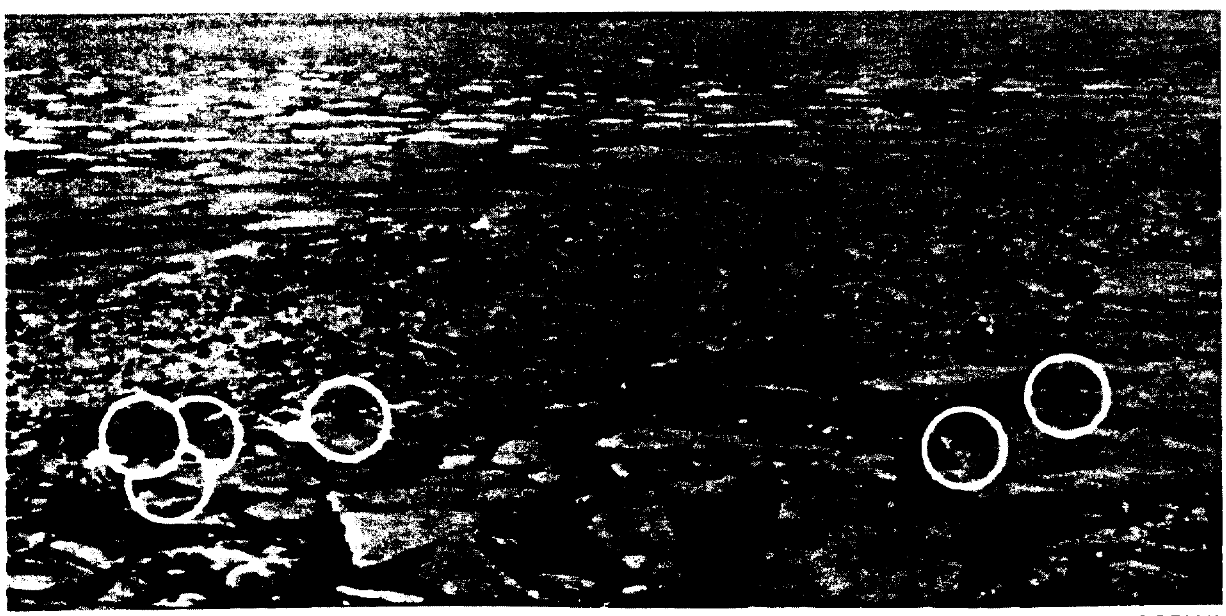

PLATE 4.2-3 *Icebreaker track research done in 1980 found that ringed seals reoccupied the track created by the KIGORIAK when it only travelled through the area twice during the course of the winter. Also, in the spring (when this photo was taken), bearded seals seemed to take advantage of the broken track by congregating on the floes. (Courtesy: L.G.L. Limited.).*

suckling pups through loss of the stable platform would be limited to situations when break-up occurred prior to late May. Potential impacts would probably not exceed MINOR given the localized nature of the effects, the widespread distribution of this species and the periodic natural occurrence of this early break-up phenomenon.

4.2.1.3 Terrestrial mammals

There is concern that tracks created by icebreaking vessels may affect some terrestrial mammals by preventing them from traversing the ice across marine channels. Peary caribou are known to occasionally cross Parry Channel (Gunn *et al.*, 1981), and may also cross Prince of Wales Strait.

During spring, cross-channel movements of caribou are unlikely to be blocked since the tracks will be filled with ice rubble initially and drift in with snow quickly (Plate 4.2-4). Since caribou would presumably encounter and cross pressure ridges perpendicular to their movements under natural conditions (Plate 4.2-5), they should have no difficulty crossing refrozen vessel tracks.

If caribou attempted to cross Parry Channel during fall, they would probably do so at a time when tanker tracks are most likely to be clear or only partially filled with rubble. Nevertheless, the tracks would refreeze within hours under most conditions to a thickness that would support caribou, and the potential impacts of icebreaking on caribou are expected to be NEGLIGIBLE.

4.2.2 BIRDS

Birds may be affected by icebreaking activities along the eastern shipping corridor mainly during spring, summer and early fall, although a few species, including the ivory gull and black guillemot, that winter along the Davis Strait ice edge or among the pack ice could be affected year-round. Some individuals may be disturbed by the passage of tankers, while others (e.g. fulmars, black-legged kittiwakes, other gull species) may benefit from increased accessibility of fish and invertebrates exposed on overturned ice along the icebreaker tracks (cf. Andriashev, 1970; MacLaren Marex, 1979).

Although birds along the shipping route may take flight in order to avoid the vessels, the number of

PLATE 4.2-4 *This picture, taken twenty-four hours after the KIGORIAK passed through this site in the Beaufort Sea during March, 1982, illustrates how drifting snow rapidly covers in the refrozen track. Conditions such as this should pose few difficulties for caribou or muskoxen should they choose to cross a ship track during most of the winter.*

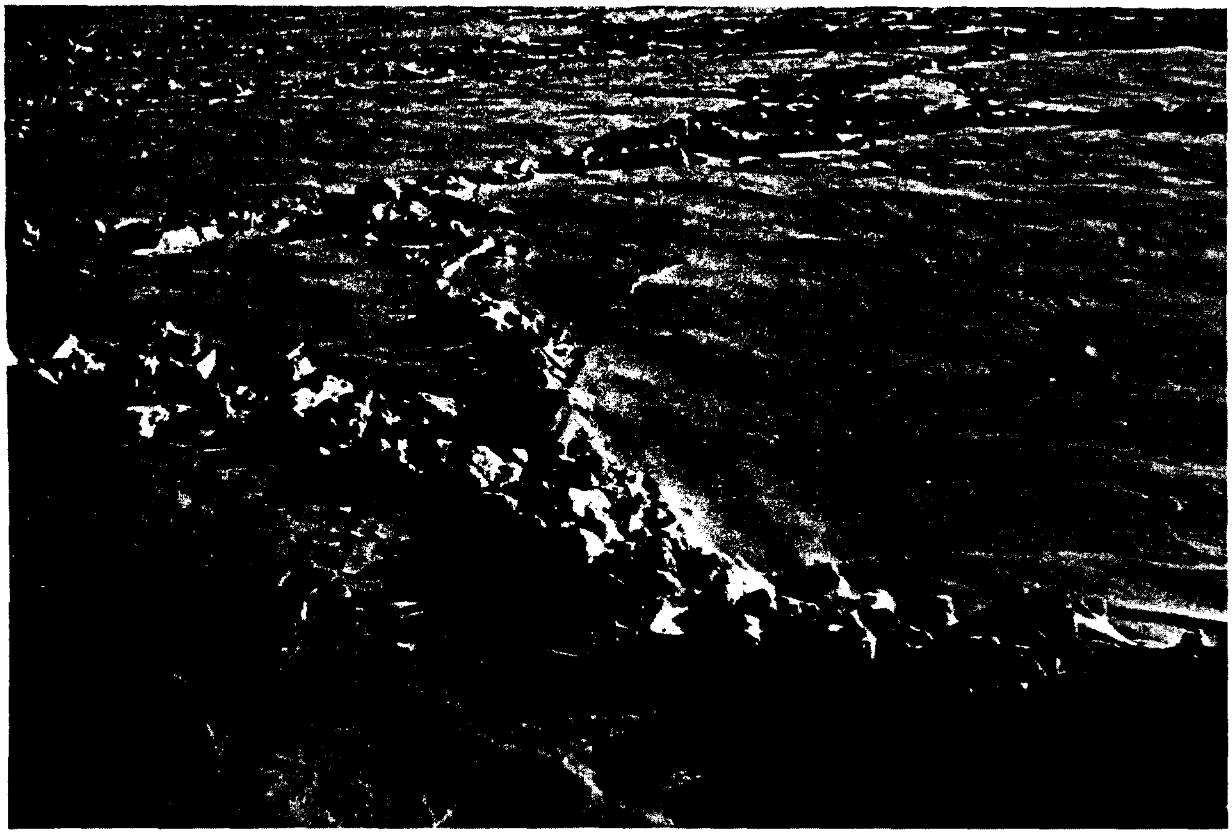

PLATE 4.2-5 *Pressure ridges up to 15 feet (5 m) high such as shown here in Viscount Melville Sound during September 1979, are a common feature of most of the Northwest Passage shipping corridor. Terrestrial mammals including caribou would encounter and cross ridges such as these during their infrequent inter-island migrations. Therefore, they would have little difficulty crossing ship tracks, which are much lower.*

birds affected would probably be small in most areas, and the energy expenditures associated with these movements would probably be inconsequential. The only area where relatively large numbers of birds may be affected temporarily is along the Lancaster Sound ice edge which is a major concentration area for birds during spring (Volume 3B). Nevertheless, the passage of a maximum of 2 tankers per day is expected to have NEGLIGIBLE impacts on birds in this and all areas along the route.

4.2.3 FISH AND LOWER TROPHIC LEVELS

The most significant effects of icebreaking activities along the tanker route on lower trophic levels would be on the epontic community which develops under the ice surface each spring. Benthic and epibenthic organisms would not be affected by icebreaking, while a small proportion of the pelagic invertebrate and fish populations may be lost through entrainment in tanker propellers during both ice-covered and open water periods, and through stranding on overturned ice. These potential effects have been detailed in ESL (1982), while the potential impacts of icebreaking in the Beaufort Sea region on fish and lower trophic levels were assessed in Chapter 2, Section 4.4.

Epontic microalgae bloom in spring, reaching maximum production in May. Algal biomass is low during winter, and little is known about the factors that seed the late winter and spring bloom (Horner, 1977). During spring, the potential effect of icebreaking on epontic flora may include localized mortality on overturned ice in the vessel tracks, decreased primary production under areas of thick or rafted ice, as well as the possibility for enhanced productivity on the irregular surfaces created in the track (ESL, 1982). In a regional context, however, the positive and negative impacts of icebreaking on epontic flora would be considered NEGLIGIBLE because of the small geographic areas affected in relation to adjacent, undisturbed areas of epontic habitat.

The immediate effect of icebreaking on fish and epontic fauna is the potential for localized stranding on overturned ice, and subsequent mortality through exposure or predation by birds. In addition, epontic fauna may be attracted to disturbed areas in the tracks as a result of increased illumination (Green and Steele, 1975; ESL, 1982). Another effect of icebreaking on epontic fauna and fish, in particular Arctic cod, would be the increase in available habitat resulting from ice rafting along the icebreaker track (Milne, 1977; Divoky, 1978; ESL, 1982). Nevertheless, the potential regional impacts associated with these effects on fish and epontic fauna would probably be NEGLIGIBLE because the areas affected would be highly localized, and the numbers affected would be insignificant in terms of the regional populations.

The possibility that a significant proportion of fish or pelagic invertebrates in an icebreaker's track would be lost through entrainment in propellers is remote (ESL, 1982), and the potential impacts on the regional populations associated with this effect are considered NEGLIGIBLE.

4.3 POSSIBLE IMPACTS OF ICEBREAKING ON INUIT HUNTING PATTERNS

During spring, hunters from Resolute regularly cross Parry Channel to Somerset and Prince of Wales islands (Kemp *et al.*, 1977), while groups from Holman cross the southern end of Prince of Wales Strait, and hunt offshore in Amundsen Gulf (MacWatt, 1980). Based on the recent ship track crossing studies (Section 4.1.1), it appears that ship tracks through landfast ice areas are not likely to cause a serious problem for either the hunters or their prey. However, since studies of this nature have not yet been conducted in Eastern Arctic locations, this kind of work will be carried out there in conjunction with the first year-round icebreakers travelling through the region (see Volume 7).

4.4 POSSIBLE IMPACTS OF UNDERWATER NOISE

There is concern that underwater noise produced by transportation activities in the Northwest Passage may affect marine mammals through disturbance and masking of sounds used for communication and orientation. For this reason, the subject will be examined in considerable detail.

In the Northwest Passage, the major sources of future underwater noise produced by transportation operations would include tankers and reconnaissance aircraft. The biological effects of underwater industrial noise on fish and marine mammals are reviewed in ESL (1982). Disturbance from underwater noise is possible only if the animals can detect the noise source. The range of detection depends on several factors which will be briefly discussed in the following sections. The factors include (1) source level ("loudness"), (2) propagation losses between the noise source and the receiver, (3) level of ambient noise at the receiver, and (4) the hearing sensitivity of the receiver. The interaction of these factors provide a basis for assessment of the potential impacts of underwater noise on marine fauna along the eastern shipping corridor. An assessment of the potential impacts of underwater noise on marine mammals and fish in the Beaufort Sea region was provided in Chapter 2.

Underwater noise associated with tanker operations would be produced by propeller cavitation, machinery and the breaking of ice. The major source of noise would be cavitation, although noise from machinery could be detectable at least close to the vessel. At the present time, however, it is not possible to predict noise levels produced by the latter, and this potential noise source is not considered further in the present assessment. Underwater noise generated during the physical breaking of ice has not been well documented, although after examination of data from the Finish icebreaker M/S VOIMA (Thiele, 1981), Brown (APP, 1982) concluded that the noise of icebreaking was insignificant in comparison with noise produced by propeller cavitation. Consequently the following assessment only addresses underwater noise produced by cavitation.

Brown, in his prepared testimony to the National Energy Board (APP, 1982) described cavitation as resulting from "the creation of local areas of low pressure on or near the propeller blades. A propeller blade produces thrust in the same way that an airplane produces lift. As the blade moves through the water in a helical path, the pressure is raised on its after side and is reduced on its forward side. The difference in pressure, multiplied by the total blade area gives approximately the propeller thrust. Since these pressures vary as the square of the speed, as speed is increased there comes a point where the reduced pressure on the forward side of the blade drops below the vapour pressure of the water. The tensile strength of the water is exceeded and a vapour cavity is formed. This is cavitation. It occurs not only on propellers but also in pumps and hydraulic turbines as well. As the propeller blade moves on, such cavities and vapour bubbles reach areas of pressure higher than that where they were formed. There the cavities are unstable; they break up into bubbles and collapse violently. It is the rapid fluctuation in the volume of these cavities and bubbles, particularly in the process of collapse, that is the strong source of underwater noise."

Opportunities for mitigation of the potential impacts of underwater noise on marine mammals include strategic vessel design and routing. Potential impacts which will be discussed in this section are likely to be reduced if the tanker design effectively reduces propeller cavitation and therefore the level of underwater noise produced. In conjunction with the Arctic Pilot Project consortium, ship designers are undertaking tests to maximize the efficiency of the propellers to be used on future Arctic ships. Preliminary data from model tank tests, which have been scaled up to full size with an accuracy of ± 5 dB, are demonstrating that the noise levels produced by these ships of the future may be encouragingly low (APP, 1982). This information will be presented in Section 4.4.1. Furthermore, the proponents are committed to using the corridor proposed for LNG carriers of the Arctic Pilot Project, which was defined on the basis of reducing potential impacts on the biological environment and resource harvesting activities, while maintaining ship and public safety (APP, 1981a).

Reducing the speed of the tankers in critical marine mammal habitats at critical times would reduce underwater noise levels, and potentially reduce possible impacts. This approach may be feasible in restricted areas for short periods.

Another opportunity for mitigation, should it be required, involves the use of convoys because although two tankers in close proximity could ensonify an area four times as large as one tanker, this would only be the case when they are operating at full power. If the second (following) tanker were able to proceed at a lower power setting with reduced cavitation, the area ensonified would be correspondingly smaller. In addition, if more than two tankers are in convoy, the level of incremental noise of the third and any subsequent ships is less than 3 dB. The proponents are committed to carrying out further studies in the future to determine how tanker noise may affect marine mammals along the shipping corridor (Volume 7).

4.4.1 SOURCE LEVELS

Potential source levels of underwater noise produced by ships and aircraft were provided in Chapter 2. (The potential impacts of underwater noise produced by reconnaissance aircraft on marine mammals in the Northwest Passage are assessed in Section 4.6). Estimates of noise levels for the proposed Class 7, 140,000 DWT LNG carriers of the Arctic Pilot Project (APP) have been made, and were based on established theoretical models and tank tests conducted at the Netherlands Ship Model Basin (APP, 1982). The design and specification of the APP carriers are similar to the proposed icebreaking oil tankers, so estimates of noise produced by the former will be adopted for the present assessment.

Source levels are measured in units of decibels (dB) relative to a pressure level of 1 uPa at a distance of 1 m from the source in a 1 Hz band width [dB at 1 m re (1 uPa)^2/Hz]. Propeller cavitation noise occurs over a wide range of frequencies, having spectra as shown in Figure 4.4-1. This figure shows estimates of cavitation noise spectra for APP carriers operating at full power in ice and half-power in open water. These are free-field* source spectra.

* Free-field source levels represent sound pressure levels which would be measured in an infinite body of water at a distance of 1 m from the noise source when shrunk to an equivalent point source of noise.

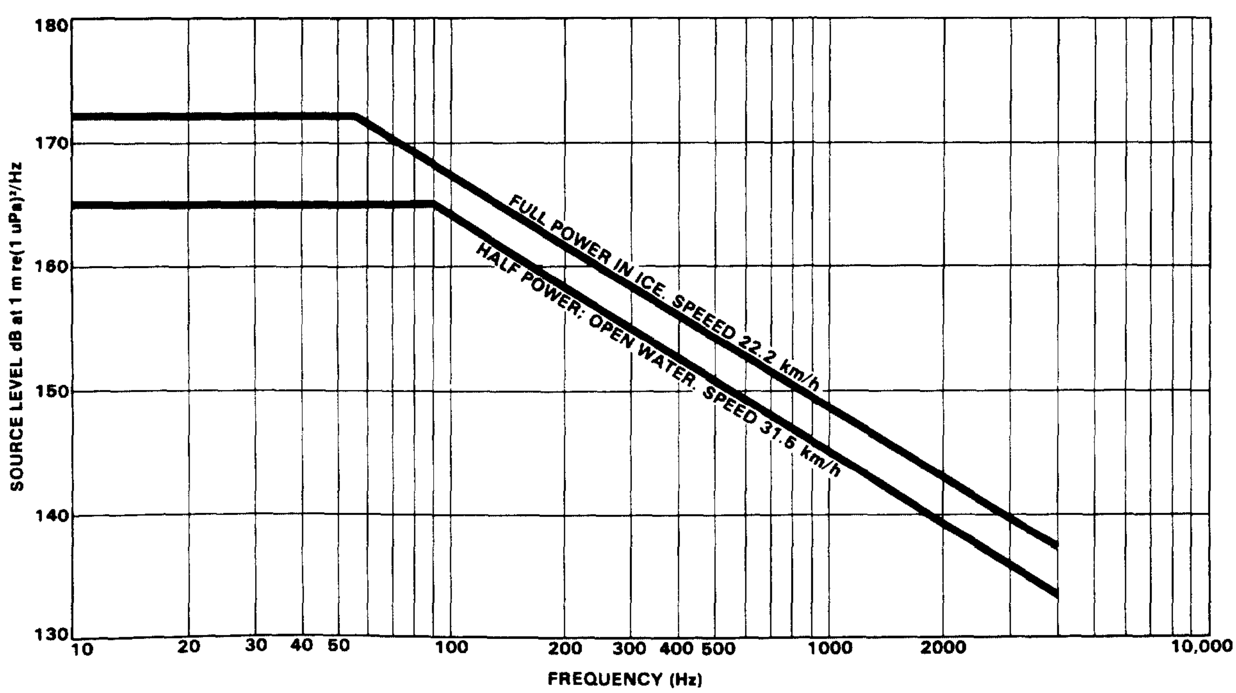

FIGURE 4.4-1 *Propeller cavitation noise estimates for APP carriers operating in ice under full power and in open water under half power (Source: APP, 1982).*

In addition to generating noise with a continuous spectrum, the vessel would also generate blade rate tonals at frequencies of 5.33 Hz and harmonics, with a maximum free-field source level of 191 dB expected to occur at the fundamental frequency of 5.33 Hz (APP, 1982). However, it should be noted that because of the shallow depth of the propeller, the noise source would be poorly coupled to the water column. This phenomenon, known as the 'Lloyd Mirror Effect,' effectively reduces the tonal source level from 191 dB to 164 dB for the purposes of long range propagation (APP, 1982).

Quoting from Brown's prepared testimony to the National Energy Board regarding LNG carriers (APP, 1982): "Small working craft which are not high speed produce overall free field source levels of 182 dB relative to a micro pascal at 1 metre or less.

Most of the world's freighters produce overall source levels of less than 192 dB. A multiple screw container ship or passenger ship at high speed will produce overall free field equivalent source levels of perhaps 192 to 198 dB. An aircraft carrier operating at high speed may produce as much as a 203 dB overall free field source level. On the other hand, small high speed craft can produce noise levels higher than would be expected for their size. Outboard motor propellers can produce overall free field acoustic source levels of 175 dB or more. The aircraft carrier employs 10,000 times more horsepower than the outboard motor to go about the same speed but generates only 100 times more underwater acoustic power."

Brown concluded his testimony by stating that the noise generated by these ships would not be particularly loud. "In full power operation in either open water at 22 kts or in ice allowing 12 kts speed, the free field acoustic power values are comparable to container ships and passenger ships at comparable speeds. At ½ power or 17 kts in open water, the estimates are lower than for most merchant ships. The effect on the underwater noise environment should be comparable to that of a trawler. Only in the condition of full power at zero speed is the estimated acoustic power large, and even then not so large as is commonly radiated by large, high speed military vessels."

It should be noted that the source levels for various types of ships given in the previous paragraphs are overall free-field source levels rather than the spectrum level source levels in a 1 Hz bandwidth used in Table 4.4.1. Thus, the overall free-field source levels for the APP LNG carriers would be 192 dB at 22 kts in open water. This translates into a spectrum level of 172 dB at 70 Hz.

The estimates for the Arctic Pilot Project ships operating at full power, either in open water or icebreaking, are remarkably close to measured data, corrected to free field, for the Canadian icebreaker LOUIS ST. LAURENT. This is a large icebreaker of 14,000 tons with a total of 24,000 horsepower distributed on three shafts. Measurements were made by DREA (Defense Research Establishment Atlantic) at 14 kts speed in open water at 130 propeller rpm.

"The same prediction technique used for the Arctic Pilot Project ships, when applied to the ST. LAURENT, is in very good agreement with the measured data. We have examined several other icebreakers and have estimated their noise in the same way. The results are somewhat lower than that for the ST. LAURENT."

4.4.2 SOUND PROPAGATION

The general principles governing sound propagation as well as the specifics of propagation in the Beaufort Sea region were discussed in Chapter 2. Propagation losses in the Northwest Passage and in Baffin Bay are somewhat different because of differences in depth, bottom configuration and bottom substrate, and are therefore discussed here.

Estimates of sound propagation losses in Baffin Bay deep water (2,000 m) were combined with source spectrum levels from Figure 4.4-1 to produce estimates of noise levels at various distances from icebreaking tankers in dB re 1 uPa^2/Hz. These estimates are shown in Figure 4.4-2 and 4.4-3 for ice covered waters and open water, respectively, for frequencies of 100 Hz, 1 kHz and 5 kHz (Brown, 1982) and for two different receiver depths: 3 m and 20 m. Receiver depths are important at low frequencies where the Lloyd Mirror Effect decouples the noise from the receiver at shallow depths. Also shown are some representative natural ambient noise levels from Table 4.4-1. Marine mammals could reduce their ability to hear low frequency tanker generated noise by swimming at shallower depths. This would also reduce the received intensity of low frequency tonals transmitted to them.

Water depth is also a factor governing sound propagation in Baffin Bay. Propagation losses are much higher over the coastal shelf, especially at low frequencies. Total propagation loss when sound travels from deep water to shallower areas over the coastal shelf is affected by water depth, the distance travelled in shallow water, bottom topography and substrate type (Leggat *et al.*, 1981). Losses due to travel over the coastal shelf of Baffin Bay averaged 19 dB at 63 Hz, with maximum losses of 25 dB (Leggat et al., 1981). Therefore low frequency propagation losses in the shallow parts of Parry Channel, Prince of Wales Strait and Amundsen Gulf will be greater than in offshore Baffin Bay (Verrall, 1981).

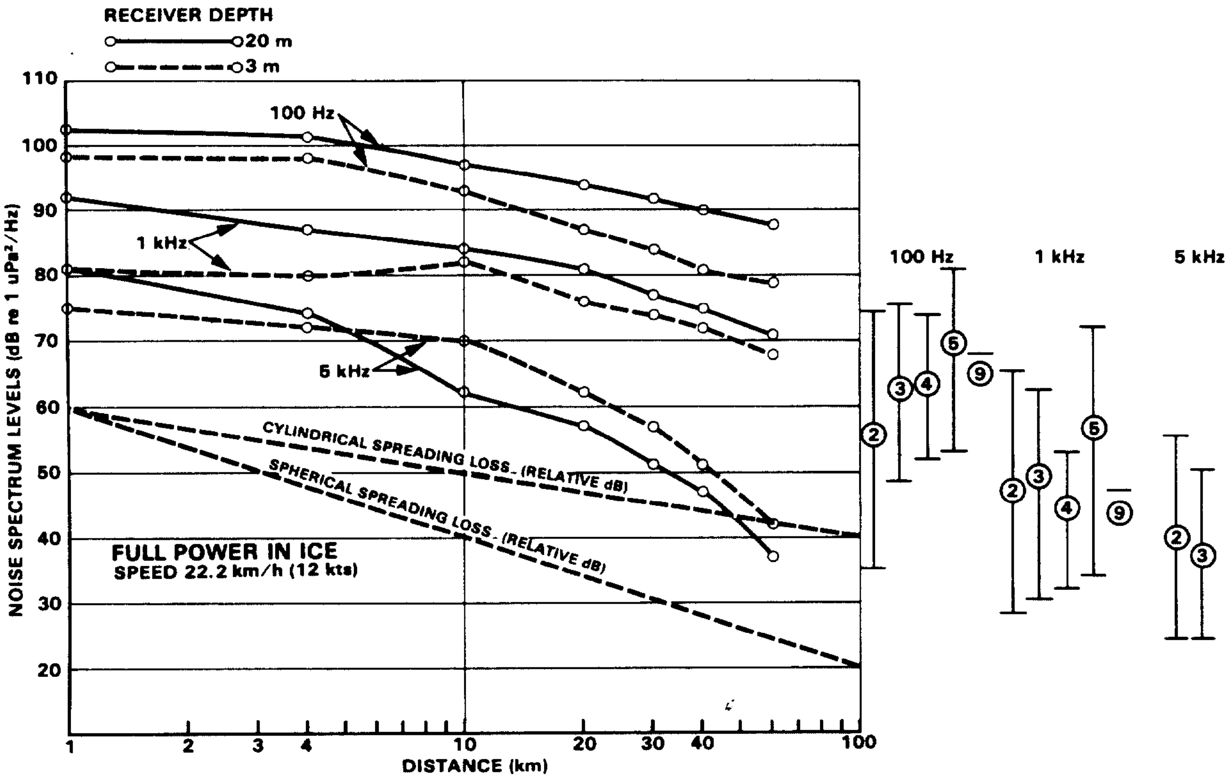

FIGURE 4.4-2 *Noise level estimates (dB re 1 uPa²/Hz) generated by an icebreaking tanker operating at full power at various distances and frequencies in continuous ice cover in Baffin Bay deep water. For comparison, cylindrical spreading loss versus distance and spherical spreading loss versus distance are plotted on a relative dB scale. Also shown are some representative natural ambient noise levels reproduced from Table 4.4-1. (Source: APP, 1982).*

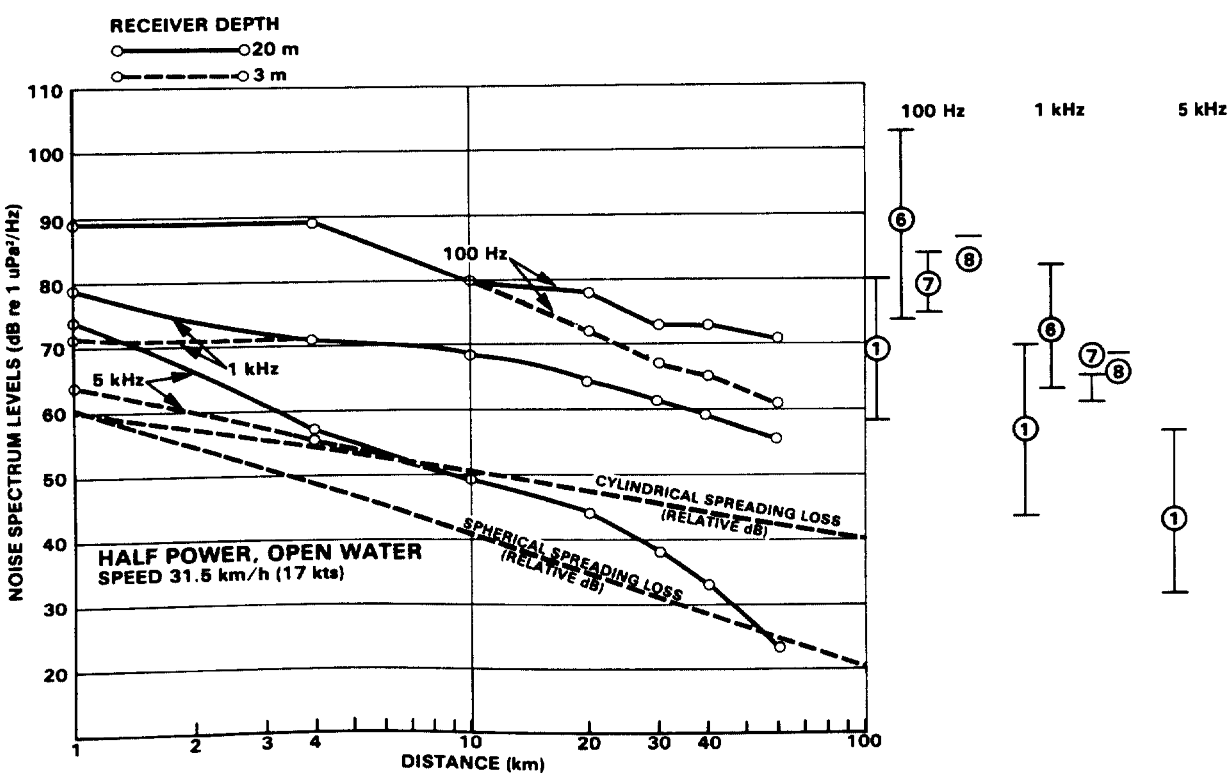

FIGURE 4.4-3 *Noise level estimates (dB re 1 uPa²/Hz) generated by an icebreaking tanker operating at one-half power at various distances and frequences in open water in Baffin Bay deep water. For comparison, cylindrical spreading loss versus distance and spherical spreading loss versus distance are plotted on a relative dB scale. Also shown are some representative natural ambient noise levels reproduced from Table 4.4-1. (Source: APP, 1982).*

4.4.3 AMBIENT NOISE

Ambient noise and its role in sound reception by marine biota is described in Chapter 2. It was noted that shipping probably contributes little to ambient noise levels in the Beaufort Sea area at present, especially in winter. The same is not necessarily true in the Davis Strait portion of the eastern shipping corridor. Leggat *et al.*, (1981) believed that ice was the major source of ambient noise in the 10 to 1,000 Hz range in Baffin Bay during all seasons and that the average ambient noise levels observed in Baffin Bay were much higher than expected in summer.

Ambient noise along the shipping corridor varies both seasonally and with area (Table 4.4-1). Quietest areas are likely to occur under fast ice (i.e. winter and spring in western Parry Channel, Prince of Wales Strait and Amundsen Gulf), while noisiest areas in winter probably occur along the Davis Strait ice edge. In the following text, noise reference levels are in decibels (dB) relative to a sound pressure level of 1 uPa in a 1 Hz bandwidth (dB re 1 uPa^2/Hz).

Although there is no published information on ambient noise levels in Baffin Bay and Davis Strait during winter, ambient noise measurements are available for a pack ice edge in the Greenland Sea (Diachok and Winokur, 1974; Diachok, 1980). In the latter area, ambient noise varied with sea state. Median noise spectrum levels for sea state 2 at a compact ice edge were 86 dB at 100 Hz, and 68 dB at 1 kHz. Levels were lower within the pack ice at a distance of 80 km from the ice edge, being 68 dB at 100 Hz and 47 dB at 1 kHz. Noise levels at diffuse ice edges tended to be about 10 dB lower than those at compact ice edges (Diachok, 1980).

Ambient noise levels in Baffin Bay have been reported only for summer, at which time levels averaged about 74 to 86 dB at frequencies from 20 to 100 Hz, gradually decreasing to about 45 to 62 dB at 3 kHz (Leggat *et al.*, 1981). Loud (about 115 dB at 20 Hz) transient noises in Baffin Bay were attributed to the rolling over of small icebergs and other ice movements (Leggat *et al.*, 1981).

TABLE 4.4-1

AMBIENT NOISE SPECTRUM LEVEL RANGES IN dB re 1 uPa^2/Hz

Sample No.	Location, Time, Condition	Frequency 100 Hz	1 kHz	5 kHz
1	Deep open ocean (Urick, 1975)	58-80	43-69	31-56
2	Viscount Melville Sound; Sept.-Oct. under moving ice (Milne and Ganton, 1971)	35-74	28-65	25-55
3	Off Ellef Ringnes I., Feb. under landfast pack ice. (Ganton and Milne, 1965)	48-75	30-62	25-50
4	Arctic Ocean pack ice; May to Oct. (Mellen and Marsh, 1965)	52-74	32-53	—
5	Arctic Ocean; full year; 10/10ths pack ice (Greene and Buck, 1964)	53-81	34-72	—
6	Baffin Bay; summer (Leggat et al., 1981)	73-102	62-81	—
7	Labrador Sea; summer (Leggat et al., 1981)	74-83	60-63	—
8	Greenland Sea; median level at ice edge, sea state 2 (Diachok, 1980)	86	68	—
9	Greenland Sea; median level 80 km from ice edge in pack ice (Diachok, 1980)	68	47	—

Noise levels under fast ice in Parry Channel are somewhat lower, ranging from 22 to 70 dB at 1 kHz (Milne and Ganton, 1964). Verrall (1981) reported an average of 40 dB and 70 dB in a 150 to 300 Hz octave band in winter and summer, respectively. The main sources of ambient noise during winter include ice movements, thermal cracking noise, blowing snow and marine organisms, while waves, rain and grinding ice are the main sources of noise during summer. Ambient noise levels are never static, and fluctuate widely.

Certain transient sounds are considerably louder than ambient noise levels. For example, Buck and Green (1979) reported tonal components of noise generated by active pressure ridge building as loud as 137 dB in the 4 to 10 Hz range. These tonals occurred intermittently and lasted for up to 15 minutes, while broadband noise generated by the ridge ranged from about 18 to 39 dB re 1 uPa^2/Hz at 100 Hz (Greene, 1981).

4.4.4 VOCALIZATIONS, HEARING THRESHOLDS AND CRITICAL RATIOS

The threshold of hearing at various frequencies (audiogram) has been determined under quiet experimental conditions for a number of species of marine mammals. However, ambient noise levels in the marine environment are frequently louder than the absolute hearing threshold of the animals. Consequently, detection of a sound (e.g., the call of a conspecific) in a noisy environment depends on the loudness of the signal in relation to background noise (critical ratio).

Critical ratios have been determined for a few species of marine mammals in frequency ranges above 2,000 Hz. For example, the critical ratio for the ringed seal is between 30 and 34 dB over the range 4 to 32 kHz (Terhune and Ronald, 1975b). Therefore, at ambient noise levels of 70 dB, a signal must be as loud as 100 to 104 dB to be detected by a ringed seal.

Critical ratios for both ringed seals and other species that have been tested (harp seal, bottlenosed dolphin) increase with increasing frequency above about 2,000 Hz (Johnson, 1968; Terhune and Ronald, 1971, 1975b). Although critical ratios for marine mammals have not been determined at frequencies below 2,000 Hz, Terhune (1981) suggests that critical ratios in the 100 to 2,000 Hz range are likely to be similar to those of humans, at least for odontocete (toothed) whales and phocid seals. Figure 4.4-4 shows the critical ratio for humans, two seal species and the bottlenosed dolphin. Payne and Webb (1971) speculated that the very large brains of baleen whales might have signal processing capabilities sufficient to allow discrimination of low frequency pure tones at critical ratios of 0 dB or less, although this has not yet been determined by experimentation.

