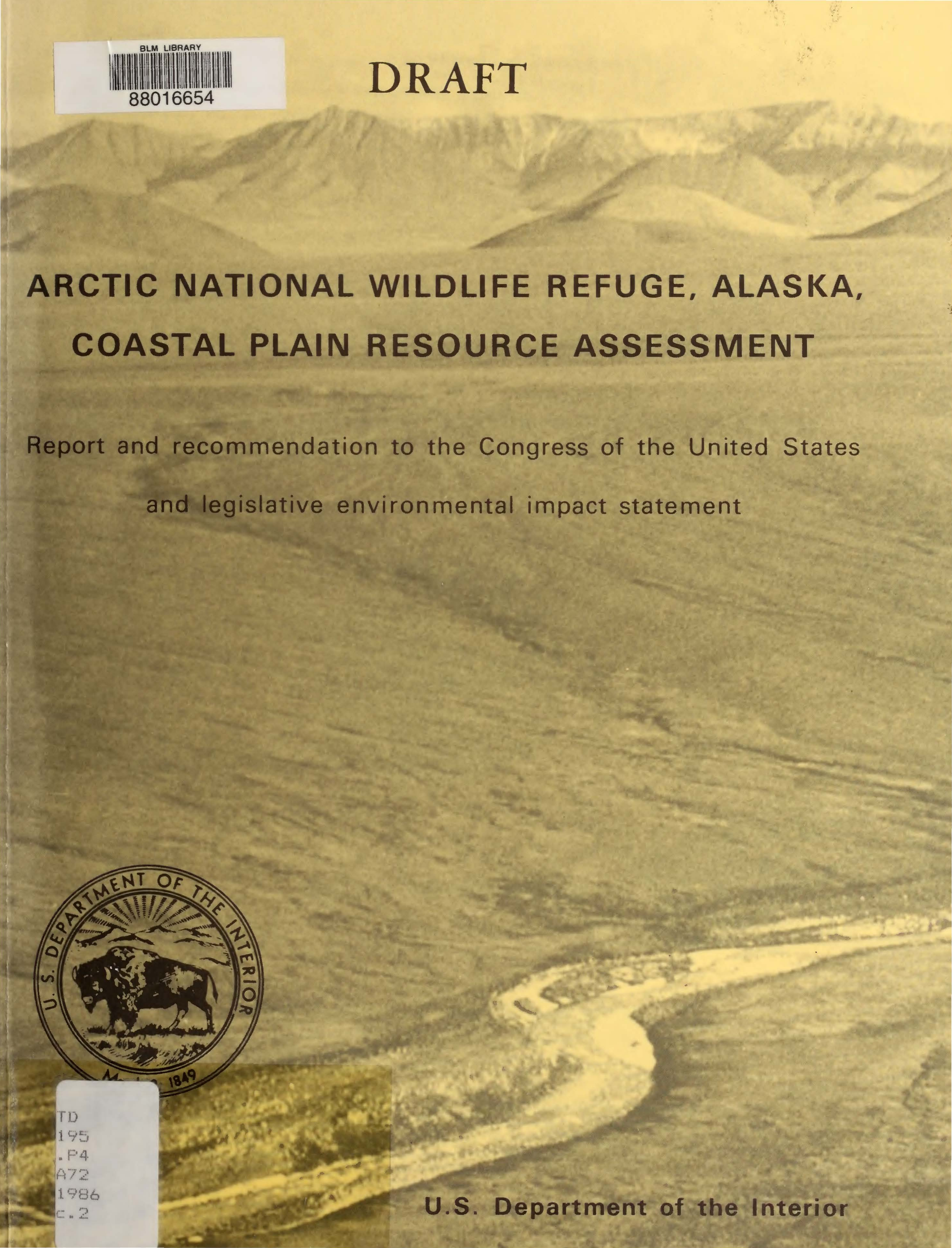
DRAFT

# ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

Report and recommendation to the Congress of the United States

and legislative environmental impact statement





U.S. Department of the Interior

UNITED STATES

DEPARTMENT OF THE INTERIOR

# DRAFT

# ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

## Report and recommendation to the Congress of the United States and legislative environmental impact statement

NOVEMBER 1986

In accordance with Section 1002 of the Alaska National Interest Lands Conservation Act, and the National Environmental Policy Act

Prepared by the U.S. Fish and Wildlife Service
in cooperation with the U.S. Geological Survey
and the Bureau of Land Management

**DRAFT ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA,
COASTAL PLAIN RESOURCE ASSESSMENT**

**Report and recommendation to the Congress of the United States
and legislative environmental impact statement
November 1986**

Copies are available from:

Noreen Clough
Division of Refuge Management
U.S. Fish and Wildlife Service
18th & C Streets, N.W., Room 2343
Washington, D.C. 20240

Clayton Hardy
Division of Planning
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

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## COVER PHOTOGRAPH

A typical view southward across the coastal plain toward the foothills and the Brooks Range.

# United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

November 1986

Dear Reader:

This resource assessment of the coastal plain of the Arctic National Wildlife Refuge, Alaska, has been prepared to fulfill the requirements of Section 1002(h) of the Alaska National Interest Lands Conservation Act. A legislative environmental impact statement has been integrated into the report to satisfy the requirements of the National Environmental Policy Act. The report culminates more than 5 years of biological baseline studies, surface geological studies, and two seasons of seismic exploration surveys. The analyses of the data represent the exhaustive efforts of more than 50 scientists of the Department of the Interior.

Section 1002(h)(6) asks for a recommendation as to whether or not the coastal plain should be opened for oil and gas activity. To assist in making this recommendation, the report analyzes a range of alternatives for management of the Arctic Refuge coastal plain: leasing the entire area for oil and gas development; leasing a limited area; permitting additional exploration, to include exploratory wells; taking no action regarding oil and gas activity but including the area in the comprehensive conservation planning process for the entire refuge; or designating the coastal plain as wilderness. The potential environmental consequences of implementing these alternatives are also examined.

Based on the analyses presented, on the national need for domestic sources of oil and gas, and on the ability of industry to minimize damage as learned from oil and gas activities elsewhere in the Alaskan Arctic, I am proposing full leasing of the coastal plain. To afford the special protection necessary to conserve the high natural resource values of the coastal plain, the recommendation asks for authority to impose restrictions to ensure environmental integrity during oil and gas operations. Development must result in no unnecessary adverse effects, and unavoidable habitat losses should be fully compensated.

Your views and opinions on this draft report are solicited to assist the Secretary in making his final decision. Comments will be responded to and included as a part of the final report to the Congress. Please send your written comments to the U.S. Fish and Wildlife Service, Attn: Division of Refuge Management, 2343 Main Interior Bldg., 18th and C Sts., N.W., Washington, D.C. 20240.

The Secretary of the Interior will make the final recommendation, but the ultimate decision for the management of the Arctic Refuge coastal plain is for the Congress to make.

Sincerely yours,

William P. Horn

WILLIAM P. HORN
Assistant Secretary for Fish and Wildlife and Parks

**ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT**
**Draft legislative environmental impact statement, 1986**

## CONTRIBUTORS TO THE REPORT

Members of Interagency Advisory Work Group
Noreen CLOUGH, FWS, IAWG leader
Clayton HARDY, FWS, IAWG Regional co-leader

Fish and Wildlife Service:
Glenn W. ELISON
Emil T. HEUER, Jr.

U.S. Geological Survey
Max C. BREWER
Oswald GIRARD
Dudley D. RICE

Bureau of Land Management:
James E. CALLAHAN
Arlan H. KOHL
Robert O. SCHROTT
Jules V. TILESTON

---

Priscilla C. PATTON, BLM, Geologist, Report Editor
Ann Coe CHRISTIANSEN, USGS, Geologist, Report Editor

### CHAPTER I. PURPOSE AND NEED FOR THIS REPORT

| | | | |
|---|---|---|---|
| Clayton HARDY | FWS | Program analyst | Anchorage, AK |
| Emil T. HEUER | FWS | Wildlife biologist | Anchorage, AK |

### CHAPTER II. EXISTING ENVIRONMENT

| | | | |
|---|---|---|---|
| Michael J. AMARAL | FWS | Wildlife biologist | Anchorage, AK |
| Steven C. AMSTRUP | FWS | Wildlife biologist | Anchorage, AK |
| Alan W. BRACKNEY | FWS | Wildlife biologist | Fairbanks, AK |
| Max C BREWER | USGS | Geologist/geophysicist | Anchorage, AK |
| Charles E. DIETERS | FWS | Archeologist | Anchorage, AK |
| Glenn W. ELISON | FWS | Arctic Refuge Manager/Wildlife biologist | Fairbanks, AK |
| Nancy A. FELIX | FWS | Botanist | Fairbanks, AK |
| Douglas J. FRUGE | FWS | Zoologist | Fairbanks, AK |
| Gerald W. GARNER | FWS | Wildlife biologist | Fairbanks, AK |
| Donald P. GARRETT | FWS | Wildlife biologist | Fairbanks, AK |
| Libby HALPIN | FWS | Wildlife biologist | Anchorage, AK |
| Clayton HARDY | FWS | Program analyst | Anchorage, AK |
| Emil T. HEUER, Jr. | FWS | Wildlife biologist | Anchorage, AK |
| William L. KIRK | FWS | Botanist | Anchorage, AK |
| Danial J. LaPLANT | FWS | Wildlife biologist | Fairbanks, AK |
| Robert R. REEDY | FWS | Wildlife biologist | Anchorage, AK |
| William H. MATTICE | FWS | Realty specialist | Anchorage, AK |
| Frances J. MAUER | FWS | Wildlife biologist | Fairbanks, AK |
| Russell M. OATES | FWS | Wildlife biologist | Fairbanks, AK |
| Larry W. PANK | FWS | Research biologist | Fairbanks, AK |
| Ann G. RAPPOPORT | FWS | Wildlife biologist/Assessment leader | Anchorage, AK |
| Gerald REID | FWS | Wildlife biologist | Anchorage, AK |
| Patricia E. REYNOLDS | FWS | Wildlife biologist | Fairbanks, AK |
| Scott L. SCHLIEBE | FWS | Biologist | Anchorage, AK |
| Jules V. TILESTON | BLM | Resource Specialist | Anchorage, AK |
| Gregory J. WEILER | FWS | Wildlife biologist | Fairbanks, AK |
| Robin L. WEST | FWS | Fisheries biologist | Fairbanks, AK |

## CHAPTER III. ASSESSMENT OF OIL AND GAS POTENTIAL AND PETROLEUM GEOLOGY OF THE 1002 AREA

| | | | |
|---|---|---|---|
| Donald E. ANDERS | USGS | Chemist | Denver, CO |
| Arthur C. BANET, Jr. | BLM | Geologist | Anchorage, AK |
| Robert J. BASCLE | BLM | Geologist | Anchorage, AK |
| Kenneth J. BIRD | USGS | Geologist | Menlo Park, CA |
| Gary W. BROUGHAM | BLM | Geophysicist | Anchorage, AK |
| Terry R. BRUNS | USGS | Geophysicist | Menlo Park, CA |
| James E. CALLAHAN | BLM | Geologist | Anchorage, AK |
| Robert A. CROVELLI | USGS | Mathematical statistician | Denver, CO |
| Raymond C. CULOTTA | USGS | Seismic data processor | Memlo Park, CA |
| Kimberly I. CUNNINGHAM | USGS | Geologist | Denver, CO |
| Theodore A. DAWS | USGS | Chemist | Denver, CO |
| David A. DINTER | USGS | Geophysicist | Menlo Park, CA |
| Gordon L. DOLTON | USGS | Geologist | Denver, CO |
| Michael A. FISHER | USGS | Geophysicist | Menlo Park, CA |
| Richard L. FOLAND | BLM | Geophysicist | Anchorage, AK |
| Donald L. GAUTIER | USGS | Geologist | Denver, CO |
| Arthur GRANTZ | USGS | Geologist | Menlo Park, CA |
| Sarah B. GRISCOM | USGS | Geologist | Menlo Park, CA |
| William S. HAUSER | BLM | Petroleum engineer | Anchorage, AK |
| John S. KELLEY | USGS | Geologist | Menlo Park, CA |
| Douglas J. LALLA | BLM | Geophysicist | Anchorage, AK |
| Leslie B. MAGOON | USGS | Geologist | Menlo Park, CA |
| Michael L. MENGE | USGS | Geologist | Anchorage, AK |
| C. M. MOLENAAR | USGS | Geologist | Denver, CO |
| Stephen L. ROBBINS | USGS | Geophysicist | Denver, CO |
| Alan A. ROBERTS | USGS | Chemist | Denver, CO |
| Charles N. THRELKELD | USGS | Physical science technician | Denver, CO |
| Phillip V. WOODWARD | USGS | Physical science technician | Menlo Park, CA |
| John S. YOUNG * | BLM | Mineral economist | Anchorage, AK |

## CHAPTER IV. DEVELOPMENT AND TRANSPORTATION INFRASTRUCTURE

| | | | |
|---|---|---|---|
| Perry G. FRANCIS | BLM | General engineer | Anchorage, AK |
| William S. HAUSER | BLM | Petroleum engineer | Anchorage, AK |

## CHAPTER V. ALTERNATIVES

| | | | |
|---|---|---|---|
| Glenn W. ELISON | FWS | Arctic Refuge Manager/Wildlife biologist | Fairbanks, AK |
| Oswald GIRARD | USGS | Geologist | Reston, VA |
| Emil T. HEUER, Jr. | FWS | Wildlife biologist | Anchorage, AK |
| Robert O. SCHROTT | BLM | Supervisory geologist | Washington, DC |
| Jules V. TILESTON | BLM | Resource specialist | Anchorage, AK |

## CHAPTER VI. ENVIRONMENTAL CONSEQUENCES

| | | | |
|---|---|---|---|
| Max C. BREWER | USGS | Geologist/Geophysicist | Anchorage, AK |
| Glenn W. ELISON | FWS | Wildlife biologist | Anchorage, AK |
| Clayton HARDY | FWS | Program analyst | Anchorage, AK |
| David E. McGILLIVARY | FWS | Wildlife biologist | Anchorage, AK |
| Ann G. RAPPOPORT | FWS | Wildlife biologist/Assessment leader | Anchorage, AK |
| Gerald REID | FWS | Wildlife biologist | Anchorage, AK |
| Patricia E. REYNOLDS | FWS | Wildlife biologist | Fairbanks, AK |
| Jules V. TILESTON | BLM | Resource specialist | Anchorage, AK |
| Robin L. WEST | FWS | Fisheries biologist | Fairbanks, AK |

## CHAPTER VII. OIL AND GAS--NATIONAL NEED FOR DOMESTIC SOURCES AND THE 1002 AREA'S POTENTIAL CONTRIBUTION

| | | | |
|---|---|---|---|
| Max TAVES | BLM | Petroleum engineer | Washington, DC |
| Daniel H. WEDDERBURN | BLM | Economist | Washington, DC |
| John S. YOUNG * | BLM | Mineral economist | Anchorage, AK |

| | | |
|---|---|---|
| CARTOGRAPHY: | USGS, Denver | Units A and B of the Thematic Mapping Section, National Mapping Division, Rocky Mountain Area, U.S. Geological Survey |
| CLERICAL SUPPORT: | FWS, Anchorage | Karen Edwards, Tauline Peppers |
| | FWS, Denver | Retah Bailey, Lynne Dickinson, Margaret Grenvik, Sharon Rose, Barbara Smith, Vicki Tilden |

* Current location--Cheyenne, WY

# ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

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## ILLUSTRATIONS

[Plates in pocket]

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## TABLES

## ACRONYMS AND ABBREVIATIONS

ANCSA -- Alaska Native Claims Settlement Act of 1971
ANGTS -- Alaska Natural Gas Transportation System
ANILCA -- Alaska National Interest Lands Conservation Act of 1980
ANS -- Alaskan North Slope
ANWR -- Arctic National Wildlife Refuge
ASRC -- Arctic Slope Regional Corporation
BBO -- billion barrels of oil
CAH -- Central Arctic caribou herd
CEQ -- Council on Environmental Quality
CCP -- Comprehensive conservation plan

DCF -- discounted cash flow
DEW Line -- Distant Early Warning Line
EOR -- enhanced oil recovery
FASP -- Fast appraisal system for petroleum
KIC -- Kaktovik Inupiat Corporation
MBO -- million barrels of oil
MBO/Y -- million barrels of oil per year
MEFS -- minimum economic field size
MMS -- [U.S.] Minerals Management Service

NARL -- Naval Arctic Research Laboratory (Barrow)
NEPA -- National Environmental Policy Act of 1969
NEPP -- national energy policy plan
NNEB -- net national economic benefit
NOAA -- National Oceanic and Atmospheric Administration
NPRA -- National Petroleum Reserve in Alaska
NSB -- North Slope Borough
OPEC -- Organization of Petroleum Exporting Countries
Members:

| | |
|---|---|
| Algeria | Libya |
| Ecuador | Nigeria |
| Gabon | Qatar |
| Indonesia | Saudi Arabia |
| Iran | United Arab Emirates |
| Iraq | Venezuela |
| Kuwait | |

PCH -- Porcupine caribou herd
PRESTO -- Probabilistic resource estimates -- offshore
TAPS -- Trans-Alaska Pipeline System
TCFG -- trillion cubic feet of gas

# EXECUTIVE SUMMARY

## ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

In December 1980, the Congress passed the Alaska National Interest Lands Conservation Act (ANILCA)--landmark legislation setting aside more than 100 million acres of Federal lands in Alaska in conservation system units (that is, parks, refuges, and so on). Prior to ANILCA, the Arctic National Wildlife Range occupied 8.9 million acres of northeastern Alaska. ANILCA enlarged the unit to 17.9 million acres and changed its name to the Arctic National Wildlife Refuge.