Loud ship noises at low frequencies will not necessarily mask reception of signals at high frequencies because of the ability of the mammalian ear to process sounds at different frequencies independently in a series of 'critical bands.' The 'critical band' of noise is defined as the bandwidth beyond which no further masking of a pure tone at the centre of the band occurs (Bilger and Hirsch, 1956; cited in Payne and Webb, 1971). In humans, 24 non-overlapping critical bands within the frequency range from 50 Hz to 16 kHz have been found (Scharf, 1970; cited in Popper, 1980). Johnson (1968) found evidence of up to 40 critical bands in the bottlenosed dolphin which can hear sounds as high as 100 kHz. The existence of critical bands suggests that the predominantly low frequency ship noise will not significantly interfere

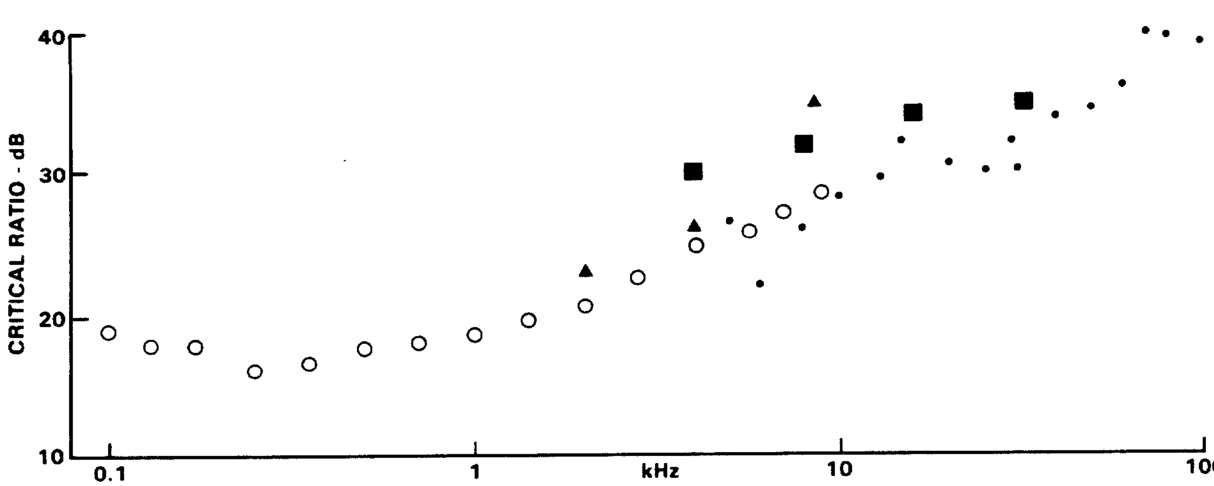

FIGURE 4.4-4 Critical ratios for the bottlenosed dolphin (dots: Johnson, 1968), ringed seal (squares; Terhune and Ronald, 1975b), harp seal (triangles; Terhune and Ronald, 1971), and human (open circles; Hawkins and Stevens, 1950). (Source: Terhune, 1981).

with detection of high frequency communication and echolocation calls. However, as described below, the vocalizations of some species, particularly the baleen whales, are themselves very low frequency.

It is generally assumed that the hearing sensitivity of species for which audiograms have not been determined encompasses at least the frequency range of the sounds they produce, and that their maximum sensitivity occurs within the frequency range of their vocalizations (Myrberg, 1978; Turl, 1980). Although this is generally believed to be true, there are exceptions. For example, harbour porpoise echolocation clicks contain most of their energy well above the frequency range to which their auditory system is most sensitive (Møhl and Andersen, 1973).

Many marine mammals use vocalizations for echolocation and social communication. The former tend to be produced at high frequencies and at intense levels of sound energy (e.g., Møhl and Andersen, 1973; Wood and Evans, 1980). Most odontocete whales are believed to be able to echolocate, but of the species found along the eastern shipping corridor, this has only been demonstrated for the white whale (Ford, 1977; Wood and Evans, 1980), harbour porpoise and killer whale (Wood and Evans, 1980). White whales can echolocate to distances of approximately 10 m (Ford, 1977). Neither baleen whales nor pinnipeds are known to echolocate, although this phenomenon has been postulated for some baleen whales (Beamish and Mitchell, 1971, 1973; Beamish, 1979) and for harbour seals (Renouf *et al.*, 1980).

Social vocalizations of both pinnipeds and odontocetes occur mainly at frequencies above 1 kHz, and there is no evidence to suggest that these calls are used over long distances. Baleen whales, on the other hand, produce calls with most of their energy concentrated below 1 kHz and frequently below 100 Hz. Vocalizations produced at these frequencies propagate well, and could be used for relatively long distance communication. Payne and Webb (1971) speculated that the very loud repetitive 20 Hz sounds produced by fin whales could be used to locate distant conspecifics.

The available information on hearing sensitivity and vocalizations of marine mammals which occur along the eastern shipping corridor is summarized in the following subsections and in Table 4.4-2.

4.4.4.1 Sperm Whale

The phonations of the sperm whale are somewhat different from those of other odontocetes. 'Clicks" are the only sounds that have been attributed to this species (Watkins, 1980a), and are probably used for communication (Backus and Schevill, 1966; Watkins, 1980a). Sperm whale clicks contain energy at frequencies ranging from 200 Hz to 32 kHz, although the dominant energy is near or below 5 kHz (Backus and Schevill, 1966).

The hearing sensitivity of the sperm whale has not been studied, but is presumably similar to the frequency range of its vocalizations. Watkins and Schevill (1975) have found sperm whales responding to 'pingers' operating in the 6 to 13 kHz range. The overall broad band (250 Hz to 16 KHz) source levels of sperm whale clicks have been measured at 171 dB (range 165.5 to 175.3 dB). Measurements of source levels in one octave bands ranged from 139 dB in the 250 to 500 Hz band, to 162 dB in the 4 to 8 kHz band. Peak source levels occurred in bands covering the 1 to 8 kHz range (Levenson, 1974). Dunn (1969) recorded levels of 175 dB for the 1/3 octave band centred at 1 kHz.

4.4.4.2 White Whale

Details of available information on white whale vocalizations and hearing sensitivity are given in Chapter 2. The social vocalizations of this species range in frequency from 250 Hz to 13 kHz, with most energy above 1 kHz. Echolocation clicks are in the range of 100 Hz to 120 kHz, with most energy between 38 and 120 kHz. The hearing sensitivity of white whales is best in the 20 to 85 kHz range.

4.4.4.3 Narwhal

Preliminary studies of the acoustic behaviour of narwhals were conducted by Watkins *et al.* (1971) and Ford and Fisher (1978). Recordings were made during 3 days in August at Koluktoo Bay, Baffin Island, and at Grise Fiord. Narwhals emitted narrow band pulses in the range from 500 Hz to 24 kHz, and pure tone whistles in the range from 250 Hz to 18 kHz, with most at frequencies less than 10 kHz. Both studies recorded narrow band clicks, with the majority between 12 and 20 kHz (Watkins *et al.*, 1971) and between 12 and 24 kHz (Ford and Fisher, 1978). Click repetition rates ranged from 4 to 370 per second, although a few slow series (less than 15 clicks per second) had frequencies in the range from 500 Hz to 5 kHz (Ford and Fisher, 1978). In addition, Bogorodskii and Lebedev (1977, 1978) recorded narwhal sounds in pack ice west of Franz Josef Land in May and June. They found that the clicks contained a simultaneous signal at 25 to 30 Hz.

It has not been demonstrated that narwhals echolocate, although it is probable that they do (Norris, 1969; Ford and Fisher, 1978). Watkins (1980b) noted that the studies of narwhal sounds conducted by Watkins *et al.* (1971) and Ford and Fisher (1978) were limited to frequencies of 24 kHz or less by the recording equipment, and suggested that narwhal clicks probably have higher frequency components used for echolocation. Møhl and Andersen (1973)

TABLE 4.4-2

KNOWN CHARACTERISTICS OF MARINE MAMMAL VOCALIZATION AND HEARING FOR THE SPECIES FOUND ALONG THE EASTERN TANKER ROUTE.

Species	Frequency (kHz) range of vocalization	Dominant frequencies (kHz) of vocalization	Hearing sensitivity (kHz): Overall	Hearing sensitivity (kHz): Most sensitive	Source level of vocalizations (dB re 1 uPa)	Sources
White Whale	Social 0.3-13 Echolocation 0.1-120	Social >1 Echolocation 38-120	<1[1]-122	20-85	160-180	Fish and Mowbray (1962), Ford (1977), White et al., (1978), Wood and Evans (1980)
Narwhal	0.18-24[1]	<10	?	?	?	Watkins et al. (1971), Ford and Fisher (1978), Bogorodskii and Lebedev (1977, 1978)
Bowhead	0.025-2	0.05-0.6	?	?	?	Ljungblad et al. (1980), Wursig et al. (1981), Ljungblad and Thompson (in prep) cited by APP (1981), Clark (pers. comm.) cited in APP (1981)
Southern Right Whale	0.025-2.5				172-187	Cummings et al. (1972)
Killer Whale	Social 0.5-31 Echolocation 0.1-30	Social 14 Echolocation	<0.5[1]-31	15	Echolocation 178	Hall and Johnson (1972), Wood and Evans (1980)
Northern Bottlenosed Whale	0.5-26	8-12	?	?	?	Winn et al. (1970)
Sperm Whale	0.2-30	≤5	?	165.5-175.3		Backus and Schevill (1966), Dunn (1969), Levenson (1974)
Harbour Porpoise	2-158	110-158	1-150+[1]	8-32	132-149	Schevill et al. (1969), Andersen (1970), Møhl and Andersen (1973)
Fin Whale	0.02-5 (28?)[2]	0.2, 1.5-2.5	?	?	173-181	Payne and Webb (1971), Thompson et al. (1979)
Sei Whale	?	3 (?)[3]	?	?	?	Thompson et al. (1979)
Minke Whale	0.06-12	0.1-0.2, 5-6	?	?	145-161	Schevill and Watkins (1972), Beamish and Mitchell (1973), Winn and Perkins (1976)
Blue Whale	0.014-8 (31?)[2]	0.02-0.03, (25?)[2]	?	?	130-188	Cummings and Thompson (1971), Beamish and Mitchell (1971), Beamish (1979)
Humpback Whale	0.12-8	<4	?	?	144-174	Thompson et al. (1979), Beamish (1979)
Walrus	0.2-1.2	0.4-1.2	?	?	?	Schevill et al. (1966), Ray and Watkins (1975)
Bearded Seal	0.2-3	>1	?	?	?	Ray et al. (1969)
Ringed Seal	<4-24	4	<1>60	1-45	?	Terhune and Ronald (1975b, 1976), Schevill et al. (1963)
Harp Seal	0.13-100	<2, 32	<1>64	2-23	131-164	Terhune and Ronald (1972), Møhl et al. (1975)
Hooded Seal	0.1-16	<1.5, 16	?	?	?	Terhune and Ronald (1973), Schevill et al. (1963)

[1] Determination limited by sensitivity of the equipment used.
[2] Not certain that these sounds were emitted by these species.
[3] Based on only one recording.
? Unknown

found that relatively low frequency clicks produced by harbour porpoise had associated high frequency (110 to 150 kHz) elements actually used for echolocation.

Studies of non-Arctic odontocetes have indicated a level of acoustic adaptability that is likely relevant when considering white whales and narwhals. Watkins (1980b) reviewed recent studies and concluded that cetaceans at sea can voluntarily control sound production by varying frequency, spectral emphasis, pulse rate and sound level. Au *et al.* (1974) found that bottlenosed dolphins at sea used more powerful echolocation clicks than animals in test tanks. These authors also noted that the dolphins increased the frequency of their echolocation clicks in the presence of high frequency noise produced by snapping shrimp.

4.4.4.4 Killer Whale

The auditory thresholds of a captive killer whale were determined by Hall and Johnson (1972) who found that the hearing range of this species extended from 500 Hz to 31 kHz. The best sensitivity occurred at 15 kHz, where sounds as low as 30 dB were detected, while relatively high sensitivity was found between 7 and 30 kHz. At lower frequencies, tank noise masked absolute hearing thresholds, and frequencies below 500 Hz could not be tested due to tank noise (Hall and Johnson, 1972).

The echolocation clicks of the killer whale range from 100 Hz to 30 kHz, with peak energy levels at 14 kHz. Source levels of 178 dB have been recorded for these clicks (Wood and Evans, 1980).

4.4.4.5 Harbour Porpoise

Early studies of the acoustic behaviour of harbour porpoises indicated that their phonations were restricted to clicks, and lacked the whistle-like squeals characteristic of most dolphins. The clicks are narrow band pulses with a frequency near 2 kHz and low intensity, with an estimated source level of 101 dB (Schevill *et al.*, 1969). Møhl and Andersen (1973) calculated that the echolocation abilities of this species could not be explained by the 2 kHz clicks, and found that the porpoise also emits a very short, narrow band pulse for echolocation between 110 and 158 kHz at a source level of 140 dB (range 132 to 149 dB). These pulses are used for echolocation. As described earlier, the frequencies of echolocatory pulses in this species are higher than the region of their best hearing sensitivity, but are at frequencies which can be easily filtered from background noise (Møhl and Andersen, 1973).

Andersen (1970) determined the underwater audiogram for a harbour porpoise. The test animal responded to frequencies from 1 to 150 kHz, the limits of the equipment. Maximum sensitivity of 45 dB was found at 8 and 32 kHz, with highest sensitivity (less than 60 dB) noted from 3 to 65 kHz. The threshold at 1 kHz was 85 dB. Using a different technique, Sukhoruchenko (1973; cited in Turl, 1980) found the average range of high sensitivity was from 10 kHz to 90 kHz in 20 test animals.

4.4.4.6 Other Odontocetes

The four other species of odontocete (toothed) whales that occur in Davis Strait are the northern bottle-nosed whale, pilot whale, white-beaked dolphin and Atlantic white-sided dolphin. The one brief recording made of northern bottle-nosed whales indicated frequencies of their vocalizations ranged from 0.5 to 26 kHz, with most energy recorded from 8 to 12 kHz (Winn *et al.*, 1970). Pacific pilot whales produce sounds with average source levels of 145 to 160 dB (per 120 Hz band), and peak levels of about 180 dB at 14 kHz (Fish and Turl, 1976). The white-sided dolphin emits whistles and squeals varying in frequency from 1 to 14 kHz, and broadband clicks with energy up to 150 kHz. Vocalizations of white-beaked dolphins are probably similar to the above species, with whistles in the 6.5 to 15 kHz range having been recorded (Cummings and Fish, 1971).

4.4.4.7 Fin Whale

The principal phonations of the fin whale are low frequency, remarkably loud, pure tone pulse trains centred around 20 Hz with overall source levels of 173 to 181 dB (Payne and Webb, 1971). Payne and Webb (1971) calculated that, in certain circumstances in deep water areas, these calls could be used for interspecific communication at distances of several hundred miles. Recent studies suggest that fin whales may also utter chirps and whistles in the 1.5 to 2.5 kHz range, with occasional energy to 5 kHz (Thompson *et al.*, 1979). These authors also report low intensity, wide band pulses in the 16 to 28 kHz range recorded in the presence of fin whales.

4.4.4.8 Minke Whale

The minke whale produces a variety of low frequency sounds from 60 to 140 Hz (Schevill and Watkins, 1972; Winn and Perkins, 1976). The latter authors recorded the distinctive "thump-train" call of the minke whale, and found frequencies ranging from less than 100 Hz to at least 800 Hz, with maximum energy between 100 and 200 Hz. Winn and Perkins (1976) also report occasional pings and clicks with frequencies between 3.3 and 12 kHz and peak energy at 5 to 6 kHz. Beamish and Mitchell (1973) reported series of clicks (about 7 per second) with principal energy in the frequency range of 4 to 7.5 kHz and source levels of 145 to 151 dB.

4.4.4.9 Blue Whale

The blue whale, the world's largest mammal, produces intense phonations (Thompson *et al.*, 1979). Cummings and Thompson (1971) made 4 measurements of blue whale calls, and found an average overall source level of 188 dB in the 14 to 222 Hz band. These sounds were low frequency moans that were sustained for up to 36 seconds, and nearly all energy occurred below 200 Hz, with the strongest components in the 1/3 octave bands centred at 20, 25 and 31.5 Hz (Cummings and Thompson, 1971).

The presence and function of higher frequency calls produced by blue whales is the subject of some debate. Beamish and Mitchell (1971) recorded powerful clicks (159 dB) in the frequency range from 21 to 31 kHz, with a narrow spectral peak at 25 kHz. These authors, however, could not fully eliminate the possibility that the sounds were made by other species in the recording area. Beamish (1979) recorded a series of clicks at 130 dB in the 6 to 8 kHz range in the presence of a blue whale trapped by ice.

4.4.4.10 Humpback Whale

The humpback whale is an extremely vocal species with a variety of complex, repetitive songs which have been recorded primarily at their tropical wintering areas and during migration. Humpbacks have a more limited vocal repertoire during summer when they are feeding at higher latitudes (Thompson *et al.*, 1979).

The most common sounds made by humpbacks are low grunts and squeals that range from 120 Hz to about 1,650 Hz. Source levels average 155 dB, with a range from 144.3 to 174.4 dB (see Thompson *et al.*, 1979). Humpback songs consist of repeating complex sounds in frequencies generally less than 4 kHz. Beamish (1979) studied a humpback entangled in fishing nets off the east coast and recorded a series of click sounds with spectral peaks at about 2 kHz and source levels not exceeding 158 dB. In three days of recording, Beamish found a single series of clicks with spectral peaks at 8.2 kHz.

4.4.4.11 Bowhead Whale

Most of the available information on bowhead vocalizations has been the result of studies of the western Arctic stock, and is reviewed in Chapter 2. Most sounds occur at frequencies between 50 and 800 Hz, with greatest intensities between 100 and 300 Hz (Ljungblad *et al.*, 1980a, 1982; Würsig *et al.*, 1981. Cummings *et al.* (1972) have estimated the source level of certain sounds of the closely related southern right whale (*Eubalaena australis*) to range between 172 to 187 dB in the 25 to 2,500 Hz band.

4.4.4.12 Walrus

Schevill *et al.* (1966) recorded a walrus in captivity, and noted a variety of rasps, clicks and bell-like tones with frequencies between 200 and 1,200 Hz. Ray and Watkins (1975) discuss the social function of some calls, although information on the source levels of phonations or about the hearing sensitivities and thresholds of walruses has not been published.

4.4.4.13 Bearded Seal

The bearded seal emits a descending song that typically starts at 2 to 3 kHz, and ends with a moan at 200 to 300 Hz. The majority of the song occurs at frequencies above 1 kHz (Ray *et al.*, 1969), but its intensity has not been measured. The underwater audiogram of the bearded seal also has not been determined, although seal songs are a widespread and conspicuous feature of the underwater acoustic environment in Arctic waters.

4.4.4.14 Harbour Seal

The vocal behaviour of the eastern North American population of harbour seals has not been reported in detail, although click vocalizations have been discussed by Renouf *et al.* (1980). The click calls recorded by these authors were broad band, with most energy between 8 and 16 kHz. There have been several studies of the European subspecies of harbour seal, the common seal (Møhl, 1964, 1967, 1968a,b). Møhl (1968a) determined the underwater audiogram of the latter subspecies, and found that the seal could detect sounds from 1 to 180 kHz. The species was most sensitive to sounds at 32 kHz, where the threshold was 63 dB, while the zone of best sensitivity (less than 70 dB) extended from 8 to 32 kHz. The hearing threshold at 1 kHz was 84 dB. Møhl (1968a) found that common seals could detect very high frequency sounds (up to 180 kHz), although thresholds at frequencies above 65 kHz were high (120 to 133 dB). In another study, Møhl (1967) suggested that although common seals could detect high frequency sounds, they could not distinguish pitch at frequencies greater than 60 kHz.

4.4.4.15 Ringed Seal

The underwater audiogram for ringed seals at frequencies from 1 to 90 kHz was determined by Terhune and Ronald (1975a). The lowest hearing threshold was 68 dB at 16 kHz, but relatively uniform sensitivity was found between 1 and 45 kHz (68 to 81 dB). Above 45 kHz, the hearing threshold increased at the rate of 60 dB/octave. Ringed seals can detect sounds above 60 kHz, but above 60 kHz they cannot distinguish frequency (Terhune and Ronald, 1976).

As noted previously, the above thresholds are absolute levels in the absence of background noise. However, in the presence of ambient noise, thresholds are determined by the critical ratio of signal to background noise. In the ringed seal, Terhune and Ronald (1975b) found that the critical ratio increased from 30 to 34 dB when frequencies of 4, 8, 16 and 32 kHz were tested (Figure 4.4-4). If background noise is 60 dB, signals must be 90 to 94 dB, depending on frequency, in order to be detected by ringed seals.

The vocal repertoire of wild ringed seals was reported by Stirling (1973) to include four types of vocalizations. Between late March and late June, 1980 and 1981, Stirling *et al.* (1982) also recorded underwater vocalizations of ringed seals, bearded seals and walruses in the High Arctic. This was done to evaluate the potential for using sub-ice vocalizations as a tool for studying their distribution and relative abundance in the High Arctic.

In 1982, T. Smith of the Department of Fisheries and Oceans began a long-term study at the northern end of Prince of Wales Strait, near Holman Island and near Nelson Head on Banks Island. The primary objective of the work carried out in Prince of Wales Strait is to obtain baseline data on the underwater vocalization of bearded seals and ringed seals under winter conditions. Continuous monitoring of sounds over a three week period without any disturbance in the area will yield information on normal diurnal vocal activity patterns.

Upon completion of the vocal activity studies the intent is to do a controlled study of the effect of disturbance on the surface of the ice. Sources of disturbance to be assessed and compared in the first year will be helicopter landings, hydrographic sounding procedures and snowmobile activity. These sources of disturbance will be of short duration and are considered as an attempt to assess the immediate response of seals and to document the recovery time. More data on undisturbed vocal behavior gathered in the next two years will be used to assess the effects of the recurring and long term disturbance of regular icebreaking ship traffic.

4.4.4.16 Harp Seal

Underwater recordings of harp seal phonations in the Gulf of St. Lawrence included 14 different calls and also directional clicks (Møhl *et al.*, 1975). Frequencies of the calls ranged from 125 Hz to about 10 kHz, and most were primarily below 2 kHz at estimated source levels of 135 to 140 dB (Watkins and Schevill, 1979).

Møhl *et al.* (1975) marshalled a variety of indirect evidence that harp seals also emit intense short duration clicks with energy ranging to 100 kHz, and maximum energy at 32 kHz. Overall source levels for the clicks averaged 148 dB, and ranged from 131 dB to 164 dB.

The hearing sensitivities and auditory thresholds of harp seals were determined by Terhune and Ronald (1972). The lowest threshold was about 63 dB and 15 kHz, with a range of best sensitivity from 2 to 23 kHz. Thresholds were higher below 2 kHz (78 dB at 1 kHz), and increased at a rate of 40 dB per octave above 64 kHz.

4.4.4.17 Hooded Seal

Source levels of calls and the audiogram of the hooded seal have not been determined, and relatively little is known about their vocal behaviour. The underwater calls of adult males have been recorded from the ice in the Gulf of St. Lawrence during the breeding season, and contained energy ranging from 100 Hz to 6 kHz, with most energy at frequencies less than 1.5 kHz (Terhune and Ronald, 1973).

4.4.5 POSSIBLE IMPACTS OF UNDERWATER NOISE ON MARINE MAMMALS

The possible effects of underwater noise on marine mammals is of concern because of their reliance on hearing for both communication and orientation. Potential impacts of year-round traffic in the Northwest Passage on marine mammals may include direct disturbance by the vessels and the masking of communication and environmental cues by underwater ship noise. Underwater noise and tanker movements have the potential to disturb marine mammals, possibly causing disruptive changes in behaviour and desertion of portions of their habitat.

It can be assumed that no effects of vessel noise will occur at distances where the noise attenuates to background levels, a distance which varies with frequency, area and season. High frequency noise is more rapidly attenuated than low frequency noise, and attenuation is affected by several factors including water depth, ice cover, and sea bottom characteristics.

For this assessment, it has been assumed that the first icebreaking tanker, most likely a somewhat smaller one (80,000 DWT), would be in operation by late 1985, and a maximum of 9 tankers may be in use by 1990. Assuming the technically achievable development rate (Chapter 3, Volume 2), and no use of a pipeline, the fleet could increase gradually to 26 by the year 2000. An average round trip is expected to require 28 to 30 days. Under the simplest assumptions that the tankers would be distributed uniformly along the 6,200 km route, (and none are in drydock) the vessels would be about 1,200 km apart in each direction in 1990, and 500 km apart in each direction by the year 2000. Thus, in the year 2000, there will be daily occasions when there will be a tanker about every 250 km along the shipping route. Ice and weather conditions, transportation requirements, ship maintenance schedules and other factors would in reality also influence the spacing of tankers along the route. For example, two or three tankers may travel in convoy, particularly during winter. On the other hand, one or two APP ships may also be travelling through the portion of the route between Bridport Inlet and the east coast.

In Baffin Bay in summer, tankers would likely travel at a speed of 31.5 km/h at ½ power. Figure 4.4-3 shows estimates of noise levels at various distances for a tanker travelling under these conditions. The lowest measured Baffin Bay ambient noise, shown as the lower end of the range of Sample 6 (Leggat *et al.*, 1981), would be matched by tanker noise at a range of roughly 30 km at a frequency of 100 Hz for a 20 m deep receiver. Higher frequencies of tanker noise would equal the low ambient level at shorter ranges. Figure 4.4-5 shows approximate north-bound and south-bound tanker routes in Baffin Bay and Davis Strait. Assuming 26 tankers by the year 2000 all equally spaced along the route, then tankers would be separated by 500 km in each direction. For open water, two cases are represented in Figure 4.4-5, one where tankers are passing close-by each other, and another at maximum 250 km separation. Circles represent the boundaries of the area at which tanker produced noise at 100 Hz is equal to low ambient noise in the summer open water. For tankers passing, the effective noise generated is assumed to be 3dB greater, hence doubling the radius of the circle of ensonification from 30 km to 60 km. For increasing frequencies above 100 Hz, the circular areas become progressively smaller. Leggat *et al.* (1981) indicate, however, that higher ambient noise levels occur for a greater proportion of the time; this being the case, tanker noise at 100 Hz would equal ambient noise at ranges of less than 30 km most of the time in Baffin Bay open water.

Once tankers are in the winter pack ice of Baffin Bay, and assuming full power operation, the noise estimates of Figure 4.4-2 apply. Applicable noise measurements are Samples 2 and 8, for Viscount Melville Sound moving ice and under the Greenland Sea pack ice, respectively. It is evident that tanker noise, at full power, could exceed ambient noise under ice most of the time for distances in excess of several hundred kilometres for frequencies up to 1 kHz. The ice cover effectively decouples atmospherically induced noise sources from the sea while at the same time the tankers introduce shipping noise into Baffin Bay similar to that normally introduced into temperate oceans.

In portions of the eastern shipping corridor that are covered by fast ice, winter and spring ambient noise levels are expected to be relatively low (Table 4.4-1). Ranges at which ship noise would blend into ambient would be similar to those in Baffin Bay in winter. The slightly greater transmission loss in Parry Channel and Prince of Wales Strait would likely be balanced by the slightly lower ambient levels present there.

The vulnerability of marine mammals to the possible effects of a reduction in communication distances or to masking of environmental cues varies among species because of differences in their hearing abilities, behaviour and seasonal distributions. The following sections discuss the possible vulnerability to the effects of underwater noise of each species that occurs along the eastern shipping corridor. An assessment of possible impacts is provided where sufficient information is available to do so; also indicated are areas where additional information is required for a more confident assessment. The proponents of Beaufort region development and the Arctic Pilot Project, are committed to monitoring the possible effects of increasing levels of underwater noise over time in Arctic waters (see Volume 7). Although, based on experience in other parts of the world, it is doubtful that significant impacts to marine mammals will occur, the results of future monitoring will have a bearing on the nature and ultimate level of shipping activity permitted through the Northwest Passage.

4.4.5.1 White Whale

The three white whale populations that occur along the eastern shipping corridor north of 60°N are the Mackenzie, Cumberland Sound, and High Arctic populations. The Cumberland Sound population occurs in Cumberland Sound, Frobisher Bay and eastern Hudson Strait, and is unlikely to be affected by tanker traffic. Tankers would be more than 200 km away from areas occupied by this population at all times. At this distance, noise levels would be well below the white whale hearing threshold at all frequencies and potential impacts on this population would therefore be NEGLIGIBLE.

Although most white whales of the High Arctic population winter in loose pack ice off the coast of Greenland south of Disko Island, small numbers winter in the Baffin Bay North Water (Volume 3B). In the high frequency bands (over 20 kHz) used by white whales for echolocation, tanker noise would be essentially non-existent at distances of 20 km even when the vessel is using full power in thick ice. Noise levels would be less than the hearing threshold of white whales at distances of 1 or 2 km. At the lower frequencies used for social communication (1 to 5 kHz), noise produced by tankers travelling in heavy ice (worst case) would be below the threshold of white whale hearing at a distance of 1 km for frequencies of 1 kHz, and a distance of 4 km for frequencies of 5 kHz (see White *et al.*, 1978). Therefore, tankers travelling 100 km off the coast of Greenland in winter would have little or no effect on white whales in wintering areas off Greenland. In some years, this population could occur as far offshore as the shipping route, but the potential effects are likely to be transitory and to involve only local movements of the whales to avoid the tankers.

The spring migration of this population from Greenland wintering areas follows the landfast ice edge north to Thule District, and then crosses Baffin Bay north of 76°N (Volume 3B). Both the spring (May through June) and fall (September) migrations

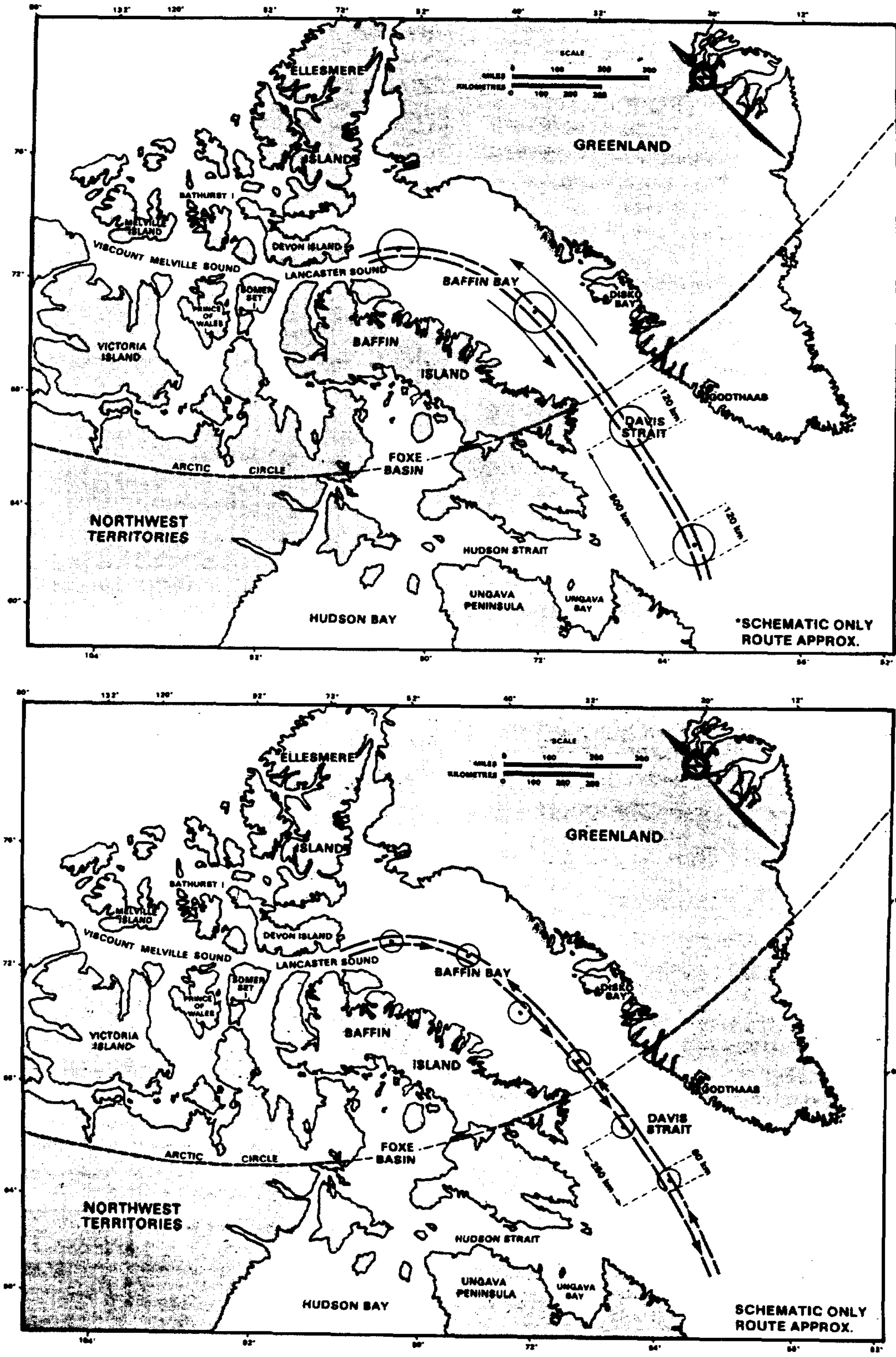

FIGURE 4.4-5 *Approximate moving circular areas in which tanker noise in summer will be above ambient noise. In the year 2000, assuming a maximum technically achievable production rate, tankers may be spaced 500 km apart on both northbound and southbound routes. Two hypothetical situations are shown. Above, tankers are passing each other so that the net source strength is 3 dB greater than for a single tanker. The result is circular areas ensonified above ambient noise (in summer) which have twice the radius of the areas ensonified above ambient for tankers well separated from each other as in the diagram below.*

through Parry Channel follow coastal waters of Devon Island. During late July and early August, the population summers in estuaries along northern Somerset Island and in Prince Regent Inlet. The tankers will always be at distances greater than 20 km from the coasts of Lancaster Sound and Barrow Strait. Therefore, underwater noise produced by the tankers would not affect migrating and summering white whales, although some disturbance could occur as the whales cross Barrow Strait in July and September. The fall migration through Baffin Bay retraces the spring migration along the Greenland coast, so noise from the tankers would not affect white whales at this time.

White whales from the Mackenzie population are present in the Beaufort Sea and Amundsen Gulf from about mid May to September (Volume 3A). Migrants begin to arrive in Amundsen Gulf during mid May and continue to arrive until late June. At that time, there is a concentrated westward movement of the population along the fast ice edge to the Mackenzie estuary. It is concentrated in the estuary for most of July, and dispersed in Amundsen Gulf and the eastern Beaufort Sea from late July through August (Evans and Davis, 1982).

Possible effects of underwater noise in the Beaufort Sea production region on this population were discussed in Chapter 2. In offshore areas of Amundsen Gulf, communication distances between animals may be reduced within about 5 km of the tankers for short periods during spring when the ships are operating at high power levels.

In summary, communication distances between white whales within a few kilometres of the tankers may be reduced in some areas and in some seasons. However, white whales travel in compact groups and communication within the social groups would not likely be seriously impaired by ship noise except in close proximity to the source. There is no evidence to suggest that long distance communication between groups is important to white whales. Consequently, the overall impacts of tanker activities on the Cumberland Sound population will be NEGLIGIBLE. Impacts on the Mackenzie population while in Amundsen Gulf are also considered NEGLIGIBLE (see Chapter 2).

Possible impacts on the High Arctic white whale population should be NEGLIGIBLE during migration and in summer throughout the duration of the development. Prior to about 1990, effects of tanker noise on this population during winter should also be NEGLIGIBLE. After 1990, the potential for disturbance and masking signals of whales in wintering areas could increase with the level of tanker activity in years when the loose pack ice zone is traversed by the tankers. Possible impacts on the High Arctic white whale population during this period are uncertain, but could be MINOR.

4.4.5.2 Narwhal

There are no studies of narwhal vocalizations at frequencies above 24 kHz, the most likely range used for echolocation. Narwhals are believed to be widely distributed in small groups in the heavy pack ice of northern Davis Strait and Baffin Bay from about November to April. During May and June, major movements of narwhals occur through offshore Baffin Bay toward Lancaster Sound (Volume 3B).

Source levels from tankers would be greatest during periods when breaking through areas of heavy ice, and resulting ambient noise levels in the pack ice zone would be increased substantially. There are no reported measurements of ambient noise in winter in northern Davis Strait and Baffin Bay, although median levels from similar pack ice areas in the Greenland Sea were 68 dB at 100 Hz and 47 dB at 1 kHz (Diachok, 1980). Assuming similar levels occur in Baffin Bay, noise produced by the tankers would raise ambient levels at 1 kHz by about 24 dB to a level of about 71 dB at distances of 60 km (Figure 4.4-1). However, assuming narwhal hearing thresholds are comparable to those of the white whale (i.e. 95 to 100 dB at 1 kHz and 65 to 68 dB at 5kHz: White *et al.*, 1978), masking effects of increased ambient noise would only occur within a range of a few tens of kilometres at 1 kHz.

The passage of a tanker would have the potential to temporarily disturb narwhals over some distance. Those wintering among heavy pack ice have limited access to open water for breathing, and it would seem likely, that disturbed individuals which temporarily move away from their breathing areas in response to a passing ship would return or could find other leads and cracks in the pack ice in which to breathe.

The high frequency (12-24 kHz) clicks produced by narwhals are assumed to be used in echolocation, and assuming similar hearing abilities as white whales, the potential for interference with this process would be restricted to areas within a few kilometres of the tankers.

During summer, narwhals occupy deepwater bays, fiords and inlets (e.g. fiords along east Baffin Island, Eclipse Sound, Admiralty Inlet and Prince Regent Inlet), and are unlikely to be affected by tankers operating at low power through the centre of Baffin Bay and Parry Channel. However, during spring (June and July) and fall migration (late September and early October) through Lancaster Sound, narwhals may be exposed to tanker noise in relatively restricted areas. The potential effects during spring would be similar to those previously described for winter in Baffin Bay, while in fall, the vessel-radiated noise would be lower and effects would probably be minimal.

On the basis of the available information, assuming narwhals habituate and adapt to frequent ship passages then impacts could be NEGLIGIBLE. If narwhals do not habituate, then impacts could range from MINOR to perhaps MODERATE. The results of ongoing monitoring programs will be very important in identifying possible effects and mitigative measures.