Of special interest to the Congress during its ANILCA debates was the coastal plain of the Arctic Refuge. Not only was the area prized for its outstanding wildlife values, it was also suspected of having the most outstanding oil and gas potential of any unexplored onshore area in the country. The Congress created section 1002 of ANILCA to develop information about wildlife and energy values of the 1.5-million acres Arctic Refuge coastal plain ("1002 area"). Section 1002 required further study of the area's fish and wildlife resources, and limited exploration of its oil and gas potential. A report to the Congress on the results of these studies and recommendations by the Secretary of the Interior for future management of the coastal plain area were also required.

In the years since ANILCA was passed, the U.S. Fish and Wildlife Service conducted a series of biological studies of the area's fish and wildlife resources and their habitats. During the same period, the Bureau of Land Management, the U.S. Geological Survey, and exploration crews from private industry conducted surface geologic studies. Approximately l,300 gravity readings and more than l,300 line miles of seismic data were acquired by industry, under special-use permits issued by the Fish and Wildlife Service.

The Department's analysis of the geologic studies and surveys predicts a 95-percent chance of the 1002 area containing more than 4.8 billion barrels of oil and 11.5 trillion cubic feet of gas in-place. There is a 5-percent chance that the area contains more than 29.4 billion barrels of oil and 64.5 trillion cubic feet of gas in-place. The average of the range of in-place estimates yields a mean estimate of 13.8 billion barrels of oil and 31.3 trillion cubic feet of gas in-place. The area is clearly the most outstanding oil and gas frontier remaining in the United States, and could contribute substantially to our domestic energy supplies. Moreover, development of 3.2 BB of recoverable oil resources could yield Net National Economic Benefits from $79.4 billion, based on an oil price of $33 per barrel, to more than $325 billion, if a more optimistic economic and resource assumption of 9.2 BB of recoverable oil at $40 per barrel is used (1984 dollars). These benefits would be manifested in jobs, lower balance-of-trade deficits, and increased tax revenues to all levels of government.

These oil resources are likely to be found in the 26 identified subsurface structures scattered across the coastal plain, and each represents an opportunity for a significant oil discovery. Additionally, other areas within the coastal plain have excellent potential for containing hydrocarbon accumulations in stratigraphic traps and other structures that cannot be defined with currently available geologic data.

A range of options exists for the future management of the 1002 area. In light of the information obtained, the entire coastal plain, or portions thereof, have the resource potential for a successful oil and gas leasing program. Or, to acquire more definitive data, an exploration program obtaining additional seismic surveys and drilling offstructure exploratory wells in selected areas could be authorized by the Congress. On the other hand, the Congress could take no further legislative action and the 1002 area would be managed as an integral part of the entire refuge under the direction of its comprehensive conservation plan. Finally, the Congress could designate the area as a wilderness addition to the refuge's current 9 million wilderness acres.

On the basis of the analysis presented, and in consideration of this country's need for domestic sources of oil and gas, the Department proposes that the Congress authorize the Secretary to lease the entire 1002 area for oil and gas exploration and development. An area of approximately 242,000 acres in the southeast part of the 1002 area is used as a core calving area by the Porcupine caribou herd. To afford protection to this special area, the Department would want to structure a leasing program that offered this area last for leasing. This would permit experience obtained from development in the rest of the 1002 area to be applied in developing mitigation for activities in the calving area. The Congress would also be asked to grant authority to the Department to impose any restrictions necessary to ensure that unnecessary adverse effects are avoided and to require compensation in the event of significant unavoidable losses of habitat quality.

Section 1002 also required an assessment of potential environmental consequences if oil and gas development occurred in the 1002 area. To facilitate this assessment, scenarios were developed using the mean estimated recoverable oil and gas resource figures for the area, considering prospects that would be economically recoverable under a most likely situation. Using these scenarios, the U.S. Fish and Wildlife Service determined possible environmental consequences.

The assessment predicted environmental consequences of developing the entire 1002 area to be some long-term effects on the area's water resources, on caribou from the Porcupine herd, and on muskoxen. The presence of infrastructure supporting oil and gas development and a pipeline to transport the oil to the near by Prudhoe Bay area would eliminate the wilderness character of the 1002 area. Most adverse effects would be minimized or eliminated through carefully applied mitigation, using the lessons learned and technology acquired from development at Prudhoe Bay and from construction of the Trans-Alaska Pipeline System (TAPS). The evidence generated during the 18 years of exploration and development at Prudhoe Bay indicates minimal impact on wildlife resources. Hence, it is reasonable to assume that development can proceed on the coastal plain and generate similar minimal effects.

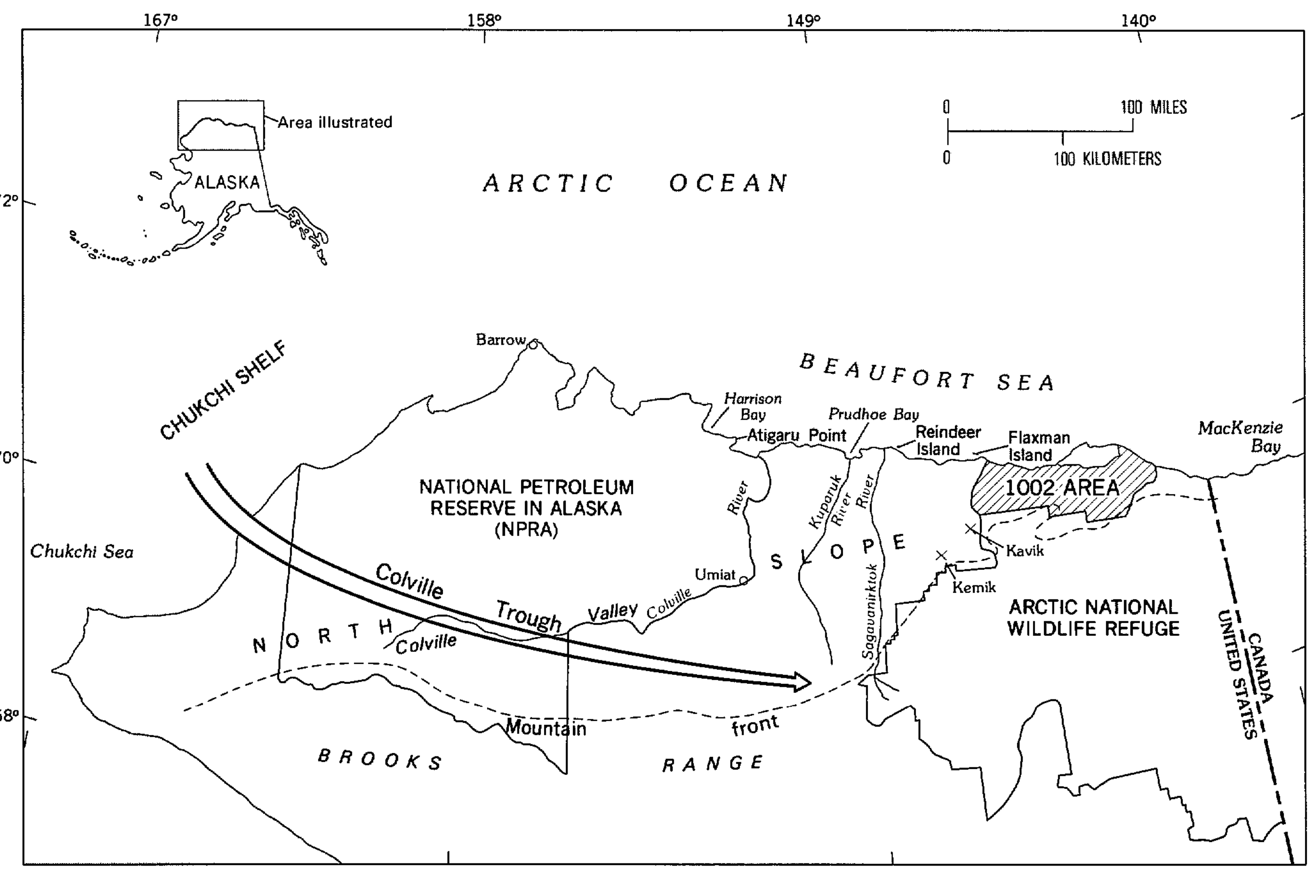
Highlights of the report to the Congress, prepared by the U.S. Fish and Wildlife Service in cooperation with the Bureau of Land Management and the U.S. Geological Survey, follow.

## THE 1002 AREA

The 1.55-million-acre 1002 area, part of the tundra-covered Arctic Coastal Plain Province, is located in the remote northernmost part of the Arctic Refuge. It is bounded on the east by the Aichilik River, on the west by the Canning and Staines Rivers, to the north by the Beaufort Sea, and to the south by township lines through the foothills of the Brooks Range. The 1002 area constitutes about 75 percent of the total coastal plain of the refuge; the rest is east of the Aichilik River to the Canadian border, and is part of the refuge's designated wilderness area.

Its arctic marine climate has extremely cold winters and short, cool summers. Summer temperatures average about 40°F; in the winter temperatures drop well below 0°F, with wind-chill factors to minus 80°F. Persistent winds blow throughout the year. Precipitation over the 1002 area is light but frequent, with summer drizzle and light winter snows. Regardless of season, clear days on the coastal plain are uncommon. Fog and stratus clouds prevail during the summer. In the winter, fog and blowing snow reduce visibility. The sun is continuously above the horizon from mid-May to the end of July, and continuously below the horizon from the end of November to mid-January.

Freezeup begins by mid-September, and the ground in the 1002 area remains frozen until June. Snowfall is greatest from September through November, and again in January. Numerous measurements indicated that average snow accumulations were 12 inches in 1984 and 9 inches in 1985. The almost-continuous winds redistribute the snow, filling valleys and swales, but leaving ridgetops bare. Drifts along stream cutbanks can be as high as 20 feet.



Rivers are fed by melting snow in the foothills and do not begin to flow until mid-May. Only a few large lakes occur and most of these are so shallow they freeze to bottom in winter. A few shallow thaw lakes are found near the coast, east of the Canning River delta.

The entire 1002 area is underlain by continuous permafrost except for a small area near the warm Sadlerochit Spring which flows year round. The upper layer of the surface of the ground that freezes and thaws annually is called the "active layer."

## Vegetation and Terrain Types

Despite its barren and desolate appearance, the 1002 area actually consists of a variety of tundra vegetation and landform types.

Foothills cover about 45 percent of the 1002 area. These areas are rich in mosses and lichens, important components of the tundra vegetation. Barren deltas and braided river channels of the river flood plains make up as much as 25 percent of the area. Gently rolling, hilly coastal plains cover 22 percent of the 1002 area. Here numerous slightly elevated ridges and depressions cover the landscape. Vegetation includes sedges, mosses, lichens and prostrate shrubs in well-drained areas. Tussock tundra occurs frequently in this hilly terrain, and its vegetative complement includes cottongrass, dwarf willows, and birches. Flat thaw-lake plains comprise only about 3 percent of the 1002 area, and contain unusual surface features called polygons, a ground pattern similar in appearance to rice paddies. Polygons are caused by seasonal thawing and freezing of the active layer in wetter areas. Vegetation in the thaw-lake plains is dominated by aquatic and wet tundra species. Virtually the entire 1002 area can be classified as wetland.

Sadlerochit Spring is one of the largest perennial springs on the Alaskan North Slope. Located in the foothills in the southern part of the 1002 area, the spring and its surrounding area of approximately 4,000 acres has been nominated as a National Natural Landmark. The spring is unique owing to its large warm water discharge which maintains an open channel for nearly 5 miles downstream during the coldest part of the year.

## Fish and Wildlife Species

Except for muskoxen and denning or burrowing animals such as polar bears and arctic ground squirrels, the harsh winters drive most species from the 1002 area. The brief spring, summer, and fall seasons, however, find the area host to large numbers of mammals and birds which use the coastal plain for important parts of their annual life cycles.

### CARIBOU

Caribou of the Porcupine and Central Arctic herds are the most numerous large mammals using the 1002 area.

The Porcupine caribou herd, named for the Porcupine River in Canada where they winter, is the larger of the two herds that use the refuge. The Porcupine herd is currently estimated by the Alaska Department of Fish and Game at 180,000 animals. Each year the herd returns to its traditional calving grounds between the Babbage River in Canada and the Canning River in Alaska. Although distribution on the calving grounds varies from year-to-year, most calving usually takes place in the area between the Hulahula River and the Canadian border. Certain areas appear to be favored by pregnant cows for calving. During the last 14 years, a 2.1-million-acre area has been identified by biologists as a concentrated calving area. Of this, 934,000 acres, or 44 percent of the area, is within the 1002 area. In 1985, 82 percent of the pregnant cows in the Porcupine caribou herd used the 1002 area for calving.

The Central Arctic caribou herd uses a range entirely north of the Continental Divide, from the Itkillik and Colville Rivers on the west to the Sadlerochit River on the east. The TAPS, Dalton Highway, and Prudhoe Bay and Kuparuk oil fields all lie within this herd's range. Despite this, the herd has been increasing, and in 1985 numbered about 12,000 to 14,000 animals. Cows tend to calve in an area on or near the Canning and Staines River deltas; calving activity has been concentrated near the lower Kuparuk River and Canning River delta. Most years as many as 1,000 females calve on the Canning River delta within the 1002 area, with some scattered calving as far east as the Sadlerochit River.

After calving in late May and early June, when huge swarms of mosquitoes emerge, caribou from both herds cluster in large aggregations and travel to coastal habitats for relief from insect harassment on points, river deltas and mudflats. Some groups may move to higher elevations in the southern mountains for relief.

In early July most of the Porcupine caribou move east and south, and vacate the 1002 area by mid-July, heading for their wintering grounds in Canada and in the southern Brooks Range. Occasionally, remnant groups may winter in the northern mountains and foothills. In late summer and fall, caribou of the Central Arctic herd are found scattered across the coastal plain south of Camden Bay, in the foothills north of the Sadlerochit Mountains, and in uplands south of the Sadlerochit Mountains where they winter. During most winters scattered groups of caribou of the Central Arctic herd range throughout the 1002 area west of the Katakturuk River and the adjacent uplands to the south.

### OTHER MAMMALS

Muskoxen were exterminated from the North Slope by the late 1800's by hunters. The animal's instinctive defense of forming a circle of bulls surrounding cows and calves, although effective against predators, makes them especially vulnerable to hunters. In 1969 and 1970, 69 muskoxen were reintroduced to the Arctic Refuge to establish an indigenous population. High productivity and low natural mortality caused this population to expand rapidly. In 1985, the refuge population was estimated at 476 animals. Muskoxen move with seasonal changes in vegetation and snow cover. In summer and fall they frequent major drainages to feed on willows and forbs. In winter and spring many animals move to the uplands where snow cover is light and tussock sedges readily available.

Polar bears roam the pack ice of the Arctic Ocean throughout most of the year. Some females move to coastal areas and inland during October and November to seek suitable maternity den sites. Pregnant polar bears and, later, their cubs probably spend more time on the 1002 area than other segments of the population. At least 15 dens have been located in the 1002 area; 5 dens have been found on ice near the 1002 area.

Brown bears use the 1002 area seasonally. At their time of greatest abundance on the area, about 108 bears are found on the coastal plain. The bears appear in late May and remain through June and July to prey on caribou, ground squirrels and rodents. Food habits change with the seasons--spring finds a combination of meat and vegetation in their diets, and mid -to late summer, almost all berries and vegetation. Although the bears breed while on the 1002 area, they leave in September and October for den sites in the foothills and mountains.

Other predators using the 1002 area include wolves, wolverines, and arctic foxes. There are very few wolves and wolverines on the 1002 area. Arctic fox populations tend to fluctuate according to the abundance of the small rodents on which they prey.

Ringed and bearded seals, and, occasionally, spotted seals occur along the coast of the Beaufort Sea. The endangered bowhead and gray whale, as well as beluga whale, migrate through waters north of the 1002 area.

Other mammals using the 1002 area include small numbers of moose and Dall sheep, which are near the northern limits of their range, and large numbers of arctic ground squirrels and other rodents. Although these animals are of lesser importance, they indicate the biological diversity of the area.

### BIRDS

The majority of bird species using the coastal plain are migratory, and occur in large numbers from May to September. A total of 108 species have been recorded. Six species are considered permanent residents--rock and willow ptarmigan, snowy owl, common raven, gyrfalcon, and American dipper, which winters in the warmer area around the Sadlerochit Spring. The lagoon systems are important feeding areas for oldsquaw, eider, scoter, and other ducks; loons, phalaropes, terns, gulls, jaegers and black guillemots. Raptors nesting in the area include rough-legged hawks, golden eagles, gyrfalcons, snowy owls, short-eared owls, and threatened arctic peregrine falcons.

Tundra swans are common breeding birds of the thaw-lake plains. As many as 150 nests and 400-500 adult swans have been counted on the 1002 area during annual surveys. Black brant and Canada, greater white-fronted, and lesser snow geese regularly use the 1002 area. Canada geese and black brant breed there each year. Part of the Banks Island, Canada, population of lesser snow geese use the 1002 area as a staging area for their annual fall migration. At their maximum, as many as 325,000 snow geese have been counted on the area.

Erect riparian willow stands support a diversity of perching birds such as hoary redpolls and white-crowned, American tree and savannah sparrows. Snow buntings are found on coastal bluffs. Lapland longspurs are the most abundant species, and nest in all tundra types.

### FISH

Fish in the Arctic survive because of extreme adaptations to a harsh environment. Relatively few species occur in the marine, estuarine, and fresh-water environments of the 1002 area. Arctic char, arctic cisco, arctic flounder, arctic cod, boreal smelt, and fourhorn sculpin have been reported offshore of the 1002 area. The nearshore waters are important spawning and overwintering areas. Arctic char, arctic grayling, arctic cisco, arctic flounder, fourhorn sculpin, least cisco, round whitefish, broad whitefish, ninespine stickleback, chum salmon, and burbot have been reported in the Canning River system. Other streams that support fish populations include the Tamayariak, Sadlerochit, Hulahula, Akutoktak, Okpilak, and Aichilik Rivers, and Itkilyariak Creek. The remaining streams in the 1002 area apparently do not support major fish populations, most probably because they freeze to bottom or otherwise fail to provide suitable overwintering habitat.

## KAKTOVIK AND ITS INUPIAT VILLAGERS

The village of Kaktovik, located on Barter Island on the Beaufort seacoast, is the only village within the boundaries of the Arctic Refuge. Nearly 90 percent of its 200 residents are Native Inupiat Eskimo, who have strong cultural links to lands in and adjacent to the 1002 area.

Barter Island was an important trading center for centuries. Canadian Inuit people met on the island to trade with Barrow area residents; inland people came down from the mountains to trade. Barter Island was an important stop for commercial whalers during the 1890's and later, but it was not until 1923 that a permanent settlement was established as a trading post, which served as an exchange point for furs and was the beginning of the village of Kaktovik.

Kaktovik has survived as a community because of strong family and cultural ties, ties to the land, and economic opportunity for both jobs and subsistence. Participation in subsistence activities is a major aspect of Kaktovik residents' life. Approximately 68 percent of Kaktovik's present subsistence land use is within the Arctic

Refuge, including the entire 1002 area. Kaktovik residents depend primarily on caribou, Dall sheep, bowhead whales, fish, waterfowl, and other birds. Seals, polar bears, furbearers, and small game are secondary. Brown bears and moose are taken occasionally. A few residents harvest berries, wild rhubarb, and roots.

Changes in the economy have changed the living patterns of Kaktovik residents. The Inupiat traditionally have had a subsistence economy. However, increasing contact with other cultures has changed the nature of their economic system. Since 1890 economic activity has vacillated from whaling, to trapping, reindeer herding, and construction of the Distant Early Warning (DEW Line) system on Barter Island. Kaktovik residents have relocated their village three times since 1947. The current village was established in 1964, and was incorporated as a second-class city in 1972.

Economic activity in the area has recently increased in response to the passage of the Alaska Native Claims Settlement Act (ANCSA) in 1971, to oil and gas development in the Prudhoe Bay area, to the capital improvement program of the North Slope Borough, and to the KIC/ASRC exploratory well drilled on Native land. Kaktovik Inupiat Corporation (KIC), the village profit corporation formed as a result of ANCSA, operates a village store, selling fuel oil, aviation fuel, and snowmachines. Kaktovik residents are also shareholders in the Arctic Slope Regional Corporation (ASRC), the regional profit corporation organized under ANCSA.

## OIL AND GAS POTENTIAL OF THE 1002 AREA

A high potential for significant discoveries of oil and gas in the 1002 area has long been recognized. Explorers at the turn of the century found oil seeps and oil-stained sands on this part of the Arctic coastal plain.

Oil and gas exploration in the Arctic began in 1944 on the National Petroleum Reserve-Alaska. Exploration by oil companies on Federal and State lands east of the Colville River in the 1960's culminated in 1968 in the discovery of the Prudhoe Bay oil field, the largest in North America. In 1982 the adjacent Kuparuk River field came on line, and the Milne Point field was productive by 1985.

Exploration offshore in the Beaufort Sea began in the mid-1970's. In 1978, the Endicott field was discovered near the Sagavanirktok River delta; it is scheduled to begin production in 1987. The joint State-Federal Lease Sale BF in 1979 increased the pace of offshore exploration. Federal Lease Sale 71 in 1980 resulted in two discoveries. Exploration began in the summer of 1985 on Federal Sale 87. State lease sales within the 3-nautical-mile limit along the coast of the 1002 area in Camden Bay have been scheduled for 1987, and near Demarcation Point for 1988.

Section 1002(a) of ANILCA authorized oil and gas exploration on the 1002 area in a manner that avoided significant adverse effects to fish and wildlife and other resources. Exploration included surface geological and geophysical exploration, but not exploratory drilling. The favorable geology of the 1002 area, which lies between areas where significant oil discoveries have been made, was confirmed by recent surface geology studies and seismic surveys.

During the summers of 1983-85, exploration crews from 15 companies visited the 1002 area by helicopter. The crews made field observations and measurements, and collected rock samples that were analyzed for age and geochemistry (hydrocarbon-generation potential) and porosity and permeability (potential reservoir characteristics). Approximately 1,300 gravity readings along a 1x2-mile grid covering the 1002 area were collected by a helicopter-supported gravity survey during the late summer of 1983. Seismic operations, permitted during two winter seasons in 1983-84 and 1984-85, acquired more than 1,300 line miles of seismic data. The seismic program provided the detailed subsurface data on the area's oil and gas potential.

The U.S. Geological Survey and Bureau of Land Management analyzed these data in assessing the hydrocarbon potential of the area. The results indicate that the 1002 area has the geologic elements necessary for hydrocarbon formation and entrapment. Sedimentary rocks in the area include organic source rocks necessary to produce oil, and thick sequences of reservoir rock where hydrocarbons can accumulate. Equally as important, the area appears to have favorable geologic structures for trapping and holding hydrocarbons, such as the Marsh Creek anticline in the western portion of the 1002 area.

The U.S. Geological Survey and Bureau of Land Management made, based on their analyses, estimates of the potential volumes of oil and gas in-place and likely to be economically recoverable. Although the geologic indications and seismic interpretations are extremely encouraging, only exploratory drilling can confirm the presence of oil. The estimates contain a high degree of uncertainty as reflected in the methods and assumptions used by each agency. In-place and recoverable figures are presented as ranges of probability from the 5-percent probability level to the 95-percent probability level.

There is a 95-percent chance the 1002 area contains more than 4.8 billion barrels of oil and 11.5 trillion cubic feet of gas in-place. There is a 5-percent chance the area contains more than 29.4 billion barrels of oil and 64.5 trillion cubic feet of gas in-place. The average of the range of in-place estimates yields a mean estimate of 13.8 billion barrels of oil and 31.3 trillion cubic feet of gas in-place.

Total recovery of oil and gas in-place is impossible. To estimate the amount of in-place resources that may be recoverable, technological and economic conditions were applied to in-place resource estimates for the area. This resulted in an estimated 95-percent chance of 0.6 billion barrels of oil recoverable, a 5-percent chance of 9.2 billion barrels of oil recoverable, and an average conditional economically recoverable resource estimate of 3.2 billion barrels of oil.

The Department did not include gas in its recoverable calculations as it was determined that the gas resources were unlikely to be economic at any point in the 30-year period considered in the report.

The onshore basins in the United States that hold the greatest potential for very large discoveries have already been explored, except for the 1002 area. Although there are some very attractive offshore areas yet to be explored, the 1002 area is particularly promising because it contains extensions of other producing trends; wells on adjacent properties show highly favorable evidence of petroleum deposits. These evidences, combined with the 26 structural traps mapped or inferred for the area, indicate that the 1002 area is currently the unexplored area in the U.S. with the greatest potential of containing giant (100 million barrels or more) or supergiant (500 million barrels or more) fields.

## DEVELOPMENT AND TRANSPORTATION OF OIL FROM THE 1002 AREA

Generic scenarios were devised for the exploration, development, production, and transportation of economic quantities of oil from the 26 potential oil prospects located throughout the 1002 area. Gas production was not considered.

These scenarios were used for assessing environmental consequences. In assessing development requirements, it became apparent that the water and gravel necessary for construction and development are in very limited supply on the 1002 area.

An inland pipeline, roughly bisecting the 1002 area from east to west, was selected for transporting oil to Prudhoe Bay to connect with the existing TAPS. This pipeline would be elevated across most of the area to protect the permafrost. The distance from the easternmost development in the 1002 area to TAPS Pump Station 1 would be about 150 miles, including the 50 miles of State of Alaska land between the western boundary of the 1002 area and Pump Station 1. Declines in Prudhoe Bay oil production would coincide with the time at which production might begin in the 1002 area. Therefore, it was assumed that TAPS would have the capacity to transport oil from the 1002 area.

The development scenarios depicted typical infrastructures in three areas for full development of the 1002 area, and in two areas if the Porcupine caribou core calving area was not leased.

## ENVIRONMENTAL CONSEQUENCES OF OIL DEVELOPMENT ON THE 1002 AREA

Biologists from the U.S. Fish and Wildlife Service assessed potential effects of each alternative: A--Full leasing of the 1002 area; B--Leasing limited to a portion of the 1002 area; C--Further oil and gas exploration; D--No further Congressional action; and E--Wilderness designation.

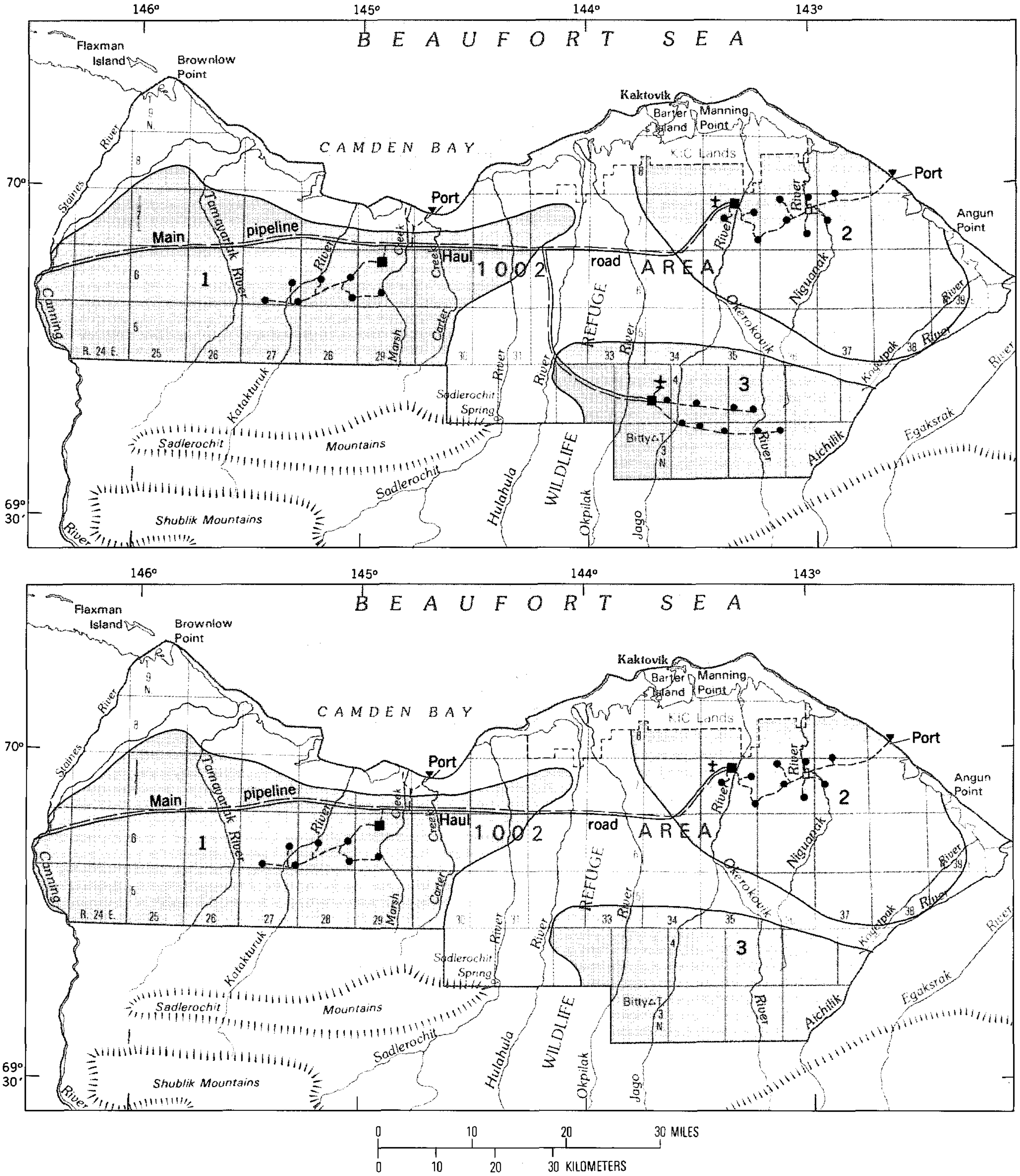
Alternatives D and E would result in no adverse impacts on the fish and wildlife resources of the 1002 or on its wilderness value; however, they would preclude further exploration to determine the real hydrocarbon potential of the 1002 area and production of any economically recoverable resources.

Short-term activities associated with further exploration, such as exploratory wells, of the 1002 area will lead to generally short-term displacement and disturbance of fish and wildlife resources and Native subsistence users. There will probably be little or no residual or long-term effect on wildlife populations. Wilderness attributes of the area will be affected for a longer period of time.

Long-term losses in fish and wildlife resources, subsistence uses, and wilderness values would be the inevitable consequences of a long-term commitment to oil and gas development, production, and transportation. If producing fields were discovered, petroleum operations would last for 30-90 years. Oil and gas discovery will lead to industrial development. There will be pressure to use this area as a base to service exploration and development on the outer continental shelf, or to intertie with projected oil and gas development in the Canadian Arctic. An oil development infrastructure in the 1002 area would be an impetus to develop State lands between the Canning River and the TAPS. Infrastructure in the 1002 area would serve potential offshore or other fields, adding to the long-term industrial commitment.