4.4.5.3 Other Odontocetes

There are seven other species of odontocetes that occur in Baffin Bay and Davis Strait during the open water season. The vocalizations and hearing capabilities of these species are discussed in Sections 4.4.4.1 and 4.4.4.4 to 4.4.4.6. All of these species are unlikely to be affected by ship noise at low frequencies of 1 kHz or below since they are adapted to higher frequency vocalizations and hearing. The tankers in open water will be travelling at half power and ship noise levels at high frequencies will be relatively low and will attenuate rapidly. Ship noise will merge into quiet ambient levels within about 20 km of the ship at frequencies of 1 kHz and above (Figure 4.4-3). Therefore, ships moving at 31.5 km/h would have only transitory effects on a relatively small number of individuals in open water and possible impacts are expected to be NEGLIGIBLE.

4.4.5.4 Bowhead Whale

Both the eastern and western Arctic populations of bowhead whales could be affected by underwater noise produced by tankers. Although bowhead vocalizations range from 25 Hz to 2 kHz, greatest intensities occur between 100 and 300 Hz. A few calls contain sounds as low as 25 Hz, but there is no indication that bowheads produce intense low frequency calls similar to those of fin and blue whales.

The eastern Arctic bowhead population was severely depleted by commercial whaling, and is still considered an endangered stock despite 70 years of protection. Historically, it is probable that this population wintered in the loose pack ice within the pack ice edge that extends from the Disko Island area to northern Labrador. Recent studies on behalf of the Arctic Pilot Project (McLaren and Davis, 1981) have confirmed the presence of bowheads southwest of Disko Island and in Hudson Strait during winter.

On entering the close pack ice, the tankers could use full power generating relatively intense noise (Figure 4.4-2). Noise spectrum levels 60 km from the vessel could reach 88 dB at 100 Hz. Beyond 60 km, in-ice noise levels would reduce by about 3 dB per distance doubled, declining for example to 82 dB 240 km away from the vessel (N. Brown, pers. comm.).

Recent sightings of 14 bowheads wintering in Baffin Bay showed that most of these were located well within the pack ice at an average distance of 70 km north of the diffuse ice edge. One was sighted 300 km north of the ice edge while another was a few kilometres south of the ice edge. In spring, as the ice retreats and loosens, bowheads migrate north, at times within ice of 9/10ths concentration (R. Davis, pers. comm.).

Diachok (1980) measured a median noise level of 86 dB at the Greenland Sea pack ice edge compared with only 68 dB 80 km within the pack. Assuming that similar noise levels will exist at and north of the Baffin Bay ice boundary (see Volume 3B), then bowheads within the pack ice would be located where ambient noise levels would be 18 dB lower than at the pack ice edge.

At the pack ice edge, tanker noise would equal ambient at a point about 90 km from the tanker at 100 Hz (compare estimated noise levels under ice in Figure 4.4-2 with noise Sample 9 in Table 4.4-1). Then assuming a transmission loss of 3 dB per distance doubled, tanker noise within the pack would theoretically equal ambient at about 5,700 km away from the tanker, ensuring that tanker noise would be the operating noise threshold within ice covered regions of Baffin Bay.

For impact assessment purposes, some assumptions need to be made regarding underwater noise and communication for bowheads. These are as follows:

(a) Bowheads do not echolocate.

(b) They have a need, on occasion, to communicate with other bowheads primarily for species positions and identification. They also receive acoustic cues. For these purposes, they transmit and receive signals mainly in the 50 to 600 Hz band (see Table 4.4-2).

(c) They are capable of transmitting tonals at source spectrum levels in excess of 172 dB in the 50 to 600 Hz band (at levels similar to the closely related southern right whale; Table 4.4-2).

(d) They have hearing sensitivities equal to low ambient noise levels in the 50 to 600 Hz band and have a critical ratio equal to 0 dB. (These are likely to be conservative assumptions).

(e) They are able to tolerate continuous loud sounds without being unduly disturbed.

(f) They generally overwinter near ice edges and in loose pack near ice boundaries, and migrate as these boundaries retreat. While they overwinter, they do not mate, give birth to young or undertake group activities critical to the survival of the species.

With respect to assumption (e), studies of the responses of bowhead whales to offshore industry activities including boat traffic are being conducted on the summering grounds in the Canadian Beaufort Sea by LGL Ltd. for the U.S. Bureau of Land Management (see Richardson 1981, 1982). These studies indicate that bowheads tolerate increased ambient noise of some types, especially when the noise continues for prolonged periods with little change in level or spectral characteristics. Bowhead behaviour was normal or only slightly altered in the presence of ongoing dredging, drilling or seismic noise, including dredge and drilling noise, whose most intense tonal as received near the whales had a level of over 100 dB, and ongoing seismic noise had levels ranging between 140 and 150 dB (Fraker *et al.* 1981, 1982). In contrast, pronounced behavioural reactions were evident with sharply increasing levels of noise — i.e., as boats approached within about 1 km, or as aircraft approached or descended over the whales. Even in the latter cases, however, there was no evidence that bowheads moved out of the area where they had been disturbed. Noise from distant tankers would remain very similar for prolonged periods, so tolerance by bowheads might be expected based on the Beaufort Sea studies.

Based on assumptions (b) and (c), the source level for bowhead tonals in the 50 to 600 Hz band may be equivalent to tanker source levels at full power while breaking ice (Figure 4.4-1). Consequently, the range of bowhead two-way communication may be about the same as the distance tanker noise equals ambient noise at 100 Hz, according to assumption (d). This means that, in general, the communication distance between bowheads will be identical to the range that noise from a tanker is transmitted before it equals ambient noise, if the bowheads are swimming in areas external to the areas of higher noise caused by tankers. However, these ranges will be shorter in ice fields where tanker noise is expected to exceed natural ambient levels. For example, at 100 Hz the range at which a signal from a distant bowhead might be detected by another bowhead located within 40 km of a tanker would equal 40 km, according to assumptions (c) and (d) and Figure 4.4-2. Communications at short ranges while in groups are unlikely to be disrupted. It is important to note that bowhead whales at moderate distances (10 to 20 km) from tankers are not likely to be unduly disturbed (assumption c). It is also important to note that there is no documentation on the hearing sensitivy of bowheads. If contrary to assumption (d), they are unable to hear low levels of ambient noise (due to the noise within their own auditory system), then tanker noise could rise well above ambient underwater noise without diminishing communication ranges between bowheads. A consequence would be that long-range interspecies communication would depend on the signal processing ability of bowheads rather than their hearing sensitivity.

Bowheads of the eastern Arctic population summer in deep bays, fiords and inlets along eastern Baffin Island, Eclipse Sound, Admiralty Inlet and Prince Regent Inlet where they would not be affected by tanker noise. Parry Channel is apparently used only as a migration route by bowheads enroute to the above areas (Volume 3B).

During fall, the principal migration of this population occurs along southern Lancaster Sound and the east coast of Baffin Island. During this period, the tankers would probably operate at low power levels with relatively little propeller cavitation. For example, the tankers would travel over 100 km from the northeast coast of Baffin Island, and sound levels in coastal waters would be at quiet ambient levels most of the time. Additional propagation losses associated with shallow coastal shelf areas would reduce the levels further. In Lancaster Sound, the tankers would travel at a distance of about 40 km from the coast, and noise levels in coastal waters could be somewhat higher than those described for northeastern Baffin Island.

During the early stages of hydrocarbon development in the Beaufort Sea region, only a few tankers would use the eastern shipping corridor. Consequently the possible impacts on bowheads should be NEGLIGIBLE because of the transient nature of the disturbance. As discussed earlier, between 16 and a maximum of 26 tankers could use this route by the year 2000, and portions of the shipping corridor would be ensonified for extended periods. Possible impacts of tanker noise on bowheads distributed in bays and fiords during summer, and along the south shore of Lancaster Sound and the northeast coast of Baffin Island during fall would likely still be NEGLIGIBLE. In winter and during spring migration, a potentially large proportion of the estimated few hundred bowheads in the eastern Arctic population could be affected in northern Davis Strait, Baffin Bay and eastern Lancaster Sound. However, based on the assumptions stated previously regarding underwater noise and communications for bowheads, the possible impacts of year-round tanker traffic, in numbers projected for the year 2000, could range from NEGLIGIBLE to MINOR, depending on the proportion of the eastern Arctic population that overwinters and migrates offshore. If some or all of the stated assumptions are invalid, then the degree of possible impact could rise or fall, depending on the nature of new data on bowhead behavior and responses. The monitoring program instituted to address this concern will be important in determining the actual impacts on this endangered species and the application of further mitigative measures, should they be required.

The western Arctic population of bowhead whales occurs in Amundsen Gulf from late May until September (Volume 3A), although the distribution of bowheads on their summering grounds varies between years. Underwater noise produced by tankers in Amundsen Gulf would be highest during May and June when they would be breaking heavy ice. Noise levels would be lower during the open water period from July through early September. Potential impacts of tanker noise on bowheads in Amundsen Gulf would probably be NEGLIGIBLE based on the assumptions regarding bowhead acoustic behavior when tanker trips are infrequent (e.g. 2 to 4 per month), but could increase to MINOR in 1990 and beyond to the year 2000 when between 16 and a maximum of 26 tankers may be required. The results of ongoing monitoring programs will be important in clarifying actual impacts.

4.4.5.5 Other Baleen Whales

Five species of baleen whales occupy the eastern half of Davis Strait and the southeastern half of Baffin Bay during the open water season. All species produce low frequency calls, with the fin and blue whales emitting very intense, low frequency phonations in the 20 to 30 Hz range. Humpback, minke, and probably sei whales produce sounds as low as 100 Hz. Since these species only occur in areas of the proposed shipping corridor during summer, they would be exposed to tanker noise during a period when ambient noise levels are naturally high. At 100 Hz, median ambient noise spectrum levels in Baffin Bay are approximately 78 dB (Leggat *et al.*, 1981). At the open water cruising speed of 17 kts (31 km/h), underwater noise produced by an APP carrier (assumed to be similar to an Arctic oil tanker) at a frequency of 100 Hz would be attenuated to below median ambient levels at 20 km.

Although these species occupy the eastern half of Davis Strait and the southeastern half of Baffin Bay during the open water season, minke whales, fin whales and probably sperm whales tend to concentrate over the western slope of the offshore banks off west Greenland between 65° N and 71° N (Kapel and Larsen, 1982). These areas correspond to the proposed shipping routes and thus, a substantial proportion of these populations could be exposed to the tankers during the summer. In the early phases of development the effects of infrequent ship passages would be NEGLIGIBLE. However, when full production is reached, impact from direct disturbance and noise on fin whales and minke whales could approach MINOR if the whales move to waters adjacent to the shipping corridor. In addition, the Greenland fishery also takes place on these banks, (see Volume 5, Chapter 13). Trawlers operate on the Greenland shelf waters; trawling activity ranging between 200 to 400 hours per week within ½ degree blocks is usual. Of interest is that the noise from trawlers may be comparable to that from a proposed tanker operating at ½ power in open water (Section 4.4.1; APP, 1982). Consequently, the additional possible impacts due to noise from maximum projected tanker traffic by the year 2000 is likely to be NEGLIGIBLE.

4.4.5.6 Walrus

Information on walrus distribution suggests that the tankers could possibly affect them mainly at the wintering areas. In summer and during migration, walruses usually occur in shallow coastal areas where noise levels produced by tankers offshore would be relatively low or attenuated to background. However, in winter, walruses are present in the loose pack ice zone of eastern Davis Strait, and in some years this could include the proposed shipping corridor. Available information on the distribution, abundance and annual variability of this species suggests that the potential impacts of tanker activities on walruses in this area, are unlikely to exceed the MINOR category.

4.4.5.7 Harp Seal

Harp seals are present along the eastern shipping corridor north of 60°N (southern Davis Strait) from May to October (Volume 3B), the period when the tankers would be operating at reduced power levels. In Baffin Bay, vessel noise at 1 kHz would reach quiet ambient levels within 20 to 30 km. If harp seals require a signal-to-noise ratio similar to that of ringed seals, then tanker noise at 1 kHz would not be detected at distances of more than a few kilometres. In most instances, the tankers would not travel close to concentrations of migrating harp seals except for occasional groups in open water or loose pack ice in eastern Lancaster Sound, Baffin Bay and Davis Strait. Thus, the potential impacts of disturbance and temporary masking of communications are expected to be NEGLIGIBLE.

4.4.5.8 Ringed Seal

As described earlier, ringed seals have a relatively uniform hearing sensitivity (68 to 81 dB) at frequencies from 1 to 45 kHz, with a peak sensitivity of 68 dB at 16 kHz (Terhune and Ronald, 1975a). Masked hearing thresholds are about 25 to 30 dB higher for pure tones.

The distribution of adult ringed seals at breathing holes is believed to be fairly stable throughout the winter, with individuals restricted to relatively small areas. Consequently, ringed seals resident in the shipping corridor would be exposed more regularly and to higher noise levels than individuals occupying territories elsewhere. In addition, nearby tanker noise may cause ringed seals to temporarily or permanently abandon their breathing holes, haul-out lairs, and birth lairs. It is possible that repeated tanker transits through the fast ice in Prince of Wales Strait and Parry Channel may render traffic corridors unusable by ringed seals. The amount of sea ice habitat that might be lost is unknown in the absence of documentation on the reactions of ringed seals to repeated noise disturbance during winter. Only the seals within a few kilometres of the tankers would be able to detect the noise, although low-level masking could occur to distances of several tens of kilometres. The maximum habitat loss due to lack of habituation to tanker noise is likely to be in a corridor about 2 km wide when the ice is landfast, assuming that tankers generally re-use tracks previously broken, or break new tracks adjacent to old ones (see also Section 4.2.1.2). This chronically disturbed area would comprise about: 1% of the area of Viscount Melville Sound, 2% of the area of Barrow Strait, and 7% of Prince of Wales Strait. Habitat loss in Viscount Melville Sound, Barrow Strait and Prince of Wales Strait due to noise effects could have impacts on ringed seals ranging from MINOR to MODERATE. There is a need for additional information on reactions of seals to noise disturbances during winter. Work currently being conducted by T. Smith of the Department of Fisheries and Oceans will be of considerable assistance in this regard.

In pack ice areas of Davis Strait and Baffin Bay, winter densities of ringed seals are lower than in fast ice areas of Parry Channel and Prince of Wales Strait, and a smaller proportion of Baffin Bay would be ensonified by tanker noise at frequencies equal to or greater than 1 kHz (Figure 4.4-3). Seals in Baffin Bay occupy moving pack ice which generally drifts southward in the bay. The tankers would not generally break the same ice in each successive transit. This means that the disturbed corridor would effectively be wider than in fast ice but that the frequency of disturbance would be lower than in fast ice areas. However, it is not presently possible to predict the proportion of the population that would be exposed to ship noise over the 7 to 8 month period of ice cover. Potential impacts of tanker noise in Baffin Bay on the ringed seal population would likely be MINOR but could approach MODERATE.

4.4.5.9 Bearded Seal

Although the hearing thresholds of the bearded seal have not been determined, they are probably comparable to those of the ringed seal (Terhune and Ronald, 1975a). Bearded seals are believed to be widely distributed throughout the Baffin Bay pack ice during winter, and move to coastal areas as the pack ice breaks up (Koski and Davis, 1980). Bearded seals are likely to be affected by tanker activities mainly during winter. The potential impacts of disturbance and masking on bearded seals in Baffin Bay are likely to be MINOR.

4.4.5.10 Other Pinnipeds

The hearing abilities and vocalizations of hooded seals are assumed to be similar to those of other phocid seals (cf. Terhune and Ronald, 1975a). Large numbers of hooded seals occur in offshore Davis Strait during the whelping period in March (Volume 3B). Potential impacts of tanker operations on the hooded seal population of Davis Strait are expected to be NEGLIGIBLE, assuming that the vessels would avoid the whelping patches (Section 4.2.1.2).

The only other pinniped in the region, the harbour seal, has a coastal distribution. Therefore, it would not detect increased ambient noise levels as a result of tanker activities and would not be subject to the effects of masking. Potential impacts on the Davis Strait-Baffin Bay harbour seal population are therefore considered NEGLIGIBLE.

4.5 POSSIBLE IMPACTS OF COMMON WASTES ASSOCIATED WITH TANKER OPERATIONS

There is concern that the routine discharge of treated sewage, warm cooling water and emission of gases and particulates from icebreaking tankers may affect water and air quality, and biological resources along the route. The main propulsion system for the tankers would consist of either diesel engines, or the more clean burning aerodrive gas turbines (Volume 2, Chapter 6).

Based on the constant movement of these ships, it is anticipated that air emissions would be rapidly dispersed, and result in only SHORT-TERM and highly LOCAL impacts on air quality along the Northwest Passage.

The volume of treated domestic waste which could be produced by personnel operating a tanker was discussed in Chapter 2, and was estimated at 68 m^3 of effluent/day/tanker. All effluent would receive secondary treatment and would be discharged to the sea. The treated effluent would be rapidly diluted and would be expected to have a NEGLIGIBLE impact on the receiving environment.

Some clean ballast sea water (which is intended to remain segregated from oil cargo compartments) may be discharged from time to time but most of it will not be released until the tanker reached the loading terminal in the Beaufort Sea (Chapter 2). Clean seawater, used for cooling the ship's engines, would be discharged continuously. Solid wastes generated during the course of a trip would be incinerated on board and the residue and all non-combustible wastes stored for authorized disposal on land. No environmental impacts are expected to occur in relation to any of these activities in the shipping corridor.

4.6 POSSIBLE IMPACTS OF ICE RECONNAISSANCE ACTIVITIES

Helicopters stationed on each ship will be used for local ice reconnaissance and real-time route selection throughout the Northwest Passage (Plate 4.6-1), and may result in some localized disturbance of birds and marine mammals along the route. The extent of the disturbance and type of effects would vary with species, season, and the vertical and horizontal distance of the aircraft from the affected individuals.

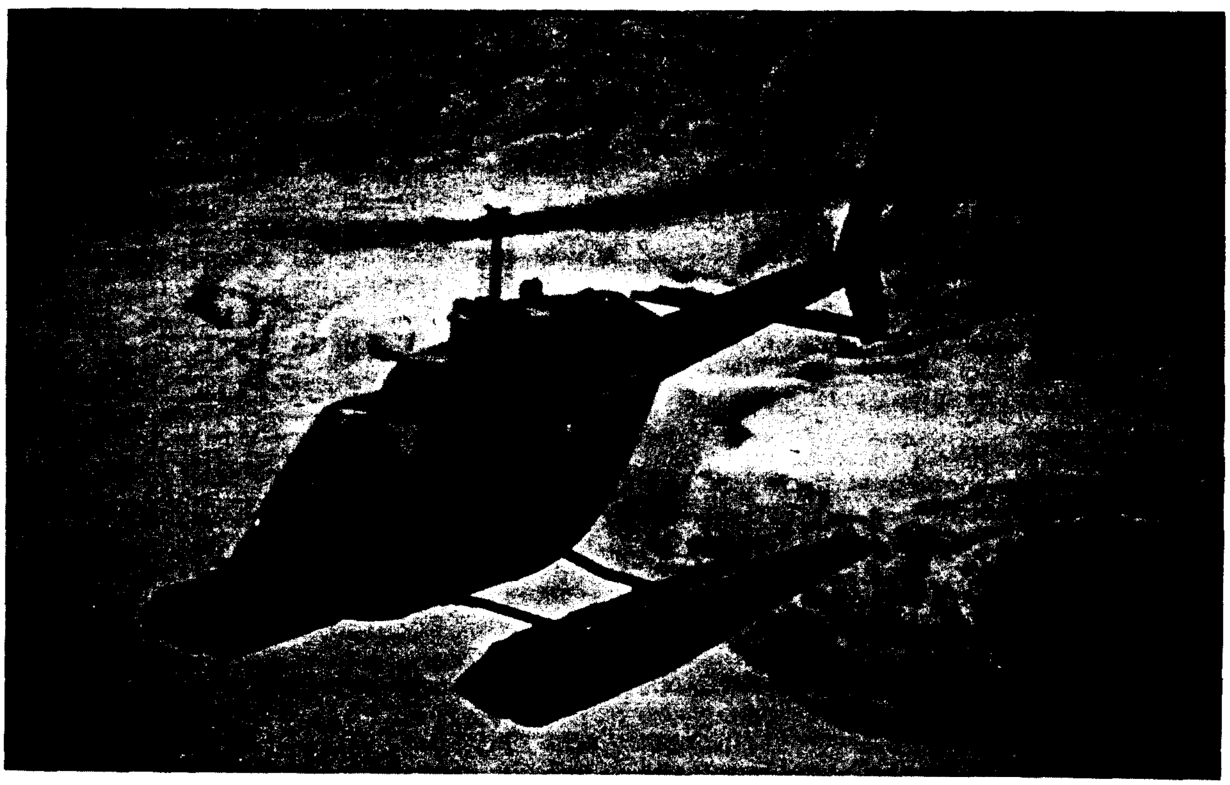

PLATE 4.6-1 *Helicopters stationed on each ship will be used for local ice reconnaissance and real-time route selection. With the application of altitude and routing restrictions, these types of activities are expected to have a NEGLIGIBLE impact on the natural environment.*

4.6.1 MARINE MAMMALS

Studies of the effects of aircraft disturbance on marine mammals are reviewed in ESL (1982). Noise from low-flying aircraft is transmitted reasonably well into the water column. Greene (1982) found that underwater noise levels received from a Bell 212 helicopter at an altitude of 150 m ranged from 80 to 105 dB at frequencies below 250 Hz. At frequencies from 1 kHz to 8 kHz, received levels ranged from 50 to 70 dB. However, because noise from aircraft is transitory and of short duration, it is more likely to affect marine mammals in the water by startling them rather than by significantly affecting their communications. For example, Hay and McClung (1974) observed panic behaviour of white whales in an estuary when they were overflown by a low-flying aircraft. However, helicopters associated with ice reconnaissance activities in the Northwest Passage would not overfly estuarine areas.

Marine mammals that spend time on land (walruses) or on the surface of the ice (ringed, and bearded seals, polar bears, Arctic foxes, walruses) may also react to aircraft disturbances. The most detailed information concerning the effects of aircraft on any of these species relates to the studies of the reactions of walruses at terrestrial haul-out sites conducted by Loughrey (1959) and Salter (1979). Salter (1979) noted that some walruses raised their heads when a helicopter was as far away as 8 km, and that they entered the water only when aircraft were at horizontal distances of 1.3 km or closer. Ringed and bearded seals hauled-out on the sea ice frequently dive when approached by low-flying survey aircraft (e.g. 100 m asl) (LGL Ltd., unpubl. data). Polar bears usually retreat from low-flying survey aircraft (e.g. 100 m asl), although they may occasionally react aggressively (LGL Ltd. unpubl. data). Flights at altitudes of 305 m asl or greater probably have little or no effect on this species (I. Stirling, pers. comm.).

Given the small proportion of the ringed and bearded seal populations which could be affected, and the extremely short-term nature of the event, the potential regional impacts on these species would be NEGLIGIBLE. Similarly, few polar bears are likely to be affected and the potential regional impacts would also be NEGLIGIBLE. Walruses at terrestrial haul-out sites are unlikely to be affected by ice reconnaissance aircraft, and large numbers are not expected to haul-out in pack ice areas within or near shipping corridors where they might be affected. Aircraft will maintain an altitude of at least 300 m asl whenever possible. Furthermore, harassment of wildlife would be prohibited as is present policy for industry personnel in the Beaufort Sea region.

4.6.2 BIRDS

Birds most likely to be affected by helicopter overflights along the shipping corridor include seabirds and gulls because they migrate and forage offshore. Other groups that occur along the route (loons, waterfowl, shorebirds) have a predominantly coastal distribution (Volumes 3A and 3B), and few occur in offshore areas likely to be traversed by helicopters. The impacts of disturbance of coastal species in the Beaufort Sea production region were assessed in Chapter 2, while potential biological effects of aircraft disturbance on birds were described in detail in ESL (1982).

Birds are probably most vulnerable to helicopter disturbances when they concentrate at ice edges. The species most likely to be affected in these areas include the northern fulmar, thick-billed murre, and black-legged kittiwake (Volume 3B). Although there are no quantitative studies of the reactions of birds feeding at ice edges to overflights, most have been observed to flush or dive when overflown by survey aircraft at low altitudes of 30 to 50 m asl (LGL Ltd., unpubl. data).

Safety considerations would normally restrict aircraft from approaching nesting cliffs within distances reported to cause disturbances (ESL, 1982). Consequently, the potential impacts of helicopter activity on nesting seabirds would be NEGLIGIBLE. Likewise, the cumulative effects of two or more flights per day over concentrations of birds at ice edges would probably also be NEGLIGIBLE. Adherence to flight regulations designating minimum distances of 5 km from nesting cliffs and minimum altitudes of 300 m over concentrations of birds at ice edges or elsewhere whenever possible would ensure that potential impacts were NEGLIGIBLE.

4.7 SUMMARY OF POSSIBLE BIOLOGICAL IMPACTS OF YEAR-ROUND SHIPPING

The preceding sections provided an assessment of the potential impacts of tanker activities on the physical environment and biological resources of the Northwest Passage. The following section and Table 4.7-1 summarize these impacts by geographic area and principal biological resources.

4.7.1 AMUNDSEN GULF

Icebreaker operations in Amundsen Gulf could potentially impact ringed seals, white whales and bowhead whales. Ringed seals along the vessel corridor may be temporarily disturbed by the passage of a

TABLE 4.7-1

SUMMARY OF POSSIBLE IMPACTS OF YEAR-ROUND SHIPPING THROUGH THE PRIMARY EASTERN SHIPPING CORRIDOR, BY THE GEOGRAPHIC AREA AND BY SEASON

	Amundsen Gulf			Prince of Wales Strait		
Species	**Type of Impact**[1]	**Season**[2]	**Level of Impact**	**Type of Impact**	**Season**	**Level of Impact**
White whale	N, D	Sp, S	NEGLIGIBLE	—	—	—
Narwhal	—	—	—	—	—	—
Bowhead whale	N, D	Sp, S	NEGLIGIBLE - MINOR	—	—	—
Ringed seal	N, D	Sp, S	MINOR	N, D, M	W, Sp	MODERATE
Bearded seal	N, D, M(?)	Sp, S, F	NEGLIGIBLE	N, D, M(?)	Sp, S, F	NEGLIGIBLE
Birds (all species)	D, A	Sp, S, F	NEGLIGIBLE	D, A	Sp, S, F	NEGLIGIBLE

	Viscount Melville Sd.			Barrow Strait		
Species	**Type of Impact**[1]	**Season**[2]	**Level of Impact**	**Type of Impact**	**Season**	**Level of Impact**
White whale	—	—	—	N, D	Sp, S, F	NEGLIGIBLE
Narwhal	—	—	—	N, D	Sp, F	NEGLIGIBLE
Bowhead whale	—	—	—	N, D	Sp, F	NEGLIGIBLE
Ringed seal	N, D, M	W, Sp	MINOR	N, D, M	W, Sp	MODERATE
Bearded seal	N, D, M(?)	Sp, S, F	NEGLIGIBLE	N, D, M(?)	SP, S, F	NEGLIGIBLE
Birds (all species)	D, A	Sp, S, F	NEGLIGIBLE	D,A	Sp, S, F	NEGLIGIBLE

	Lancaster Sound Area			Baffin Bay/Davis Strait		
Species	**Type of Impact**[1]	**Season**[2]	**Level of Impact**	**Type of Impact**	**Season**	**Level of Impact**
White whale	N, D	Sp, F	NEGLIGIBLE	N, D	W, Sp	NEGLIGIBLE - MINOR
Narwhal	N, D	Sp, F	NEGLIGIBLE - MINOR	N, D	W, SP	NEGLIGIBLE - MODERATE
Fin whale	—	—	—	N, D	S	MINOR
Sei whale	—	—	—	N, D	S	NEGLIGIBLE
Minke whale	—	—	—	N, D	S	MINOR
Blue whale	—	—	—	N, D	S	NEGLIGIBLE
Humpback whale	—	—	—	N, D	S	NEGLIGIBLE
Bowhead whale	N, D	Sp, F	NEGLIGIBLE - MINOR	N, D	W, Sp	NEGLIGIBLE - MINOR
Walrus	N, D	Sp, S, F	NEGLIGIBLE	N, D	W, Sp	MINOR
Harbour seal	—	—	—	—	—	NEGLIGIBLE
Harp seal	D	S	NEGLIGIBLE	D	S	NEGLIGIBLE
Hooded seal	—	—	—	D	Sp	NEGLIGIBLE
Ringed seal	N, D, M	W, Sp	MINOR - MODERATE	N, D, M	W, Sp	MINOR - MODERATE
Bearded seal	N, D, M (?)	Sp, S, F	NEGLIGIBLE	N, D, M(?)	W, Sp	MINOR
Birds (all species)	D, A	Sp, S, F	NEGLIGIBLE	D, A	Sp, S, F, W	NEGLIGIBLE

[1]N = Effects of noise, D = Disturbance, M = Mortality, A = effects on food availability
[2]Season of greatest impact. Sp = Spring, S = Summer, F = Fall, W = Winter
— Indicates species not present or no impact
(?) Indicates greater uncertainty but impacts potentially at the level

tanker, and subsequently make local movements to avoid them. Pups in subnivean birth lairs along the track may be crushed during the six week pup rearing period from late March to May. Most of Amundsen Gulf is covered by first year fast ice in winter, and densities of birth lairs are probably relatively high (Volume 3A). However, because the highest densities of birth lairs in Amundsen Gulf occur in bays and coastal areas where tankers would not travel, potential impacts of icebreaking on ringed seals in this region would probably be MINOR. White whales may be disturbed by underwater noise during spring and late summer, although serious effects are not anticipated and potential impacts should be NEGLIGIBLE. Tanker noise may interfere with conspecific communication of bowheads in Amundsen Gulf during spring and summer. During the early years when few tankers would be travelling, impacts are likely to be NEGLIGIBLE although they could rise to MINOR during the full production phase.

Potential impacts of icebreaking on the epontic community in Amundsen Gulf are expected to be NEGLIGIBLE because effects would be highly localized, and the proportion of the population which could be affected would be regionally insignificant. Potential impacts on birds are also expected to be NEGLIGIBLE, although gulls and other birds feeding in offshore areas during spring would benefit through increased food availability in vessel tracks. Ice reconnaissance activities and associated disturbances would not occur in the vicinity of any coastal nesting colonies, but some birds staging in the Amundsen Gulf polynya during spring may be temporarily disturbed by reconnaissance aircraft. This effect could be mitigated by adherence to flight altitude restrictions whenever possible.

4.7.2 PRINCE OF WALES STRAIT

Whales do not normally occur in Prince of Wales Strait, and bird densities are low. However, moderate densities of ringed seals are present (Stirling *et al.*, 1981), and because the strait is usually covered by first year fast ice, densities of birth lairs are probably high (cf. Smith *et al.*, 1979). The projected passage of up to two tankers per day through Prince of Wales Strait by the year 2000 could result in the loss of 7 to 10% of the ringed seal habitat. If this occurs, impacts could approach the MODERATE rating. This degree of impact, were it to occur, could be mitigated to some degree by re-routing ships through M'Clure Strait during years when ice conditions permit. Data collected over the last 10 years indicate that there have been four winters when it may have been easier to travel through the M'Clure Strait alternate route (Volume 3B). Since M'Clure Strait ice does not become landfast, the area is likely to have a low density of ringed seal birth lairs.

4.7.3 VISCOUNT MELVILLE SOUND

Whales do not usually occur in Viscount Melville Sound and densities of adult ringed seals and birth lairs are believed to be low. Nevertheless, the potential impacts of icebreaking in this area on seals would be MINOR because about 3% of the first year ice habitat could be lost to breeding seals, but overall seal densities are relatively low. Densities of birds are low, and the only known coastal nesting colonies have only a few pairs of glaucous gulls. The proportion of the epontic community in Viscount Melville Sound that could be affected by icebreaking would be insignificant in terms of the regional populations. Potential impacts of tanker operations in this area on whales, birds, fish and lower trophic levels are likely to be NEGLIGIBLE.

4.7.4 BARROW STRAIT

There is concern that icebreaking activities in Barrow Strait may result in a reduction in usable habitat for wintering and pupping ringed seals, and also result in the loss of pups by tankers moving through breeding areas. Barrow Strait supports moderate to high densities of both overwintering adult seals and birth lairs (Volume 3B). Between 2 and 4% of this general habitat could be lost to breeding seals,leading to perhaps MODERATE impacts. However, if some habituation and adaptation occurs then impacts might only be MINOR.

White whales are the most abundant whale species in Barrow Strait. While in the strait, they occur mainly in shallow coastal areas where tanker noise would not interfere with either echolocation or communication. However, they could be affected for a short period during their migration from southern Devon Island to summering areas along and south of Barrow Strait. Nevertheless, potential impacts on white whales in Barrow Strait should be NEGLIGIBLE. Most narwhals and bowheads do not move as far west as Barrow Strait, and those that do, summer in adjacent channels where they would not be affected by vessel noise. Consequently, impacts on these species in Barrow Strait should also be NEGLIGIBLE.

4.7.5 LANCASTER SOUND

The ice in Lancaster Sound is usually in restricted motion during winter, and may not support the high densities of breeding ringed seals typical of fast ice areas. However, densities may approach those typical of the Baffin Bay pack ice. On this basis, it is likely that the possible impacts on the resident population would be MINOR although this rating could rise to MODERATE especially in years when the ice in Lancaster Sound consolidates.

White whales migrate through Lancaster Sound along the coast of Devon Island, and would not be affected by high noise levels produced by tankers operating in the icebreaking mode. Consequently, potential impacts on this species would be NEGLIGIBLE. Both narwhals and bowheads migrate through Lancaster Sound, and at least part of the migration occurs in offshore waters near the proposed shipping corridor. They then move into summering areas in bays and inlets south of Lancaster Sound where they would not be affected by tanker activities. Potential impacts on these species when they are in Lancaster Sound are likely to range from NEGLIGIBLE to perhaps MINOR because they are only present for a brief period in areas traversed by tankers.

There are several large seabird colonies along the shores of Lancaster Sound. Certain offshore areas, particularly the cross-sound ice edge, may be used by large concentrations of birds in spring. Birds at the nesting colonies and at the ice edge could be disturbed by ice reconnaissance aircraft, while birds at the ice edge would probably flush during the passage of a tanker. However, adherence of aircraft to altitude and routing regulations whenever possible would ensure that potential impacts to birds were NEGLIGIBLE. Energy expenditures associated with flushing would probably be inconsequential. Positive but also NEGLIGIBLE impacts on some species may result from increased food availability along the icebreaker track.

4.7.6 BAFFIN BAY AND DAVIS STRAIT

Baffin Bay and Davis Strait support a larger number of marine species in both summer and winter than do other portions of the eastern shipping corridor. Several species of odontocete and baleen whales summer along the fishing banks off west Greenland, and white whales, narwhals and bowheads all winter in this region. Ringed seals, bearded seals, walruses and probably hooded seals are present in Baffin Bay and Davis Strait all year, whereas harp seals are present in spring, summer and fall.

Historically, bowheads are known to winter within the loose pack ice edge zone from Disko Island to northern Labrador. Recent surveys have found them south of Disko Island and in Hudson Strait. The ice edge zone across central and western Davis Strait has not been surveyed. It is possible that the bowheads that winter in Hudson Strait summer in the eastern Arctic or in Hudson Bay and Foxe Basin. Therefore, it is likely that most bowheads could be exposed to ship noise in winter only when they are within the loose pack ice edge zone. In spring bowheads move north through the Baffin Bay pack ice and along the west coast of Greenland. Animals along the coast would not be exposed to ship noise, whereas those migrating north in the loose pack ice in the offshore region likely would be. Although there is a lack of information on winter ambient noise in Baffin Bay and Davis Strait and on the potential effects of increased masking caused by shipping noise in ice-covered waters, it is likely that shipping noise could affect bowheads mostly while they are within the region north of the loose pack ice edge. In summer, ambient noise levels are such that shipping noise effects would only be significant at relatively short ranges compared to the area under consideration. Effects could range from NEGLIGIBLE to MINOR depending on the proportion of the bowhead population that migrates offshore.

Narwhals winter throughout the heavy pack ice of Davis Strait and Baffin Bay. Thus, a portion of the population would be exposed to ship noise and disturbance on every passage during the 6 to 7 month period of ice cover. Impacts in the vicinity of the shipping corridor could range from NEGLIGIBLE to MODERATE.

White whales winter in the loose pack ice off the coast of Greenland. There is a limited potential for masking white whale communication and disturbance in some years when the loose pack zone coincides with the shipping routes. The degree of potential impact would probably range from NEGLIGIBLE to MINOR.

Several species of odontocete and baleen whales summer in substantial numbers off western Greenland. During summer, the tankers would be travelling at relatively low power settings, and ship noise above 1 kHz would attenuate to ambient levels within a few kilometres of the ship. Therefore, potential impacts on odontocete species, which use primarily frequencies above 1 kHz, should be NEGLIGIBLE. Baleen whales communicate at lower frequencies, but even at 100 Hz, tanker noise would reach average ambient noise levels within about 30 km of the vessel. Potential impacts on fin and minke whales are therefore expected to be MINOR.

Bearded seals are widely dispersed during winter in pack ice areas including the shipping corridor, and potential impacts of vessel noise on this species would likely be MINOR. Impacts on ringed seals could be MINOR to MODERATE. Although walruses winter in coastal areas where they would not be affected by tanker activities, others winter in loose pack ice areas where potential impacts may be MINOR. Potential impacts on harp and hooded seals should generally be NEGLIGIBLE.

Major seabird colonies occur along the shores of both Baffin Bay and Davis Strait. However, the tanker route and the probable routes of ice reconnaissance aircraft would be located far offshore and are unlikely to affect birds at colonies. Overturned ice along the tanker tracks would provide a highly localized increase in food sources for seabirds foraging in offshore areas. Densities of birds in offshore areas are low, so short-term disturbances in these areas by aircraft would be unlikely to affect regional populations. Thus the potential impacts on birds in Baffin Bay/Davis Strait are expected to be NEGLIGIBLE.

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4.8.2 PERSONAL COMMUNICATIONS

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CHAPTER 5

MACKENZIE VALLEY OVERLAND PIPELINE REGION

The impact assessment in this chapter considers the environmental implications of the construction and operation of a large diameter warm oil pipeline in the Mackenzie Valley. The pipeline could range in diameter from 900 to 1,067 mm and would have elevated and buried sections. The decision to construct such a pipeline will depend mainly on having sufficient proven oil reserves.

The chapter begins with a brief description of the pipeline system in Section 5.1. Impacts and mitigative measures associated with preconstruction and construction are described in Sections 5.2. and 5.3. Impacts and mitigative measures associated with operations, maintenance, and abandonment are described in Section 5.4. These sections assess, where applicable, the possible effects of specific activities on various natural resources including geology and soils, hydrology and water quality, the atmospheric environment, vegetation, mammals, birds, and fish. The assessment of the impacts assumes that all effective and feasible mitigative measures are employed. Impacts described in the following sections are summarized in Matrix 5.1-1.

Other pipeline developments have been approved or proposed for the Mackenzie River Valley. The Norman Wells Oilfield Expansion and Pipeline has been

MATRIX 5.1-1

POTENTIAL ENVIRONMENTAL IMPACTS RESULTING FROM DEVELOPMENT OF AN OIL PIPELINE IN THE MACKENZIE VALLEY

		GEOLOGY AND SOILS				HYDROLOGY AND WATER QUALITY			AIR		VEGETATION			MAMMALS								BIRDS					AQUATIC RESOURCES	
		SOIL CHEMISTRY	SURFACE STABILITY	SLOPE STABILITY	GENERAL TERRAIN	WATER QUALITY	SURFACE WATER	GROUNDWATER	AIR QUALITY	MICROCLIMATE	RIPARIAN	CONIFEROUS FOREST	TUNDRA	REINDEER	BARREN GROUND CARIBOU	MOOSE	GRIZZLY BEAR	BLACK BEAR	AQUATIC FURBEARERS	TERRESTRIAL FURBEARERS	GENERAL MAMMAL CONCERNS	RAPTORS	GEESE/SWANS	DUCKS	OTHER	GENERAL/AVIAN CONCERNS	LOWER TROPHIC LEVELS	FISH
PIPELINE PRECONSTRUCTION AND CONSTRUCTION 5.2	RIGHT-OF-WAY PREPARATION		L-s	L-s	L-s	L-s	L-s	L-s			L-s	L-s	L-s	◊	◊	◊	◊	◊	◊	◊	◊	●	◊	◊	○		○	◊
	BLASTING					L-s	L-s														○	○	○	○	○		○	◊
	PIPELINE DITCHING, INSTALL. & BACKFILLING		L-s	L-s	L-s	L-s	L-s		L-s		L-s	L-s	L-s	◊	◊	◊	◊	◊	◊	◊	◊						○	○
	PIPELINE TESTING AND FLUID DISPOSAL	L-s	L-s	L-s	L-s	L-s	L-s				L-s	L-s	L-s	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◊
	STREAM CROSSINGS		L-s	L-s	L-s	L-s	L-s				L-s	L-s	L-s	○	○	◊	○	○	◊	○							◊	◊
	ELEVATED PIPELINE		L-s	L-s	L-s						L-s		L-s	◊	◊	◊	○	○	○	○	◊							
	BURIED PIPELINE		L-s	L-s	L-s		L-s	L-s			L-s	L-s	L-s	◊	◊	◊	○	○	○	◊	◊							
	PUMP STATIONS		L-s	L-s	L-s						L-l	L-l	L-l								◊	●	●			●		
SUPPORT FACILITIES PRECONSTRUCTION AND CONSTRUCTION 5.3	SITE PREPARATION		L-s	L-s	L-s	L-s	L-s	L-s			L-l	L-l	L-l								◊	○	○	○	○	○	○	○
	GRANULAR BORROW		L-s	L-s		L-s	L-s					L-m	L-m								◊	◊	◊	◊		◊	○	○
	WHARVES AND BARGE TRAFFIC																						◊	◊			○	○
	TEMPORARY ACCESS ROADS		L-s	L-s	L-s	L-s	L-s				L-s	L-s	L-s	◊	◊	●	◊	◊	◊	◊						○	○	○
	PERMANENT ACCESS ROADS		L-s	L-s	L-s	L-s	L-s	L-s			L-l	L-l	L-l								◊	◊	◊	◊		◊	○	○
	STAGING SITES AND STOCKPILES																				◊	◊	◊	◊	◊			
	CONSTRUCTION CAMPS													◊	◊	◊	●	◊	○	◊		◊	◊	◊			○	○
	AIRCRAFT AND AIRSTRIPS													◊	◊	◊	◊	◊	○	○		●	●	◊				
	WASTE DISPOSAL													○	○	○	●	○	○	◊					○	○	◊	◊
	OFF-DUTY ACTIVITIES BY PIPELINE PERSONNEL																				◊					◊		○
OPERATION MAINTENANCE AND ABANDONMENT 5.4	PIPELINE SURVEILLANCE													○	○	○	○	○	○	○	○					○		
	PERMANENT ROADS AND WHARVES					L-s	L-s														◊					◊		
	OTHER PERMANENT SUPPORT FACILITIES																				◊					◊		○
	PUMP STATIONS	L							L	L	L	L	L								○					○		○
	FIRE HAZARD																											
	ABANDONMENT		L-s	L-s	L-s						L-s	L-s	L-s								○							
	RECLAMATION		L-s	L-s	L-s						L-s	L-s	L-s								○					○	○	◊

LEVEL OF POTENTIAL IMPACT

BIOTIC
○ : NEGLIGIBLE
◊ : MINOR
● : MODERATE
■ : MAJOR

PHYSICAL
L : LOCALIZED
R : REGIONAL
m : MEDIUM-TERM
l : LONG-TERM
s : SHORT-TERM

BLANKS INDICATE NON-APPLICABILITY OR ADDRESSED ELSEWHERE approved. Esso Resources is currently investigating the possible use of a 300 to 400 mm small diameter buried pipeline to connect onshore and nearshore Beaufort region oil discoveries to the approved Norman Wells pipeline. Natural gas pipeline proposals, described in Volume 2, include the Dempster Lateral link to the Alaska Highway Gas Pipeline Project and the Polar Gas Y-line Pipeline Project. Section 5.5 provides an overall summary of likely impacts on the natural resources as a result of any of the possible pipeline developments involving the Mackenzie River valley.

5.1 DESCRIPTION OF OVERLAND OIL PIPELINE SYSTEM

An overland oil pipeline would likely originate near North Point on Richards Island (Figure 5.1-1), and proceed to the south, east of Inuvik. It would then parallel the Mackenzie River to a point southeast of Fort Simpson, where it would cross the Mackenzie River. Proceeding to Zama in northwest Alberta, the line would then parallel the Rainbow Pipeline system to Edmonton. Final destination would be the terminal of Trans-Mountain Pipeline and Interprovincial Pipelines of Edmonton. The total distance from North Point to Edmonton is approximately 2,250 kilometres. Major river crossings north of 60° latitude would include the Mackenzie River at East Channel, the Great Bear River, and the Mackenzie River at Fort Simpson. Numerous route and alignment alternatives have been studied by groups consisting of geotechnical, environmental, socio-economic, mechanical design, and construction specialists.

The diameter of the pipeline would depend on the production rate, ranging from 1,067 mm for a technically achieveable scenario (218,000 m^3/day) to smaller diameters for lower production scenarios. However, the route and design criteria developed for warm oil pipelines of various diameters would be similar. Approximately 720 km of the pipeline will be constructed above ground, including the first 360 km extending south from North Point. Under the current design, the pipe would be mounted on vertical support members, and cryoanchors will be installed where necessary to prevent thawing of the permafrost in the discontinuous permafrost regions. Approximately 1,530 kilometres will be buried under a minimum of 1 metre of cover. The pipeline right-of-way will be up to 37 m wide.

The northern terminal will share a common site with Pump Station No. 1 and contain crude oil storage tanks within a dike system. At peak production, up to 24 pump stations could be required. Stations would be built on gravel pads to maintain stable permafrost. It is estimated that 8 million cubic metres of gravel will be required for the construction of the pipeline and its pump stations.

The pipeline will take about four years to construct, with the majority of activity taking place in winter when the terrain is frozen. To ensure the integrity of the line, and to minimize adverse environmental impacts, special Arctic pipeline construction procedures are required in both continuous and discontinuous permafrost areas. These have evolved from winter pipelining in northern areas and from actual test programs and include the use of elevated sections, snow and ice roads and work pads, hand clearing, snowfill instead of excavating terrain, debris burning on sleds, selective removal and replacement of active layers, and a variety of soil stabilizing methods. Summer construction would include the building of the north and south terminals, pump stations, and completion of the major river crossings.

Where feasible, temporary facilities such as camp sites, access roads and airstrips would be established during winter. Material, fuel and machinery would be stockpiled using the existing waterways such as the Mackenzie River and roads such as the Dempster and Mackenzie Highways. North of the 60th parallel, personnel and camp supplies would be flown in by aircraft; as many as 12 additional airstrips may be required (Figure 5.1-2).

As with all pipelines, aerial and ground surveillance and monitoring will identify any undesirable subsidence or erosion of the ground along the right-of-way. In sensitive permafrost terrain areas, maintenance would, as much as possible, be conducted only during cold weather when the right-of-way is frozen. At other times of the year, aircraft will be the preferred way of transporting personnel and equipment to the work sites in these areas.

Leak detection systems, included as part of the control system, will be able to detect and identify the location of oil leaks in the order of 0.25 to 0.50% of pipeline flow. Flow valves will be spaced at regular intervals (maximum 30 km apart) to isolate segments of the line in the event of a leak. In addition, block valves and mainline check valves will be installed at pump stations, and at locations deemed environmentally sensitive (e.g., river crossings). Valves will be installed above ground and can be operated at the site, or remotely from Edmonton or North Point.

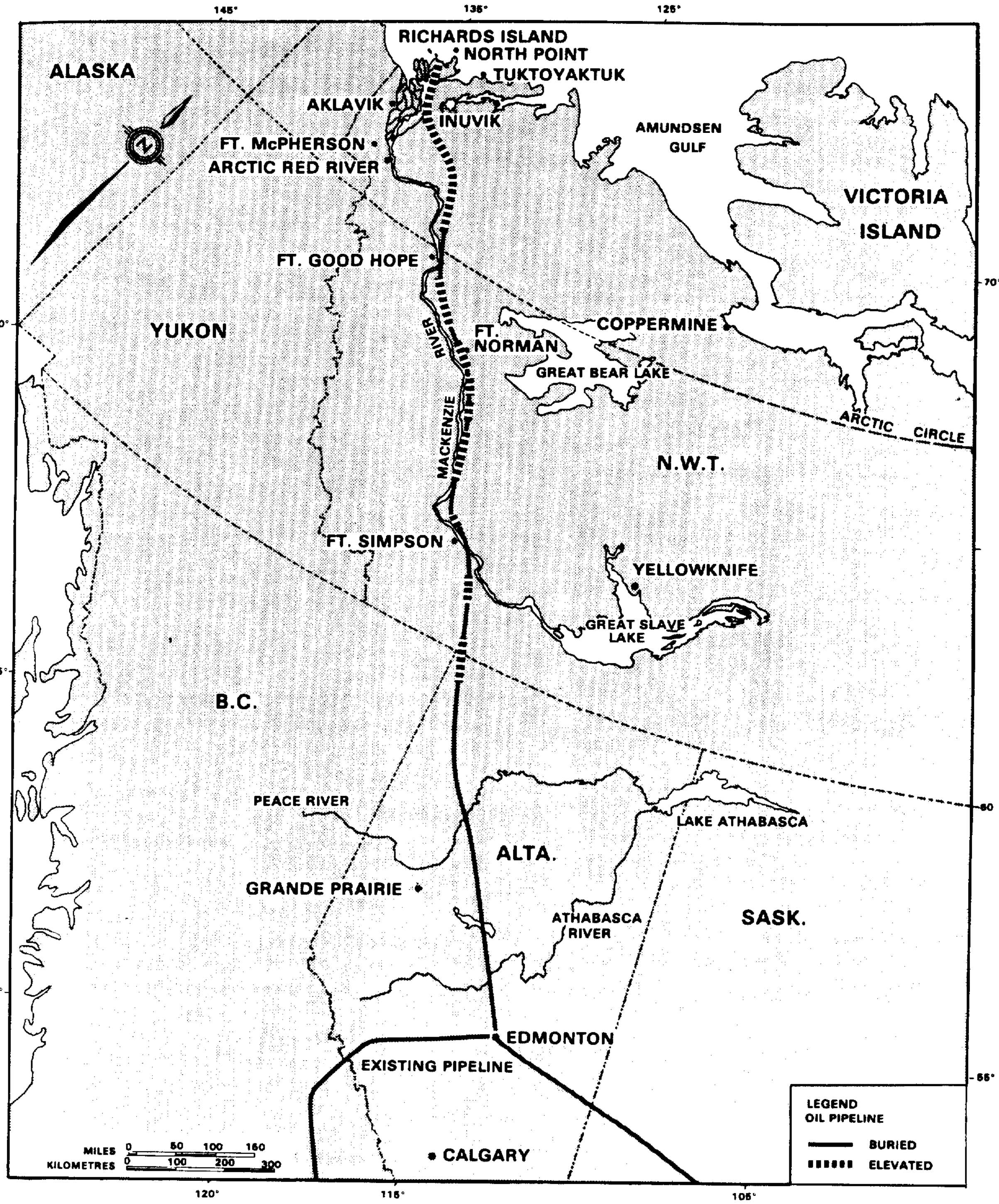


FIGURE 5.1-1 *The Mackenzie Valley Overland Oil Pipeline System would extend 2,250 km from North Point to Edmonton. Elevated segments are indicated by the dashed lines.*

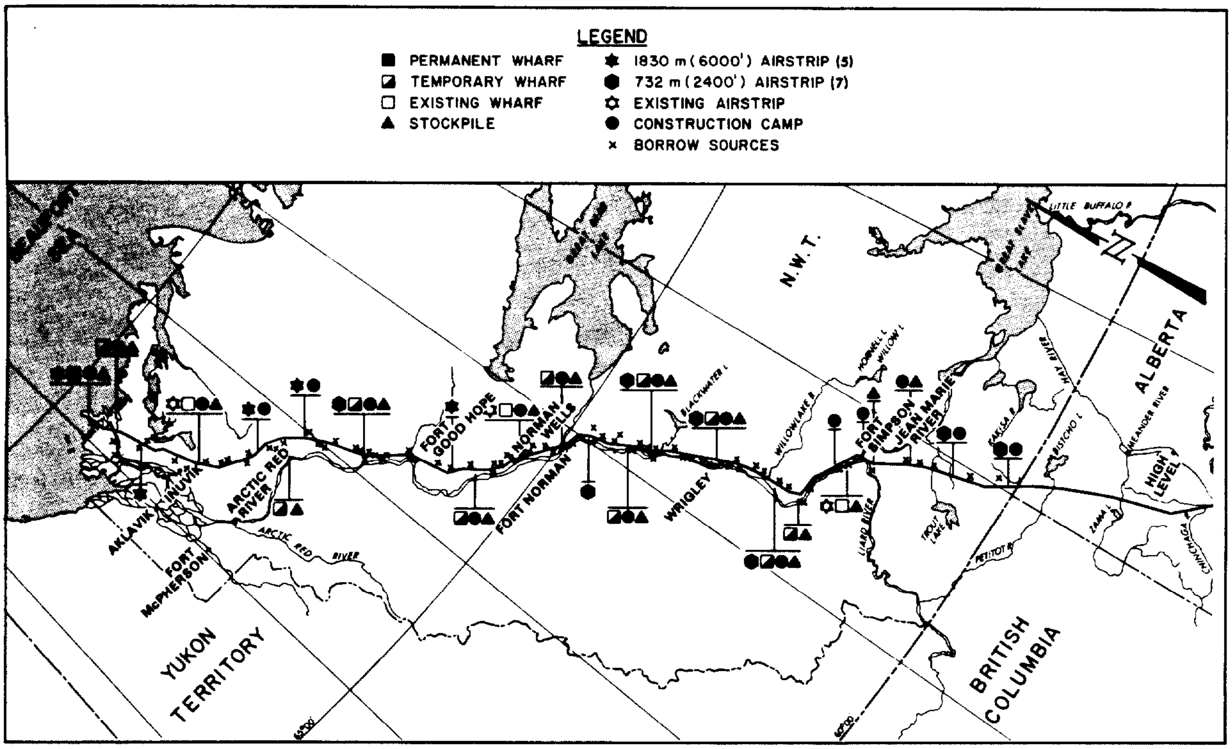


FIGURE 5.1-2 *Construction facilities associated with a pipeline system in the Mackenzie Valley from the Beaufort Sea to 60° Latitude.*

5.2 IMPACTS FROM THE PRECONSTRUCTION AND CONSTRUCTION OF THE PIPELINE AND PUMP STATIONS

Preconstruction and construction activities include right-of-way preparation, blasting, pipeline ditching, installation and backfilling, pipeline testing and fluid disposal, and the construction of stream crossings, elevated and buried pipeline sections, and pump stations.

5.2.1 RIGHT-OF-WAY PREPARATION

The pipeline right-of-way will require a corridor of land up to 37 m wide. Right-of-way preparation would be done primarily during winter and includes all activities associated with surveying, clearing, grading, and brush-burning. Arctic pipeline construction procedures will be employed to minimize adverse effects on the environment.

5.2.1.1 Geology and Soils

Right-of-way clearing and grading will likely initiate some increased frost penetration in unfrozen ground and increased thaw in perennially frozen ground resulting in shallow thaw settlement and localized thermal erosion. Thaw settlement could cause ponding on the right-of-way and alterations in normal surface and subsurface drainage patterns, resulting in accelerated erosion of soil surfaces (Hughes *et al.*, 1973; Rutter *et al.*, 1973; Rampton, 1974). On sloping terrain, especially at major stream crossings and near the Franklin Mountains, slope cuts and drainage alterations may result in an increased frequency of slope instabilities adjacent to the right-of-way.

Surface disturbance to landforms and soils will be minimized mainly by winter construction, when surfaces are frozen. In addition, the right-of-way will be located on existing clearings and cutlines where possible. The width of the clearing will be kept to the minimum necessary for the safe and efficient operation of construction equipment. In sensitive areas, primarily north of 65°N latitude, the presence of high ice content soils will require the following Arctic pipeline construction procedures: hand clearing will be undertaken on slopes in areas of high ice content soils where machine clearing might produce thaw settlement, erosion or slope instabilities; cleared debris will be burned on portable sleds or gravel pads to prevent thaw settlement; extensive use of filling techniques with snow rather than cutting of side slopes will be undertaken during grading operations.

The application of these procedures is expected to reduce the incidence of thaw settlement, erosion, and slope failures to a minimum. Shallow erosion and localized slope failures are most likely to occur in ice-rich soils on some steep slopes, especially at principal stream crossings and at the foot of the Franklin Mountains. The magnitude of the impact of right-of-way preparation is variable, depending on slope and ice content and is considered to be LOCALIZED and SHORT-TERM.

5.2.1.2 Hydrology and Water Quality

Surface disturbance resulting from clearing and grading of the right-of-way will interrupt surface and subsurface drainage patterns, resulting in localized surface ponding and channelization and blockage of subsurface flow. Clearing near waterbodies may cause increased surface erosion and sediment loading. Increased sediment loads from surface disturbance will occur during periods of peak runoff, such as during spring freshet and periods of intense precipitation, and will thus coincide with times of normally high sediment loads.

Measures to minimize erosion and siltation will be specified in a drainage and erosion control plan which will be developed during final design. Specific procedures will include breaching of temporary water crossings, such as ice bridges and fill, prior to the spring freshet. Most right-of-way clearing will take place during winter to minimize the potential for water erosion. A buffer strip of undisturbed land will be maintained where feasible along all aquatic systems paralleled by the route. The impact of clearing on drainage patterns and water quality is considered LOCALIZED and SHORT-TERM.

5.2.1.3 Vegetation

The largest single effect of the project on vegetation will be due to right-of-way clearing. Prior to construction, all trees and shrubs more than about 50 cm tall will be cleared from the 37 m wide right-of-way. North of Inuvik, where tundra predominates, little vegetation clearing will be required. South of Inuvik to the Alberta-NWT border, the route lies predominantly in forests, scrub forests and shrub vegetation and clearing will affect about 40 km^2 of vegetation. In small areas of mature white spruce and aspen forests, clearing will likely initiate some windthrow of trees along the edges of the clearing. Removal of woody vegetation is expected to stimulate the growth of herbaceous ground cover in most areas. Effects of clearing on timber resources will be slight since there is little marchantable timber along the route (Volume 3C).

All exposed soils along the entire length of the pipeline route will be revegetated by grass and legume species proven successful in long term, northern field trials such as those conducted by Hardy Associates (1980). Shrub cuttings may be included in the revegetation of slopes at river crossings and erosion control techniques will be used as required to maintain surface stability. Special geotechnical measures will be applied in areas of especially unstable surfaces where erosion, slope failure or thermal degradation may occur. Revegetation is expected to ultimately replace most of the lost vegetation. In forested areas, trees and tall shrubs will be kept from the right-of-way for the life of the pipeline. Mature vegetation communities will become re-established following abandonment. The impact of right-of-way clearing on vegetation is considered LOCALIZED and SHORT-TERM.

5.2.1.4 Mammals

Mammal populations will be affected mainly by local changes in their habitat. The net effect may be to temporarily reduce the value of the habitat for some species while increasing its value for others. The carrying capacity will be increased for edge-adapted species such as moose, mule deer and those species such as meadow voles that prefer early seral vegetation. Species such as woodland caribou, marten, fisher and red squirrels will more likely be adversely affected, although there is some evidence that small-scale habitat alteration may be beneficial to woodland caribou (Euler *et al.*, 1976; Miller, 1976).

Results of studies conducted in the Northwest Territories and Alberta (Penner, 1976; Riewe, 1977) indicate that most terrestrial furbearing mammals such as marten, ermine, canids, snowshoe hares and red squirrels, tend to avoid recent seismic lines except while crossing them, although wolves used seismic lines extensively for travel (Horejsi, 1979) and for hunting (Mech, 1970; Peters and Mech, 1975). Some species may therefore avoid using the pipeline right-of-way. The semi-aquatic furbearers, muskrat, beaver and mink, would be minimally affected by vegetation clearing. Movements of ungulates are also expected to be only minimally affected by the pipeline right-of-way. Slash piles along the right-of-way will be burnt and will not cause a barrier to ungulate movements. Studies of the response of Porcupine caribou to seismic lines and winter roads showed that use of cutlines was mostly local and random until there was strong motivation for unidirectional movement such as during spring migration (McCourt *et al.*, 1974). Whether cutlines were crossed or followed during spring migration depended on the angle of approach. The distance that cutlines were followed was inversely proportional to the angle of deflection.

Changes in vegetation which may occur as a result of alterations in drainage patterns are likely to be so minor and localized as to have little consequence on wildlife populations. There is, however, a possibility that some beaver dams may be destroyed and small ponds may be drained to the detriment of small numbers of beaver and muskrat.

Several measures have been designed to minimize potential effects of clearing on mammals. Existing cleared areas will be used for location of the pipeline right-of-way where possible; the width of clearing on the right-of-way will be kept to the minimum necessary for the safe and efficient operations of the pipeline and construction equipment; environmental inspections will ensure that unnecessary habitat alteration is avoided; reclamation will ensure revegetation of the right-of-way; brush control on the right-of-way will be minimized to that which is absolutely necessary for reconnaissance and fire hazard control; drainage control measures will be carefully designed to reduce alteration of habitat in the vicinity of the right-of-way; and care will be exercised to avoid destruction of beaver dams and to avoid drainage of ponds used by overwintering beaver and muskrat.

Where beaver dams on drainage channels and culverts create problems, special beaver control culverts will be used where feasible. Additional concerns regarding beaver will be solved in a manner acceptable to the NWT Wildlife Service.

Overall, while some alteration in the habitat available to mammal populations will occur as a result of right-of-way preparation, this change will be very small in relation to the total available habitat and by itself is unlikely to affect mammal population levels. Impacts from right-of-way preparation on mammals are expected to be MINOR.

5.2.1.5 Birds

Impact on birds will arise largely from the results of habitat modification rather than from the activities themselves. Some wetland areas may be altered or lost and others possibly created. Linear clearing will create an edge condition in forested areas that will cause local changes in bird species composition and population levels.

Survey parties could be active during all seasons and will have some very local impact on birds. Waterfowl could be disturbed during spring migration down the Mackenzie River. The sandbars and islands in the section between Norman Wells and Arctic Red River are of particular importance to swans and geese for resting, feeding and mating during spring migration (Volume 3C). Establishment of aircraft flight corridors designed to avoid river islands during May are expected to reduce impacts on waterfowl from this source and impacts are considered to be MINOR.

Ground and airborne survey crews could disturb raptors such as peregrine falcons, golden eagles, bald eagles, ospreys and rough-legged hawks in the vicinity of their nest-sites during the April 15 to August 31 nesting period (White and Sherrod, 1973; Fyfe and Olendorff, 1976; Nelson, 1976). Surveys for raptor nest-sites prior to commencement of full-scale survey work will aid in final route planning. The important nesting areas for peregrine falcons and golden eagles in the corridor are already known: a region from Chick Lake south through the Gibson Gap and along the western border of the Norman Range, south to Great Bear River (Windsor and Richards, 1976); and a region paralleling the McConnell Range between km 830 and 1,000 (Koski, 1977). Final planning of right-of-way location and facility locations will consider recommendations of Roseneau *et al.* (1981) for the protection of raptors (see Tables 5.1-1 and 5.1-2). These include recommendations for no development within 3.2 km of active or historic nest-sites of peregrine falcons, within 0.8 km of golden eagle nest-sites, or within 0.4 km of the nest-sites of gyrfalcons, rough-legged hawks, bald eagles, and ospreys. Some raptors which have low tolerance to human activity can be expected to decline in the vicinity of the pipeline route subsequent to clearing (Roseneau *et al.*, 1976). If, for geotechnical or engineering reasons, it may not be reasonable or possible to avoid raptor nests by the recommended distances, each case will be reviewed individually in consultation with the appropriate government agency.

Given the general sensitivity of raptors to disturbance and the low population levels of some species, potential impacts could approach MODERATE in localized areas.

5.2.1.6 Aquatic Resources

Except prior to freeze-up and after break-up the following spring, watercourses will be frozen during most right-of-way preparation activities and will not be subject to sedimentation. Timber clearing prior to winter construction and right-of-way preparation adjacent to the three major summer river crossings (north of 60° latitude) of the Mackenzie and Great Bear rivers are of some concern since these activities might introduce sediments affecting concentrations of fall spawning fish species (e.g. whitefish, ciscoes, and lake trout) or their eggs.

Sedimentation resulting from right-of-way preparation will have the greatest effect on clear tributary streams and lakes that provide spawning, rearing, or overwintering habitat. A discussion of the effects of sediments on aquatic organisms and their recovery is provided in Section 3.4.1.6. During most of the open

TABLE 5.1-1

RECOMMENDATIONS FOR PROTECTION OF THE ENDANGERED PEREGRINE FALCON*

I. Recommended Protection Standards for Nesting Activities:
The following standards apply to all active peregrine falcon nesting sites during the nesting season (April 15-August 31). All known nesting sites should be considered active (whether or not birds are present) between April 15 and June 1. Nesting sites not having a peregrine falcon present by June 1 may be considered inactive.

A. Within 1.6 km lateral distance of peregrine falcon nesting sites the following are not recommended:
   1. aircraft flying lower than 500 m above nest level;
   2. all other human activities.

B. Within 3.2 km of peregrine falcon nesting sites the following are not recommended:
   1. major construction or other noise producing activities such as mining, blasting, and operation of aggregate crushers.

II. Recommended Protection Standards for Hunting Habitat:
The following standards apply to all peregrine falcon nesting sites (active and historic) and at all times.

A. Within 24 km of nesting sites the following activities are not recommended:
   1. ground surface disturbance on a large scale which could detrimentally and significantly alter the habitat of falcon prey (i.e. waterfowl).
   2. the use of pesticides or other environmental pollutants which could be detrimental to the peregrine falcon or its food source.

III. It is understood that the above recommendations may not be appropriate in all situations and that a qualified biologist should review specific cases and determine appropriate protective measures. It is further understood that protection standards for hunting, as listed above, do not recommend against all development within a 24 km radius of a nesting site; rather, they are intended to recommend against major changes such as draining of marshes, or other extensive habitat alteration.

IV. Definitions

A. Nesting site - any cliff, bluff, tree or other structure which could reasonably be used as an eyrie by peregrine falcons and for which a pair or single bird demonstrates, or has in the past demonstrated, an affinity.

B. Active nesting site - all known peregrine falcon nesting sites during the period April 15-June 1 and those nesting sites for which a pair or single bird demonstrates an affinity at any time during the current nesting season (April 15-August 31).

*Adapted from Table 16 in Roseneau et al. (1981).

water season, the Mackenzie River mainstem, a major migratory corridor, is already subject to high ambient sediment loads (Campbell *et al.*, 1975). Sedimentation as a result of right-of-way preparation is not expected to appreciably exceed normal levels. Most tributary streams in the corridor freeze to the bottom and support neither fall-spawning fish species nor overwintering fish (McCart *et al.*, 1974).

Portions of the Mackenzie River, notably the Delta, are known to support large concentrations of overwintering fish but these areas will be frozen over during right-of-way preparation and sedimentation is considered unlikely.

Except where slope stabilization problems are encountered, most areas disturbed by right-of-way preparation will be stabilized within one year of the initial disturbance. As a result, effects will be limited to a single open water season. Some local sedimentation, possibly lasting several years, may occur near bank failures or where revegetation and reclamation are not wholly effective (Section 5.2.3.6). Post-construction surveillance of the route will be conducted to identify sites where remedial reclamation

TABLE 5.1-2

RECOMMENDED TEMPORAL AND SPATIAL PROTECTION CRITERIA FOR NESTING GYRFALCONS, ROUGH-LEGGED HAWKS, GOLDEN EAGLES, BALD EAGLES AND OSPREYS.

			Protection Criteria			
Species	**Sensitive Time Period**	**Aerial[1] Activity**	**Minor Ground Activity**	**Major Ground Activity**	**Facility Siting**	**Habitat Disturbance**
Gyrfalcon	15 February-15 August	0.4 km h or 300 m v	0.4 km	0.4 km	0.8 km	0.2 km
Golden Eagle	1 April-31 August	0.8 km h or 300 m v	0.4 km[3]	0.8 km	0.8 km	0.2 km
Rough-legged Hawk	15 April[2] 31 August	0.4 km h or 300 m v	0.4 km	0.4 km	0.8 km	0.2 km
Bald Eagle	15 March-31 August	0.4 km h or 300 m v	0.4 km	0.4 km	0.8 km	0.2 km
Osprey	15 April-31 August	0.4 km h or 300 m v	0.4 km	0.4 km	0.8 km	0.2 km

[1] h = horizontal; v = vertical
[2] 15 February for Rough-legged Hawk nests that are likely to be occupied by Gyrfalcons
[3] Provided that these activities are short-term, quiet and at least 30 m below the nest level and provided that they do not occur during incubation.

(Adapted from Table 79 in Roseneau et al. [1981]).

measures are necessary. By following terrain contours, pipeline routing will avoid large lakes and minimize the number of stream crossings, thereby reducing the potential for long-term sedimentation by minimizing the disturbance adjacent to water bodies.

Recovery of both the lower trophic levels and fish populations from local sedimentation will be rapid, requiring less than a single generation. Lower trophic levels will be recolonized by drift from adjacent undisturbed areas and any losses of fish or their eggs will be replaced through recruitment from younger, immature year classes and reinvasion from adjacent areas. Habitat alteration resulting from sedimentation will be short-term, generally lasting only until the spring freshet scours deposited sediments from the substrate.

The following mitigative measures will ensure that the effects of sediment introductions during right-of-way preparation are minimized. Except for some preliminary clearing, slope stabilization, and preparation of access to summer stream crossings, all rights-of-way will be prepared on frozen terrain. To avoid disturbance of sensitive terrain, winter roads will be used for access, and work pads and grading will be kept to a minimum. Adjacent to watercourses containing open water, buffer strips of undisturbed vegetation will be left until stream crossing installation begins. Effective measures will be developed to stabilize actively eroding terrain, enabling these areas to be identified and repaired promptly. During right-of-way preparation, the size of the area disturbed will be kept to a minimum. Preliminary clearing within the banks of watercourses will not commence until after the terrain is frozen.

Because of the localized and brief nature of sedimentation, together with rapid recovery rates, cosmopolitan species distribution, and mitigative measures, the effects of sedimentation resulting from site preparation on regional populations of lower trophic organisms should be NEGLIGIBLE.

Fish, in contrast, display a somewhat slower recovery rate, are more restricted in their distribution, and are dependent to a greater extent on sensitive habitats subject to short-term damage. Assuming, however, the proposed mitigative measures and the localized nature of sediment introductions, the effects of sedimentation resulting from site preparation on regional fish populations are considered to be MINOR.

5.2.2 BLASTING

Blasting includes any detonation of explosives on land or in waterbodies, either during construction of facilities or seismic exploration. During pipeline installation, blasting may be required where rock occurs in streams or adjacent banks, where pipeline trenching is necessary in bedrock or frozen material, where right-of-way contouring is necessary and where quarried rock is required to produce granular materials. Most blasting will take place during winter. Judicious choice of explosive type, plus suitable timing, will mitigate many potential impacts on both fish and wildlife populations.

5.2.2.1 Hydrology and Water Quality

Blasting in streams or other waterbodies, if required, may cause a LOCALIZED and SHORT-TERM increase in siltation which could affect aquatic habitat. However, the effects of siltation can be minimized by selective use of blasting to avoid sensitive aquatic habitat.

5.2.2.2 Mammals

A discussion of the reactions of ungulates to sudden loud noises such as blasting, sonic booms, diesel horns, and seismic activity is provided in Section 3.4.3.3. Overall, the impact of blasting on mammals is expected to be NEGLIGIBLE.

5.2.2.3 Birds

If blasting is restricted to winter when most birds are absent, immediate effects caused by noise and air shock are expected to be negligible. During spring and summer, blasting for rock quarrying could have a negative effect on raptors nesting nearby (Roseneau *et al.*, 1981), and blasting on islands and sandbars of the Mackenzie River and main tributaries, to improve river navigation or to borrow gravel, could affect migrant and nesting waterfowl and shorebirds. Blasting in such locations will not take place during spring or summer and, in the case of rock quarries, at no time where the resultant habitat modification will destroy or damage known raptor nest-sites. With such mitigative measures, the overall impact on birds is expected to be NEGLIGIBLE.

5.2.2.4 Aquatic Resources

During the installation of pipeline and support facilities, blasting may be required in streams where unrippable rock occurs in stream substrates or adjacent banks. Underwater blasting may, under certain circumstances, result in local fish kills in the immediate vicinity of the blast. A discussion on the effects of blasting on fish is provided in Section 3.4.3.5.

Since most minor stream crossings will be frozen to the bottom during pipeline installation, blasting in these streams will not impact aquatic species. There are, however, concerns in streams with sufficient winter discharge to support concentrations of overwintering fish, and at crossings constructed in summer where there are aggregations of either migrating or spawning fish.

A summer crossing of the Mackenzie River East Channel is not a major concern since, given the nature of underlying materials, instream blasting is unlikely to be required. Summer crossings of the Great Bear River and Mackenzie River near Fort Simpson will require preliminary borehole drilling and may also require some instream blasting during pipeline installation.

Several winter crossings traverse restricted habitats which may support overwintering fish or their eggs. As discussed in Section 3.4.3.5, a number of mitigative measures, such as blasting in early summer rather than in fall or winter to avoid fish concentrations, and using delayed series charges, can be employed to minimize fish kills. Accordingly, the effects of underwater blasting on fish are likely to be MINOR.

5.2.3 PIPELINE DITCHING, INSTALLATION AND BACKFILLING

Wintertime construction activities include pipeline stringing, welding, wrapping, weighting, laying in and burying of pipe, plus machinery operation and maintenance. Over most of the pipeline route, terrain stability and drainage-pattern concerns will be mitigated by Arctic pipeline or conventional winter construction procedures (Canuck Engineering Limited, 1981). These procedures include winter construction, avoiding traffic-induced damage to vegetation and terrain, retention of vegetation mats, the use of snow roads and working pads, and minimizing the size of work areas.