Oil and gas development will result in widespread, long-term changes in wildlife habitats, wilderness environment, and Native community activities. Changes could include displacement and reduction in the size of the Porcupine caribou herd. The amount of reduction and its long-term significance for herd viability is highly speculative. Geography apparently limits the availability of suitable alternative calving or insect-relief habitats for the herd. Mitigation measures can minimize some adverse effects to the Porcupine caribou herd as well as to other wildlife species, wilderness characteristics, and subsistence uses.

Industrial development could profoundly affect the Native culture. Although it may provide jobs for villagers from Kaktovik, it will hasten changes from a life style based on subsistence and community sharing and a dependence on the land to a society with a cash-based economy. Increased education, employment, and health services would be positive benefits of this change in life style.




## EXPLANATION

| Central production facility | | |
|---|---|---|
| ■ 90 acres | ● Drill pad—23 acres | – – Connecting road |
| □ 40 acres | ✝ Airstrips—30 and 130 acres | ▼ Seawater treatment plant |

**Hypothetical generalized development of the 1002 area under full leasing (upper) or limited leasing (lower) if economic quantities or oil are discovered.**

Numbers indicate three localities (shaded) having typical prospect characteristics.

## THE CONTRIBUTION TO U.S. NEEDS FOR DOMESTIC ENERGY SOURCES

The 1002 area's oil fields could be the largest domestic fields discovered since Prudhoe Bay and Kuparuk River. Except for these, no U.S. field with reserves exceeding l billion barrels of oil has been discovered since 1948. Today, Prudhoe Bay contributes approximately 20 percent of domestic production, but production from Prudhoe Bay has peaked and a decline is expected by 1988.

A leasing program on the 1002 area could contribute billions of barrels of additional oil reserves toward the national need for domestic sources. Oil consumption in the U.S. has exceeded domestic production for more than 20 years. Not only might discovery of a giant or supergiant field significantly contribute to domestic reserves and production, it could do so at a relatively low average cost per barrel because of economies of scale.

Oil from the 1002 area could also help achieve several national economic and security objectives. Since 1970 this Nation has been heavily dependent on petroleum imports to meet domestic demand. Imports in 1985 were expected to supply about one-third of domestic oil needs. The most recent forecast by the Department of Energy indicates that U.S. dependence on oil will increase significantly by the end of the century due to declines in domestic reserves.

As imports have increased, the U.S. has become vulnerable to the actions of oil-exporting countries. Because domestic production supplants imports, benefits accrue not only from savings that result when domestic oil costs are lower than imported oil costs, but also from the reduction in economic vulnerability to disruptions of supply.

Continued dependence on imports for a substantial portion of total U.S. oil consumption creates national security concerns. The potential for supply disruption limits flexibility in foreign security policy, including the ability to respond to threats to national security. The United States could potentially be drawn into dangerous political and military situations involving the exporting nations.

Another objective of leasing the 1002 area would be production of additional domestic sources of oil as one means of achieving a more favorable balance of international trade. In 1984 the gross cost of importing crude oil and refined petroleum products amounted to almost 50 percent of the trade deficit. Production from the 1002 area not only would reduce the need to import oil, but would reduce the amount of foreign exchange required to pay for the imported oil.

The economic benefits from producing oil on the 1002 area would include an increase in Net National Economic Benefits expected to accrue as bonuses, royalties, rental fees, taxes, and after-tax business profits. If the entire 1002 area were leased, these benefits could be almost $15 billion in discounted dollars. Lease production would generate revenues to the public as lease bonus payments and rentals, royalties, Federal corporate income taxes, severance tax payments to the State, and State corporate income taxes.

# ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

## CHAPTER I

## PURPOSE AND NEED FOR THIS REPORT

### INTRODUCTION

The Arctic National Wildlife Refuge, in the northeastern corner of Alaska, was first established as the Arctic National Wildlife Range by Public Land Order 2214 in 1960, for the purpose of preserving unique wildlife, wilderness, and recreational values. The original 8.9-million-acre Range was withdrawn from all forms of appropriation under the public land laws, including mining laws, but not mineral leasing laws. This order culminated extensive efforts begun over a decade earlier to preserve this unique part of Alaska.

During the 1970's the Alaskan arctic coastal plain was the site of several studies on the area's oil and gas potential, possible oil and gas transportation corridors, and biological resources (U.S. Department of the Interior, 1972, 1976). The Alaska Natural Gas Transportation System studies on the Range included extensive biological studies, as did studies for the planning and development of the Trans-Alaska Pipeline System (TAPS) to the west of the Range.

The Alaska National Interest Lands Conservation Act (ANILCA), passed in 1980, established 16 National Wildlife Refuges in Alaska, among them the 19-million-acre Arctic National Wildlife Refuge, hereafter referred to as Arctic Refuge. The Arctic Refuge encompasses the existing 8.9-million-acre wildlife range and approximatley 10 million additional acres of adjoining lands west toward TAPS and south to the Yukon Flats. Approximately 8 million acres, comprising most of the original Arctic National Wildlife Range, was designated wilderness.

ANILCA also redefined the purposes of the Arctic Refuge:

(i) To conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, the Porcupine caribou herd (including participation in coordinated ecological studies and management of this herd and the Western Arctic caribou herd), polar bears, grizzly bears, muskox, Dall sheep, wolves, wolverines, snow geese, peregrine falcons and other migratory birds and Arctic char and grayling;

(ii) To fulfill the international treaty obligations of the United States with respect to fish and wildlife and their habitats;

(iii) To provide, in a manner consistent with the purposes set forth in subparagraphs (i) and (ii), the opportunity for continued subsistence uses by local residents; and

(iv) To ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in paragraph (i), water quality and necessary water quantity within the refuge.

The Arctic Refuge offers wildlife, scientific, recreational, and esthetic values unique to the arctic coastal ecosystem. In the Arctic Refuge, a person traveling on foot or by boat can traverse a full range of North Slope landscape and habitats, because of the proximity of the arctic coast to the mountains. Mt. Isto, 9,049 feet; Mt. Chamberlin, 9,020 feet; Mt. Hubley, 8,914 feet; and Mt. Michelson, 8,855 feet--the four tallest peaks in the Brooks Range--are located in the Arctic Refuge. The Arctic Refuge contains the only extensive active glaciers in the Brooks Range. Found on the refuge is the full complement of arctic flora and fauna, including the calving ground for the Porcupine caribou herd, one of the largest in Alaska (approximately 180,000 caribou); and habitat for the threatened arctic peregrine falcon, lesser snow geese, and other migratory bird species, and reintroduced muskoxen.

### LEGISLATIVE HISTORY

During the 9 years ANILCA was being considered in the Congress, and particularly during 1977-80, the issue of oil and gas exploration and development on the 1.55-million-acre Arctic Refuge coastal plain was fully debated. Some members wanted the coastal plain designated as wilderness, and some favored opening it to oil and gas leasing. As explained in the 1979 Senate Report:

> "The Committee was particularly concerned with the ANWR. In hearings and in markup, conflicting and uncertain information was presented to the committee about the extent of oil and gas resources on the Range and the effect development and production of those resources would have on the wildlife inhabiting the Range and the Range itself. The nationally and internationally recognized wildlife and wilderness values of the Range are described in the discussion of the Committee amendments to Title III. The Committee was determined that a decision as to the

development of the Range be made only with adequate information and the full participation of the Congress." (Senate Report 413, 96th Cong. 1st Sess. at 241(1979)).

Therefore, the Congress created section 1002 of ANILCA to deal with the issue.

## PROGRAM DESCRIPTION AND IMPLEMENTATION

Specifically, section 1002 of ANILCA requires the Secretary of the Interior:

1. To conduct a comprehensive, continuing baseline study of the fish and wildlife resources of the Arctic Refuge 1002 area (fig. I-1). [Throughout this report the term "1002 area" refers to that part of the Arctic Refuge defined as the "coastal plain" by section 1002(b) of the ANILCA];
2. To develop guidelines for, initiate, and monitor an oil and gas exploration program; and
3. To prepare a "Report to Congress" which describes the fish and wildlife resources of the 1002 area; identifies and estimates the volume and area of potential hydrocarbon resources; assesses the potential impacts of development; discusses transportation of oil and gas; discusses the national need for domestic sources of oil and gas; and recommends whether further exploration, development, and production of oil and gas should be allowed.

The U.S. Fish and Wildlife Service (FWS) has lead responsibility for meeting these Congressional mandates. Under an interagency memorandum of understanding (MOU) dated June 1983, the Bureau of Land Management (BLM) and the Geological Survey (GS) have assisted the FWS by providing technical expertise in reviewing industry-proposed exploration plans, conducting geologic studies and assessing the hydrocarbon potential of the 1002 area, as well as developing this report. The status of these activities is reported herein.

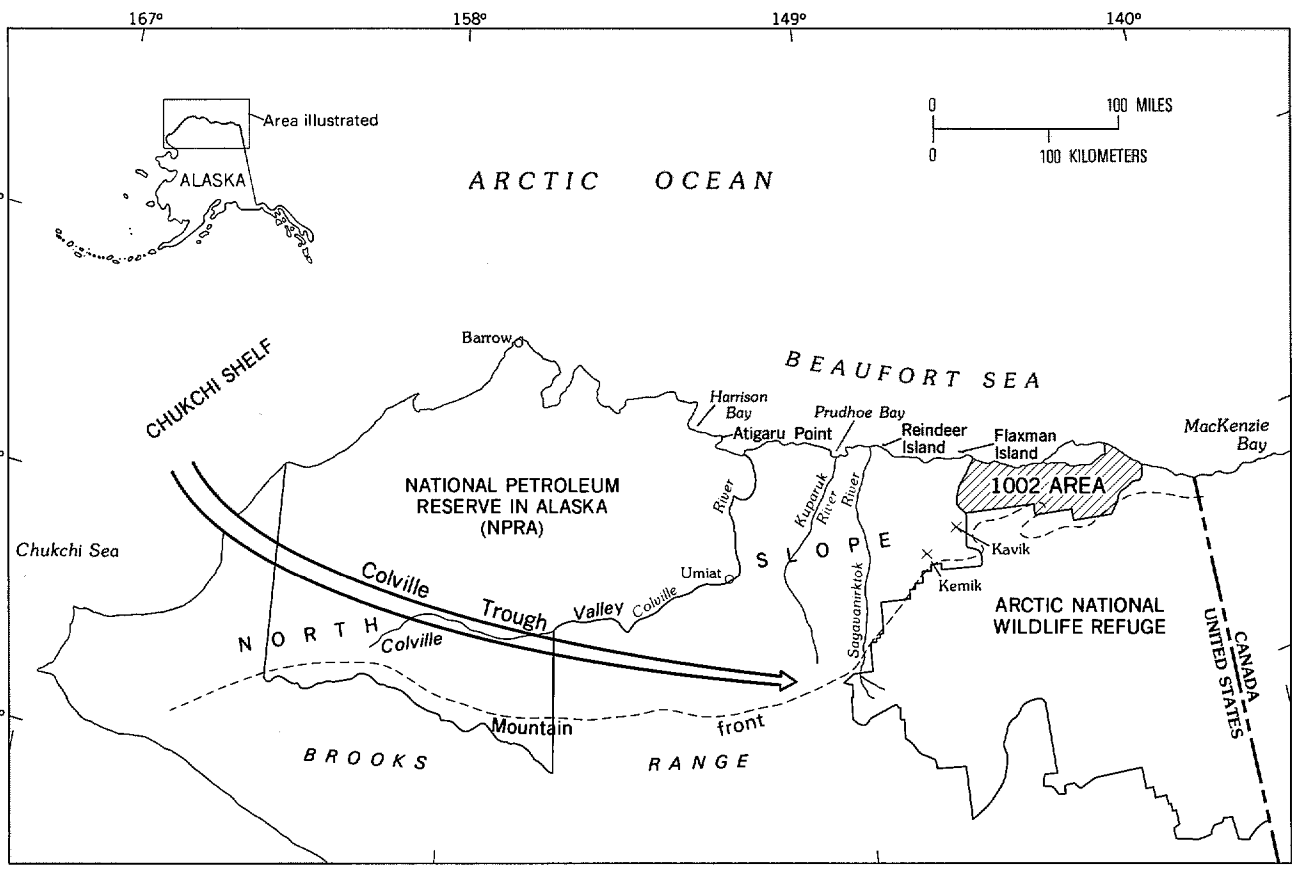



**Figure I-1.**--Index map of northern Alaska showing location of 1002 area in relation to the Arctic National Wildlife Refuge (Arctic Refuge), the National Petroleum Reserve in Alaska (NPRA), and Prudhoe Bay.

## Baseline Study of Fish and Wildlife Resources

The FWS began biological baseline studies of selected fish and wildlife species of the 1002 area during the spring of 1981. An initial baseline report that described the 1981 field season (spring-fall) and reviewed existing literature was published in April 1982. The results of subsequent field seasons (1982-85) were documented in four annual baseline update reports and a final baseline report. (See "References cited" for listing of these publications.)

The 1002 area baseline studies represent more than 60 staff-years of research effort (that is, data collection, analysis, and synthesis). Fifty-seven separate field studies defined (1) the ecology, distribution, and abundance of fish and wildlife species; (2) wildlife habitats within the 1002 area; and (3) the impacts of seismic exploration on tundra vegetation.

Section 303 of ANILCA, which reestablished existing refuges, specified that a purpose of the Arctic Refuge was to conserve fish and wildlife populations. Among the species or groups of species mentioned in section 303(2)(B)(i) that were studied on the 1002 area were caribou, muskoxen, wolves, brown bear, wolverines, migratory birds, and fish, as well as the vegetation. The Arctic Refuge staff was assisted by the State of Alaska Department of Fish and Game, Canadian Wildlife Service, Yukon Department of Renewable Resources, researchers from the Cooperative Wildlife Research Unit at the University of Alaska, and volunteers. Investigative techniques included visual observations, aerial censuses, radio telemetry, and satellite tracking. These baseline studies of the 1002 area are the basis for the description of the biological environment in Chapter II and the analysis of environmental consequences in Chapter VI.

## Oil and Gas Exploration Programs

Section 1002(a) of ANILCA authorized oil and gas exploration on the 1002 area in a manner that avoided significant adverse effects to fish and wildlife and other resources. Exploration included surface geological and geophysical exploration but not exploratory drilling.

The FWS published an environmental impact statement (EIS) in February 1983, and final regulations governing exploration on the 1002 area were published in the Federal Register on April 19, 1983 (48 Federal Register 16838-16872; 50 CFR 37). As required by section 1002(d), the regulations were developed to ensure that exploratory activities did not have a significant adverse effect on fish and wildlife, their habitats, or the environment.

During the summers of 1983-85, exploration crews from 15 companies visited the 1002 area. No surface vehicles were allowed; access was by helicopter. The work involved field observations, surface measurements, mapping, and collection of rock samples. Samples were analyzed for age and geochemistry (hydrocarbon-generation potential) and porosity and permeability (potential-reservoir characteristics). The FWS carefully monitored all activities, and no adverse effects to fish or wildlife were observed.

The FWS issued one permit for a helicopter-supported gravity survey that was conducted during the late summer of 1983. The permittee (International Technology Ltd.) collected approximately 1,300 gravity readings from the ground along a 1x2-mile grid covering the entire 1002 area.

During the winter months, when most wildlife species were absent or were present in lesser numbers, seismic operations were permitted. More than 1,300 line miles of seismic data was acquired. The seismic program provided the most detailed subsurface data on the area's oil and gas potential. As the only exploration technique involving mechanized surface transportation, it posed the greatest possibility of adverse environmental effects. Therefore, to avoid significant adverse impacts, the FWS:

1. Allowed only one permittee (Geophysical Service Inc.) representing an industry group of 23-25 companies to collect seismic data,

2. Restricted activities in sensitive wildlife areas (such as bear dens) or where snow cover was insufficient to protect the tundra,

3. Limited the number of line miles of seismic survey to only that amount necessary to yield data from which to develop a credible oil and gas resource assessment, and

4. Placed full-time FWS monitors on each seismic crew.

By restricting or rerouting overland travel in areas of inadequate snow cover or sensitive vegetation types, the monitors effectively limited adverse environmental impacts. They also collected data on the severity of the seismic surveys' surface impact in relation to snow depth, topography, and vegetation type. Several more seasons of followup studies on long-term impacts, if any, will supplement their observations of short-term surface disturbance.