5.2.3.1 Geology and Soils

The impact on landforms and soils from ditching, pipe installation and backfilling will vary according to ground ice content, slope grade, soil material type, organic and vegetative cover, and drainage conditions. Hughes *et al.* (1973) and Van Everdingen (1979) noted that most of the interactions between pipelines and northern terrain are related to the occurrence and movement of surface water and subsurface water or to the occurrence or formation of ice. The following paragraphs discuss the implications of thaw settlement, thermal erosion, and hydraulic erosion as related to soil disturbances.

(a) Thaw Settlement and Thermal Erosion

Thaw settlement and other surface disturbances associated with construction could result in ponding on the right-of-way and will alter surface and subsurface drainage patterns. Although thaw settlement may occur to some degree across the cleared right-of-way, it may be accentuated in the vicinity of the pipe and form a shallow, ditch-like depression. This depression would alter normal drainage patterns and channel runoff along the right-of-way. On sloping terrain, especially at major stream crossings and near the Franklin Mountains, the incidence of slope instabilities may be increased by pipeline construction.

Disturbance to geological and soil materials will be minimized by incorporating the special techniques and safeguards outlined below. In areas of extensive high ice content soils, the pipeline will be elevated and, as a result, only local areas of these soils will be affected by ditching (Plate 5.2-1). In wet or muskeg terrain, the right-of-way will be cleared of tree cover well in advance of the main construction activities to allow for accelerated frost penetration. In sensitive permafrost areas, primarily north of 65°N latitude, special construction techniques will be used to minimize impacts. Snow roads and snow pads will be constructed to provide temporary access to and along the right-of-way. On high ice content soils (approximately one-third of the route) where the predicted degree of thaw settlement would exceed 90 cm, the pipeline will be elevated on vertical support members. This will minimize surface disturbance. Topsoil will be selectively salvaged from the ditchline for subsequent replacement on top of the backfill mound to speed and enhance reclamation. Local fill material will be used for ditch bottom padding to reduce bending of pipe subjected to differential settlement. Special construction procedures including the use of ditch plugs, weights, and select soil, will be adapted as necessary for drainage and erosion control, buoyancy control, and thaw settlement control. Structural measures will be used throughout construction to avoid slope failure due to thermal or alluvial erosion. All disturbed areas will be reclaimed immediately after construction.

Application of the above mitigative measures is expected to minimize thaw settlement and thermal erosion along the right-of-way so that impacts are expected to be LOCALIZED and SHORT-TERM.

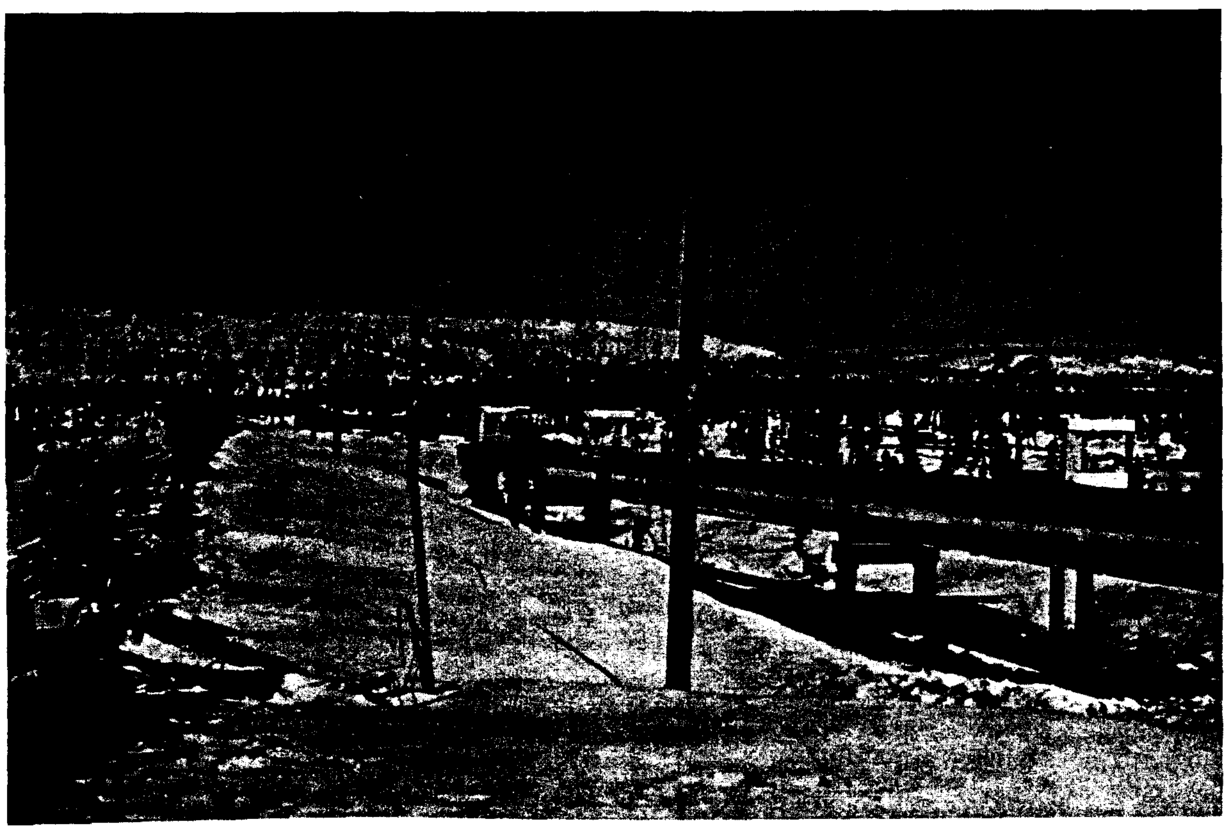


PLATE 5.2-1 *The Inuvik Test Facility, built by Mackenzie Valley Pipeline Research Ltd., consisted of a 600 m closed loop of 122 cm pipe, one half constructed above ground on piles and the remainder installed in a gravel embankment or berm above ground level. Insulation of various types was used and oil was circulated at 70° C at a rate equivalent to 700,000 BOPD.*

(b) Hydraulic Erosion and Slope Failure

The potential for shallow hydraulic erosion is substantially increased where drainage is diverted from natural water courses. In areas of diffuse flow, the raised berm over the ditch may interrupt small water courses and, together with thaw settlement to the side of the berm, channelize surface water along the right-of-way. Icing caused by freezing of exposed groundwater can also divert surface flows, especially during the spring run-off. Icing may be induced either naturally or by the pipeline interrupting or blocking normal surface and subsurface drainage.

Areas of greatest potential for hydraulic erosion, such as steep river banks, will be avoided where possible during route selection. The following protective and mitigative procedures are proposed for potentially erodible areas. Where cuts are required, measures will be implemented to control direct surface water flow across the disturbed area, using techniques developed on a site-specific basis. Design specifications will allow for maintenance of natural drainage patterns and fish passage. Since a low mound will be left over the pipeline to accommodate settlement of the backfill, breaks in the mound will be provided where necessary for drainage across the right-of-way. Portions of the berm and drainage breaks that are exposed to flowing water will be armoured with granular blankets and erosion mats in conjunction with reclamation measures including shrub planting as necessary. The use of dikes, ditches, rock aprons, or settling ponds will be considered where there is threat of excessive erosion. The impact of shallow hydraulic erosion is likely to be LOCALIZED and SHORT-TERM.

The pipeline will cross some slopes where construction activities will result in changes which could ultimately affect slope stability. Increased thaw depths may result from disturbance of the thermal balance of surface and subsurface soils. Removal of lateral slope support and alteration of porewater pressures and groundwater conditions may occur as a result of excavation and grading.

Maintenance of slope stability is a major concern and as a result, detailed stability analyses will be conducted prior to construction for all major slopes. Several methods will be implemented to stabilize slopes as necessary and may include the following: relocation and minor rerouting to avoid potentially unstable slopes wherever feasible; placement of drain pipes and granular filters at the toes of unfrozen slopes to relieve internal pore pressures and increase shearing resistance; stabilization of slopes by construction of toe berms or buttresses; use of rip-rap or other protective construction material to protect river and stream banks subject to erosion; deep pipe burial and replacement of weaker soil with granular fill on some slopes; and the implementation of special designs involving backfill replacement or gravel buttresses to ensure the stability of cuts in ice-rich soil. As a result, slope failures are expected to be small and LOCALIZED and will have a SHORT-TERM impact.

5.2.3.2 Hydrology and Water Quality

Ditching and construction of a berm over the ditch will interrupt minor surface drainage patterns, especially diffuse runoff and small streams. The berm may redirect these waters along the right-of-way, and create some ponding in level areas. In areas of ice-rich permafrost, thaw settlement along the ditch may create local shallow, linear depressions which would further channel water along the right-of-way. Subsurface flow may be interrupted and redirected by the trench or the pipe (Owen and Van Eyk, 1975). Hydraulic erosion of the berm materials and of other surfaces as a result of thermal degradation of ice-rich soils may result in increased silt loading of nearby waterbodies. This would occur mainly during periods of high runoff, thus coinciding with normally high sediment loads.

The major factor reducing potential drainage and erosion problems will be the timing of construction during winter. A drainage and erosion control and reclamation plan will be implemented to minimize potential problems. Other safeguards will include berm breaks and diversion berms to maintain natural drainage patterns and direct runoff away from the right-of-way. Temporary water crossing structures such as ice-bridges and fill will be removed prior to the spring freshet. Where necessary, impermeable plugs will be installed to prevent drainage along the trench. A buffer strip of undisturbed land will be maintained where feasible along all aquatic systems parallel to the right-of-way. Settling ponds and basins will be used where feasible in areas susceptible to excessive erosion. The impacts are likely to be LOCALIZED and SHORT-TERM.

5.2.3.3 Atmospheric Environment

The operation of construction equipment used for ditching, installation and backfilling will produce noise and small amounts of unburned hydrocarbons, nitrogen oxides, sulphur dioxide, carbon monoxide, water vapor and suspended particulates. Standard mufflers on vehicles will reduce noise. Emissions will be local and temporary, will have a minimal effect on air quality, and will be within Federal air quality guidelines. Because construction will occur in winter, dust from vehicular movements and operations is not expected. The impact of construction equipment on air quality is considered LOCALIZED and SHORT-TERM.

5.2.3.4 Vegetation

Vegetation will be affected where drainage patterns are altered. Upslope ponding in these areas may cause very localized mortality of shrubs and trees (Jeglum, 1975) and improved growth of semi-aquatic species. Drying within the downslope shadow may result in localized mortality of mosses and sedges but improved growth of trees.

The drainage and erosion control measures described earlier will stabilize soils and re-establish drainage patterns. As a result of these mitigative measures, the impacts of ditching, pipeline installation and backfilling on vegetation should be LOCALIZED and SHORT-TERM.

5.2.3.5 Mammals

Several possible effects of pipeline ditching, installation, and backfilling on mammals will be similar to those caused by right-of-way preparation (Section 5.2.1.4). However, the amount of wildlife habitat altered will be insignificant in relation to the amount available. Some beaver ponds may be drained if ditching proceeds through beaver dams. Water flow may be obstructed by backfill material possibly resulting in ponding or channelization of water. Resulting changes in vegetation communities may, in turn, lead to alterations in the associated mammal community. Disturbance from machinery and human activity associated with pipelining may also cause short-term avoidance of an area surrounding the site of the activity. In addition, the open ditch and strung pipe may produce a temporary barrier to movements of caribou and moose. Also, smaller mammals may fall into the open ditch and be unable to escape.

To mitigate these possible effects, drainage control measures will be designed to reduce alteration of habitat in the vicinity of the right-of-way. Care will be exercised to avoid destruction of beaver dams and to avoid draining ponds used by overwintering beaver and muskrat. Excavated trench at any particular location will normally not remain open for more than a few days to minimize disruption of wildlife movements. Strung pipe will be placed at an angle to allow passage of wildlife. Overall, the anticipated level of impact will be MINOR.

5.2.3.6 Aquatic Resources

Installation of a large diameter pipeline will require the excavation of a ditch 1.5 to 2 m wide where the pipeline is to be buried. Except on slopes adjacent to watercourses, erosion from the ditchline will normally be filtered through vegetation before entering a watercourse. Effective slope stabilization, ditch plugs, reseeding, and berms to divert surface runoff into adjacent vegetation, will greatly reduce the amount of sediment reaching waterbodies.

Any sedimentation in waterbodies, resulting from erosion along pipeline rights-of-way, is anticipated to be both local and short-term, and will be greatest immediately following break-up in the first year after pipeline burial. With an effective revegetation plan and an aggressive program to repair or stabilize areas of active erosion, little sedimentation will occur after the first one or two open water seasons. A discussion of the effects of sediments on aquatic organisms and their recovery is provided in Section 3.4.1.6.

After sediment introductions cease, the recovery of lower trophic levels will be rapid. Adult fish will not be affected by local sedimentation but, where sediments enter water used as spawning habitat, spawning success may be reduced for one to two seasons.

Descriptions of those habitats most sensitive to sediment introductions, together with mitigative measures to reduce the effects of sediment, are described in Section 5.2.1.6. Because pipeline ditching, installation, and backfilling are scheduled for the winter months, no specific mitigation in addition to these general measures is required. Assuming general mitigative measures are followed, the effects of sediment introduced by ditching, installation, and backfilling on all aquatic trophic levels are anticipated to be NEGLIGIBLE.

5.2.4 PIPELINE TESTING AND FLUID DISPOSAL

Once the pipeline is completed, it will be pressure tested for overall integrity using water if testing is conducted in summer. In winter, a solution of water and methanol will be used as testing fluid.

5.2.4.1 Geology and Soils

Spills of the testing fluid, particularly during the mixing of methanol and water, could affect the thermal balance of soils and result in thaw settlement. On slopes, spills may also kill the protective vegetation cover and initiate hydraulic erosion (Hardy Associates, 1980). Small spills of methanol, for example 9 L/m^2 of 20% methanol, had little effect but larger spills may severely affect vegetation and cause increases in the active layer thickness.

A contingency plan will be developed to deal with methanol spills during the final design stage. The plan will include personnel education and awareness programs; and surveillance, detection, containment, clean-up, and reclamation procedures. Overall, testing activities should have only LOCALIZED and SHORT-TERM impacts on the geology and soils of the region.

5.2.4.2 Hydrology and Water Quality

Water withdrawal will be regulated so as not to adversely affect other industrial, domestic, or recreational interests, or fishing, trapping or wildlife resources. A water withdrawal plan will be designed and discussed with the appropriate government agency prior to final application. The testing fluid containing the methanol will be collected, reused, and disposed of at approved disposal wells or sites.

Toxic liquids contingency measures will be implemented to minimize the effects of any testing fluid spills. Hydrostatic testing procedures and disposal of testing fluids will be done in accordance with existing regulations and in consultation with appropriate government agencies. Protective erosion control measures will be used at sites chosen for the discharge of non-toxic test fluids. The potential impacts of testing are considered LOCALIZED and SHORT-TERM.

5.2.4.3 Vegetation

The effects of pipeline hydrostatic testing and fluid disposal on vegetation are discussed in Section 3.6.2.3. Environmental concerns are considered minimal for most aspects of these activities, however, spills of methanol solution are viewed as more serious. A contingency plan to deal with testing fluid spills will be designed to minimize possible effects. Overall, the potential effects of water-methanol spills on vegetation are expected to be LOCALIZED and SHORT-TERM.

5.2.4.4 Mammals

Pipeline testing and fluid disposal will be conducted in a manner that will minimize impacts on mammals. Water will not be withdrawn from ponds in quantities that will adversely affect overwintering beaver and muskrat. Non-toxic testing fluids will be disposed of in ponds or streams. Impacts on mammals and their habitat are expected to be NEGLIGIBLE

5.2.4.5 Birds

If pipeline testing occurs after April 15, the movement of machines and personnel would be based on the recommendations regarding raptor nest-site protection (Section 5.2.1.5). If the test fluid is water it will be disposed of so as not to cause local flooding. If the test fluid contains a freezing point depressant such as methanol, it will be collected, reused, and disposed of at approved disposal wells. The resultant impacts on birds are considered to be NEGLIGIBLE.

5.2.4.6 Aquatic Resources

Within the Mackenzie Valley corridor, there are few isolated fish populations similar to those found in the Beaufort Sea - Mackenzie Delta region. For example, Arctic char populations, often reproductively isolated in Yukon coastal streams, are not found in the Mackenzie Valley corridor. Some isolated lake trout exist in a few lakes within the corridor but most populations that might be affected by local methanol spills would be rapidly replaced from outside areas through reinvasion. Since methanol testing will occur only during the winter months when most streams are frozen, the risk of a major spill entering water containing major concentrations of overwintering fish is low. Should such a spill enter a waterbody, a substantial fish kill could result, requiring up to an entire generation for recovery through recruitment and reinvasion. The impacts of testing fluid spills are considered to be NEGLIGIBLE on lower trophic levels, because of their rapid recovery rate and cosmopolitan distribution, and MINOR on fish populations, because of their sensitivity in certain habitats. A discussion of the potential impacts and mitigative measures of pipeline testing and fluid disposal on aquatic resources is provided in Section 3.6.2.5.

Depending on the spacing of pipeline valves, hydrostatic testing will require water withdrawals of up to 15, 000 m^3 per test section. Water will be withdrawn from sources approved by regulatory agencies. Where water availability is low, special measures, including shunting water ahead to the next test section for re-use, may be necessary. Testing is scheduled for winter months when water availability in Mackenzie River tributaries and many shallow lakes is low. Overwintering habitat for fish in these waterbodies is generally limited, and fish are often concentrated in a few areas. Since water withdrawals from overwintering areas that already have low water availability could result in high mortalities of fish and their eggs, these areas will be avoided whenever feasible. The Mackenzie River provides an almost unlimited year-round source of water to much of the pipeline corridor but where the right-of-way deviates from the river, alternate sources will be necessary. With careful selection of sources and rates of winter water withdrawals and disposal methods, the impacts of the removal of water for pipeline testing are considered to be NEGLIGIBLE. A discussion on the potential impacts of winter-time water use on aquatic resources is provided in Section 5.3.7.3.

5.2.5 STREAM CROSSINGS

Pipeline construction across major rivers such as the Mackenzie River at East Channel, Great Bear River, Mackenzie River at Fort Simpson, and the Peace, Athabasca, and North Saskatchewan rivers will take place in summer. Each of these crossings will involve site specific designs and procedures. Most smaller or intermittent streams which are generally frozen to the bottom will be crossed in winter using standard crossing design; hence many terrain and habitat impacts can be avoided. Many impacts related to stream crossings have been discussed previously in Section 5.2.3.

5.2.5.1 Geology and Soils

The effects of stream crossings on geology and soils include erosion, slumps and slides, thermal degradation, and alteration of drainage. The most erodible terrain along a pipeline right-of-way will commonly be found at crossings where approach slopes are relatively steep. Slope instability may be initiated by construction especially where cut grading is required. Suggested measures to mitigate these possible effects include careful route selection to avoid steep slopes, minimized grading, and strict maintenance of normal drainage patterns and slope stability. Overall, the impact of stream crossings on geology and soils should be LOCALIZED and SHORT-TERM.

5.2.5.2 Hydrology and Water Quality

Numerous major and minor rivers and streams will be crossed by the pipeline. Hydrological and water quality concerns at these sites are related to the possible alteration of surface and subsurface drainage patterns, and erosion and resultant downstream siltation. Also, during construction, small streams may be blocked by ice bridges or debris. In-stream construction activities, particularly on the major crossings, may result in temporary erosion and downstream siltation. Special attention will be given to minimize siltation near communities at crossings of the Hare Indian, Great Bear, and Mackenzie rivers. Proper route selection to avoid unstable slopes and the winter construction of most crossings will minimize effects on streams. Drainage and erosion control measures, as discussed in Section 5.2.3, will maintain downstream flow at water crossing structures and maintain natural drainage. In-stream construction activities will be minimized as much as possible. Water crossings will be monitored regularly after construction, and a preventative maintenance program will be implemented. The impact of stream crossings on water quality and hydrology should therefore be LOCALIZED and SHORT-TERM.

5.2.5.3 Vegetation

Although the possible effects on terrain would also influence adjacent vegetation and affect subsequent revegetation success, drainage and erosion control measures at stream crossings will minimize these possible effects. Stabilization measures are expected to encourage a return of natural vegetation and, as a result, the impact of stream crossings on vegetation should be LOCALIZED and SHORT-TERM.

5.2.5.4 Mammals

Stream crossings will cause a small amount of habitat alteration and disturbance due to construction equipment and human activity. The habitat in the vicinity of streams is often of greater value to wildlife than adjacent upland habitat. Wildlife often congregate along riparian areas in winter. Habitat alteration therefore may be of greater concern at stream crossings than in some other areas, but will be so confined that no measurable effects on wildlife populations using the river valleys crossed will likely occur. Disturbance by the construction of crossings in river valleys may also disrupt movements of animals along valleys, although the relatively short duration and localized nature of construction activities at stream crossings will minimize this concern. Reclamation by shrub planting to replace riparian vegetation removed during construction will enhance habitat. Impacts on moose and aquatic furbearers are considered MINOR while impacts to other mammals will likely be NEGLIGIBLE.

5.2.5.5 Aquatic Resources

Concerns for aquatic resources resulting from the construction of stream crossings include sedimentation effects on fish and fish food resources, entrapment of fish, barriers to fish migration, and general aquatic habitat modification.

(a) Sedimentation

Installation of the pipeline within a stream bed will result in sedimentation of all watercourses crossed. Most streams will be frozen to the bottom when the pipeline is installed and sedimentation will occur for only a brief period at break-up. Crossings scheduled for summer installation include the Mackenzie River East Channel, the Great Bear River, and the Mackenzie River at Fort Simpson. In the vicinity of both Mackenzie River crossings the river already carries high suspended sediment levels during the summer months, and pipeline installation is not expected to greatly increase these levels. No major spawning areas occur in the vicinity of these two crossings (McCart *et al.*, 1974; Aquatic Environments Limited, unpublished data).

The Great Bear River, in contrast, remains relatively clear during all the summer months. Although this river supports a major spawning run of Arctic cisco, investigations of the timing of this run suggest that mid-summer construction will have no effect on cisco spawning. During 1981, Arctic cisco were concentrated at the mouth of the Great Bear River in late August, and moved upstream during September and early October (Aquatic Environments Limited, unpublished data). Little or no spawning occurred either in the vicinity of the pipeline crossing or downstream to the mouth of the river. Consequently, sedimentation resulting from summer pipeline installation is not expected to affect spawning at any of the three proposed summer crossings.

Dredges will probably be used for digging both Mackenzie River crossings; however, a detailed construction plan has not yet been developed. A general discussion of the effects of dredging in the Mackenzie River is provided by McCart (1981). A summary of the effects of suspended solids on aquatic resources is provided in Section 3.4.1.6.

Since most other streams will be frozen to the bottom during installation, sedimentation in these streams will occur only as a result of incidental erosion from disturbed substrates and adjacent stream banks. Sedimentation will occur during spring freshet, when natural sediment loads are high and when many streams are subject to considerable scour. Stabilized stream crossings will clear up shortly after break-up and crossings will contribute little to the sediment load thereafter.

During the second and third break-up seasons following construction, the banks of some stream crossings may have a tendency to erode. These problem areas will be identified during routine inspections of the pipeline, and eroding surfaces will be stabilized with rip-rap or surface and subsurface drainage control. With such erosion controls, little stream sedimentation is anticipated after the first two to three years of operation.

Recent studies suggest that the proposed winter construction schedule may introduce sediment into at least eight streams that have winter flows and are capable of supporting overwintering fish, including the Trout River, Jean-Marie Creek, Trail River, Willowlake River, Blackwater River, Hodgson Creek, Birch Island Creek, and Vermilion Creek. The first five of these streams may be used as spawning areas for fall spawning species, but this has yet to be verified by field studies. If future studies reveal that any of these streams serve as important overwintering sites or fall spawning areas near these crossings, consideration will be given to constructing these crossings during the summer months.

Sedimentation from stream crossing construction and subsequent erosion may result in local reductions in the reproductive success of fish species and in decreased productivity of certain lower trophic levels, particularly algae and benthic invertebrates. Because of recruitment and reinvasion from unaffected areas, recovery will be short-term, requiring less than a single generation at all trophic levels.

In addition to the mitigative measures detailed in Section 5.2.1.6, the effects of sedimentation at stream crossings will be minimized in the following ways. Prior to break-up, stream substrates and banks will be returned to their original configuration and measures taken to ensure substrate and bank stability. Spoils will not be left piled on the ice cover of streams. Where overwintering fish may occur, consideration will be given to summer installation or the use of overhead crossings. To identify those crossings which require additional stabilization and maintenance, stream crossings will be monitored after installation.

Sedimentation at stream crossings will have local short-term effects on all trophic levels within aquatic ecosystems. Although recovery of all trophic levels is anticipated within a single generation, stream crossings will affect a large number of watercourses over a broad geographic area. Considering the widespread distribution of local effects and assuming proposed mitigative measures are adhered to, the effect of sedimentation at stream crossings on all aquatic trophic levels is expected to be MINOR.

(b) Entrapment and Migration Barriers

In major streams, creation of obstructions to fish passage is considered unlikely and no documentation exists on such obstructions resulting from pipeline installations. Experience with the Alyeska Pipeline suggests that installation of crossings on small streams during the winter months may result in problems after break-up, by causing fish entrapment and migratory barriers (Gustafson, 1977). In winter, locating very small stream channels and restoring their original hydraulic configuration after construction is often a difficult task. Failure to achieve these objectives may lead to restriction in the free movement of fish, particularly when water flows are low. Two common phenomena may result from the creation of barriers: prevention of access to important habitats, and entrapment and mortality of fish unable to escape declining water levels.

Stream blockages can be greatly reduced or eliminated by the following: small stream channels scheduled for winter construction will be accurately located prior to freeze-up; the Department of Fisheries and Oceans will be consulted regarding streams which require fish passage; stream channels will be reconstructed prior to break-up; to ensure the original stream configuration is maintained, regular inspections will be made during operations to ensure continuous fish passage is possible throughout the open water season; and extremely sensitive habitats will be avoided where feasible.

Although some blockage will undoubtedly occur in a few small streams, the effects of stream crossing installations on fish movements in the region should be MINOR.

(c) Habitat Modification

Burial of pipe at stream crossings will result in localized changes to stream configurations and their substrates. Such changes will include removal of boulders in the stream, downstream sedimentation, removal of bank vegetation, and modification of bank configuration, all of which may affect the quality of fish habitat.

Protection of stream crossings and prevention of channel migration may require installation of stream training structures, channel diversions, and, in a few streams, extensive use of bank armour. These structures may further alter fish habitat quality either adversely or, in some instances, beneficially.

Generally, the area affected by a buried stream crossing is limited, representing a very small percentage of the total available habitat. Optimum route selection will avoid many important fish habitats by eliminating unnecessary stream crossings and following drainage contours. Mitigative measures described in Section 5.2.5.5(a) will further reduce habitat loss caused by sedimentation of downstream habitats.

Elevated stream crossings installed during the winter months could eliminate all the detrimental effects of habitat modification associated with buried crossings (Plates 5.2-2 and 5.2-3). At overhead crossings, both streambanks and bottom substrates remain intact, and there is little or no stream sedimentation during the ensuing open water months. Although there is an increased potential for accidental oil spills to enter water courses, elevated crossings will virtually eliminate fish habitat alterations at stream crossings.

Stream crossings will have the most serious detrimental effects where spawning, rearing, and overwintering habitat cannot be avoided. Many of these areas are described in Volume 3C. Since adult and large juvenile fish readily seek alternate feeding areas when habitat becomes unsuitable, limited damage to summer feeding habitat will have little or no effect provided there are alternative feeding areas.

In most streams, natural hydraulic forces will return substrates and banks to their original configuration within a few years. As a result, the effects of most habitat modification will be relatively short-term with recovery of local fish populations expected within a single generation. Where permanent stream training structures are necessary, habitat modification will be permanent, as will any effects on fish distribution. In all cases, the stream location affected by permanent modifications will represent a very small percentage of the total available habitat. The pipeline alignment would cross most streams at right angles. No sections of stream will be paralleled, as was the case during construction of the Alyeska Pipeline, which required extensive permanent stream training.

Mitigative measures designed to minimize habitat modifications will include: minimizing the size of the disturbed area within streams; avoiding areas of sensitive fish habitat wherever feasible; using overhead crossings where sensitive fish habitats cannot be avoided, and the restoration of stream channels and banks to a condition as close as possible to the original configuration.

Given these mitigative measures, and the relatively small fraction of total habitat affected by stream crossing installation, the effects of habitat modification on fish are anticipated to be NEGLIGIBLE.

5.2.6 ELEVATED PIPELINE

The Mackenzie Valley overland oil pipeline would be elevated for about one-third of its total length to minimize disturbance of ice-rich permafrost and subsequent thaw settlement (Plate 5.2-4). Vertical support members will be spaced at intervals of approximately 37 m along the pipeline. Clearance between the bottom of the pipeline and the ground will vary from 1.2 to 3.6 m, depending on the topography and the requirements for wildlife passage.

5.2.6.1 Geology and Soils

The pipeline will be elevated where buried pipeline construction could result in long-term thaw settlement in excess of 90 cm. Compared to the buried construction mode, elevated pipeline construction will reduce vegetation and soil organic layer disturbances, which are very important in maintaining stability of ice-rich soils. In addition, alteration of surface and subsurface drainage patterns as well as the risks of slope failures will be reduced. However, since the ice-rich soils on which the elevated pipeline will be constructed are especially sensitive to surface disturbance, construction activities and traffic on these soils will likely initiate some localized thaw settlement, and thermal and hydraulic erosion.

Surface disturbance and erosion will be controlled by the use of Arctic construction procedures, drainage and erosion control measures, and reclamation and the building of structural devices as necessary. Snow and ice roads and compacted snow will be used on ice-rich soils to reduce disturbance to vegetation and the soil organic layer. Where required, special ther-

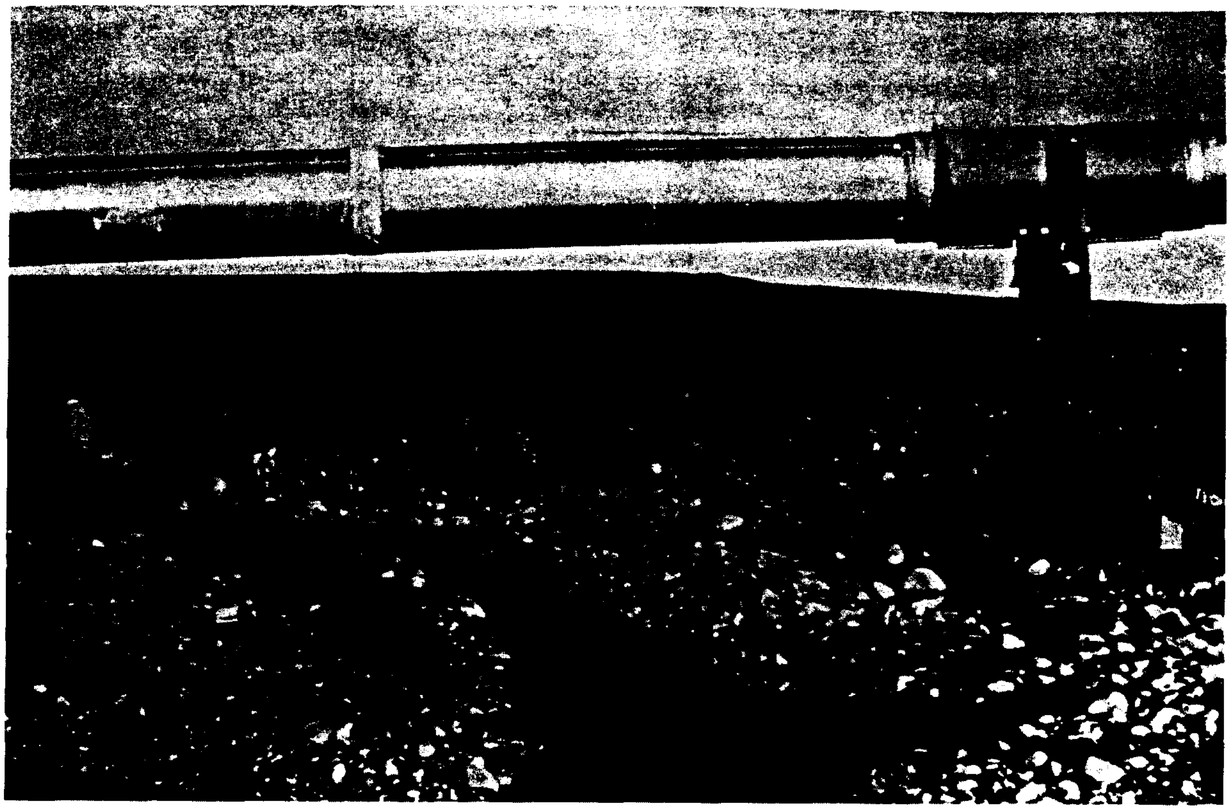


PLATE 5.2-2 *An elevated section of the Alyeska Pipeline at a typical tundra stream overhead crossing. (Courtesy: J. DenBeste. Aquatic Environments Limited).*

PLATE 5.2-3 *An elevated section of the Alyeska Pipeline at a stream crossing. Note banks armoured with rip-rap. Installed in winter, these crossings have been shown to have little or no effect on aquatic resources. (Courtesy: J. DenBeste, Aquatic Environments Limited.)*

PLATE 5.2-4 *Typical section of the Alyeska Pipeline in elevated mode. 'Cryoanchors' will be installed where necessary to prevent thawing of the permafrost in the discontinuous permafrost regions. (Courtesy: J. DenBeste, Aquatic Environments Limited).*

mal devices, known as cryoanchors, will be installed in each support member in the discontinuous permafrost region. As a result, the terrain and soil impacts of the elevated line are expected to be LOCALIZED and SHORT-TERM.

5.2.6.2 Vegetation

Most of the pipeline north of Fort Good Hope will be built on vertical support members above ground in order to minimize disturbance of ice-rich permafrost terrain. This is considered necessary for pipeline integrity and for environmental protection, since destruction of the vegetation and surface organic layers in this region could lead to extensive thaw settlement and thermal erosion, particularly on slopes.

Other measures will be employed in conjunction with the elevated pipeline to minimize disturbance to vegetation on ice-rich permafrost terrain. Snow and ice roads, packed snow, and snow pads will be used on the working area and haul road area. Fill techniques employing snow rather than cutting the side slopes will be used wherever feasible during grading operations. Previous studies (Adam and Hernandez, 1977; Hardy Associates, 1980) indicated that snow roads are an effective means of reducing damage to vegetation. Because snow roads may delay the growing season, however, reclamation procedures in these areas will incorporate the use of selected seed mixes tolerant to cold soils and short growing seasons. Impacts of the elevated pipeline on vegetation are considered LOCALIZED and SHORT-TERM.

5.2.6.3 Mammals

The responses of large mammals to elevated pipelines have been investigated in Alaska (Alyeska Pipeline and the Chatanika water pipeline near Fairbanks), and in the Soviet Union (the Taimyr Peninsula gas pipelines). Although there is some conflicting evidence, the longer term studies indicate that the Alyeska Pipeline has not blocked or altered the overall migration patterns of large mammals.

(a) Caribou and Reindeer

Prior to the construction of the Alyeska Pipeline, there was concern that caribou, moose, and other big game species would not pass beneath an elevated pipeline. As a result of this concern, state and federal biologists in Alaska developed standards for construction of both elevated and buried big game crossings in areas where extensive sections of the pipe were elevated. These standards were based in part on studies by Child (1973) and Child and Lent (1973) on the effects of simulated elevated pipelines on caribou at Prudhoe Bay and Nome, and in part on the judgement of experts on caribou migration.

Caribou are now known to pass under the normal elevated sections of the Alyeska Pipeline. Studies by Cameron and Whitten (1976, 1977, 1978, and 1980) and Roby (1978) indicated that the most apparent effects of the pipeline and haul road on the behaviour of caribou was avoidance of the corridor by cows with calves from the time of calving until rut. This avoidance was largely a consequence of traffic on the haul road and of construction activity on the workpad. Now that construction is complete, the pipeline and workpad appear to have little effect on caribou movements (Plate 5.2-5). In fact, adult male caribou appear to be attracted to the pipeline and, to a lesser extent, the haul road and other disturbed sites, and often use these areas as shelter from biting insects, as trails, and as feeding grounds (Klein, 1980). Special ramps, underpasses, and special sections of buried pipe appeared to receive only limited use.

There is a tendency for caribou to cross the haul road beside the pipeline in open areas where visibility in all directions is good and vegetation offers little cover for predators (Roby, 1978). In forested terrain or where riparian vegetation reduces visibility, caribou often move across the pipeline and haul road at a fast trot. Surrendi and DeBock (1976) reported similar behaviour for caribou passing willow patches remote from roads, presumably as a response to predators which might be using the vegetation as cover. Animals that avoid the haul road appear to be avoiding the traffic rather than the presence of the haul road itself. Roby (1978) observed that large trucks caused a stronger reaction than smaller vehicles, and that avoidance was greater in the summer months when large dust clouds were generated by passing vehicles.

Early studies of the effects of simulated elevated pipelines on caribou movements (Child, 1973) reported that most caribou preferred to go around the ends of the pipeline rather than use gravel ramps or elevated crossings and that groups under female leadership were more successful at crossing the simulated pipeline than groups with male leaders. However, later studies (Cameron and Whitten, 1980) done after the pipeline was in operation, appear to contradict some of the findings of the earlier reports, and indicate that caribou may not be as wary of the pipeline as previously thought. It is likely that the avoidance rates at the simulated pipeline were high because the line was

PLATE 5.2-5 *Barren ground caribou in Alaska have been found to use the Alyeska Pipeline right-of-way as a travel corridor and foraging area. (Courtesy: Alyeska Pipeline Service Company).*

located in a relatively undisturbed area and the studies covered a comparatively short period. The completed Alyeska Pipeline Project, on the other hand, is a source of several activities - the pipeline, workpad, haul road, facilities sites, vehicles and aircraft - covering a wide geographical area and the caribou have had time to become accustomed to the intrusion and even to be attracted to certain of its features.

Although local movements of caribou have been altered by the elevated pipeline, overall migration patterns have not changed. Despite the exposure of the Central Arctic herd to the elevated Alyeska Pipeline and to traffic on the associated haul road, the population of the herd is currently increasing.

A portion of the Alyeska Pipeline was also constructed through the range of the Nelchina herd, paralleling the Richardson Highway across which the Nelchina herd migrates twice annually. The population of this herd is also currently increasing following the introduction of a management plan to reduce predation and hunting. Current studies of the Nelchina herd are not complete, but observations reported by Klein (1980) indicate that caribou frequently feed on fertilized revegetated areas along the workpad and even under the elevated pipeline. Winter tracks reveal that some animals cross both under the pipeline and over the refrigerated buried sections, although some are deflected and travel some distance parallel to it or turn back.

Skrobov (1972) reported on the response of wild reindeer on the Taimyr Peninsula, USSR, to a gas pipeline which was 0.7 m in diameter, about 1 m above the ground, and perpendicular to their migration route. During spring migration, reindeer often moved parallel to the line until they found a place blown over with snow or where the ravines were deep enough so that they could pass under the pipeline. In other areas, the pipeline was a complete obstruction to the wild reindeer. Subsequently, Klein (1980) reported that the greatest adverse impact of the gas pipelines in the Taimyr area was considered to be local overgrazing and trampling of vegetation where concentrations of reindeer occurred adjacent to the pipelines.

(b) Moose

Alaska's Department of Fish and Game (1973) investigated the effect on moose movements of an existing 122 cm water pipeline in the Chatanika Valley near Fairbanks. They concluded that "...pipe elevated to 4.5 feet (1.4 m) or more will probably be passable by moose providing minimum bents are spaced at least 20 feet (6.1 m) apart...," a conclusion based largely on the movements of antlerless animals.

Since moose occur along most of the Alyeska corridor (Hemming and Morehouse, 1976) and since there was some question whether these animals would cross under the elevated pipe, the State of Alaska initiated studies to determine the effects of the Alyeska Pipeline in the Nelchina Basin, an area of relatively high moose density. The studies (Van Ballenberghe, 1978; Eide and Miller, 1979) examined crossing rates under pipe which had been installed at several heights ranging from less than 1.4 m to greater than 4.0 m. Both of these latter studies revealed that moose are highly selective in their choice of pipeline crossing sites and do not cross at random. Depending on the area however, there is considerable variation in the type of crossing site they select. Eide and Miller (1979) reported that the type of crossing selected is probably influenced by adherence to traditional crossing areas by individual moose regardless of pipeline characteristics and habitat types adjacent to crossing locations.

Except where the pipe was less than 1.5 m in height, both studies reported a relatively low rate of moose deflections at all pipeline elevations. Deflections reported for all other elevations, including crossings higher than the 3.3 m elevation requested by the Joint State/Federal Fish and Wildlife Advisory Team (JFWAT), ranged from only 2 to 7% of total observations. The effects of other environmental factors potentially affecting moose movements under the pipe were also assessed (Eide and Miller, 1979) and included snow depth, sound, and icicle formation. None of these factors significantly affected moose movements.

Moose do not appear to be any more susceptible to elevated pipelines than caribou. Appropriately designed pipelines do not appear to alter moose behavior. Van Ballenberghe (1976, 1977, 1978) noted that moose will readily pass underneath the Alyeska Pipeline where it has been constructed with 1.8 to 2.4 m clearances.

(c) Bears

Effects of the Alyeska Pipeline on movement of bears have not been studied, but it appears that the haul road and pipeline rarely serve as physical barriers to these animals. Along the haul road, grizzlies occasionally avoid vehicles by crossing at night, but both grizzly and black bears are often observed standing on the haul road waiting for an approaching vehicle and a possible handout. Attracting bears appears to be a greater concern than deflecting them.

(d) Summary

In summary, elevated pipelines which do not pose an impassable barrier and which are not accompanied by other sources of disturbance, such as vehicle traffic, are not likely to have a significant effect on wildlife populations. There are a number of mitigative measures available to minimize the impact of an elevated pipeline on large mammals. The pipeline will be buried along as much of its length as possible. Any elevated portions will have sufficient clearance to allow unobstructed animal passage. Clearance between the pipeline and ground surface along sections of elevated pipeline will be maximized in areas where important ungulate movements occur, such as: the section within the Mackenzie Reindeer Grazing Reserve where reindeer may cross the route; in the Travaillant Lake area where caribou movements occur; and in some of the longer sections of elevated pipeline south of Travaillant Lake where moose and caribou movements take place. Given implementation of the above mitigative measures, the impact of elevated pipelines on mammals is considered MINOR.

5.2.7 BURIED PIPELINE

Approximately two thirds of the pipeline (1,530 km) will be buried using conventional pipeline construction techniques. The pipe will be buried with a minimum of one metre overburden and will have weights attached to keep it negatively buoyant in high water-table areas (Plate 5.2-6). An anti-corrosive coating will be applied to protect the integrity of the buried pipe. In some sections, strips of metal acting as sacrificial anodes will be laid parallel to the line to protect it from electrolytic corrosion caused by electric currents between the pipe and the soil.

5.2.7.1 Geology and Soils

Concerns with respect to the buried pipeline include thaw settlement, thermal and hydraulic erosion, alteration of surface and subsurface drainage patterns, and increased risk of slope failure. These have been discussed under Right-of-Way Preparation (Section 5.2.1.1) and under Ditching, Installation and Backfilling (Section 5.2.3.1). The southern buried portion of the pipeline is located in the least active seismic zones, thus special designs related to soil stability are not required (National Building Code of Canada, 1980). The impact of the buried pipeline on terrain and soils is considered LOCALIZED and SHORT-TERM.

5.2.7.2 Hydrology and Water Quality

Thaw settlement around the buried pipe in localized areas of ice-rich permafrost terrain may create a shallow, ditch-like depression along the berm, which

PLATE 5.2-6 *Transition from buried to elevated pipeline mode of the Alyeska Pipeline. In areas of ice-rich soils, the pipeline will be constructed above ground at a height sufficient to allow for unimpeded movement of wildlife.*

would redirect runoff along the right-of-way. Applicable mitigative measures are discussed in Sections 5.2.1.2 and 5.2.3.2. Possible thaw settlement effects resulting from the buried pipeline are expected to be LOCALIZED and SHORT-TERM.

5.2.7.3 Vegetation

Possible effects of a buried pipeline on vegetation are discussed under Right-of-Way Preparation (Section 5.2.1.3) and Ditching, Installation and Backfilling (Section 5.2.3.4).

5.2.7.4 Mammals

Little information is available on the response of wildlife to buried pipelines. However, there is information on the response of mammals to seismic lines which appear similar to buried pipelines. Urquhart (1973) observed that caribou on Banks Island often travelled parallel to new seismic lines and crossed at locations of reduced snow cover. Intensive studies of the response of caribou to seismic lines and winter roads were conducted within the range of the Porcupine herd in 1972 (McCourt *et al.*, 1974). Observations showed that the use of cutlines was largely local and random until there was strong motivation for unidirectional movement (e.g. spring migration). Whether cutlines were followed or crossed during spring migration depended on the angle of approach. The distance cutlines were followed was inversely proportional to the angle of deflection.

Whereas Klein (1980) has stated that movements of caribou and reindeer may be deflected by roads because they offer an easy surface on which to travel, Geist (1975) expressed concern about the energetic costs to caribou of deflections along cutlines and winter roads as a result of the increased travel distance. Alternatively, Jakimchuk (1980) hypothesized that deflection along these linear features is part of an energy conservation adaptation, involving a search for the least demanding route which may be beneficial, rather than detrimental in terms of energy costs. In other words, the energy saved by easier travel along the cutline or winter road may more than compensate for the energy required to travel a longer distance.

Research conducted in the Northwest Territories and Alberta indicates that distribution and movements of furbearing mammals on cutlines is different from that in undisturbed habitat (Penner, 1976; Riewe, 1977). Marten and ermine tracks were more common in mature spruce forest than on recent seismic lines. Mink signs were generally restricted to within 100 m of a waterbody. Canids did not appear to commonly use seismic lines but sometimes followed them for considerable distances. Snowshoe hares and red squirrels also appeared to avoid recent seismic lines and usually crossed seismic lines at right angles.

In summary, impacts from buried pipelines on most wildlife are considered to be MINOR.

5.2.8 PUMP STATIONS

Present plans allow for the initial placement of four pump stations to provide adequate pumping power for the first two years of operation. During the next 10 years, up to 20 additional stations could be added to bring the line to its capacity of 218,000 m^3 of oil per day. Pump stations along the more northerly portion of the pipeline will be specially designed for Arctic conditions. These facilities will be built on gravel pads and refrigerated foundations will be used where necessary to ensure permafrost stability. Seven of the northern stations will have facilities to cool the oil from 27°C to 21°C, thereby reducing thermal stresses in the pipeline. Most pump stations will have their own small topping plant, to refine the oil and provide fuel to drive the turbine engines and other related equipment.

Fuel storage facilities will be surrounded by dyke systems having impermeable flexible liners capable of containing all fluids stored in the storage tanks. Maintenance, safety and inspection personnel can be housed at the stations to oversee the electrical generators, heating plant, water treatment facility and sewage and waste disposal systems. All stations will have fire detection and automatic fire extinguishing equipment.

5.2.8.1 Geology and Soils

Clearing of sites for pump stations may initiate localized thaw settlement and hydraulic erosion. However, these effects will be minimized by locating stations on well drained soils with low ice content whenever possible and by constructing the stations on gravel pads to insulate the underlying permafrost. Existing clearings will be used, if feasible, and the size of any new clearing will be kept to the minimum necessary for safe operation. Drainage and erosion control measures, coupled with reclamation, will be applied to ensure the stability of the site. The impact of site preparation for pump stations is considered LOCALIZED and SHORT-TERM.

5.2.8.2 Vegetation

Principal effects of pump stations on vegetation will result from clearing of all woody vegetation from the sites. Some windthrow may occur around the edges of new clearings located in forested areas. Disturbance to vegetation will be minimized by locating pump stations on existing clearings wherever feasible.

In addition, the size of the clearing will be kept to a minimum necessary for safe and efficient operation. All merchantable timber will be salvaged and stockpiled beside the site. Slash from brush removal will be burned on mineral soil in the clearing and if necessary, burning sleds will be used to prevent damage to ice-rich or thick peat soils. Wherever feasible, edges of the clearing and other disturbed areas not in permanent use will be seeded and fertilized according to the reclamation plan. The impact of pump stations on vegetation is considered LOCALIZED and LONG-TERM.

5.2.8.3 Mammals

Construction of pump stations will result in a small amount of habitat loss as a result of the placement of a gravel pad at the site where the pump station is assembled. Additional habitat in the immediate vicinity of the pump station will be made unavailable as a result of the displacement response of wildlife to noise and activity of men and machines involved in construction. The total area made unavailable to wildlife will, however, be very small in relation to the habitat available. Although the construction activity may also interfere with animal movements, it will result in only small deflections rather than a barrier to movement. Anticipated impacts to mammals are considered MINOR.

5.2.8.4 Birds

Some sites considered for pumping stations are more ecologically sensitive than others. For birds, the more sensitive sites are on the Ramparts Plateau; at Chick Lake in the vicinity of Gibson Ridge; between the Norman Range and the east bank of the Mackenzie River about 7 km south of Norman Wells; at the foot of the McConnell Range; and near the Mackenzie River about 15 km north of Fort Simpson. Concerns involve primarily raptors -especially peregrine falcons - but also waterfowl.

Sites of pump stations will be carefully selected in consultation with appropriate government agencies. Efforts will be made to minimize air traffic and other activities near raptor nest-sites between April 15 and August 31.

Anticipated impacts on raptors and other birds include loss of habitat (MINOR), alteration of habitat (MINOR), sensory impacts such as noise and flares (MINOR), and increased presence of humans (MODERATE).

5.3 IMPACTS FROM THE PRECONSTRUCTION AND CONSTRUCTION OF SUPPORT FACILITIES

Support facilities would include granular borrow sites, temporary and permanent wharves and access roads, staging areas, work camps, and airstrips.

5.3.1 SITE PREPARATION

Site preparation for support facilities includes surveys, clearing and grading, brush burning, and the cutting and use of timber pilings.

5.3.1.1 Geology and Soils

Site preparation effects on geology and soils may include those related to surface instability (permafrost integrity, thaw settlement, frost heave, thermal erosion) and problems related to slope instability (permafrost integrity, slumping, shallow hydraulic erosion). These potential impacts and applicable mitigative measures have been discussed in Section 3.4.1.1. Since the location of sites for support facilities can be flexible, thermal subsidence problems are likely to be minimal. Other mitigative measures would include using existing clearings, if feasible, and minimizing the size of new clearings. Permanent facilities such as roads, staging areas and air strips will be built on gravel pads and insulation boards where required to insulate the underlying ice-rich soil. Finally, drainage and erosion control measures and reclamation will ensure surface and slope stability. The impact of site preparation is considered LOCALIZED and SHORT-TERM.

5.3.1.2 Hydrology and Water Quality

The clearing of sites for support facilities will result in surface disturbances which will alter some local drainage patterns and may cause localized ponding, hydraulic erosion, and some siltation of waterbodies. Drainage and erosion control measures (e.g., location of facility, buffer strips, drainage plans) will be applied to minimize drainage alteration, erosion and subsequent siltation. The impact of site preparation on hydrology and water quality is considered LOCALIZED and SHORT-TERM.

5.3.1.3 Vegetation

Shrubs and trees will be cleared from all new support facility areas including borrow areas, temporary and permanent access roads, staging areas, work camps and air strips. Since the area of clearing for support facilities is only about 7% of the total area required for the pipeline and its support facilities, the effect will be small. Some additional minor alterations to vegetation will occur due to drainage alterations, hydraulic and thermal erosion, and windthrow along the edges of new clearings in forested areas.

Vegetation disturbance will be minimized by the same type of mitigative measures planned for pump stations (Section 5.2.8). Impacts from site preparation on vegetation are likely to be LOCALIZED and LONG-TERM.

5.3.1.4 Mammals

Site preparation for support facilities will result in vegetation removal, terrain modifications and alterations in drainage regime. Unlike the right-of-way, which will be revegetated, wildlife habitat at facility sites will be eliminated because of the placement of gravel pads and the land surface occupied by the facilities themselves. The total amount of habitat removed will, however, be very small compared to the surrounding habitat available. In addition to the habitat directly affected, some habitat near the site may be altered as a result of obstruction of surface water flow by gravel pads or other terrain modifications. Changes in vegetation which occur as a result of such alterations in the drainage are likely to be so minor and localized as to be of little consequence to wildlife populations. Disturbance from men and machines during site preparation will also result in some displacement of wildlife in the vicinity of the site. This displacement is not likely to be extensive and will be relatively short-term, provided there are no additional disturbing aspects of the facility after construction.

In addition to measures to minimize adverse impacts on vegetation, there are measures planned specifically to minimize impacts on wildlife. The locations of all facilities such as borrow sites, pump stations, airstrips and access roads will be planned so that critical wildlife habitat will not be destroyed. Inspections will ensure that unnecessary habitat alteration is avoided. On this basis, only MINOR impacts on wildlife are expected.

5.3.1.5 Birds

Because clearing of sites will take place in winter, the impact on birds is considered NEGLIGIBLE. Activities of survey crews during other seasons will be subject to restrictions regarding raptors and waterfowl as set forth in Section 5.2.1.5.

5.3.1.6 Aquatic Resources

Site preparation for support facilities, particularly those located next to waterbodies, may result in siltation, producing possible effects similar to those described in Section 5.2.1.6. Since most of these sites will be prepared during winter when both waterbodies and the surrounding terrain are frozen, sedimentation will occur only after break-up at locations which have not been adequately stabilized.

To facilitate the stockpiling of equipment and materials brought in by barge prior to the onset of construction, it will be necessary to prepare a few offloading sites and stockpile sites during the summer months. Preparation of these sites may result in sediment introductions for a brief period during initial clearing, grading, and leveling. No effects, however, are anticipated once these sites are stabilized, usually after the first construction season.

Support facilities for offloading barges will be required at regular intervals along the Mackenzie River. Staging areas will also be required at major summer river crossings to provide for pipe assembly, fuel storage, and other requirements of crossing installation. During the summer months, sediments added to the river will have little effect because suspended sediment loads in the Mackenzie River are already high at this time of year (Campbell *et al.*, 1975; Volume 3C).

The pipeline crossing of the Great Bear River would be located only a few hundred metres upstream of the river mouth, therefore only a very short stretch of river could be affected by increased sedimentation.

Most sediment introductions resulting from site preparation would be limited to a single open water season. Where slope stability problems are encountered, particularly in high ice content slopes next to watercourses, sediment introductions may continue for several years. These areas will be identified by routine site inspection and measures will be taken to stabilize them.

The recovery of lower tropic levels from sediment introductions is expected to occur in a single generation, generally in less than one open water season, by recolonization from undisturbed areas. Effects on fish populations resulting from mortality of eggs or young-of-the-year, or reduction in habitat quality, will be short-term, with recovery expected usually within a single generation. Effects on both fish and lower trophic levels are expected to be local, generally within 1 to 2 km of disturbed areas. Since most sites will be located on streams near their confluences with the Mackenzie River, the area potentially affected by sediment introductions will be limited.

A number of mitigative measures will serve to reduce potential adverse effects of sedimentation on aquatic organisms. To limit erosion during clearing, grading, and stabilization, sites will be prepared in winter whenever feasible. Sites scheduled for preparation during the open water season will be located to avoid sensitive fish habitats. Erosion control measures will be used to limit sedimentation at all disturbed sites. All disturbed areas will be regularly inspected and measures taken as required to repair and stabilize them.

Assuming that: most sites will be constructed during winter; sites scheduled for summer construction are near the Mackenzie mainstream; sediment introduction into waterbodies will be localized; and that proposed mitigation measures are implemented, the effects of sedimentation resulting from site preparation on both lower trophic levels and fish will be NEGLIGIBLE.

5.3.2 GRANULAR BORROW

Granular borrow operations include gravel deposit survey, extraction, crushing, and washing activities conducted prior to stockpiling or transport as required for permanent support facilities. Several recognized problems associated with granular borrow operations will be mitigated by measures such as winter operations, Arctic construction procedures, utilization of existing borrow sites, and avoidance of stream channels. Most gravel hauling and stockpiling would be performed during the winter months on winter roads. This would allow summertime dewatering prior to gravel spreading the subsequent winter. Gravel hauling might continue by barge through the summer. In any case, hauling, stockpiling, and gravel spreading would continue through a number of construction seasons.

The viability of borrow sites will be viewed within the context of overall development and the needs of local communities. Site rehabilitation will be conducted in a manner which will minimize interference with reopening of sites for future use. The pipeline will not require a gravel work pad or year-round roads. Most construction will be performed during the winter using winter roads, and only permanent facilities such as camps, airstrips, and a few all-weather access roads will require gravel.

5.3.2.1 Geology and Soils

The disturbance associated with extracting borrow material may result in some thaw settlement and hydraulic erosion (Section 3.4.2.1). In addition to selecting stable areas for borrow sources, erosion problems may be minimized by using existing pits. Drainage and erosion control measures will be applied including recontouring of pit slopes to stable angles. The impact of granular borrow extraction is considered LOCALIZED and SHORT-TERM.

5.3.2.2 Hydrology and Water Quality

The disturbances associated with extracting granular material may result in some thermal degradation and possible erosion and siltation in adjacent waterbodies. Erosion from borrow sites will be minimized by selecting stable areas and by applying appropriate drainage and erosion control measures (Canuck Engineering Ltd., 1981). These may include recontouring of pit slopes to stable angles and surface reclamation. Buffer zones will be left between gravel extraction areas and waterbodies or roads. The impact of granular borrow extraction is expected to be LOCALIZED and SHORT-TERM.

5.3.2.3 Vegetation

Effects of new borrow site construction will result in removal of all vegetation and local alteration of drainage patterns. The borrow sites will be rehabilitated according to standard procedures. Specific measures include recontouring of slopes to stable angles and the replacement of topsoil on recontoured slopes. The recontoured slopes will then be seeded with species proven successful in Arctic field trials and fertilized (Hardy Associates, 1980). The impact of borrow sites on vegetation should be LOCALIZED and MEDIUM-TERM.

5.3.2.4 Mammals

Development of granular borrow pits will result in some habitat alteration and disturbance of wildlife. However, alteration of most wildlife habitat will be minimal because of the small area involved in relation to the habitat available. Concern about the possible destruction of active den sites of grizzly bears will be allayed by site inspections of proposed borrow areas to ensure that sites selected do not contain dens of these animals. Some ungulates, bears and other wildlife which encounter borrow operations may be disturbed by vehicles and humans. Because of the anticipated low frequency of encounters and minimum habitat alterations, the impacts of granular borrow operations on mammals are considered to be MINOR.

5.3.2.5 Birds

Borrow sites will be developed and material hauled to construction sites during the winter. Careful selection of hillside or cliff-face borrow sites will avoid impinging on raptor nest-sites by adhering to recommendations set forth by Roseneau *et al.* (1981). Borrow sites on the east side of the Mackenzie River might have a local effect on nesting bird populations, including Canada geese. Farther south, known nest sites of bald eagles and ospreys will be avoided by conducting borrow operations beyond the recommended distances. Consequently, impacts of granular borrow operations on birds are expected to be MINOR.

5.3.2.6 Aquatic Resources

Extraction of granular material from upland sites is generally considered to have little effect on aquatic resources unless these sites are located sufficiently close to streams to modify hydraulic regimes. Possible adverse effects of granular borrow extraction on aquatic resources will be greatly reduced by using upland sites only, and washing gravels in a closed system or a settling pond to prevent the silting of fish-bearing waters. Also, where feasible, the requirement for granular fill can be kept to a minimum through the use of winter roads and winter construction. Overall, the impact of granular borrow extraction on aquatic resources is expected to be NEGLIGIBLE.

5.3.3 WHARVES AND BARGE TRAFFIC

Wharf construction includes the erection of pilings, bank preparation, and construction of access to wharf sites.

5.3.3.1 Birds

Wharf construction and operation are likely to have only a very local impact on birds. Increased barge traffic, particularly if associated with dredging, might be disturbing to birds feeding or nesting along the river (Barry, 1976). Moulting waterfowl or waterfowl with young would probably be most affected. The selection of wharf sites to avoid sensitive areas, together with fuel spill contingency plans will occur in consultation with government agencies. Overall, impacts on birds are likely to be MINOR.

5.3.3.2 Aquatic Resources

Plans call for wharf sites to be located along the Mackenzie River mainstem. Piling installation and bank preparation will take place during the open water months, when natural sediment loads are high. The effects of sediments on aquatic resources are described in Section 3.4.1.6. Given the limited number of wharf sites, their locations, the limited disturbance associated with their construction and the timing of their construction, possible impacts on all aquatic trophic levels are considered NEGLIGIBLE.

5.3.4 TEMPORARY ACCESS ROADS

Temporary access roads include snow and ice roads, and interim bridges, all of which are generally used only in winter. Snow and ice roads will be constructed to provide access to construction sites and to minimize the effects of construction or maintenance traffic on permafrost. Snow will be harvested using snow fences, mined from nearby drifts, or manufactured from water drawn from approved sources. In the event that snow compaction does not produce a sufficiently hard surface, roads will be strengthened by icing them with water.

5.3.4.1 Geology and Soils

Previous studies (Adam and Hernandez, 1977; Hardy Associates, 1980) indicate that snow and ice roads cause relatively little permafrost degradation provided they are properly constructed and maintained. Small increases in active layer depths and some localized thaw settlement may occur; however, with the application of Arctic engineering practices, possible impacts of temporary access roads on geology and soils are likely to be LOCALIZED and SHORT-TERM.

5.3.4.2 Hydrology and Water Quality

Temporary access roads will be constructed with snow and/or water drawn from approved sites. These approved sites will have sufficient volume so that aquatic habitat will not be affected. Consequently, possible impacts on hydrology and water quality are expect to be LOCALIZED and SHORT-TERM.

5.3.4.3 Vegetation

A discussion of the impacts of snow and ice roads on vegetation is provided in Section 3.6.6.3. In consideration of this discussion, possible impacts on vegetation are expected to be LOCALIZED and SHORT-TERM.

5.3.4.4 Mammals

Access roads may affect wildlife populations through habitat alteration, disturbance from traffic, the barrier effect, and through providing temporary access to hunters and trappers. These impacts are discussed in Section 3.6.6.4.

A number of measures exist to mitigate potential impacts. Routes of access roads will be planned to minimize the crossing of important wildlife habitat. Movements of ground vehicles will be limited to designated access roads, ancillary facility sites, and right-of-way boundaries. When mammals are encountered by ground vehicles, operators of the vehicles will slow or stop to allow animals to move off the road. Existing access will be used wherever possible to avoid creating access to previously inaccessible areas. No privately-owned firearms will be permitted at project facilities. Sealed firearms may be issued to work party heads when operations are being conducted in areas where there are threats of bear attacks. Use of firearms will be permitted only in cases of direct risk to human life. A written report to the appropriate government and company authority will be required in all cases where the seal on a firearm is broken. No development facility will be permitted to be used as a base for hunting or trapping. With the implementation of these measures, regional impacts on wildlife resulting from temporary access roads are likely to be MINOR, although the local impact on moose could be MODERATE, because of increased hunting.

5.3.4.5 Birds

NEGLIGIBLE impact on birds is to be expected if temporary access roads are limited only to winter use.

5.3.4.6 Aquatic Resources

Construction of temporary winter roads involves compaction of snow to the density required to support vehicular traffic, and, where the proper densities cannot be achieved, augmenting road strength by applying water. Water withdrawals and sources will be governed by the same concerns described for Pipeline Testing (Section 5.2.4.6). With the application of these measures, the possible impact of water use for temporary roads on aquatic resources is expected to be NEGLIGIBLE.

5.3.5 PERMANENT ACCESS ROADS

Permanent access roads will be required only sparingly for the oil pipeline. For example, permanent access roads would be required between an airstrip and a pump station, either under construction or operating, or between a wharf on the Mackenzie River and a pump station. Generally, movements of personnel and materials from stockpile sites to pipeline construction areas will take place in winter on temporary access roads. No permanent access road would parallel the oil pipeline. Associated activities would include road survey, clearing, grading, and culvert and bridge installation. These roads would be built in accordance with standard Arctic construction procedures, with specific regard to maintenance of terrain stability and drainage patterns, thus avoiding secondary environmental effects such as stream siltation and habitat or vegetation disruption (Curran and Etter, 1976).

5.3.5.1 Geology and Soils

Permanent access road construction may alter surface and subsurface drainage patterns, resulting in shallow thaw settlement and surface erosion. The extent and magnitude of these effects are expected to be minimal due to the short distances involved and the flexibility in route location. In addition, resultant impacts will be reduced by implementing drainage and erosion control and surface reclamation measures. The impact of permanent access roads is considered LOCALIZED and SHORT-TERM.

5.3.5.2 Hydrology and Water Quality

Permanent access roads will interrupt minor drainage systems, including unchannelized flows and very small streams, resulting in localized upslope ponding. Bridges and culverts will be used to limit the area and volume of ponding. Resultant impacts are likely to be LOCALIZED and SHORT-TERM.

5.3.5.3 Vegetation

Aside from the permanent removal of vegetation, the principal effect of roads on vegetation will be due to alterations of surface and sub-surface drainage patterns. Where the roads cross lowland areas with slow diffuse flow or seepage, localized upslope ponding may cause localized mortality of trees and shrubs and improved growth of semi-aquatic species. Downslope drying may result in the improved growth of trees.

After construction, exposed soils will be stabilized and revegetated to control erosion. Drainage and erosion will be controlled using culverts, berms and berm breaks. These will stabilize road surfaces and re-establish the major drainages. The impact of permanent roads is therefore considered LOCALIZED and LONG-TERM.

5.3.5.4 Mammals

The types of possible impacts of permanent access roads on wildlife are similar to those expected for temporary access roads (Section 3.6.6.4). Wooley and Wooley (1976) suggested that increased access and activity associated with the Mackenzie Highway may have been the reason why concentrations of moose reported by Slaney (1974) on McGern Island were not present in 1976. Mitigation measures applied to reduce impacts of temporary access roads will also be applied to permanent access roads. On this basis, possible impacts on wildlife are considered MINOR.

5.3.5.5 Birds

Impacts from activities along roads on birds will result primarily from the movement of machines and people and the accompanying noise levels (Jehl and Smith, 1970). There will be some effect from increased access provided for hunters (Section 5.3.7). The locations of waterfowl staging, nesting, and moulting areas and raptor nest-sites will be considered in the final siting of permanent access roads and the facilities they service. Some limitation of traffic may be possible for brief periods of the year such as during nesting. Monitoring will establish the needs for limitations on a site-specific basis. With appropriate mitigations, impacts on birds from permanent access roads are considered MINOR.

5.3.5.6 Aquatic Resources

Possible impacts of permanent access roads on aquatic resources may result from fish passage obstruction, sedimentation, and increased angling pressure. Morehouse *et al.* (1978) reported that fish passage barriers were one of the most common problems associated with construction of the Alyeska Pipeline. Low water crossings (a type of stream ford) along the Alyeska Pipeline caused a number of problems for fish passage, such as outwashes and siltation (Gustafson, 1977). A discussion of impacts and mitigative measures related to fish passage obstruction and sedimentation is provided in Section 3.6.7.6.

Since pipeline construction will be completed using temporary ice and snow roads rather than all-weather permanent roads, the requirement for permanent access roads is limited to those providing access to support facilities. Consequently, there will be few small streams crossed by permanent access roads. Design specifications will ensure that fish passage is not obstructed. With the implementation of mitigative measures, and given the relatively small number of permanent roads required for access to support facilities, impacts on fish are expected to be NEGLIGIBLE. Increased recreational fishing is discussed in Section 5.3.10.2.

5.3.6 STAGING SITES AND STOCKPILES

Facilities to receive and store materials and equipment would be established at Hay River, Fort Simpson, and Enterprise. In addition, stockpiles will be provided along the river and pipeline route. Sites and stockpiles serviced by roads will be situated close to the right-of-way. Where serviced by temporary wharves, staging sites and stockpiles will generally be located next to off-loading areas. To minimize surface disruption, stockpiles along the right-of-way will be located, where possible, on pump station pads. Discussions of impacts on geology and soils, hydrology and water quality, and vegetation from staging sites and stockpiles are provided in Section 3.4.1.

5.3.6.1 Mammals

The construction of staging areas will result in a direct removal of habitat which is very small in relation to surrounding available habitat. In addition, some wildlife will avoid a small area surrounding staging areas because of disturbance and human activity. Overall, the possible impact on mammals is likely to be MINOR.

5.3.6.2 Birds

Once general locations for staging areas are established, detailed examination of the use of these areas by birds will be an important factor in determining precise staging locations. Particular attention will be given to waterfowl concentrations (swans, geese and ducks), and the presence of raptors and other birds such as sandhill cranes. The resultant impacts from staging sites and stockpiles on birds are expected to be MINOR.

5.3.7 CONSTRUCTION CAMPS

Camps will be required for both preconstruction and construction activities (Plate 5.3-1). Mainline camps will be relocated during pipeline construction to maximize productive working time. Camps are of three types and sizes: small (10-50 personnel) for survey and clearing; intermediate (100-400 personnel) for site preparation, borrow, staging, and pump station construction crews; and large (800-1,200 personnel) for mainline pipeline construction crews. Discussions of impacts from construction camps on geology and soils, and vegetation are provided in Section 3.4.1.

5.3.7.1 Mammals

Camps will result in some short-term and local habitat loss as a result of the area occupied by the camp. The area in the vicinity of the camp will be subject to disturbance from noise and human activity. The total area from which wildlife will be displaced will be very small. Camps will also be located to avoid critical wildlife habitat. Impacts from camps on mammals are considered to be MINOR for most wildlife but possibly locally MODERATE for grizzly bear. Potential problems with bears, foxes and other wildlife being attracted to garbage are discussed in Section 5.3.9 (Waste Disposal). The congregation of pipeline personnel in work camps, plus the potential for hunting and other recreational activities, is discussed in Section 5.3.10 (Off Duty Activities).

5.3.7.2 Birds

Noise from generators, vehicular traffic and personnel movements can be expected to cause behavioral changes to birds in adjacent areas (Gollop and Davis, 1974; Barry and Spencer, 1976; Fyfe and Armbruster, 1977). Camp sites will be selected in consultation with government agencies to avoid swan and goose concentration areas. Accordingly, impacts from construction camps on birds are considered MINOR.

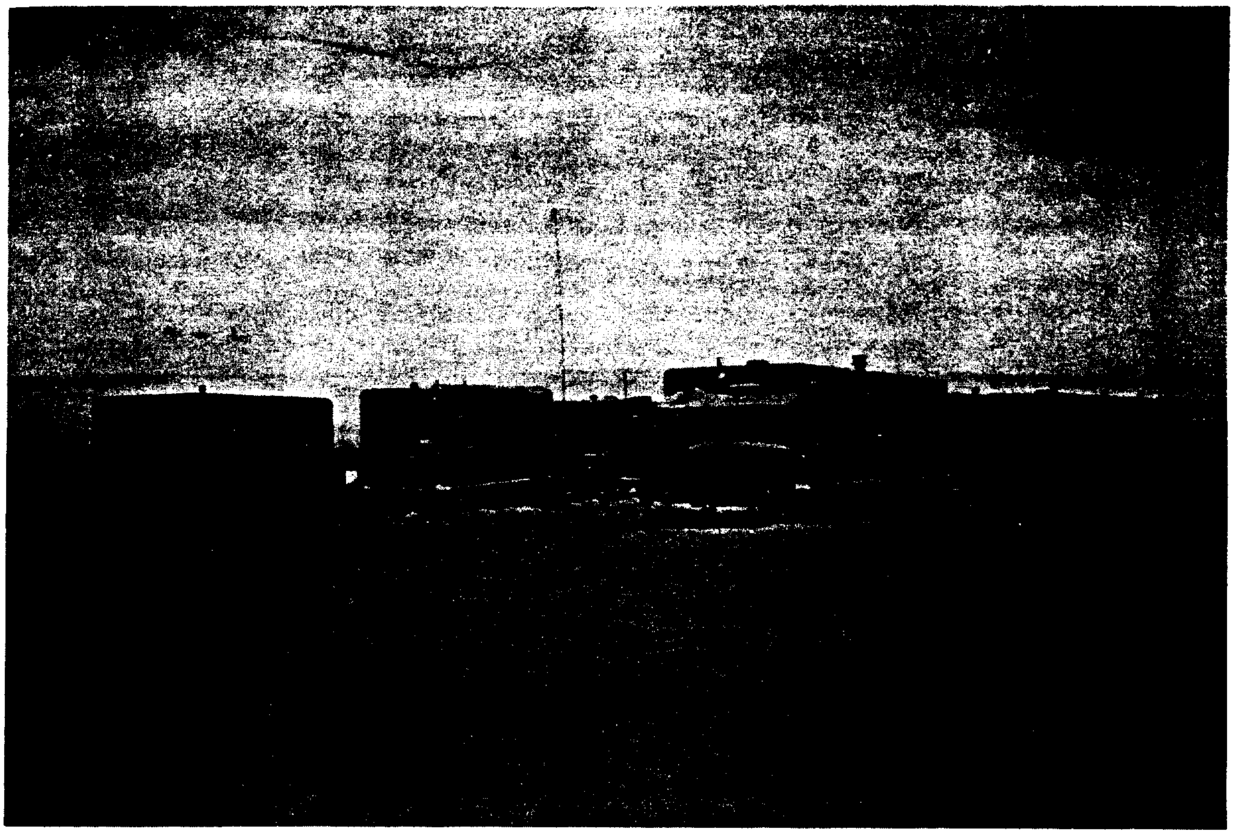


PLATE 5.3-1 *A typical construction camp used for survey, clearing, or site preparation activities.*

5.3.7.3 Aquatic Resources

Possible adverse effects on aquatic resources arising from work camps are related to water use, sewage disposal (Section 5.3.9.2), and increased recreational fishing (Section 5.3.10.2).

(a) Water Use

During the winter months when most streams and shallow lakes are frozen to the bottom, water availability can become a concern. The Mackenzie River will provide an adequate year-round water supply without affecting overwintering fish populations. Where the pipeline route departs from the Mackenzie, deep lakes and streams with perennial discharge will meet all water requirements, including those of work camps, winter roads, and hydrostatic testing. Where these waterbodies support overwintering fish, it is important that sufficient well-oxygenated water remains to meet fish requirements.