## Report Preparation

Under provisions of the MOU, an "Interagency Advisory Work Group" was formed in March 1984 to oversee the preparation of this report. The work group, headed by the FWS, comprised FWS, GS, and BLM representatives. The group called on more than 50 technical experts within the three bureaus to contribute to various sections of this report. Contributors are listed at the front of this report.

This document provides the basis for the Secretary of the Interior's recommendation to the Congress concerning future management of the 1002 area. The document fulfills the requirements of both section 1002(h) of

ANILCA and section 102(2)(C) of the National Environmental Policy Act (NEPA).

Section 1002(h) of ANILCA mandates that the report must contain:

1. The identification by means other than drilling of exploratory wells of those areas within the coastal plain that have oil and gas production potential and an estimate of the volume of the oil and gas concerned (Chapter III).

2. The description of the fish and wildlife, their habitats, and other resources that are within the areas identified under paragraph (1) (Chapter II).

3. An evaluation of the adverse effects that the carrying out of further exploration for, and the development and production of, oil and gas within such areas may have on the resources referred to in paragraph (2) (Chapter VI).

4. A description of how such oil and gas, if produced within such area, may be transported to processing facilities (Chapter IV).

5. An evaluation of how such oil and gas relates to the national need for additional domestic sources of oil and gas (Chapter VII).

6. The recommendation of the Secretary with respect to whether further exploration for, and the development and production of, oil and gas within the coastal plain should be permitted and, if so, what additional legal authority is necessary to ensure that adverse effects of such activities on fish and wildlife, their habitat, and other resources are avoided or minimized (Chapter VIII).

The document also comprises a legislative EIS (LEIS) pursuant to section 1506.8 of the Council on Environmental Quality's (CEQ) regulations to implement NEPA (40 CFR 1500-1508). Chapters V and VI in particular discuss and evaluate five major alternatives from which the Secretary's recommendation (Chapter VIII) has been derived. Those alternatives are: (A) full leasing of the entire 1002 area, (B) leasing limited to a part of the 1002 area, (C) further exploration, (D) no action, and (E) wilderness designation. Estimates of economically recoverable resources described in Chapter III form the basis for hypothetical oil exploration, development, production and transportation scenarios outlined in Chapter IV which are used in the LEIS to determine and measure environmental impacts, and to discuss the national need in Chapter VII. Major environmental issues addressed are those that were identified through the exploration activities, and baseline studies: Fish and wildlife resources (especially caribou, snow geese, and fish), water quality and quantity, and socioeconomics.

## STANDARD FOR ENVIRONMENTAL PROTECTION

Any decision to develop oil and gas resources requires advanced planning so as to minimize conflict between environmental values and energy development. One purpose of this report is to identify potential environmental impacts from Arctic Refuge development. This analysis will provide preliminary information to facilitate planning to mitigate impacts to ensure that development, should it occur, is conducted in a responsible manner that results in no unneccessary adverse effects.

In assessing the environmental consequences of possible oil and gas development on the 1002 area, the FWS has chosen to apply its FWS mitigation policy (46 Federal Register 7644-7663, January 23, 1981). FWS uses this policy in conducting fish and wildlife impact investigations and in recommending suitable mitigation for development projects of all kinds. Furthermore, the policy complements NEPA, and CEQ regulations recognize that any analysis of options, including the proposed action, requires consideration of mitigation measures.

Development and use of natural resources may affect the quality and quantity of habitat upon which plant and animal species depend. The FWS mitigation policy focuses on losses of habitat value. The type and degree of mitigation imposed should be tailored to the value and scarcity of the affected habitat. According to the policy, the following steps represent a desirable sequence in mitigation planning: (a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impact by limiting the degree or magnitude of the action; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the project; and (e) compensating for the impact by replacing or providing substitute resources or environments. Each of the five alternatives for the 1002 area is evaluated in terms of this sequence.

Chapter V of this report describes the alternatives. Chapter VI then assesses the impacts associated with each alternative; proposed mitigation is identified in conformance with the FWS mitigation policy.

Any Congressionally authorized oil and gas program on the 1002 area would have some degree of cumulative effect with other existing and potential activities on the North Slope of Alaska, including State and Federal offshore leasing programs, oil and gas exploration programs to the east in the Canadian Arctic, and further Federal or State leasing on the North Slope. Also possible is the expansion of oil and gas activities in and around Prudhoe Bay.

Leasing and operations would be subject to all appropriate Federal and State regulations and further environmental evaluation at appropriate stages of the development. It is expected that this LEIS will suffice for initial leasing. However, exploration proposals normally require site-specific NEPA evaluations, and a development/production proposal will require a site-specific EIS. Any future EIS on development of the 1002 area will, to the extent appropriate, be tiered on the present LEIS.

If leases are eventually developed, all applicable Federal and State regulations would apply to oil exploration, development, production, and transportation unless they were superseded by the legislation enacted by the Congress to open the 1002 area to leasing, and any implementing regulations. Currently more than 36 Federal and 5 State of Alaska laws, and 111 separate regulations found in 6 separate titles in the Code of Federal Regulations apply to oil and gas activities in Alaska. Some examples are the National Wildlife Refuge System Administration Act; Fish and Wildlife Coordination Act; Clean Water Act; Coastal Zone Management Act; Alaska Native Claims Settlement Act; Alaska Environmental Conservation Act, Title 46; Alaska Oil Pollution Control Law; and Alaska Coastal Management Act.

The final report and LEIS, with the Secretary's recommendations, will be submitted to the Congress as required by section 1002 of ANILCA for review and further decisions regarding management of the Arctic Refuge's coastal plain. At the time the final report is submitted to the Congress, a Notice of Availability will be published concurrently in the Federal Register and in major Alaska newspapers.

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## ADDENDUM

After all the figures in this report were completed, Kaktovik Inupiat Corporation (KIC) received documents of interim conveyance on approximately 20,000 adjacent acres of land within the 1002 area. This boundary modification is not shown on any of the figures or plates. Corrections will be shown in the future and all discussions herein pertaining to KIC lands do apply to the lands in this latest interim conveyance.

# CHAPTER II

# EXISTING ENVIRONMENT

## PHYSICAL GEOGRAPHY AND PROCESSES

### Physical Geography

The 1.55-million-acre 1002 area, located in the northernmost part of the Arctic Refuge between the Brooks Range and the Beaufort Sea (fig. II-1), more than 250 miles above the Arctic Circle, is in the tundra-covered Arctic Coastal Plain Province, the only extension of the Interior Plains of North America in Alaska (Wahrhaftig, 1965). It is bounded on the north by the Beaufort Sea, and on the east by the northeast-flowing Aichilik River. The south boundary follows township lines and approximates the 1,000-foot elevation contour. The north-flowing Canning and Staines Rivers are the west boundary of the 1002 area and the Arctic Refuge. The 1002 area constitutes about 75 percent of the total coastal plain of the Arctic Refuge.

The 1002 area is about 104 miles in length at latitude 69°51'N. Maximum width is about 34 miles; minimum is 16 miles, south of Camden Bay. The area has 10 major northward-flowing rivers and 14 smaller rivers or named creeks. The majority of large rivers within the 1002 area are braided; nearly all the creeks, even the many small unnamed ones, have extensive tributary systems.

Except for about 4 percent of scattered bedrock outcrops, the 1002 area is covered by a thin mantle of unconsolidated, frozen sediments of Cenozoic age that range in thickness from a few feet to about 100 feet (fig. II-2). The outcrops are mainly poorly consolidated Tertiary siltstone, mudstone, sandstone, and conglomerate in the Marsh Creek and middle Jago River areas; a few minor outcrops of Cretaceous and Jurassic shales along the lower Jago River; and Cretaceous and Jurassic shale near the Niguanak River and in the Sadlerochit Spring area.

Oil seeps have been found in the Manning Point area, about 6 miles north of the 1002 area, and near Angun Point, within the 1002 area. Oil-stained sandstones are found in outcrops near the middle reaches of the Katak-

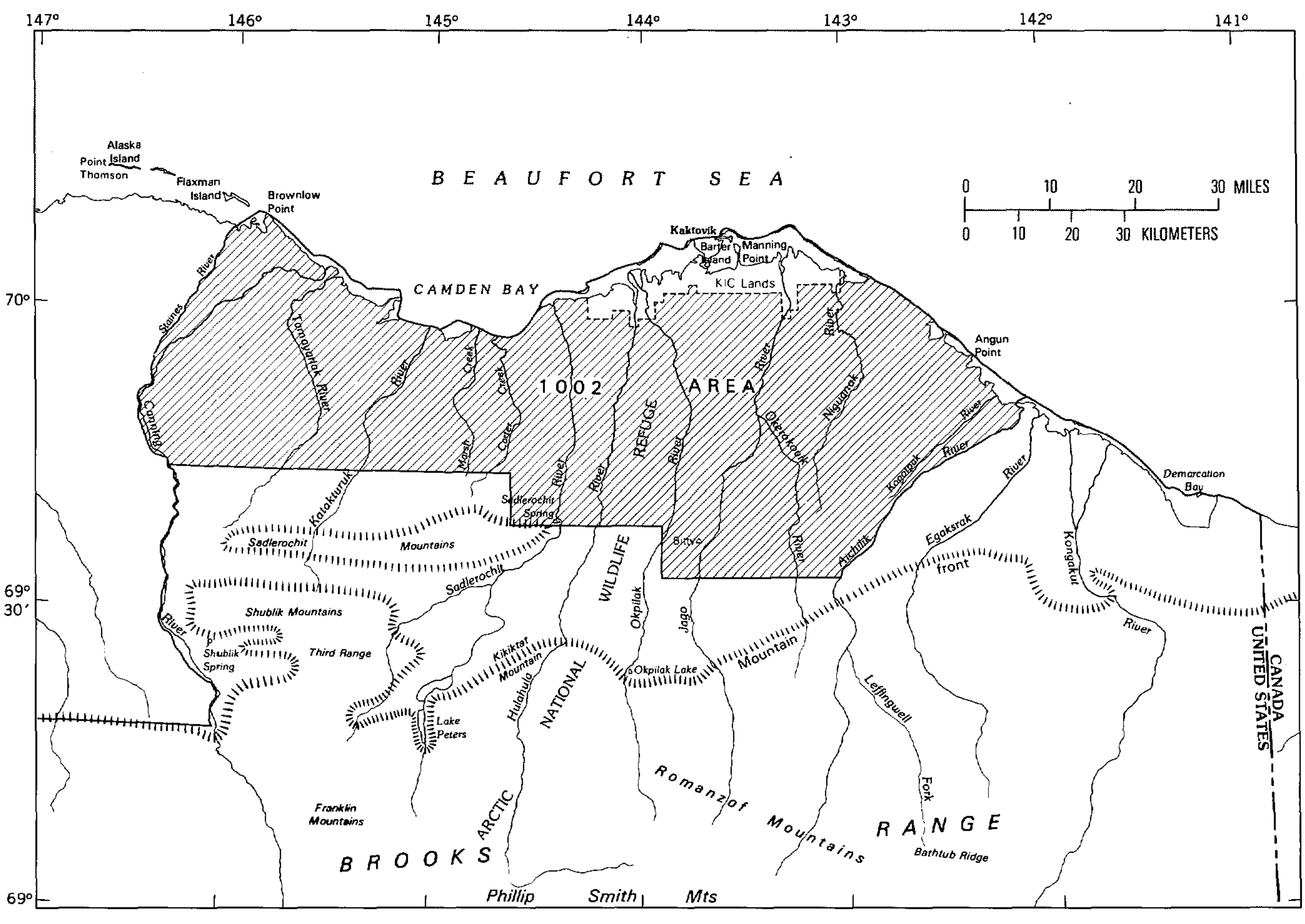


**Figure II-1.**--Map of northeastern Alaska showing the 1002 area and important nearby geographic features.

turuk River; and oil-bearing sands and shales having an odor of oil occur in outcrops along the lower Jago River, about 10 miles south of Barter Island.

Despite the arctic climate prevailing during the Pleistocene, about 90 percent of the 1002 area is unglaciated. A large valley glacier formed a piedmont that extended approximately 12 miles into the area and probably about 7 miles along the Tamayariak River. Smaller valley glaciers extended about 4 miles into the area along the Hulahula River, just across the 1002 area boundary along the Jago River, and 2 miles along the Aichilik River. Glacial fluvial deposits and eolian materials are widespread, even in unglaciated areas.

The Beaufort Sea coastline, with its narrow beaches, is low-lying, gradually receding, and irregular in shape. It has numerous points, many offshore shoals, mudflats, spits, bars, and low-lying barrier islands behind which are shallow lagoons. The coast is punctuated by deltas, the most pronounced being those of the Canning, Hulahula-Okpilak, Jago, and Aichilik Rivers. Tides are small; the daily tide rarely exceeds 1 foot, and the maximum annual tide is less than 3 feet. Wind tides occasionally exceed the maximum lunar tides during periods of open water, particularly in late September-early October. The coast is characterized by bluffs commonly 4-5 feet high, locally as high as 25 feet. The 50-foot contour is generally 2-3 miles inland, except at Barter Island, which is only about 3 miles wide but is higher than 50 feet in the central area. In the low-lying Canning River delta a comparable elevation is found about 8 miles inland.

Lagoons and bays are generally shallow, 3-12 feet deep, except for the greater-than-15-foot depths in Camden Bay, where the 18-foot depth contour is within about 200 yards of shore. Camden Bay offers the best reasonably deep, protected harborage along the coast of the 1002 area.

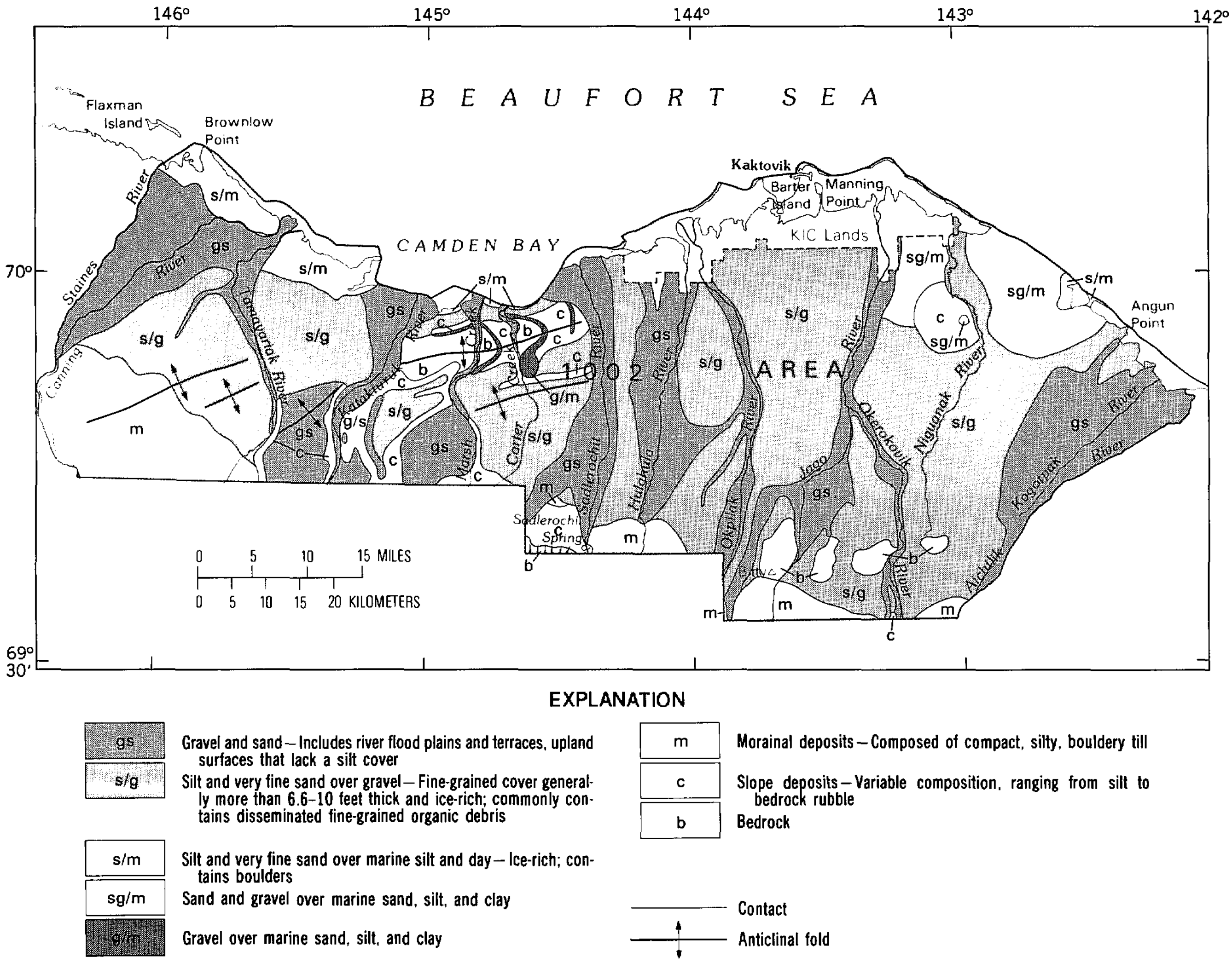


**Figure II-2.**--Generalized surficial deposits of the 1002 area. Map indicates surface materials only and not what could be borrowed for fill. Geology by Carter, Ferrians, and Galloway (1986).

## Climate

The climate of the 1002 area is arctic marine, having extremely low winter temperatures and short, cool summers. Persistent winds occur throughout the year. Frequent blizzards occur during the long, dark winter. Along the coast the climate is moderated by the sea and is less extreme. Meteorological data are limited; those of most value for this study are the marine data from Barter Island (Kaktovik) and the data from Umiat (to the west and about 75 miles inland, fig. I-1), which has more of an arctic continental climate. Umiat is the closest area for which inland climate records exist. The recorded minimum for Barter Island was -59°F in February 1950; the maximum was +78°F, July 1978. For Umiat the minimum was -65°F in February 1977, and a maximum of +85°F in July 1977. The maximum and minimum temperatures are of very short duration, often only minutes, and thus do not really affect either the environment or man's activities.

The average monthly temperatures, however, can markedly affect the environment and man's activities. From year to year, the average monthly temperatures, especially in winter, can vary widely. At Barter Island, the average January temperature was +4.5°F in 1981, and -21.8°F in 1983. At Umiat, the average January temperature was -11.2°F in 1982 and -42.1°F in 1984. In summer, variations are less pronounced but more important because the accumulation of the degree days above freezing (thaw index) greatly influences the depth of thaw in the soil and the rate of the melting of ice on water bodies. Some of the important average monthly temperature data and temperature-related parameters are tabulated below. The thaw indices show that usually approximately three times as much heat energy is received at the ground surface in the Umiat area during the summer months, but that the effect of an unusually warm summer can be relatively much greater at Barter Island.

Average temperatures and thaw index,
Barter Island and Umiat, 1976-84

| | Barter Island | Umiat |
|---|---|---|
| Average temperature (°F): | | |
| Coldest month | -33.1 | -42.1 |
| Warmest month | 42.9 | 58.0 |
| Thaw index (degree days above freezing): | | |
| Maximum (summer) | 793 | 2183 |
| Minimum (summer) | 456 | 1371 |
| Average (summer) | 549 | 1671 |

In the Arctic, chill factor is more important than air temperature in evaluating temperature's effect. Strong winds coupled with cold temperatures produce chill temperatures sometimes colder than -100°F (-35°F with a 30-mph wind) (Selkregg, 1975). The average wind-chill factor at Barter Island during February 1984 was -80°F (-33.1°F and 15.5-mph wind).

Precipitation over the 1002 area is light but frequent; it occurs as drizzle in the summer and as light snow in the winter. Published summaries indicate that the annual precipitation at Barter Island averages 6.28 inches and ranged from 2.93 inches in 1974 to 12.22 inches in 1955. Average summer precipitation is 0.52 inch in June; 1.01 inches in July; and 1.09 inches in August. The reported remaining 3.66 inches generally occurs as snow throughout the rest of the year. Rainfall rarely exceeds 0.5 inch in any one day (three times in the last 15 years). On the North Slope, relative humidity is generally high during the summer--80-95 percent along the coast. During winter it falls to about 60 percent. Absolute humidity in winter is generally low, often 5-20 percent.

Snow can occur at any time on the 1002 area, although snowfall is greatest during September-November and January, with a lesser fall in May. Melting begins in late May and is largely completed in early June. Winds continually redistribute snowdrifts, baring inland ridgetops and drifting in the valleys, with drifts adjacent to stream cutbanks sometimes becoming 20 feet deep. Higher microsites, such as tussock tops and high-center polygons, are frequently exposed with hard-packed snow drifted between them. Felix and others (1986), traveling with the seismic crews in the spring of 1985, noted that the area west of the Sadlerochit River had significantly less snow than the eastern part of the 1002 area. According to numerous measurements taken throughout the 1002 area from January to May, average depths of snow actually accumulated on the ground were 12 inches in 1984 and 9 inches in 1985; measured depths ranged from 0 inches to at least 32 inches (Felix and others, 1986).

During 1955-84, the recorded average seasonal snowfall at Barter Island was 42.1 inches; the minimum was 19.9 inches in 1980-81, and the maximum, 71.4 inches in 1961-62. Because the wind blows almost continuously, the snow crystals are broken up and pack much like fine sand; and the snow often develops a density of about 0.4. This could result in actual winter precipitation about four times the 3.66 inches officially reported (Black, 1954).

Easterly winds predominate most of the year in the 1002 area. However, during January-April westerly winds are often associated with storms. The windiest month usually is January (mean 15.0 mph); and the calmest month, July (mean 10.7 mph). The peak gust (westerly) recorded at Barter Island was 75 mph in January 1980. Ice storms, or occasionally heavy rains, occur in October and January. The coastal part of the 1002 area can be subjected to storms rolling in from the Beaufort Sea during the open-water season. Even though Barter Island, the barrier islands, the shallow lagoons, and often nearby sea ice provide some shelter to coastal areas, these storms can cause severe erosion of the coastline.

In the 1002 area, particularly along the coastline and up to 5 miles inland, fog frequently reduces visibility. Along the coast, fog occurs most frequently during summer. At Barter Island, it reduces visibility to 6 miles or less about 27 percent of the time during May-September, reaching a maximum of 31.5 percent in August. Fog occurs an average of 10 percent of the time during the rest of the year. Inland, Umiat has fog about 15 percent of the time during September-May, and less than 10 percent during June-August.

Stratus clouds are prevalent in the Arctic during summer months, often persisting for weeks. The base of these clouds is often below 700 feet. At Barter Island and Umiat, skies are cloud-covered 54 percent of the year.

In the winter, blowing snow and whiteouts can create conditions in which neither shadows, nor horizon, nor clouds are discernible, and depth perception and orientation are lost. At Barter Island, blowing snow reduces visibility to 6 miles or less about 10-22 percent of the winter. This is in addition to loss of visibility caused by fog.

At Barter Island, the sun is continuously above the horizon from May 15 to July 27, and continuously below the horizon from November 24 to January 17. In winter, when the sun is not more than 6$^{\circ}$ below the horizon, twilight permits many activities; at that latitude moonlight can be an important source of illumination. In the 1002 area twilight amounts to 6 or 7 hours in late November and is reduced to about 3 hours by December 21.

The arctic winter is characterized by frequent temperature inversions. Whereas the lower atmospheric air temperature normally decreases with altitude, in a temperature inversion, colder air is overlain by a warmer air layer. During the summer surface temperatures are warmer, fewer inversions occur.

Freezeup normally begins in early to mid-September. Drier areas begin freezing first, sometimes cycling between freeze and thaw for several days. Wet tundra and ponds freeze over next, then lakes and rivers and protected shallow lagoons. In wet areas as much as 8 weeks may be required to completely freeze the "active layer" (that layer above the permafrost which annually freezes and thaws). A sudden cold snap, particularly if accompanied by wind, can cause all the areas to freeze over within a day or two. Freezeup on the sea depends on late summer water temperatures, nearness of the ocean icepack, winds, and prevailing air temperatures. Generally, at least the nearshore sea areas are iced over by early to mid-October.

Ice thickness is determined by numerous factors, including thickness and insulating value of the snow cover. Data from the Arctic coast indicate ice thickness of 2 feet in mid- to late November, 3 feet in mid- to late December, and 4 feet by mid- to late January. At the end of winter, the average maximum thickness of seasonal sea ice and fresh-water lake ice is about 6 feet. Near the cutbank of a river or a sea bluff where deep snowdrifts may occur, the ice may be only 15-20 inches thick, whereas in the middle of the river it may be 6 feet thick. Similarly, should the winter temperature remain average or even mild with a very light snowpack, the ice may be as much as 7.5-8 feet thick.

In the 1002 area, the ground is frozen until June. Rivers fed from melting snow in the foothills may start to flow as early as mid-May. Ponds, lakes, lagoons, and nearshore sea ice begin to melt in early June. Ice on deeper lakes may not completely melt until early to mid-July. Ice breakup in coastal lagoons and nearshore areas depends on runoff from the land, offshore grounding, and ocean currents. Where runoff is negligible, melting follows a pattern similar to that in deeper lakes. Melting off river mouths is markedly different: fresh-water runoff begins in late May, depositing river sediments on top of the ice; channels are often cut on both top and bottom ice surfaces, and large holes may be cut through by river waters draining in a swirling, fast-cutting manner. Nearshore, landfast sea ice often does not completely melt in place but floats away, beginning as early as late June.

## Permafrost

Permafrost is defined as a thickness of soil or other superficial deposit, or even of bedrock, at a variable depth beneath the surface of the earth in which a temperature below freezing (32$^{\circ}$F) has existed continuously for a long time (from 2 years to tens of thousands of years) (Muller, 1947). It may include soil, rock, minerals, interstitial and segregated ice (the latter as wedges or, less frequently, lenses), organic matter, or other materials both naturally occurring and those buried by man. Permafrost is often considered to be synonymous with "perennially frozen ground"; however, it need not be "frozen hard," because the material could contain water having an elevated salinity, as is often found in the NPRA, or could contain liquid hydrocarbons, such as oil seeps found in northern Alaska. Because of confining pressures, such as at the base of permafrost, the contained water could have a depressed freezing point. Or, because of low water content and particle-surface forces, the material could be unfrozen. The volume of ice in permafrost soils, particularly in the first few tens of feet below the ground surface, can be several times the volume of the mineral components; it can even approximate pure ice. At the other extreme some gravel may contain little, if any, ice.

Except for a small area at Sadlerochit Spring, which flows year round, the 1002 area is believed to be completely underlain by permafrost (Ferrians and others, 1969).

The minimal permafrost-temperature data available for Barter Island suggest an average permafrost temperature of +17.8$^{\circ}$F to 15.8$^{\circ}$F. Similar temperatures have been found in a series of shotholes extending from the coast inland for 20 miles on the 1002 area (T. E. Osterkamp, oral communication to Max Brewer, 1986). Temperatures also vary with season and depth (Brewer, 1958a, fig. 3). Near Barrow, at a depth of 70 feet, where annual change is negligible (Brewer, 1958a), permafrost temperatures range from about 31°F under the ocean, to about 18.5°F beneath sandy unvegetated beaches, to about 15°F under dry tundra areas, to a minimum of about 13°F under very wet, low-centered polygonal tundra areas (Brewer, 1976). Similar temperatures and variations in temperature are believed to occur throughout the 1002 area.

The greatest reported thickness of permafrost in Alaska is about 2,250 feet near Prudhoe Bay, believed to result from an anomalous thermal conductivity because of the usually thick gravel in that area. Permafrost thickness decreases markedly in all directions within a few miles. In the NPRA, the maximum known thickness is 1,330 feet, inland near Barrow (Brewer, 1955b). At Umiat the thickness ranges approximately from 700 to 960 feet. No wells have been drilled through the permafrost in the 1002 area; about 9 miles south of the southwest corner of the 1002 area, at the Exxon Canning River well, the measured thickness of permafrost is 928 feet. Thickness of the active layer ranges from less than 1 foot to 5 feet and averages about 2 feet.

Depending on their depth and areal extent, lakes and rivers influence the shape of the permafrost table. Shallow lakes freeze to the bottom and are directly underlain by permafrost. Deep lakes (7+ feet deep) typically do not freeze to the bottom and consequently are underlain by a thaw bulb in the permafrost table (Brewer, 1958a, b). Shallow rivers and creeks freeze to the bottom, with the permafrost table usually a few inches to a few feet beneath. Some deeper rivers, such as the Canning, may have unfrozen pockets of water in deeper parts (7 feet or more at freezeup), but may be frozen to the bottom in shallower areas. Thus, the permafrost table beneath a river may be very irregular. The effects of surface features on distribution of permafrost are shown in figure II-3.

Studies of sea-water temperatures, seismic surveys, and boreholes in the Mackenzie Bay, Flaxman Island, Prudhoe Bay, Harrison Bay, and Barrow areas (fig. I-1) indicate that subsea permafrost occurs in the nearshore of the Beaufort Sea and probably extends in a thin layer out to water depths approximating 500 feet. Subsea temperatures range between the fresh-water freezing point and the sea-water freezing point, that is, from approximately 30.1°F at 15.0 feet below sea bottom in the Chukchi Sea off Barrow (Brewer, 1955a, 1958a) to 29.5°F at 22.3 feet in Harrison Bay off Atigaru Point, to 29.3°F at 17.7 feet in Prudhoe Bay off Reindeer Island (the latter two temperatures from Osterkamp and Harrison, 1985). Permafrost temperatures in the nearshore Beaufort Sea parallel mean annual bottom-water temperatures (Selkregg, 1975), approximately 31.1°F to 30.8°F for the Chukchi Sea, and

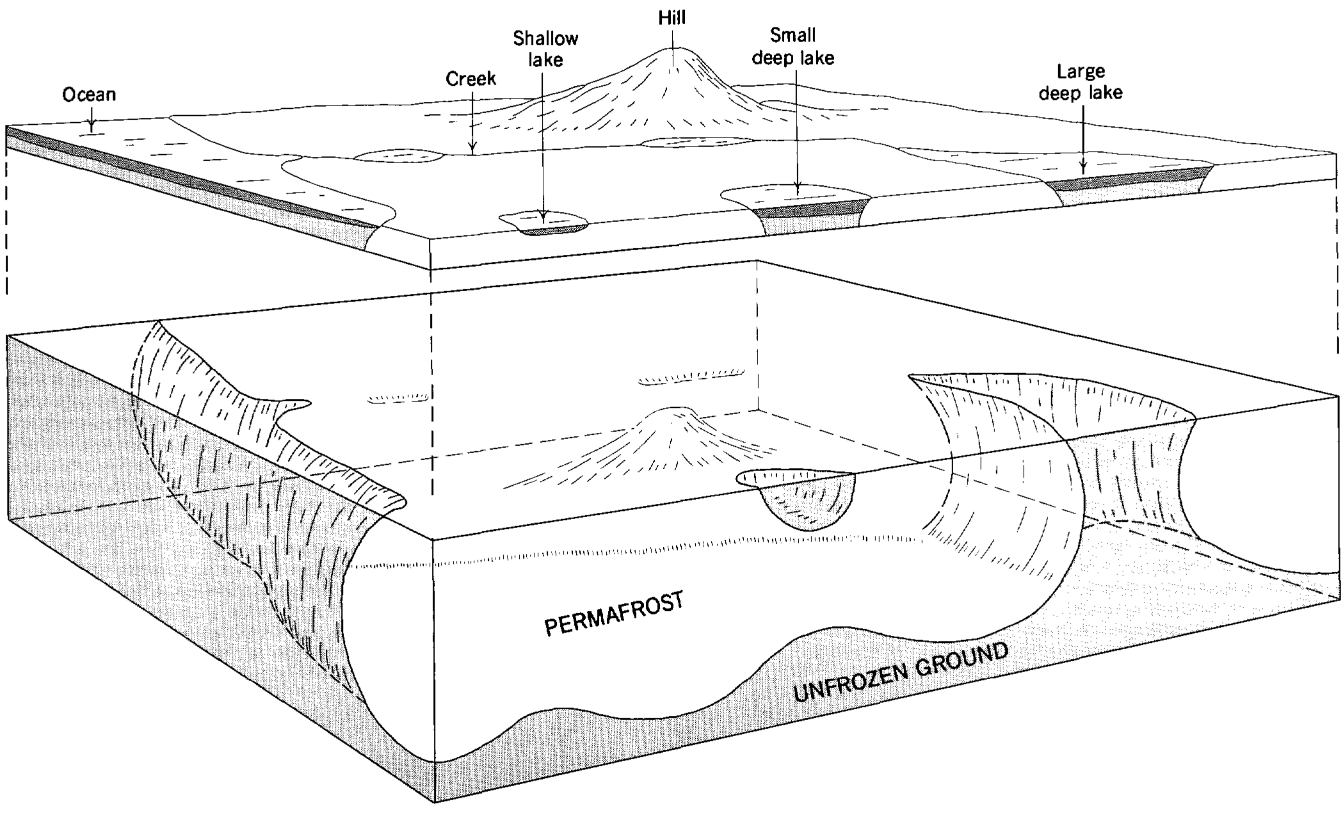


**Figure II-3.**--Schematic representation showing the effect of surface features on the distribution of permafrost in the continuous permafrost zone. From Lachenbruch, Brewer, Greene, and Marshall (1962).