Overwintering fish and their eggs are subject to stress during late winter when ice thickness is greatest, water availability lowest, dissolved oxygen reduced, and energy reserves least. Water withdrawal from shallow lakes and streams with very limited discharge, or from pools fed by intergravel flow, can result in considerable mortality of both eggs and overwintering fish. If withdrawal sites are not located elsewhere, fish with extremely limited overwintering habitat in shallow lakes and near perennial groundwater sources can be seriously affected by camp water requirements.

Including requirements for hydrostatic testing and winter road construction, total project water requirements during the four-year construction period are estimated at 43,000,000 m^3. Domestic water requirements for the project are currently estimated at less than 10% of this total. Daily water requirements are estimated at 318 L per capita, necessitating a daily withdrawal of 381,000 L for a large 1,200 man mainline construction camp.

Protection of overwintering fish from the effects of camp water withdrawals will be accomplished through placement of camps near adequate year-round water supplies where water withdrawal will not interfere with overwintering fish. Where there is doubt regarding the adequacy of water in an area, water availability will be determined prior to facilities construction. With these measures in place, the effects of camp water use on aquatic resources are likely to be NEGLIGIBLE.

5.3.8 AIRCRAFT AND AIRSTRIPS

Existing airstrips at Inuvik, Norman Wells, Fort Simpson, and Hay River will be utilized. In addition, 5 long (1,830 m) and 12 short (732 m) airstrips would be required along the pipeline route to serve construction, operation, and maintenance activities. Helicopters would be used in early development stages of the project. Highest levels of activity will be centred around construction camps.

5.3.8.1 Mammals

Caribou and grizzly bear are more sensitive to aircraft than moose, wolves, and other, smaller mammals (Klein, 1974; McCourt *et al.*, 1974). The effects of aircraft on wildlife decrease rapidly with increasing distance.

Aircraft disturbance of caribou has been studied by several researchers over the past decade (Calef and Lortie, 1973; Klein, 1974; McCourt *et al.*, 1974; McCourt and Horstman, 1974; Calef *et al.*, 1976; Surrendi and DeBock, 1976; Fischer *et al.*, 1977; Miller and Gunn, 1977). The results of these studies show that the degree of response of caribou is dependent on several factors including the type of aircraft, the nature of aircraft manoeuvres, the season, prior exposure to aircraft, and the distance between the aircraft and the animal. This latter factor is of overriding importance. Caribou do not often show strong reactions to light fixed-wing aircraft flying higher than 180 m agl. Calef *et al.* (1976) suggested that over-flight elevations of 300 m avoids most injurious reactions by caribou.

It is generally thought that aircraft disturbance does not adversely affect moose behaviour (Doll *et al.*, 1974; Jakimchuk *et al.*, 1974; Klein, 1974; Kucera, 1974; McCourt *et al.*, 1974; Ruttan, 1974; Horejsi, 1975). However, since moose usually exhibit a delayed response (McMillan, 1954; de Vos, 1958; Geist, 1963; Tracy, 1977) it is possible that the true state of alarm is never witnessed by aerial observers.

Aircraft disturbance of deer is not well documented. Horejsi (1975) reports mule deer are more reactive than moose or elk but as with elk, this depends on the amount of available cover. By monitoring heart rate, Moen and Chevalier (1977) noted deer were more disturbed by presence of another deer than by an airplane.

There is evidence that a number of ungulate species habituate to an initially disturbing stimulus after subsequent exposures, if no immediate harm results to the animals (Geist, 1971; McCourt and Horstman, 1974; Reynolds, 1974). The long exposure of wildlife in the Mackenzie Valley to aircraft travelling along the valley has probably resulted in some degree of habituation (Plate 5.3-2).

Aircraft flights with no specific requirements for low level flying will be made above minimum flight altitudes of 600 m agl. Pilots will be informed of sensitive areas, minimum altitudes and flight corridors. Use of project aircraft to harass mammals or transport mammal carcasses, furs, or hides will be prohibited. Possible impacts resulting from aircraft overflights are therefore expected to be MINOR.

5.3.8.2 Birds

Construction of airstrips will cause some loss of habitat. Concerns are similar to those for other development activities addressed previously in Section 5.4.7, however, construction requirements for an airstrip such as being located away from boggy wetlands and cliffs, are more likely to impact on upland and forest birds than they are on waterfowl and raptors.

A greater potential for impact exists from aircraft traffic using the airstrips because many waterfowl and raptor species are particularly sensitive to the sight and sound of aircraft in flight (Schweinsburg, 1974; Ward and Sharp, 1974; Barry and Spencer, 1976; Fyfe and Olendorff, 1976). Some researchers have noted that snow goose flocks on the ground are so sensitive to aircraft overflights that no practical altitude of overflight was found that would not induce them to take flight (Schweinsburg, 1974; Koski, 1975, 1977). However, in studying the effects of hydrocarbon development at Norman Wells, Webb (1980) reported a number of occasions in which snow geese did not react to aircraft that flew within 0.4 to 2.5 km and at altitudes of 20 to 900 m agl. Raptors are considered especially sensitive to disturbance during the breeding-nesting period (April 1-August 31), and Roseneau *et al.* (1981) have set forth recommended temporal and spatial criteria for mitigating effects of flying aircraft; these restrictions will be adopted for known nest-sites. Similar criteria have not been developed for waterfowl. However, the avoidance of very sensitive areas and the establishment of flight corridors and altitude restrictions for less sensitive areas during certain specific periods of the non-winter months will reduce disturbance to most waterfowl of the region. Under these conditions, anticipated impacts should generally be MINOR, although they may approach MODERATE in some local instances.

5.3.9 WASTE DISPOSAL

At all temporary work camps and construction sites, domestic sewage waste will be released to approved disposal sites after treatment to the satisfaction of appropriate government agencies. All combustibles,

PLATE 5.3-2 *In northern Alaska caribou have become habituated to airstrips and roads. (Courtesy: Alyeska Pipeline Service Company).*

such as kitchen wastes, will be incinerated and residues deposited at approved landfills. Liquid and solid wastes and scrap metals will be disposed of in a manner approved by regulatory agencies: techniques used may include incineration, burial in approved sites, injection into approved disposal wells, storage in designated impermeable sites, or shipment out to be recycled.

5.3.9.1 Birds and Mammals

Solid wastes, such as kitchen wastes, and containers will be produced throughout the life of the project although most will be generated during the construction phase. Landfills will attract ravens, gulls and some other scavenging birds. Over a period of years this is likely to result in a local increase in their numbers and some increase in competition with raptors for nest-sites. Generally, the effect of garbage dumps is to concentrate scavengers such as bears from the surrounding area to an artificial food source (Retfalvi, 1972; Cole, 1976; Nagy and Russell, 1978). There are a number of mitigative measures available to minimize the number of animals frequenting garbage dumps. The storage and disposal of solid and liquid wastes will be handled to ensure that these materials pose no environmental hazard. The attractiveness of facilities to various mammals will be reduced by several methods including storing food in secure buildings, incineration of all garbage on a daily basis, and regular cleansing of food storage facilities. All non-combustible solid wastes will be removed or buried in a landfill in accordance with government regulations.

In cooperation with the appropriate government agencies, problem bears will be removed, and project personnel will be instructed on methods to avoid and deal with mammal encounters. All incidents involving problem mammals, or the presence of potentially troublesome mammals in the vicinity of activities will be reported. On a local basis, impacts on grizzly bears are expected to range from MINOR to MODERATE. Impacts on other mammals and birds are likely to range from NEGLIGIBLE to MINOR.

5.3.9.2 Aquatic Resources

In many northern streams, low nutrient concentration is one of several factors limiting productivity (Volume 3C). Adding sewage effluent may cause nutrient enrichment of these waters, triggering localized algal blooms and depressing dissolved oxygen concentrations during the winter months. The net effect of these nutrient introductions is an increase in the productivity of lower trophic levels, and an ensuing increase in BOD. These increases may adversely affect fish survival in waters which already have low winter oxygen concentrations.

At construction camps and support facilities, treated sewage will be discharged for one to four years. Thereafter, sewage will be incinerated at all permanent facilities and, except in emergencies, the release of further effluent is not anticipated. Where winter discharge is insufficient for adequate dilution, sewage will be held in lagoons or small ponds for release during the openwater period. In waters where dissolved oxygen concentrations become critically low during the winter months, this approach will greatly reduce the potential for affecting fish populations. Since dilution and scour will act to remove excess nutrients and algae in all but the most confined lakes and tundra ponds, recovery will be short-term once sewage introductions cease.

Sewage effluent will conform to government standards. Consequently, the effect of sewage introductions on aquatic resources should be MINOR.

5.3.10 OFF-DUTY ACTIVITIES OF PIPELINE PERSONNEL

Pipeline construction, operations, and maintenance will greatly increase the opportunity for hunting and fishing. Increased access to remote areas will be facilitated by permanent and temporary access roads, aircraft, snowmobiles, and all-terrain vehicles.

5.3.10.1 Mammals and Birds

Game birds in the region most likely to be hunted are primarily waterfowl such as dabbling and diving ducks and geese. Possible impacts of increased access by hunters and trappers on wildlife have been discussed in Sections 3.6.6.4 and 5.3.4.4. Project personnel will not be permitted to have privately owned firearms at project facilities. Also, no hunting or trapping will be permitted by project personnel in the vicinity of the right-of-way. Specific regulations will be implemented in consultation with appropriate government agencies. Therefore, impacts from off-duty activities of pipeline personnel on mammals and birds are expected to be MINOR.

5.3.10.2 Aquatic Resources

Most waterbodies in the Mackenzie Valley corridor have poor access except by boat along the Mackenzie River, by snowmobile in winter, or by aircraft to the large lakes and streams. Heavy angling pressure in spawning and overwintering waters could result in serious declines in local fish populations.

Experience along the Alyeska Pipeline, where an all-weather access road parallels the pipeline for 580 km, indicates that improved access can result in increased angling pressure within 1 km of access points. Although this increased pressure has caused local declines in relative abundance of some species, notably grayling, there has been little apparent effect on overall population levels. Pipeline personnel have demonstrated little willingness to travel great distances on foot over the tundra to remote streams and lakes, preferring to fish in the most accessible areas. (Aquatic Environments Limited, unpublished data).

Due, in part, to their concentration in certain habitats and in part to their slow growth and vulnerability to anglers, Arctic char and lake trout populations in the Northwest Territories are generally considered to be sensitive to heavy exploitation. Arctic char, however, do not occur in the corridor, and project activities will not provide new access to areas supporting this species. Lake trout are found in several lakes within the corridor and, in at least one instance, they occur in a stream (Great Bear River).

As a result of a low recruitment rate and slow growth, lake trout populations have displayed rapid changes in their age-class structure when subjected to heavy fishing pressure. Lake trout in Ya-Ya Lake on Richards Island have been exploited by residents of Inuvik and Aklavik, by fly-in fishermen, and by personnel working on the south shore of the lake. This exploitation has caused reductions in the mean size of lake trout caught in this lake (Machniak, 1977).

In Great Bear Lake, sports fishing has had adverse effects on the population structure of lake trout (Healey, 1978). Studies in Great Slave Lake indicate a similar response in the east arm of the lake as a result of commercial fishing pressure (Anonymous, 1975, McCart and DenBeste, 1979). To minimize the loss of fish in younger age classes, Falk *et al.* (1973) suggested managing lake trout sport fisheries in large lakes by restricting the fishery to trophy fishing.

Depending on the species involved, recovery varies greatly. Because of their high reproductive potential and rapid recruitment, whitefish species have generally shown rapid recovery from heavy exploitation (Healey, 1975). By virtue of their high reproductive potential and relatively rapid growth, grayling would presumably display a similar recovery rate; however, data describing the recovery of this species from exploitation are few.

Lake trout, in contrast, do not appear to have the same capacity to recover from fishing pressure (Healey, 1978). The rate of recruitment of juveniles is often too slow to sustain the population, resulting in a gradual decline in numbers (McCart and DenBeste, 1979). In addition, recovery of lake trout from excessive fishing pressure can be extremely slow, with a single generation requiring up to 20 years to mature. Some populations may never recover if the numbers of fish become too low.

Improved access and the increasing numbers of people drawn to the region will result in some increased fishing pressure for the life of the project and probably for the foreseeable future. As the more remote fishing areas are made accessible, public awareness of them is likely to increase. However, new permanent access roads will only connect support facilities sites and offloading sites along the Mackenzie River. Increased pressure on remote fishing sites will therefore be less than if an all-weather road connected all support facilities to major communities. Access to communities and, more importantly, to southern areas, will be provided only by ice roads in winter, by boat in summer, and by air throughout the year.

The effects of increased fishing pressure can be mitigated as follows: entry onto access roads will be controlled; where feasible, temporary and permanent access roads will be routed to avoid sensitive fish habitats; all facilities, rights-of-way, and access roads under control of the operator will be posted to acquaint anglers with the relevant regulations and to restrict angling pressure; the operator will prohibit the use of company-owned or chartered aircraft in transporting anglers; personnel will be encouraged to follow applicable fishing regulations; and specific regulations will be implemented in consultation with appropriate government agencies. Assuming that these mitigative measures are adhered to and that adequate fishing regulations are in place prior to creation of new access, the effects of increased human presence on fish populations are expected to be NEGLIGIBLE.

5.4 IMPACTS FROM OPERATIONS, MAINTENANCE AND ABANDONMENT

Once the pipeline is constructed, activities to operate and maintain the pipeline system will begin. Surveillance of both elevated and buried pipeline sections will identify undesirable subsidence or erosion. During operations, there will be a marked reduction in the intensity of mechanical and human activity. Pump stations will be designed for remote control operation, however during planned maintenance shutdowns, approximately 20 personnel could be working at a pump station site.

5.4.1 PIPELINE SURVEILLANCE

The condition of the pipeline and right-of-way will be monitored remotely and by frequent aerial and ground patrols (Plate 5.4-1). In sensitive terrain areas, use of the right-of-way for maintenance will be limited to winter whenever possible. For maintenance or repairs which must be done at times when the terrain is not frozen, aircraft will be the preferred way of transporting personnel and equipment. At all times, personnel will ensure that use of the right-of-way is kept to a minimum. Restrictions on altitude and on flying over certain areas will be observed to minimize ground level noise.

5.4.1.1 Mammals

The effects of aircraft disturbance during pipeline surveillance will be similar to these expected during the construction period, with the exception that there will be fewer aircraft flights. Provided that the mitigation measures listed in Section 5.3.8.1 are applied to aerial surveillance flights, impacts on mammal populations are expected to be NEGLIGIBLE.

Ground surveillance activities during the operations phase will cause some short-term local displacement of mammals but, because of their relative infrequency and short-term nature, likely impacts will be NEGLIGIBLE.

5.4.1.2 Birds

Pipeline surveillance would have little effect on birds if these activities are confined to the pipeline route itself. Possible adverse effects may result from flights over certain temporarily-sensitive areas, such as river islands during May to July (waterfowl) and raptor nest sites from April 15 to August 31. Such effects will be reduced by using specific air corridors which avoid these areas during sensitive periods. Anticipated impacts are therefore expected to be NEGLIGIBLE.

5.4.2 PERMANENT ROADS AND WHARVES

Permanent roads would only be required to connect a wharf on the river to a pump station on the right-of-way or to connect an airstrip to a camp. Disturbances will arise from the physical presence of these facilities and from activities associated with them.

5.4.2.1 Hydrology and Water Quality

The design specifications for water crossing structures along roads will allow for fish passage and will ensure that drainage alteration is minimized. The monitoring of water crossings together with preventative maintenance will ensure that the impacts of

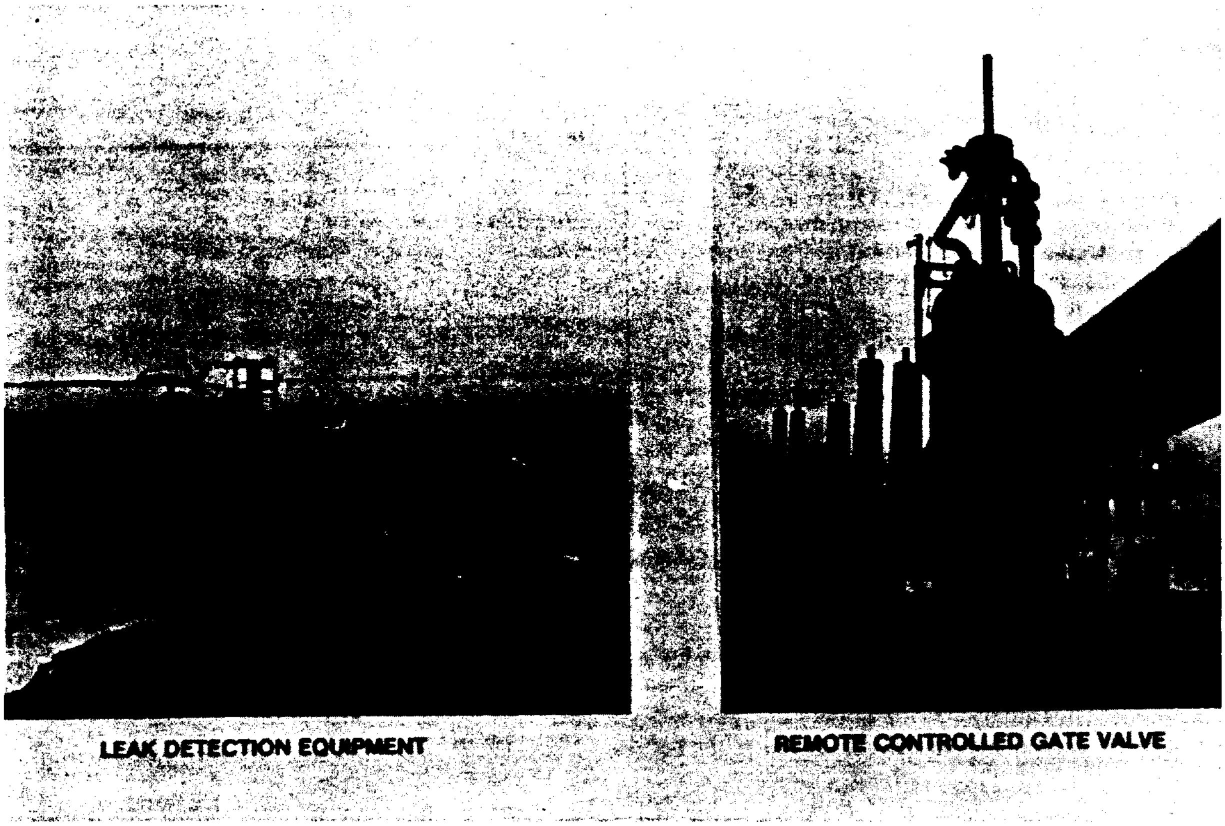


PLATE 5.4-1 *Leak detection equipment and control valves enable remote surveillance and automatic shutdown capability for the Alyeska Pipeline. These safety measures ensure that potential oil leaks are minimized.*

permanent roads on water quality will be LOCALIZED and SHORT-TERM.

5.4.2.2 Mammals

The impacts of permanent roads used during the construction phase will continue throughout the operations phase. Where access is created into previously inaccessible areas, permanent roads may result in local depletions of ungulate and furbearing mammals as a result of hunting and trapping. However, since permanent roads will only service pump stations and support facilities, the likely impacts on regional populations of mammals in the Mackenzie Valley and Delta will be MINOR.

The impacts of wharves which continue to be used during the operations phase will also be similar to their impacts during the construction phase. However, despite the longer term during which habitat is made unavailable at wharf sites, the amount of habitat involved is small, and the effects on wildlife populations are considered to be NEGLIGIBLE.

5.4.2.3 Birds

Operation and maintenance of permanent roads and wharves will influence birds directly through loss or modification of habitat. Road and river traffic plus human presence will also have local effects. Depending on their location, wharves are expected to have less influence on birds than permanent roads, where the greatest influence would result from increased access. Positioning of roads more than 3 km from known raptor nests will reduce impacts on these species to MINOR.

5.4.3 OTHER PERMANENT SUPPORT FACILITIES

Permanent support facilities would include permanent airstrips, staging areas for equipment and fuel storage, warehouses and maintenance camps at Inuvik, Norman Wells, and Fort Simpson.

5.4.3.1 Mammals

The existence of permanent camps is not expected to result in local depletions of ungulates and furbearers in the vicinity as hunting and trapping activities by personnel using the camp as a base will be controlled. Some problems with bears and other wildlife attracted to camps may occur as a result of the presence of solid waste. These local effects are not likely to measurably affect regional populations, however, and are therefore considered MINOR.

5.4.3.2 Birds

Some impacts from previous loss or modification of habitat will remain during the post-construction period. With adequate control of off-duty activities of operations personnel, impacts on birds are expected to be MINOR.

5.4.3.3 Aquatic Resources

Maintenance camps, and other permanent support facilities will concentrate relatively few personnel in small isolated areas within the corridor. As a result, angling pressure will increase near these facilities. However, assuming that the mitigation measures outlined in Section 5.3.10.2 are followed, impacts on fish resources are likely to be NEGLIGIBLE.

5.4.4 PUMP STATIONS

Possible effects of the location and construction of pump stations are discussed in Section 5.2.8. Pump station operation will result in emissions of noise, water vapour, carbon dioxide and very small amounts of carbon monoxide, sulphur dioxide, and oxides of nitrogen. Operation of pump stations will comply with government air quality regulations regarding noise and air emissions (Plate 5.4-2).

5.4.4.1 Geology and Soils

The effect of sulphur on the soil surrounding emission sources depends on the concentration and length of exposure to sulphur contamination as well as the buffering capacity of the soils. Crude oils in the Mackenzie Delta - Beaufort Sea region are "sweet" and the hydrogen sulphide content is almost nil. Pump stations will be equipped with emission stacks of sufficient height to maximize mixing with the air. Emission concentrations will be far lower than the maximum permissible Federal ambient air quality objectives. The impact of pump station emissions on soil productivity is considered LOCALIZED and NEGLIGIBLE.

5.4.4.2 Atmospheric Environment

Noise emissions from pump stations will normally be less than, but in any event will not exceed, the criteria established in AR/71 of the Alberta Noise Protection regulations. Since all major equipment will be installed in insulated buildings, the noise levels on the outside will be further reduced. Noise attenuation devices will be employed as necessary.

The pumps will be operated with fuel from small topping plants at each station. Air emissions from

PLATE 5.4-2 *Alyeska Pipeline: typical pump station. Impermeable dykes encircle tank farms to ensure containment of accidental tank spills. (Courtesy, J. DenBeste, Aquatic Environments Ltd.).*

each station will likely include small amounts of unburned hydrocarbons, nitrogen oxides, sulphur dioxide, carbon monoxide and suspended particulates. However, effects of these emissions on air quality will be minimal and very localized since concentrations are expected to remain well below Federal air quality guidelines. The possibility of ground level ice fog is expected to be low since the high exhaust velocities will carry vapors to elevations well above ground level where they can be dispersed by air currents at high elevations.

Mitigative measures at pumping stations will include locating them at a sufficient distance from communities or recreation areas to minimize noise or air quality concerns. Additional sound attenuation equipment may be installed if noise is a special concern. Pumping stations will be located away from local depressions or small valley bottoms to reduce the likelihood of atmospheric inversion conditions. The emission stacks will be of sufficient height to ensure the dispersion of gases under normal atmospheric conditions. Government guidelines for air quality will be met. Therefore, the impacts of pump stations on air quality will be LOCALIZED and NEGLIGIBLE.

5.4.4.3 Vegetation

Carbon monoxide, sulphur dioxide, and oxides of nitrogen are not expected to cause injury to vegetation because of their very low concentrations and the short duration of exposure of plants to the gas. Water vapour emissions may result in very localized icing of vegetation.

Pumping stations will be located, where possible, on terrain where the probability of inversion conditions is comparatively low. Emission levels will ensure that concentrations of these gases in surrounding areas are within Federal objectives for desirable air quality. Emission stacks will be of sufficient height to ensure adequate mixing with ambient air. With these measures, the impacts of gaseous emissions from pumping stations on vegetation are expected to be LOCALIZED and NEGLIGIBLE.

5.4.4.4 Mammals

Concerns for mammal populations are related to their responses to pump station noise. Observations of ungulate reactions to stationary machinery indicate that noise rather than physical appearance is the major factor influencing their response (Kelsall, 1968; Bergerud, 1974; McCourt *et al.*, 1974). This is probably the case for other mammal species. Several authors have noted the low level of caribou response to stationary man-made structures (Urquhart, 1973; Jakimchuk *et al.*, 1974; McCourt *et al.*, 1974; Roby, 1978; Cameron and Whitten, 1979). McCourt *et al.*, (1974) reported that barren-ground caribou avoided an area within 0.2 km of a simulated gas compressor station and that there was a lower level of habitat use within a 0.8 km radius of the device.

Moose tend to ignore loud noises (Geist, 1963) and generally pay more attention to smells (Murie, 1934; Peterson, 1955). However, they react more to subtle noises that can be associated with predation, such as the rustling of brush or the breaking of twigs (McMillan, 1954).

To minimize the possible adverse effects on mammals, pump stations will be located away from critical habitat wherever feasible, and all facility sites will be fenced to exclude ungulates and other large mammals. Noise emissions will be limited as discussed in Section 5.4.4.2. Since the amount of habitat avoided by wildlife is considered to be small, anticipated impacts are NEGLIGIBLE.

5.4.4.5 Birds

During operations, the level of human activity will decline sharply, thereby reducing the effects of human presence on birds. However, noise and air emissions will continue during operations. Nevertheless, anticipated impacts on birds are expected to be NEGLIGIBLE.

5.4.4.6 Fish

Pump stations will concentrate a small number of personnel resulting in increased fishing pressure in nearby waterbodies. This impact is considered to be NEGLIGIBLE for reasons discussed in Section 5.3.10.2.

5.4.5 FIRE HAZARD

The incidence of fires is not expected to increase as a result of pipeline construction and operation. A contingency plan to deal with fires will be prepared in cooperation with the appropriate government agency. The plan may include employee awareness and training programs, fire-fighting equipment stockpiling at pump stations, and liaison with appropriate government personnel. To further protect against fire, metal buildings will be used to house hazardous equipment, and gravel pads and fire guards will be incorporated into the design of project facilities. Measures such as restriction of activity during periods of high fire hazard may be implemented, and men and equipment employed by the operator of the pipeline will be made available to assist fire fighting agencies if fires threaten the pipeline or its facilities.

In the event of a natural fire, the cleared right-of-way could act as a fire break. The presence of pipeline personnel and equipment together with routine aerial surveillance of the right-of-way will allow for prompt mobilization and improve local fire-fighting capability. Widespread fire is not expected in areas of the above-ground pipeline, due to the wet, lowland nature of terrain in these areas.

The destruction by fire of the surface vegetation and the organic layer in areas of ice-rich soils could cause thaw settlement, hydraulic and thermal erosion and, possibly, slope failures (Heginbottom, 1973; McRoberts and Morgenstern, 1974; Rowe *et al.*, 1974). The erosion potential resulting from a fire will vary among terrain types, surficial materials, and permafrost conditions, and will be determined largely by fire intensity and extent of organic layer destruction. Site inspections, stabilization, and revegetation of the terrain where required (as described in Sections 5.2.1 and 5.3.1) will ensure continued pipeline integrity.

5.4.6 ABANDONMENT

Abandonment will entail the dismantling and removal of all surface facilities including pump stations, elevated sections of the pipeline, camps, docks, warehouses and other facilities. Over the short term, these activities will result in increased traffic and personnel presence during abandonment. Timing for dismantling, removal, and transportation of this equipment will depend on the location at each site, such as its proximity to all-weather roads and river transport facilities. For example, pump stations and camps might be dismantled and removed in summer. Elevated sections of the pipeline would be dismantled and removed in winter because of the lack of an all-weather work pad.

5.4.6.1 Geology and Soils

Removal of all surface facilities and abandonment of the pipeline will likely disturb portions of the revegetated right-of-way and may initiate localized hydraulic erosion. Drainage and erosion control and reclamation measures will be applied to restore terrain stability. These measures will include restoration of natural surface and subsurface drainage patterns wherever feasible, as well as revegetation by seeding and fertilizing. Therefore, the impact of equipment removal is expected to be LOCALIZED and SHORT-TERM.

5.4.6.2 Vegetation

The potential for erosion and disturbance to vegetation is increased by site clearing. Drainage and erosion control and reclamation measures will be reestablished during abandonment to ensure that newly disturbed areas are revegetated. Measures will include restoration of natural surface drainage systems, as well as application of appropriate seed mixes and fertilizer. Natural vegetation succession will continue on the right-of-way and facility sites and eventually even the visual evidence of the pipeline should disappear. The impact of equipment removal on vegetation is therefore likely to be LOCALIZED and SHORT-TERM.

5.4.6.3 Mammals

Equipment removal will reverse the impact of wildlife habitat loss caused by the land surface occupied by the equipment. This removal of equipment will result in a beneficial impact on wildlife although it will be negligible because of the small area involved in relation to the extent of surrounding available habitat. The activity of men and machines involved in removing the equipment will result in some local short-term displacement of wildlife, but the effects on regional wildlife populations will be NEGLIGIBLE.

5.4.7 RECLAMATION

The objective of a reclamation program is to return the pipeline right-of-way and other activity areas to a land use capability similar to that which presently exists. Land use priorities would be determined in consultation with appropriate government agencies. The major activities would include recontouring, terrain stabilization to ensure integrity of surface and subsurface drainage, surface preparation, mulch application, fertilizing, and seeding/revegetation.

5.4.7.1 Geology and Soils

Terrain recontouring around abandoned surface facilities may initiate localized hydraulic erosion, shallow thaw settlement and possible bank instability. Drainage and erosion control measures as well as reclamation procedures will be applied to recontoured areas. Physical erosion control measures will include grading to stable slope angles and the construction of berms, berm breaks and water diversion ditches. Surface reclamation measures to reduce thermal degradation and erosion may include erosion control mats, mulches, tree and shrub plantings, as well as application of seed and fertilizer. Assuming these measures, impacts on geology and soils are expected to be LOCALIZED and SHORT-TERM.

5.4.7.2 Vegetation

Reclamation objectives can be achieved by promoting soil stability and encouraging the re-establishment of natural plant communities. Soil stability, as the primary objective of the reclamation program, will form the basis for the revegetation specifications for potentially unstable areas. Structural measures must provide the initial erosion control; however, vegetation soil stabilization will be used to both supplement and protect the structural measures and will aid in the re-establishment of surface stability and the normal soil heat flux regime.

Recontouring of terrain during abandonment of surface facilities will destroy some newly established vegetation but will encourage a more rapid return of vegetation similar to that on surrounding terrain. Drainage and erosion control measures as well as reclamation procedures will be applied to recontoured areas. Physical erosion control measures will include those described in Section 5.4.7.1. Surface reclamation measures may include erosion control mats, mulches, tree and shrub planting, as well as application of seed and fertilizer.

Where erosion is not a problem, the main objective of the reclamation program will be to aid in the re-establishment of the native plant communities. In these areas, high seed and fertilizer application rates may serve only to retard natural recovery; therefore applications will be minimal and used to encourage, rather than substitute for, natural revegetation.

Reclamation schedules will be coordinated with engineering activities so that reclamation can be implemented as soon as possible after clean-up. Reclamation measures will initially focus on controlling erosion. On the basis of erosion potential, surface conditions will be divided into two broad categories, those with a low erosion potential and those with medium to high erosion potential. A third potential category, sites affected by accidental spillage of harmful materials, will also be considered. Contingency plans for containment and clean up of spills are described in Volume 6.

(a) Disturbed Surfaces of Low Erodibility

This category will include areas of the right-of-way where slope angles are low, the soil surface is quite stable and no major waterways are transected and areas required for temporary facilities and borrow sites. Reclamation measures in these areas will likely include revegetation with grass and legume species, and fertilization in order to assist establishment of native species and provide desirable wildlife habitat vegetation cover. Rehabilitation of gravelled areas and borrow sites may require some additional treatment, such as deep ripping, prior to revegetation.

Prior to revegetation, it may be necessary to restore surface drainages across the ditchline, and contour and dyke the right-of-way to avoid excessive ponding of water. The suitability of many species of grasses and legumes for use in reclamation in the Mackenzie Valley has been under study since 1970. Information gained from species and seed mix trials (Dabbs *et al.*, 1974; Younkin, 1976; Hardy Associates, 1980) suggest that two to three seed mixtures combining adapted grasses and a legume would provide an adequate protective cover on areas with low susceptibility to erosion (Plates 5.4-3, 5.4-4, 5.4-5 and 5.4-6).

The species selected would provide the following traits in the seed mixture: tolerance of a cool, short growing season; ability to establish rapidly; tolerance of low nutrient levels; tolerance of a range of soil moisture conditions; ability to allow native species invasion; ability to provide limited above ground growth to minimize fire hazard.

The rate of application would be approximately 50 kg/ha for broadcast methods, however, this may be altered if other application methods are employed or as site conditions prescribe. Because of limited right-of-way access to some sites, aerial broadcasting may be the best method of applying both seed and fertilizer.

Studies of the soils in the area and similar studies elsewhere have shown that nutrient levels are generally low over the entire area (Younkin, 1972, 1976; Janz, 1974; Mitchell and McKendrick, 1974). Therefore, fertilizer will be required to assist the seedlings during establishment. A complete fertilizer, containing nitrogen, phosphorous, potassium and micronutrients, in a formulation determined by standard agronomic analysis of soils collected along the route prior to construction, should be applied at low rates in low erodible areas.

Planting of locally available shrub cuttings, to enhance desirable wildlife habitat, may be feasible where critical habitat has been disturbed. Species of willow have been successfully established from cuttings in the area of the pipeline route (Younkin, 1976).

(b) Disturbed Surfaces of Medium to High Erodibility

Some disturbed surfaces will require more intensive reclamation measures to ensure protection from erosion. These surfaces will be identified on a site-specific basis and may include slopes at major stream and river crossings and most mineral soil surfaces with slopes greater than 3°. A suitable combination of seeding, fertilizing, tree and shrub planting, mulch and tackifier application or erosion control mat placement will likely be applied to stabilize these areas.

PLATE 5.4-3 *Results of seed mixture revegetation studies near Arctic Red River, showing seeded cover produced after the first year (a), and after the fourth year (b). (Source: Hardy Associates, 1980).*

a

b

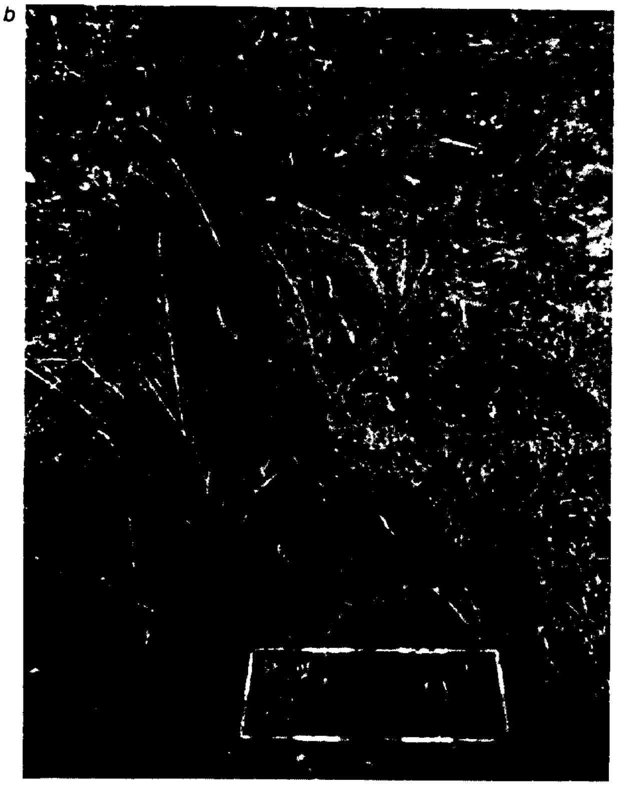
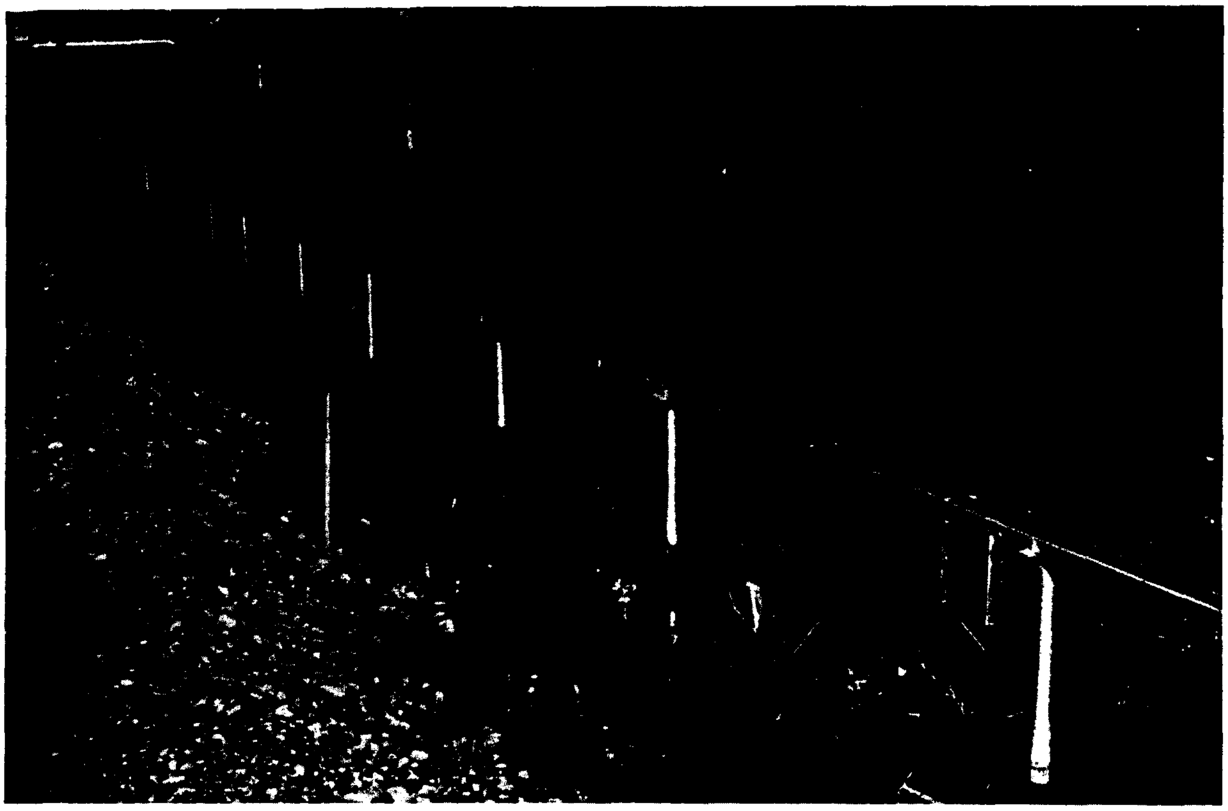


PLATE 5.4-4 *Results of seed mixture revegetation studies near Fort Simpson, showing seeded cover produced after the first year (a) and after four years (b). (Source: Hardy Associates, 1980).*

PLATE 5.4-5 *The ditcher test site near Norman Wells in August, 1981, after five growing seasons. The backfilled ditches are well vegetated with seeded grasses. (Courtesy: Hardy Associates [1978] Ltd.).*

a



b

PLATE 5.4-6 *Species trials for grasses and shrubs at Sans Sault Test Facility area. (a) 1972 (b) 1975 (c) 1981 (d) 1981.*

c

d

PLATE 5.4-6 *Continued.*

Procedures that may be implemented prior to revegetation include: provision of diversion dykes or ditches to guide runoff water off the right-of-way and prevent runoff concentration on the right-of-way; gravel lining or capping of surfaces exposed to rapid water flow; and contouring slopes to appropriate angle and length.

A grass and legume seed mixture which has the same traits as those previously listed will be used. Fertilizer formulation and methods of seeding and fertilizing will likely be similar to those used in areas of low erodibility. On steep slopes and waterway crossings, stem cuttings of willow or aspen may be planted, where locally available, to assist in preventing soil movement.

For highly erodible surfaces, a cover of mulch and tackifier will be applied to protect soils from water erosion and to conserve soil moisture while seedlings are establishing. Mulch materials include cellulose woodfibre for use with a hydromulcher or hay and straw applied with a mechanical blower or spreader. The rate of application would be approximately 1,000 to 1,500 kg/ha woodfibre or 2,000 to 4,000 kg/ha straw, depending on the slope and degree of protection required. Tackifiers would be used with mulch to hold it in place. Suitable types include polymer binders, plant gum binders and netting. Erosion control mats may be considered on the most erodible slopes include polymer binders, plant gum binders and netting. Erosion control mats may be considered on the most erodible slopes.

Reclamation measures will be implemented in winter as soon after construction and cleanup as possible. Planting of shrub and tree cuttings will be done in specified areas following spring thaw. The entire route will be inspected the year following implementation of the reclamation procedures. Areas requiring additional measures will be identified and reclaimed. With the above overall reclamation procedures, the potential impacts resulting from recontouring are considered to be LOCALIZED and SHORT-TERM.

5.4.7.3 Mammals

Recontouring may cause some short-term vegetation removal but in many cases will be done at recent borrow areas, or roads where vegetation is likely to be sparse. The objectives will be to re-establish drainage patterns and generally prepare areas for revegetation. Short-term disturbances will occur, but they will be oriented toward a longer term result which will be beneficial to wildlife. In addition revegetation will tend to reverse the impact of habitat loss caused during site preparation and construction. Some mammals, including meadow voles and ungulates, may be attracted to the initially luxurient vegetation which would result from re-seeding and fertilization of disturbed areas. As native vegetation communities gradually become re-established, the corresponding mammalian fauna will gradually become re-established as well. Because the extent of disturbed areas which will have to be reclaimed will be limited, the beneficial impact on wildlife will be correspondingly limited. Impacts are considered to be NEGLIGIBLE.

5.4.7.4 Birds

Changes in drainage patterns may affect the local distribution of birds, but these changes will be planned in accordance with standard engineering practices so as to prevent serious drainage problems. Revegetation practices may in time reduce edge effects originally produced by activities such as right-of-way clearing. As planted species mature and native vegetation encroaches, there will be a trend toward the original, pre-construction condition. In those areas where habitat gradually reverts to its predevelopment state, avian species composition in the area will also approach pre-development levels. Overall, anticipated impacts will be NEGLIGIBLE.

5.4.7.5 Aquatic Resources

Surface disturbance associated with recontouring of sites, stabilizing stream banks, and removing bridges and culverts will result in incidental sedimentation of adjacent waterbodies. A discussion of the impacts and mitigative measures of reclamation on aquatic resources is provided in Section 3.4.4.6.

5.5 SUMMARY OF IMPACTS FROM PIPELINE DEVELOPMENTS IN THE MACKENZIE VALLEY

The effects of pipelines on resources in the Mackenzie Valley have been summarized by Hunt *et al.* (1974). The authors cautioned on the difficulty of predicting the cumulative effects of various disturbances, the effects of which are generally viewed in isolation. In the following sections anticipated overall impacts on each resource category are estimated as they might result from pipeline developments in the Mackenzie Valley. These overall impacts will arise, not only from construction and eventual physical presence of pipelines and pump stations, but also from operations, maintenance, and monitoring activities.

There is ample space parallel to the Mackenzie River for other pipeline routes in the corridor. The impacts of additional pipelines are not expected to be greater than those for the first pipeline, although alignment criteria may differ. Recommendations to eliminate or minimize cumulative impacts from pipeline developments in the Mackenzie Valley have included better design and operations technology (Berger, 1977) and a corridor development concept within a land use plan (Hunt *et al.*, 1974).

5.5.1 GEOLOGY AND SOILS

Geological and soil materials will be affected by pipeline activities such as vegetation removal, surface soil disruption, gravel borrow and ditching which may cause shallow thaw settlement, drainage alteration, and localized hydraulic erosion and slope failures. Thaw settlement may result in local ponding on the right-of-way.

Drainage alterations and localized hydraulic erosion of surface soils are likely to occur on sloping terrain of the pipeline right-of-way and on adjacent areas. Support facilities such as access roads, borrow pits, and airstrips are expected to cause some drainage alteration and shallow hydraulic erosion. These effects can be minimized with the application of appropriate drainage and erosion control measures. The overall impact of additional parallel pipeline routes on drainage alterations and erosion is expected to be LOCALIZED and SHORT-TERM.

The potential for slope failure is greatest in fine grained ice-rich soils on sloping landforms. In the event of a pipeline rupture due to a slope failure, emergency repairs would be necessary, and this activity could result in additional terrain damage. The overall impact of additional parallel pipeline routes could aggravate stability problems on slopes, but effects are likely to be LOCALIZED and SHORT-TERM.

5.5.2 HYDROLOGY AND WATER QUALITY

Stream flow and water quality will be unavoidably affected by several pipeline construction and operation activities such as ditching, stream crossing, and permanent access roads which may cause drainage alterations and siltation. The mitigative measures outlined previously will minimize these effects. The overall impacts of additional parallel pipeline routes on drainage alteration are expected to be LOCALIZED and SHORT-TERM.

5.5.3 ATMOSPHERIC ENVIRONMENT

The construction and operation of the pipeline will result in small localized increases in noise, air emissions and ice fog. In the event of inversion conditions, plant emissions as well as ice fog may be trapped near ground level for a brief period of time. The duration and extent of this condition will depend on the duration of the cold spell, prevailing wind conditions, and strength of the inversion. High exhaust temperature and emission velocity will cause ice fog at elevations well above ground levels, where it will be dispersed by air currents. The overall impacts of additional parallel pipeline routes and compressor stations on air quality are expected to be LOCALIZED.

5.5.4 VEGETATION

Vegetation will be removed or destroyed on all permanent facility sites including permanent roads, pump station sites, and permanent camps during the lifetime of the pipeline. The impact of this disturbance is considered LOCALIZED due to the small area involved. All temporary facility locations and the pipeline right-of-way will be revegetated to restore plant cover within a short period of time. However, in the forested area, trees and tall shrubs will be kept from growing in the right-of-way for the life of the pipeline. The overall impact of additional parallel pipeline routes along the Mackenzie Valley on vegetation would be rated as LOCALIZED.

The disturbance to the soil rooting zone due to pipeline construction activities may affect surface stability and thus decrease revegetation success. The removal of the natural vegetation and surface organic layer may initiate localized hydraulic erosion, slope failure, and thermal erosion. The possible effects on vegetation will be LOCALIZED. The construction and operation of additional pipelines may increase soil disturbance and instability, however the impact is likely to be LOCALIZED and SHORT-TERM.

5.5.5 MAMMALS

Impacts on wildlife from the numerous pipeline-associated activities are best understood by the following impact categories: habitat alteration, disruption of movements, disturbance, and direct mortality.

5.5.5.1 Reindeer

Interactions between reindeer and pipeline activities will occur within the western portion of the Mackenzie Reindeer Grazing Reserve. This area south of Richards Island has been used in recent years as winter range and calving range for the reindeer herd. The small number of feral reindeer currently inhabiting Richards Island would come in contact with the pipeline corridor there. The reindeer herd may also utilize the pipeline corridor on Richards Island because of possible range expansion within the Grazing Reserve. Unherded movements of the reindeer herd may be initially disrupted by the elevated pipeline although they will probably adapt quickly because of their frequent exposure to human activity. The Nelchina and Central Arctic caribou herds in Alaska do not appear to have suffered as a result of an elevated oil pipeline across their range. Herded movements will be less likely to be disrupted than unherded movements because of the possibility of choosing the best crossing areas and because of the additional motivation reindeer will have to cross the pipeline.

Other possible barriers to reindeer movements include the open pipeline ditch, strung pipe and intensive construction activity along sections of the pipeline route. Because of the relatively short length and duration of these potential barriers in any particular portion of the right-of-way, they are not considered to be of great concern with regard to the welfare of the reindeer herd. In addition, herd movements can be controlled to avoid such areas if necessary.

Disturbance caused by human activity, land-based vehicles, aircraft, and blasting will be largely restricted to the pipeline corridor and will be intensive for only the relatively short construction period. If reindeer are using the pipeline corridor area at this time, they will be locally displaced near areas of activity. This is not expected to significantly affect the reindeer herd because they are accustomed to human activity, snow machines, and aircraft during herding. Displacement can be easily minimized by planning the range use patterns, to be executed by herding, in advance of pipeline construction. The low level of disturbance resulting from maintenance activities and inspection flights along the pipeline right-of-way and at pump station and other facility sites during the operations period is not expected to significantly affect reindeer range use or movements. Likewise, habitat lost to the pipeline right-of-way, facility sites, borrow sites, roads, etc. will affect such a small portion of the available range that it will be insignificant to the population. Additional access provided by the right-of-way and temporary and permanent roads, and the human population influx to the Mackenzie Delta as a result of the project may cause increased poaching of reindeer. It may be necessary to increase the intensity of patrols of the herd.

In general, construction and operation of the pipeline is expected to have a MINOR effect on the reindeer herd. Because the herd is managed more intensively than herds of wild caribou, possible impacts can be minimized with herding and other management procedures.

5.5.5.2 The Bluenose Caribou Herd

The pipeline corridor traverses the western extremity of the winter range of the Bluenose herd. The most frequently used winter range of the herd lies to the east of the corridor (Volume 3C). The western expansion of the winter range of the herd, discussed at the Mackenzie Valley Pipeline Inquiry and by Hawley *et al.* (1976), did not continue in 1975-76 and 1976-77 when caribou ranged only as far west as the Kugaluk River (Wooley and Mair, 1977). It is therefore unlikely that large numbers of Bluenose caribou will encounter the pipeline.

The few caribou which may winter over the pipeline route will be exposed to aircraft traffic, land-based vehicles, stationary machinery, human activity and possibly blasting. These disturbances, which will be greatest during the relatively short period of construction in this area, will result in local displacement of caribou near areas of activity. Habitat lost to the right-of-way, facility sites, borrow sites, and roads, will affect such a small proportion of the available winter range that it will be insignificant to the population. Concern with the possible barrier effect of the elevated pipeline is allayed by the fact that the pipeline will be at the western edge of the range of the Bluenose herd and that sufficiently elevated pipelines have not prevented caribou of the Nelchina and Central Arctic herds in Alaska from moving across the Alyeska Pipeline nor have the populations of these herds suffered as a result of the pipeline. Klein (1980) suggested that caribou appear to be less disturbed by elevated pipelines in forested terrain and cross under them more readily than in open tundra.

Access provided by the pipeline right-of-way and temporary and permanent roads may result in some increased hunting of the Bluenose herd. However, the impact on the herd is expected to be MINOR because of the small number of caribou which use the area.

5.5.5.3 Woodland Caribou

Woodland caribou are likely to be rarely encountered in the Mackenzie Valley because of the lack of suitable habitat in the vicinity of the pipeline corridor. Interactions with woodland caribou are, however, likely to occur along the section of the pipeline corridor south of Fort Simpson between the Redknife Hills and Bistcho Lake areas. In this area, some habitat will be lost directly to facility sites and the pipeline right-of-way. However because of the plan to use existing rights-of-way and clearings wherever possible, these losses will be very small. In any case, habitat alteration is expected to affect such a small proportion of the total available caribou habitat that the effect will be insignificant on the population. It is assumed that the potential for habitat alteration which may result from fire will be successfully mitigated. Thus, no significant impacts on caribou populations are expected to result from habitat alteration by the project. Structural alterations of the habitat, such as borrow pits or open ditch, are anticipated to produce only highly localized effects on movements of caribou and will not, therefore, significantly affect populations. Within woodland caribou range, most of the pipeline will be buried and is therefore of little concern as a potential barrier. Elevated sections will be either circumvented or crossed under, as caribou of the Nelchina and Central Arctic herds cross under the Alyeska Pipeline. Slash windrows along the right-of-way will not be continuous or high enough to result in a barrier to caribou movements across the right-of-way. The observed use of seismic lines and other rights-of-way by barren-ground caribou (McCourt *et al.*, 1974) suggests that a cleared pipeline right-of-way may actually facilitate travel by caribou in winter.

Pipeline construction within caribou range may expose some caribou to sources of sensory disturbances such as aircraft, land vehicles, blasting, and personnel. These disturbances will cause caribou to avoid the immediate vicinity of the corridor but will likely affect very few animals because of the dispersed nature of the caribou populations and the very confined area of the disturbance. Moreover, several mitigative measures, including restrictions governing aircraft flights, will be adopted to reduce the level of disturbance along the corridor during both construction and operation. Therefore, anticipated impacts of sensory disturbance on the woodland caribou population are NEGLIGIBLE.

Increased access may result in increased hunting of woodland caribou in the Redknife Hills and Bistcho Lake areas. However, the additional access will be minimized by using existing rights-of-way wherever possible. Since there is a relatively low density of caribou in this area, increased access may have a MINOR effect on the population.

Other impacts may result from accidents involving hazardous substances or collisions. Because of the linear nature of the pipeline activities and the low densities and dispersed nature of the caribou population, very few, if any, caribou are expected to be involved. Specific mitigative measures which have been adopted to reduce accidental deaths of caribou and other wildlife include regulations governing movements of vehicles, fencing of facility sites, and procedures governing backfilling of excavated trench.

In conclusion, although there will be unavoidable adverse impacts on woodland caribou, overall effects on the caribou population are expected to be MINOR.

5.5.5.4 Moose

Moose populations will be affected by habitat alteration and disturbance along almost the entire pipeline corridor. The net effect of most vegetation alterations associated with the project will be to temporarily produce seral vegetation favored by moose. The total amount of moose habitat which will be altered will be insignificant compared to the total available habitat.

Structural alterations of habitat are, in most cases, expected to be highly localized and are not expected to interfere with moose movements. Some sections of elevated pipeline paralleling the Mackenzie River could disrupt annual movements to and from their winter range on Mackenzie River islands. However, as with the Alyeska Pipeline, moose movements in the Mackenzie Valley will not be obstructed by a sufficiently elevated pipeline. Slash piles along the right-of-way, if they exist, will not be high enough or continuous enough to significantly disrupt moose movements. Sections of open ditch or strung pipe are not likely to persist long enough to delay moose movements to such an extent that the animals would be harmed.

Moose are generally not considered to be particularly susceptible to sensory disturbances. Although only a few moose will be exposed to disturbances associated with the pipeline development, some habitat will be avoided by moose near the corridor. A few moose may be killed as a result of vehicle collisions. Mitigative measures adopted to reduce sensory disturbances have been discussed in the previous section on caribou. These measures, together with route selection to avoid most of the important winter range for moose in the Mackenzie Valley, will ensure that impacts of sensory disturbance on moose will be NEGLIGIBLE.

Access provided by the pipeline right-of-way and temporary and permanent access roads, as well as the increase in human population resulting from the development may result in local increased hunting of moose. The density of moose in the vicinity of most Mackenzie Valley communities already appears depressed as a result of overharvesting. Without stringent control of hunting, the moose population in the Mackenzie Valley may be further depleted. If the human population increases in response to industrial activity, and access is increased to previously inaccessible areas, the impact from increased hunting pressure on moose could be locally MODERATE. New wildlife management measures could be developed to mitigate this impact.

5.5.5.5 Deer

White-tailed deer and mule deer will be subject to impacts as a result of habitat loss, disturbance, and barriers to movement. As is the case with other ungulates, these effects will be very localized. The net effect of development on deer populations is likely to be less than the effect on moose and caribou populations, because of the low density of deer and lack of migratory movements, which will contribute to fewer interactions. Overall, effects of development on deer will be NEGLIGIBLE.

5.5.5.6 Grizzly Bear

Interactions between grizzly bears and activities associated with construction and operation of the pipeline will occur primarily along the northernmost portion of the pipeline route. Habitat loss will be insignificant in proportion to the habitat available and all known den sites will be avoided. Disturbances from aircraft, machinery, and human activity along the pipeline route and at associated facilities will cause some local displacement and result in some stress reactions by bears, but will not likely have significant effects on the population. The greatest source of impact will be mortality of "problem bears" attracted to facilities and of those hunted for sport. Despite mitigative measures which have been adopted regarding waste disposal and the handling of problem bears, it is likely that some bears will be killed during the construction phase. However, winter construction should minimize interactions with bears.

It is expected that very few bears will be killed during the operations phase because few facilities which could attract bears will be located along the route within grizzly bear habitat. However, some bears may be encountered by personnel engaged in surveillance, monitoring, and maintenance activities. Improved access and the increased human population in the Mackenzie delta region would tend to increase hunting pressure on grizzly bears. In view of current regulations governing the numbers of bears which may be harvested, increased hunting pressure will not increase the legal harvest of bears but may result in some illegal harvest. The net effect will probably be a MODERATE impact on grizzly bears in the Mackenzie Delta area and MINOR in the Mackenzie Valley.

5.5.5.7 Black Bear

Black bears are widely dispersed throughout forested areas adjacent to the pipeline corridor, making it unlikely that a significant proportion of the black bear population will interact with the pipeline facilities. The general effects of interactions will be similar to the effects of interactions on grizzly bears. Habitat loss and sensory disturbance will have little effect. Some bears attracted to construction camps will probably be killed, although winter construction will minimize the incidence of problem bears. Greater access and increased number of hunters may also result in increased harvest of bears. Because of the widely dispersed distribution of bears and their relatively high reproductive potential, additional mortality of bears is not expected to have more than a MINOR effect on the population.

5.5.5.8 Aquatic Furbearers

(a) Beaver

Beaver populations are widely dispersed and will not be affected much by habitat alteration. Some local areas of short-term habitat loss will occur as a result of vegetation removal and alteration of drainage or water levels. However, beaver are adapted to early growth stages of vegetation and are capable of controlling drainage and water levels upon which they are dependent, so any adverse effects will be short-lived. Beaver are also relatively insensitive to sensory disturbances.

Increased access is also a concern, albeit a minor one, in areas where no access now exists. Beaver are susceptible to overharvesting and there is therefore the potential for local depletions along the pipeline corridor. The net effects on beaver are expected to be MINOR.

(b) Muskrat

The possible effects of the project on muskrat will be similar to those on beaver. However, because of the wide distribution of muskrats and their very high reproductive potential, development is likely to have only a MINOR effect on the muskrat population.

(c) Mink

The effects of development on mink will be similar to those on beaver and muskrat and are expected to have a MINOR effect on the population.

5.5.5.9 Terrestrial Furbearers

(a) Arctic Fox

Arctic fox, which only inhabit the northernmost portion of the pipeline corridor, are widely dispersed and not particularly abundant. Interactions with pipeline construction and operation activities will therefore likely be infrequent. Since few den sites occur in the area, chances of destruction of den sites are low. Some foxes may be attracted to construction camps and may be killed if they appear rabid. The possibility that foxes may become dependent on camp garbage or handouts and be unable to fend for themselves when the camp is abandoned is remote because of proposed methods of garbage disposal and regulations against feeding any wildlife. The increased human population during at least the construction period may result in some increased hunting and trapping of Arctic fox but is unlikely to significantly affect the population.

The total impact of all effects of pipeline construction and operation activities on the Arctic fox population is expected to be MINOR.

(b) Red Fox

Because of the widely dispersed nature of the red fox population, interactions will not occur with a significant proportion of the population. As with Arctic fox, the most important impacts could involve destruction of den sites, attraction to camps, and some increased hunting and trapping. These effects on the red fox population are expected to be MINOR.

(c) Lynx

Lynx are expected to be little affected by habitat loss and disturbance. Improved access may result in local depletion of lynx if the population cycle is low. If this does occur, the population will recover rapidly when the snowshoe hare population rises because of the high reproductive capacity of lynx when the food supply is adequate. The overall effect on the lynx population is expected to be MINOR.

(d) Marten

The widely dispersed nature of the marten population and the relatively small home ranges of individual marten will result in interactions with a small portion of the population in the Mackenzie Valley. Marten are not particularly susceptible to disturbance, perhaps because their relatively small size enables them to easily find security in escape cover. A very small fraction of the available marten habitat would be altered. The impact of greatest concern will probably arise from improved access. This may cause local depletion of marten due to overharvesting. However, because it is likely to happen in only a few areas, and because the effect will extend only to the width of the average home range of marten (approximately one kilometre), the effect on the population is expected to be MINOR.

(e) Wolf

Habitat alteration will have little impact on wolves. They often follow transportation rights-of-way when hunting (Mech, 1970; Peters & Mech, 1975; Horesji, 1979). Their food supply may be depleted in local areas as a result of over-harvesting of caribou and moose by hunters in areas where access is improved. Since these effects on ungulates are expected to be minor, the effect on the wolf population is also expected to be minor. Wolves may be occasionally affected by disturbance of den sites or rendezvous sites. Improved access and the increased human population may result in a greater harvest of wolves. In view of their relatively high reproduction potential, this increased harvest is unlikely to have a significant effect on the wolf population. The net result of all effects is likely to be a MINOR impact on the wolf population.

5.5.5.10 Other Furbearing Mammals

Populations of other furbearing mammals in the Mackenzie Valley corridor, such as weasels, squirrel, wolverine, fisher, otter and coyote, are generally widely dispersed. As a result, only very small fractions of the populations of these mammals are likely to be affected by pipeline development. Habitat alteration and disturbance will therefore have NEGLIGIBLE impacts. Increased access may result in local depletion of numbers of species susceptible to over-harvesting. The effect on regional populations may therefore be MINOR.

5.5.5.11 Other Terrestrial Mammals

Populations of other mammals, such as shrews, small rodents and hares, are widely dispersed. Only insignificant proportions of the populations of these mammals are expected to interact with pipeline development and therefore impacts on populations of these species are anticipated to be MINOR.

5.5.6 BIRDS

More than 170 species of birds occur in the Mackenzie Valley region each year (Volume 3C). A few, such as willow ptarmigan and common raven, are year-round residents; most others migrate northward into the region in spring, and some continue to more northerly breeding grounds while many others remain to nest. A return migration southward begins for some as early as late June and continues through the fall into October. The Mackenzie Valley region has continental importance for birds as a migration corridor and as a relatively undisturbed area for breeding, nesting, raising young, and moulting. Also, the Mackenzie Delta is of continental importance, particularly for waterfowl and shorebirds.

Pipeline construction and operation activities in the Mackenzie Valley raise concerns primarily for waterfowl, because of their vulnerability when concentrated in flocks at certain seasons, and raptors, because of the low numbers of some species and their known sensitivity to disturbance. Impacts on waterfowl and raptors can arise as a result of disturbances caused by noise from aircraft and vehicles, human presence, long term habitat loss or modification, increased hunting pressure, and the possibility of oil spills. The most effective mitigative measures to protect both raptors and waterfowl would be to locate the right-of-way and facilities remote from known raptor nests as suggested by Roseneau *et al.* (1981) and to avoid river habitats important to swans and geese during the spring migration. Other mitigative measures include: winter scheduling (October 16 to April 15) when most birds are absent; strict enforcement of regulations; and an effective oil spill prevention and contingency clean-up program. Specific details of measures to protect raptors and waterfowl will be finalized in compliance with wildlife ordinances and in consultation with appropriate regulatory agencies. Given the general sensitivity of raptors to disturbances and the low population levels of some species, the overall impacts to raptors are generally considered MINOR but could approach MODERATE in localized areas. Overall impacts on waterfowl are generally expected to be NEGLIGIBLE but could approach MINOR in localized areas.

5.5.7 AQUATIC RESOURCES

5.5.7.1 Sedimentation

All development activities resulting in disturbance of stream substrates, banks, or watersheds, will tend to increase the total sediment loads in waterbodies within the region. In most streams sedimentation is also a natural phenomenon, and, depending on the timing, concentration, and duration, sediment introductions may have few detrimental effects on the aquatic biota. The Mackenzie Valley Inquiry (Berger, 1977), in suggesting sediment standards, recognized the importance of both concentration and duration of sediment input in assessing any potential effects. Though arbitrary, these standards recognize the ability of aquatic organisms to tolerate longer term siltation when concentrations are low and to tolerate short-term exposure to high concentrations.

Even with an aggressive program of inspection, reclamation, and revegetation, failures in stream banks, slopes, and erosion control methods will continue to add some suspended sediments to the total hydrological load throughout the life of the pipeline development. In general, sediment contributed by the development will be associated with acute erosion problems, which means that any effects will usually be both local and short-term. Unless sedimentation becomes generalized or chronic at a single location, recovery of both lower trophic levels and fish will be rapid. Fish populations in the region are well-adapted to brief periods of extremely high sediment concentrations during sensitive periods of their life histories. Because of the scouring that occurs in high-energy streams and rivers, and the tendency of aquatic biota to recover rapidly from the effects of sediment introductions, no long-term effects of sedimentation are anticipated.

Although a few localized reductions in fish populations are probable, the overall effect of all sediment introductions on fish populations in the region is likely to be MINOR.

5.5.7.2 Habitat Modification

Stream crossings, access roads, stream training structures, spills of toxic materials, sediment introductions, and other environmental modifications that accompany development will cause alteration or loss of some aquatic habitat. Although a few of these modifications will have beneficial effects, the majority will reduce habitat quality.

Most aquatic habitats disturbed by pipeline development serve primarily as summer feeding habitats, and cumulatively, all pipeline-related disturbances will affect only a very small percentage of total available feeding habitat. As a rule, large fish will readily seek alternate habitat if unsuitable conditions are encountered. Of greater concern are habitats for spawning, rearing, and overwintering. In these areas, alternate habitat may be limited, and fish are often concentrated in confined areas. If pipeline development causes reductions in habitat quality here, regional populations could be detrimentally affected.

To reduce the possibility of disturbance to sensitive upstream fish habitats, developments in the corridor will be located to minimize the number of stream crossings, to avoid lakes, and to cross most Mackenzie tributary streams near their mouths. Of the spawning, rearing, and overwintering areas identified in the region to date, few occur directly on the general pipeline alignment. Although most of the streams crossed by the alignment serve as migratory routes for fish moving to and from sensitive habitats, it is not anticipated that habitat modifications associated with pipeline development will interfere with these migrations. Since natural hydraulic processes will quickly return most habitats to almost their original configuration, many habitat modifications will be extremely short-term, often less than one year. Given the small amount of habitat affected, the even smaller amount of sensitive habitat involved, and the brief duration of most habitat modifications, the cumulative effect of pipeline activities on fish habitat will be NEGLIGIBLE.

5.5.7.3 Direct Mortality

In addition to the indirect effects of sediments on eggs and juvenile fish, the operation of machinery, spills of toxic materials, blasting in streams, entrapment, and blockage of passage to and from critical habitats will cause direct mortality to fish. Were all these disturbances to occur at a single location, their collective effect would undoubtedly cause a considerable reduction in local populations; however, these disturbances will be dispersed over the entire length of the Mackenzie River corridor, and will not all affect a single area at any one time.

Individually, construction activities causing direct mortality will result in local, short-term effects on fish populations. With the exception of a major crude oil spill (discussed in Volume 6), the duration of the effect in each case is brief, and recovery will generally occur in a single generation or less. Collectively, these effects will also result in only short-term local declines in fish populations, and the effects are consequently rated as MINOR.

5.5.7.4 Increased Angling Pressure

Throughout the life of the project, the increased number of people in previously inaccessible areas, both pipeline-related personnel and residents, will result in increased angling pressure in sensitive areas. Lake trout populations, by virtue of their slow growth and low recruitment rates, will be most sensitive to increased fishing pressure and, without stringent measures to control angling pressure, will suffer local declines. Grayling, though considerably more tolerant of angling pressure than lake trout, may display some local declines in both size and abundance. Because of their widespread regional distribution, however, overall population levels of this species are not expected to be affected. Other species in the region are less vulnerable to angling pressure, and increased fishing pressure is not expected to affect them.

No all-weather road will be constructed beside the pipeline right-of-way. Hence the total number of areas made accessible by the pipeline is expected to be small. With appropriate regulatory controls, the cumulative effects attributable to increased angling pressure will be NEGLIGIBLE.

5.5.7.5 Water Requirements

Projected water requirements for the four year construction period total 43,000,000 m^3, including the water requirements of personnel, hydrostatic testing, winter road construction, and other incidental uses. Thereafter, water requirements will drop to only that needed for operation and maintenance of facilities and support of personnel. Since the greatest water volumes will be required for hydrostatic testing and road construction during winter months, water availability may become a problem in a few areas, particularly where facilities are located a considerable distance from the Mackenzie River.

Water withdrawals from areas providing overwintering habitat for fish can cause fish mortality by dewatering habitat or reducing dissolved oxygen concentrations. This concern does not apply to the Mackenzie River mainstem where there is an abundant year-round water supply. Smaller tributary streams, however, are of concern since water availability is often only sufficient to meet the needs of overwintering fish. Some of these areas may also serve as spawning areas for fall-spawning species. Of particular concern are suspected overwintering areas listed in Volume 3C, since most of these streams contain only very limited winter water volumes.

Development plans call for selection of water withdrawal sites in consultation with regulatory agencies. Where water availability is in doubt, studies of water availability and the status of overwintering fish will be necessary prior to any decision regarding water withdrawals. Assuming that proper consideration is given to overwintering fish and water requirements can be met without endangering local fish populations, the effect of water withdrawals will be NEGLIGIBLE.

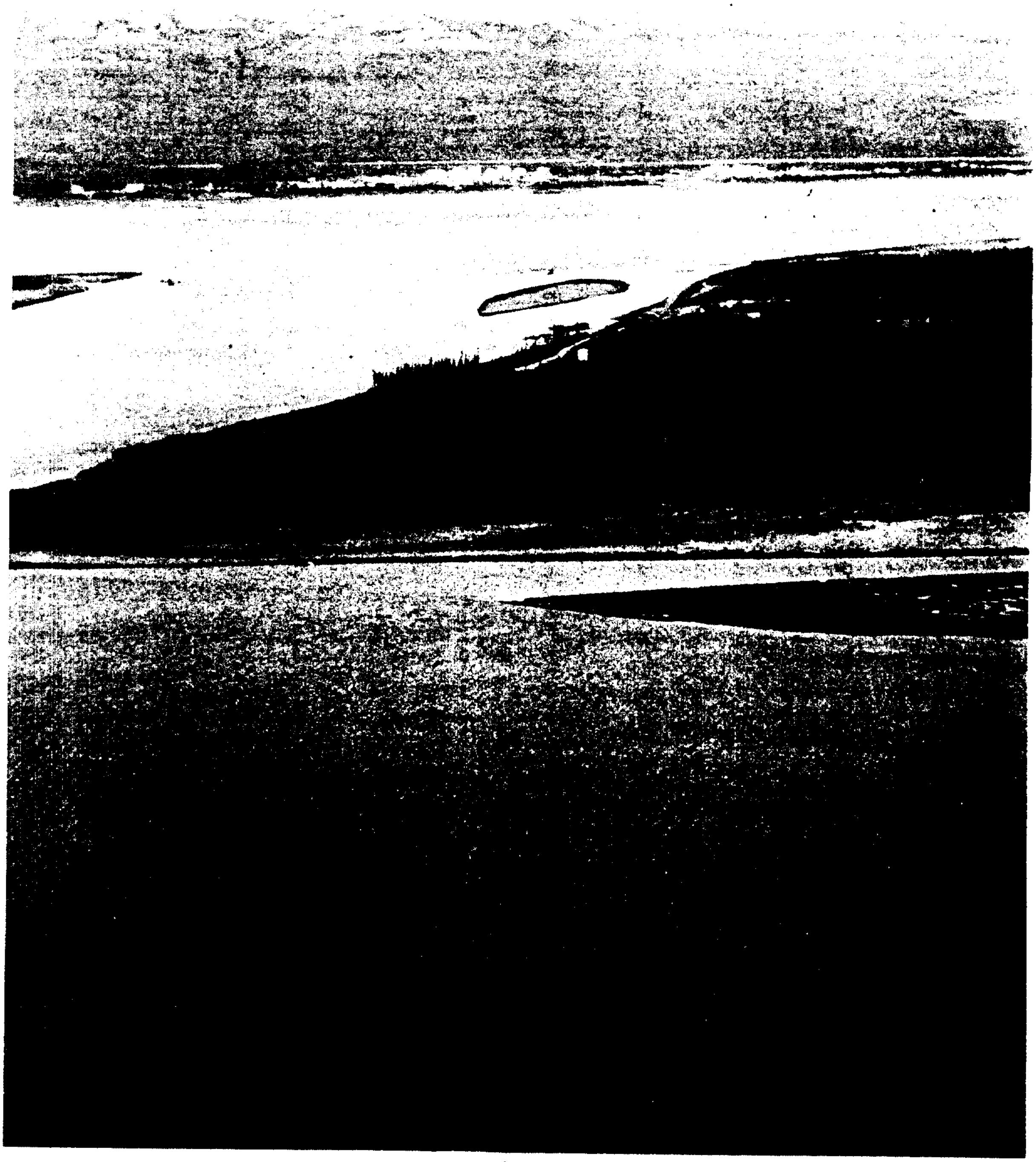
5.5.7.6 Reduced Productivity of Lower Trophic Levels

Sedimentation, nutrient enrichment, and spills of toxic materials can alter the productivity of lower trophic levels and have indirect effects on consumer organisms. With the exception of the spills discussed in Volume 6, however, such disturbances will only affect lower trophic levels in the immediate vicinity of development facilities.

Limited nutrient enrichment from sewage discharge will increase productivity of certain lower trophic levels, and sedimentation and toxic spills will cause reductions in numbers at most trophic levels. All these disturbances will alter community structure, an alteration which may affect the feeding distribution of local fish populations. Because they can quickly recolonize disturbed areas from nearby unaffected areas, lower trophic levels recover rapidly from disturbance, often in a single generation. Many species also display a high reproductive potential, often producing multiple generations in a single year, and are capable of repopulating a depleted area quickly once a disturbance has abated.

With the exception of large hydrocarbon spills and sewage introductions at permanent facilities, disturbances affecting lower trophic levels will be short-term, generally affecting an area for less than one season. Until populations of prey organisms have recovered sufficiently to provide an adequate food supply, fish feeding in an affected area may temporarily seek alternative habitats. These local redistributions, however, have little significance and fish will quickly return to disturbed areas once lower trophic levels are replenished.

In this region, the distribution of communities of consumer organisms (algae, zooplankton, and zoobenthos) is cosmopolitan, so it is unlikely that disturbance will affect any unique feature of their distribution. Most disturbance will be both local in effect and brief in duration. Given the rapid recovery rate of the lower trophic levels and the limited effects on the distribution of consumer organisms, the overall effect will be MINOR.



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5.6.2 UNPUBLISHED DATA

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