30.0°F to 29.7°F for the Beaufort Sea. Where the water in the shallow nearshore areas freezes to bottom, the permafrost temperatures decrease markedly, and the permafrost-temperature profiles are similar to those found on land (Osterkamp and Harrison, 1985). Farther east, eroded pingos, with the remains of their cores of ice, occur well offshore in Mackenzie Bay.

Few data are available concerning (1) amounts of ice in subsea sediments; (2) whether the ice is mostly interstitial; and (3) whether, at least nearshore, a significant portion of it is segregated as ice wedges. Information is also lacking regarding near-surface variability in ice content resulting from shoreline regression (about 3.3 feet per year), because of migrating spits, bars, and barrier islands, and because of warmer water inflow from major rivers.

Permafrost-related stream data for the 1002 area are sparse. However, data from the Shaviovik River, 35 miles west of the Arctic Refuge, are pertinent because the Shaviovik has many characteristics common to most rivers in the 1002 area except the Canning and Aichilik. It is shallow and it has many bars, few potholes, heavy spring runoff, summer low- and high-water periods, and low water at freezeup. The average annual temperature in shallow sediments beneath the Shaviovik (Brewer, 1958a) is about 5.4°F warmer than beneath adjacent well-drained tundra, though well below the freezing point of fresh water. Measurements from the upper part of the geothermal profile beneath a narrow sand bar in midriver do not indicate any unfrozen zone in the river channel on either side of the bar in late winter. Temperature data from the 15- and 25-foot depths suggest that water is present in the channel at the time of freezeup, which delays the freezing process. Temperature profiles through and beneath shallow lakes are similar. Apparently, shallow rivers freeze to the bottom; sands and gravels in the river bottoms rest on permafrost and, by early November, are also frozen.

Ice wedges form when the upper few feet of ground, exposed to temperatures well below freezing, contracts and cracks, usually in a polygonal pattern. Hoarfrost is formed in these cracks and is cemented by the spring meltwater, leaving a vertical stringer of ice. This ice limits summer expansion of warming permafrost, displacing the adjacent mineral soils upward; repeated cracking and widening of the ice wedges over many years eventually results in elevated ridges of material on each side of the wedges (Lachenbruch and others, 1962). Polygonal ground is the common surface feature in the 1002 area. Most polygons range in diameter from 30 feet to 200 feet and are easily recognized on the surface; some in the southern part of the 1002 area are masked by tussock-type tundra. Usually each polygon is separated from the adjacent polygons by ice wedges, a few inches to several feet wide at the permafrost table. These ice wedges are 10-18 feet deep and are interconnected. Some small streams may have originated by the melting of a long series of ice wedges. Beaded streams, with the beads located at the intersections of ice wedges, follow this pattern.

Most polygonal areas in the 1002 area contain "low-centered" polygons, characterized at the outer edges by upthrust ridges that impede drainage from the polygon, giving the enclosed area a rice-paddy appearance.

Where slopes near streams or some lake banks allow drainage, "high-centered" polygons may occur. These polygons originated in the same manner as low-centered polygons, but during exceptionally warm summers with deeper thaw, the tops of the ice wedges melt, water drains off, and the soil and tundra slump into the voids. The slumping, when continued over tens of years, produces ditches between the polygons, thus leaving the polygons as erosional remnants separated by partly filled voids.

## Soils and Other Materials

The 1002 area is crossed by numerous north-flowing rivers that head in the glaciated mountains rising about 6-12 miles south of the area's boundary. Outwash plains, active flood plains, river terraces, and eolian deposits resulting from winds during glaciation have covered much of the 1002 area with a thin mantle of unconsolidated, though frozen, sediments a few feet to about 100 feet thick.

The valleys of larger streams are underlain by large quantities of coarse sand and gravel. These include the valleys of the Canning, Tamayariak, Katakturuk, Sadlerochit, Hulahula, Okpilak, Jago, Okerokovik, Kogotpak, and Aichilik Rivers. These rivers, especially the Canning, Sadlerochit, Hulahula, Jago, and Aichilik, are heavily braided and have extensive unvegetated gravel bars. Gravel also occurs in the south part of the 1002 area between the Canning River and Marsh Creek, along tops and flanks of ridges between the Katakturuk and Sadlerochit Rivers, and on spits and bars along the coastline of the Beaufort Sea. On the spits and bars the deposits range from fine to medium sandy gravel to sand. Granular deposits typically present in stream valleys range from coarse to medium sandy gravels with cobbles, along the south boundary of the 1002 area. Downstream toward the Beaufort Sea the materials become progressively finer grained; in the deltaic areas they range from fine to medium sand. Sand dunes occur in the Canning, Hulahula-Okpilak, and Jago River deltas. Numerous sizable sandy shoals are prominent between the deltas of the Sadlerochit and Okpilak Rivers.

Soils in the 1002 area are poorly developed and frequently water saturated, and can generally be classed as tundra soils, bog soils, or sand dunes. They tend to be sticky claylike soil in the beginning process of leaching, even in better drained areas, because of cold ground temperatures, the presence of permafrost, and the thinness of the "active layer." Polygonal patterning is well developed throughout the area, although surface expressions tend to be more pronounced adjacent to breaks in slope, especially those associated with drainage. A soils study in the valleys of the upper Okpilak and Jago Rivers (Brown and Tedrow, 1964) reported mineral uniformity in the soils, with quartz and feldspar each amounting to 40-50 percent in the sands, and heavy-mineral suites consisting of opaques, epidote, tourmaline, chlorite, actinolite, zircon, and minor amounts of other minerals. In view of the geomorphic history of the 1002 area, this type of mineral composition may be assumed to prevail there.

Except in the sand dunes, on ridgetops, and in unvegetated gravel areas, much of the 1002 area is covered by a 1- to 2-inch organic mat of living vegetation overlying a fibrous layer containing sand, silt, and small cobbles. That fibrous layer, in turn, overlies mineral soils of loam, silt, or sand. In well-drained areas thaw progresses to greater depths, and mineral soils near the base of the "active layer" may have a pronounced brownish appearance, owing to an accumulation of well-humified organic matter.

## Water Resources

Water resources in the 1002 area are very limited and are confined to the surface. The estimated 800- to 1,000-foot-thick impermeable permafrost precludes obtaining nonsaline water from within this zone. Although no wells penetrate the permafrost zone in the 1002 area, any water that might occur beneath that zone probably would be brackish or at least moderately saline (Cederstrom and others, 1953; Hopkins and others, 1955; Brewer, 1958a, b, 1974; Williams, 1970).

Only a few large lakes occur in the 1002 area. A few shallow thaw lakes are found near the coast east of the Canning River delta, and east of the Hulahula-Okpilak River deltas, the latter being on Native land and outside the 1002 area. Except for two near the Canning delta, the lakes each cover less than 1 square mile; most have basins less than 7 feet deep and freeze to bottom by late winter.

Rapid spring snowmelt (10-14 days) causes water to accumulate on and flow over the river ice, fracturing and rapidly eroding it. Large chunks of ice break loose from the banks and bottoms of the river, and float downriver. In constricted areas, ice may lodge, causing jams and extensive spring flooding, particularly in the deltas. Even if this does not occur, the rivers run very full because of the rapid snowmelt. Surface runoff often resembles sheetflow, because of the frozen ground. Suspended-sediment content is very high, perhaps 75 percent of annual transport (Walker, 1973), and riverbanks are severely eroded, higher cutbanks often being undercut. By the third or fourth week in June rivers may subside to summer low-water stage. Late summer or fall rains rapidly bring the rivers to one or more flood stages. Warm weather may also cause the rapid rise of glacial rivers such as the Hulahula, Jago, and Okpilak. Low water prevails at the time of freezeup; by midwinter, most rivers in the 1002 area go dry or freeze to bottom throughout most of their length, with the possible exception of a few basins or "potholes" near the mouth of the Canning and perhaps one or two other major rivers. Even early in the freezeup period, if the basins, or potholes, in the lower Canning are connected to the sea, water may be brackish because of sea-water intrusion. The Canning River has not been intensively studied. But long-term studies of the much-larger Colville River (having 3.5 times the length and approximately 11 times the drainage basin of the Canning) show that streamflow in that river even ceases during winter; and salt-water intrusions eventually reach as far as 58 km (35 miles) upstream (Walker, 1973).

Several springs occur along the north edge of the eastern Brooks Range. The largest of these is Sadlerochit Spring, just inside the south boundary of the 1002 area (fig. II-2). The spring flows year round; rate of discharge and water temperature are variable. This spring has had a reported discharge of 21.2 cubic feet per second (cfs) (Craig and McCart, 1974), and a temperature of 43°F. Discharges of 37 cfs (FEIS, 1983) and 88.3 cfs (Williams, 1970) and temperatures of 55°F (FEIS, 1983) and 52°F (Williams, 1970) also have been reported.

Numerous small springs have been reported on rivers or in valleys south of the 1002 area where large icings have been observed (FEIS, 1983; Williams, 1970). Selected physical parameters have been measured for some springs (U.S. Fish and Wildlife Service, 1982). Icings (aufeis), especially those reported on rivers, require investigation to determine whether they result from discharge from true springs or are the result of meltwater in areas having relatively steep gradient.

Turbidity from suspended sediment impairs water quality. Suspended-sediment concentrations are highest in the major streams and rivers during spring breakup and late summer and fall high-flow periods. During low-flow periods most streams are almost clear. However, the Canning, Hulahula, Okpilak, Jago, and Aichilik rivers are somewhat turbid, owing to glacial inflow from tributaries. Some shallow lakes are turbid during summer, when wind and wave action disturb bottom sediments. Aside from periods of turbidity, the water in most rivers and lakes is virtually colorless. Tea-colored water, resulting from high concentrations of dissolved organic materials, occurs in some smaller tundra streams and ponds.

Water quality in lakes and streams is lessened in winter because salts and dissolved organic material are excluded from the downward-growing ice. The concentration of those materials depends on the ratio of water to ice as the ice thickens. Water in lakes and river pools that freezes nearly to the bottom is usually unpotable by late winter.

Dissolved oxygen (DO) is at or near saturation in lakes and streams during summer. Under winter ice cover, DO levels can be severely depressed, owing to lack of aeration and the extended darkness that limits photosynthesis.

Coliform-bacteria counts in lakes and ponds peak in early June because of the "washing action" of surface runoff. A secondary peak follows in mid- to late summer in areas where large concentrations of waterfowl arrive for molting and staging (Boyd and Boyd, 1963).

Because of the lack of fresh water for industrial use within the 1002 area, the adjacent marine waters must be viewed as a water resource. Lagoons begin breakup in early June with an influx of fresh, silt-laden, relatively warm water from river and stream runoff and snowmelt. Much water initially flows over the top of the sea ice; silt, as thick as 4-6 inches and thinning seaward, has been deposited on the ice (Walker, 1973). Overflows can continue for several miles offshore, until meeting cracks in the ice. In shallow lagoons (less than about 6 feet deep), the ice is often frozen to bottom, and water may puddle on top until the ice becomes free and floats. Moats form along the shore in early June, and by early to mid-July the lagoons are generally ice free. Freezeup begins in late September-early October.

By the time the lagoons are ice free, the influx of fresh water, coupled with some ocean current-flushing of hypersaline brines formed beneath the ice during the winter, drastically reduces salinity, often from a normal 32-33 parts per thousand (ppt) to <10 ppt. Salinity gradually increases during the balance of the summer owing to the influx of marine water through inlets and lowered discharges of fresh water.

## Erosion and Mass Movement

Water and wind are the major shapers of the landscape of the 1002 area because of permafrost which often is very susceptible to erosion, and the unconsolidated sediments supplied by earlier nearby glaciers; and exposed river channels, deltas, and offshore bars and barrier islands. Water causes the most erosion, especially during breakup. It flushes heavy sediment loads onto the sea ice; it undercuts high banks and ice-rich terraces causing frozen blocks of soil to fall into the rivers; and it builds deltas and mudflats. Even though the results of lateral erosion are obvious in the multi-channel braiding of the major rivers, stream gradients across the 1002 area demonstrate the potential for vertical erosion. Gradients range from approximately 12 feet per mile on the Canning River, to 30 feet on the Hulahula and Aichilik, to 40 feet on the Katakturuk and Sadlerochit, to about 50 feet per mile on Marsh Creek, which cuts through ridges of Tertiary sandstone and conglomerate.

Erosion along the coast and offshore during open water is less obvious. Leffingwell (1919) and MacCarthy (1953) suggested that bluffs and beaches erode approximately 3 feet per year; Leffingwell also reported an extreme shoreline recession rate of more than 30 feet per year. Wiseman and others (1973) measured 164 feet of bluff erosion on the east end of Pingok Island, west of Prudhoe Bay, during 3 weeks in 1972; this was also an extreme. Beach erosion varies greatly from place-to-place and year-to-year along the entire Beaufort coast, depending on storm intensity and nearness of pack ice. Erosion on the order of 3 to 6 feet per year may be the average. Erosion and deposition of eroded sands and gravel also produces barrier-island or spit migration. This occurs especially where no established vegetation may exist. Such migration can introduce major variations in the temperature and thickness of subsea permafrost.

Thaw lakes elongated north-south are characteristic of the Arctic coastal plain farther west, but they are not a pronounced feature in the 1002 area, where the few small lakes, except in the Canning-Tamayariak delta, are oriented either randomly or somewhat east-west. Because prevailing winds are not greatly different, the general absence of north-south orientation suggests that the small thaw lakes found there are enlarged more by thermal erosion than by mechanical (current) erosion.

Although precipitation over the 1002 area is light, in summer the soils are frequently water-saturated because (1) evaporation rates are low; (2) the permafrost barrier prevents water loss to underground aquifers; and (3) irregularities in the permafrost table impede surface drainage. Despite the fact that saturation is usually conducive to solifluction and creep or slump in areas of steeper terrain, the surface impact of these processes is not widespread on the 1002 area, because of its generally coarser material. However, once the surface is disturbed, these processes can become active, especially along coastal bluffs, terrace escarpments, lake margins, and ridge slopes. Locally along a stretch of the Katakturuk River and near Marsh and Carter Creeks, landslides have occurred in weathered and poorly indurated Tertiary shale, siltstone, and sandstone. In all areas having any appreciable slope and exposed mineral soil, the soil migrates gradually downslope because of seasonal frost-jacking of individual soil grains.

Wind erosion is generally confined to the Canning, Hulahula, Okpilak, and Jago River deltas (where active dunes are found along their western banks) and to sandy river bluffs, exposed bars in braided rivers, and exposed spits and barrier islands. Though considered to be a summer phenomenon, wind erosion actually occurs during much of the year, in exposed areas along river bluffs and on barrier islands.

## Seismicity

There has been some earthquake activity in the 1002 area, but historically the level of this activity is low. Earthquakes of magnitude 6 and larger on the Richter scale of intensity are potentially destructive; earthquakes of magnitude 5 could cause damage locally. Since the mid-1960's epicenters of at least 6 shocks (5 of them offshore) having magnitude greater than 4.0 have been located within about 40 miles of the 1002 area between longitudes 143°W and 146°W. Uncertainties in epicenter locations are estimated to be about 25 miles.

No active faults are known through surface reconnaissance on the 1002 area, but more detailed geologic investigations might reveal evidence of geologically recent movements. There is evidence of offshore seismic activity in the Beaufort Sea. The area historically is one of the least seismically active in the State (U.S. Department of the Interior, 1976, map on p. 84).

As seismically active faults are possible, earthquake potential within or adjacent to the 1002 area may be specified as a maximum expectable earthquake of magnitude 5.5 (U.S. Department of the Interior, 1976, p. 86; Page and others, 1972). The maximum expectable earthquake is the largest earthquake that may reasonably be expected to occur. The probability of such an earthquake is low.

## Air Quality

Relatively few long-term air-quality data are published for Arctic Alaska. The North Slope air is generally of good quality (Burro, 1973). The low levels of pollutants that do occur generally result from natural sources and natural atmospheric reac- tions. In recent years, however, there have been reports of Arctic haze, with the suggestion that some pollutants originate from the Ural Mountains (USSR) industrial complex.

Locally, particulate-matter content may be very high because of windblown dust from beaches, sand bars, and sand dunes, because of salt spray near the coast, or because of industrial operations such as road traffic at Prudhoe Bay. Low concentrations of carbon monoxide have been measured (Cavanagh and others, 1969), ranging from 0.055 to 0.250 ppm and averaging 0.090 ppm, with the trend toward an increase in the past 20 years. Carbon-dioxide concentrations show an annual cycle (Kelley and Weaver, 1966; NOAA, 1975). Concentrations are higher during the winter and under the snow (Kelley and Weaver, 1966). Concentrations are at their minimum in August, corresponding closely to the maximum vegetative bloom on the tundra.

The effects of human activity on air quality are currently localized, being restricted mostly to the vicinity of villages and to the Prudhoe Bay/Kuparuk development area, and are strongly dependent on local meteorological conditions and topography.

Strong temperature inversions on the coastal plain, particularly during the winter, often begin near ground level and hinder vertical air circulation and mixing. An inversion, if coupled with low, near-surface wind speeds, can produce prolonged stagnant air conditions, especially in areas having topographic obstructions such as hills and mountains. Although inversions are common in the 1002 area, persistent surface winds tend to prevent air stagnation.

## Noise

Ambient noise levels over most of the 1002 area are low and result predominantly from natural sources or processes. During the winter, the principal sounds are those associated with the wind. Noise carries considerable distances (but not upwind), especially during calm, cold (-40°F) conditions because of the increased air density. Water noises, including those of wave action, occur during the summer. Manmade sounds are confined to village activities and to some isolated activities, such as hunting. Other manmade sources are aircraft, vehicles, and equipment operations.

# BIOLOGICAL ENVIRONMENT

## Terrestrial and Fresh-Water Environments

### VEGETATION

The Arctic Refuge coastal plain is in the tundra region (Aleksandrova, 1980), where moderately wet to dry habitats are mostly continuously vegetated with low-growing plants such as sedges, grasses, mosses, lichens, small herbs, and dwarf shrubs, generally less than 1 foot high. Taller shrubs are restricted to drainages and to south-facing slopes. Soils are underlain by permafrost having thaw depths of less than 6 inches in colder coastal areas to more than 36 inches in some riverbeds.

Early classifications of the Arctic Refuge soils, landforms, vegetation, and landcover categories were developed from interpreted, color-infrared photographs (scale 1:60,000) and from a ground-truth reconnaissance survey in 1981. A preliminary Landsat land cover map based on high-altitude satellite photography and a derived simplification were produced in October 1981 (Walker and others, 1982). A second revised land-cover map was produced in 1984; field verification of that revision is ongoing. For example, verification shows that willows are not easily visible on Landsat photographs and may be underrepresented on current maps. The 17 cover classes identified in the 1002 area are one forest, three scrub, four herbaceous, four scarcely vegetated, and five other types (table II-1). Dominant vegetation within each 1002 area terrain type is discussed under that terrain type. Each vegetation type and correlations among classification systems are described in the final baseline report (Garner and Reynolds, 1986a).

The FWS is currently examining the status of 30 plant taxa in Alaska that may be threatened or endangered with extinction. This list was published December 15, 1980 (45 FR 82480), with supplements published in 1983 (48 FR 53640) and 1985 (50 FR 39526). One candidate plant species, <u>Thlaspi</u> <u>arcticum</u>, is known to occur in the 1002 area (pl. 1<u>A</u>) (Murray, 1980b; Felix, Lipkin, and others, 1985). An endemic of the Alaska-Yukon region, <u>T</u>. <u>arcticum</u> is known from several widely disjunct areas. Within the Arctic Refuge it has been found in eight locations ranging from alpine sites on the upper Okpilak, Sadlerochit, and Canning Rivers to gravel bars, river terraces, and dry bluffs on the 1002 area along Marsh Creek and the Katakturuk River. It is also found in shrub tundra, dwarf heath, and

**Table II-1.**--Landsat-identified vegetation cover classes and correlation with FWS wetland classifications, 1002 area of the Arctic National Wildlife Refuge.

[Because of rounding, does not add to 100 percent. Class names were developed during mapping for Arctic National Wildlife Refuge comprehensive conservation plan and are not identical with earlier class names by D. A. Walker and others (1982). Wetland types from Cowardin and others (1979)]

| Cover class | Acres | Percent | Wetlands: Classification | Wetlands: Acres |
|---|---|---|---|---|
| Deciduous forest tall scrub.. | 20 | <0.1 | Palustrine, forested, broad-leaved deciduous, temporarily flooded. | 20 |
| Total forest......................... | | <.1 | | |
| Dry prostrate dwarf scrub.... | 10,330 | 0.7 | Non-wetland. ........................................................ | -- |
| Moist prostrate dwarf scrub. | 389,180 | 25.2 | Palustrine, scrub-shrub, broad-leaved deciduous, saturated. | 389,180 |
| Mesic erect dwarf scrub ...... | 113,000 | 7.3 | Palustrine, scrub-shrub, broad-leaved deciduous emergent, persistent, saturated. | 113,000 |
| Total scrub.......................... | | 33.2 | | |
| Very wet graminoid............... | 3,910 | 0.3 | Palustrine, emergent, permanently flooded............ | 3,910 |
| Wet graminoid....................... | 211,430 | 13.7 | Palustrine, emergent, semipermanently flooded or seasonally flooded. | 211,430 |
| Moist/wet tundra complex.... | 238,660 | 15.4 | Palustrine, emergent/scrub-shrub, broad-leaved deciduous, semipermanently flooded or seasonally flooded. | 238,660 |
| Moist graminoid tussock tundra. | 465,350 | 30.1 | Palustrine, emergent/scrub-shrub, broad-leaved deciduous, saturated. | 465,350 |
| Total herbaceous .............. | | 59.5 | | |
| Scarcely vegetated scree ..... | 430 | <0.1 | Non-wetland. ........................................................ | -- |
| Scarcely vegetated flood plain. | 21,100 | 1.4 | Palustrine, scrub-shrub, broad-leaved deciduous, temporarily flooded. | 21,100 |
| Barren flood plain................. | 30,350 | 2.0 | Riverine, unconsolidated shore, temporarily flooded or seasonally flooded. | 30,350 |
| Barren scree.......................... | 230 | <.1 | Non-wetland. ........................................................ | -- |
| Total scarcely vegetated areas................................ | | 3.4 | | |
| Clear water (lakes, ponds, rivers). | 17,290 | 1.1 | Palustrine, open water, permanently flooded; or lacustrine, limnetic, open water, permanently flooded; or riverine, open water, permanently flooded. | 17,290 |
| Clouds-snow-ice................... | 2,530 | .2 | Non-wetland. ........................................................ | -- |
| Shallow water........................ | 450 | <.1 | Riverine, unconsolidated shore/open water.......... | 450 |
| Offshore water....................... | 40,880 | 2.6 | Marine, subtidal, open water; or estuarine, subtidal, open water. | 40,880 |
| Shadow.................................. | 1,160 | .1 | Not applicable.................................................... | -- |
| Total other.......................... | | 4.0 | | |
| TOTAL................................. | 1,546,300 | 100.1 | .................................................................................. | 1,531,620 |

occasionally in tussock tundra. At least three of these sites (Okpilak Lake, Katakturuk River, and Marsh Creek) contain more than 100 plants each. This small, white to lilac-colored mustard plant flowers very early and is easily overlooked when past flowering.

## WETLANDS

Approximately 99 percent (1.53 million acres) of the 1002 area is classified as wetland according to the U.S. Fish and Wildlife Service's (FWS) Classification of Wetlands and Deep-water Habitats of the U.S. (Cowardin and others, 1979) (table II-1). The FWS defines wetlands as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have at least one of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soils; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. (Note: FWS has prepared a preliminary list of hydrophytes and other plants occurring in wetlands of the United States in this classification system. The U.S. Soil Conservation Service has prepared a list of hydric soils for use in this classification system.)

Non-wetland, upland habitat in the 1002 area is generally restricted to sparsely vegetated sites outside of active flood plains where the depth to permafrost is great enough to allow for well-drained soil conditions. Areas with a dense vegetative cover are characterized by permafrost occurring at a shallow depth due to the insulating effect of the organic mat. The soil in these areas remains saturated at or near the surface throughout most of the growing season. The vegetation layer is composed mainly of species typically adapted for life in saturated soil conditions.

## TERRAIN TYPES

Six regionally significant terrain types (Walker and others, 1982) occur within the 1002 area. Five are discussed below. The sixth is the 131 square miles of ocean water within the 1002 boundary (5 percent).

### FOOTHILLS

Foothills cover about 45 percent of the 1002 area. Between the Canning and Sadlerochit Rivers, an east-west distance of about 47 miles, low foothills rise from Camden Bay to the base of the Sadlerochit Mountains, 18-34 miles from the seacoast. The hills in this region are as high as 1250 feet and are interspersed with the drainages of the Tamayariak River, Katakturuk River, Marsh Creek, Carter Creek, Itkilyariak Creek, and the Sadlerochit River (fig. II-2). The crests of several hills, particularly near the Katakturuk River, have barren gravel outcrops. East of the Sadlerochit River the foothills are farther from the coast.

Vegetation is dominated by sedges and tussock-forming sedges. Dwarf willow or birch are common but sparsely distributed. Mosses and lichens are important components of tundra vegetation. The main Landsat cover classes in the foothills are moist graminoid tussock tundra, mesic erect dwarf scrub, and moist prostrate dwarf scrub. Frost-scars are often a component of tussock tundra and can constitute as much as 80 percent of the surface. Parallel and subparallel water tracks, commonly present, give the slopes a ribbed appearance. These water tracks are shallow, vegetated drainage channels that conduct snowmelt waters, and perhaps subsurface waters as well, during the thaw season. Strangmoor are often found in the channels, suggesting slow mass movement of the saturated soil columns. Vegetation in the water tracks is commonly dwarf shrubs, mainly dwarf birch and diamond-leafed willow.

### RIVER FLOOD PLAINS

River environments (about 25 percent of the 1002 area) are among the most complex terrains. They include the barren deltas and braided channels of the larger rivers, the terraces and alluvial areas associated with old river channels, and the delta formations at the base of the foothills that possibly represent an ancient sea level (Institute of Arctic and Alpine Research, University of Colorado, unpublished data, 1982). Riverine systems consist of the active channel and one or more terraces. Most major rivers within the 1002 area have braided channels about 0.6 to 2.5 miles wide. Most of the diamond-shaped islands between channels are inundated sporadically each year during snowmelt from late May to early June. Two types of islands occur: those consisting of unvegetated gravels and gravelly sands (silts in the delta regions) with no soil development, and vegetated islands that have been removed from the main high-water mark because of channel cutting. Vegetated islands of the second type have widely varying vegetation coverage, depending upon the extent and frequency of inundation. The soils developed on them consist of silt, silt loam, loam, and fine sandy loam over gravel and gravelly sand.

Land cover associated with river systems ranges from totally barren river gravels and mud to tundra that is indistinguishable from that in nonalluvial areas. The braided channels are subjected to intense disturbance during spring breakup. In addition, meandering streams and braided rivers are constantly changing their channels. Slightly more stable areas are often only partially vegetated but may contain a wide variety of taxa, making them among the most floristically rich sites in the region. Willows are common on vegetated gravel bars and may form extensive thickets; however, these thickets are not nearly so extensive as the riparian willow communities found farther west along the Sagavanirktok, Kuparuk, and Colville Rivers (fig. I-1). This relatively limited supply of riverine willow within the 1002 area is of significance to several wildlife species. Riparian areas are often snow-free earlier than other areas on the coastal plain, another reason they are of considerable importance to several wildlife species. Smaller streams and stiller interchannel areas of the larger rivers have lush sedge and willow stands. Willow height varies with the amount of winter snow cover and summer temperature regime. Willows near the coast are mostly prostrate, whereas near the south boundary of the 1002 area, shrubs can occasionally exceed 6 feet in height.

Land-cover map classes for this area include clear water, barren and scarcely vegetated flood plain, wet graminoid, moist/wet tundra complex, dry prostrate dwarf scrub, and moist graminoid tussock tundra.

HILLY COASTAL PLAINS

Extensive areas of gently rolling topography cover more than 22 percent of the 1002 area. East of the Hulahula River and parallel to the coast are numerous slightly elevated ridges and depressions, mostly with less than 100 feet of relief. Flat, gently sloping (5 percent or less) interfluve areas contain complexes of moist/wet tussock tundra associated with poorly developed flat-centered ice-wedge polygons. Ridges are mainly vegetated with moist prostrate dwarf scrub, moist graminoid tussock, and moist/wet tundra complex. Frost boils and hummocky ground are common in this area. The depressions between ridges contain thaw-lakes of clear water and wet graminoid tundra. Stream drainages are well defined and have large expanses of relatively well drained terrain.

FLAT THAW-LAKE PLAINS

Thaw-lakes, drained lake basins, and expanses of low-centered ice-wedge polygons occur only locally, primarily near the flat braided river deltas, and cover only 3 percent of the 1002 area. Thaw-lakes are generally elliptical, shallow (2 to 6 ft), and geomorphologically short-lived. They form with disruption of the vegetation and organic cover of the polygonized tundra. Thaw of the ice-rich, near-surface materials and melting of ice wedges can result in a pool of standing water and development of a shallow pond that eventually becomes a thaw lake. The best examples of thaw-lake topography are: (1) confluence of the Canning and Tamayariak Rivers, (2) a narrow coastal belt extending east of the Canning and Tamayariak Rivers; and (3) a narrow zone between the delta of the Hulahula River and a point a few miles east of the Jago River.

Except for the vegetated basins of relatively recently drained lakes, some form of microrelief is nearly always present on thaw-lake plains, mostly low-centered polygons and strangmoor.

The microtopography of thaw-lake plains (elevation variations of only a few feet) plays the major influence on the distribution of plant communities, and small elevation differences create distinct patterns of plant communities and soils associations (Wiggins, 1951; Cantlon, 1961; Britton, 1957; D. A. Walker, 1981). The perched water table is very close to the surface, or slightly above, for most of the area, except for polygon rims and lake bluffs. The Landsat land-cover categories in the thaw-lake plains include moist/wet tundra complex, moist prostrate dwarf scrub, wet and very wet graminoid, clear water, dry prostrate dwarf scrub, and moist graminoid tussock.

MOUNTAINS

Alpine terrain represents only a few square miles in the 1002 area (about 0.05 percent), mostly above 1970 feet elevation west of Sadlerochit Spring. Sadlerochit Spring is of special interest because poplar and other distinct plant species occur there (Murray, 1980a).

Vegetation communities in these areas are complex and are interspersed with unvegetated rocks and talus slopes. The character of the well-vegetated slopes varies considerably, but the more completely vegetated areas have extensive moss mats with numerous prostrate shrubs, such as mountain avens, prostrate willow, and small forbs. Limestone areas are of particular interest because of the presence of unique assemblages of plants, such as the bryophytes associated with wet limestone seeps (Brown and Berg, 1980; Steere and Murray, 1976). The main land-cover classes include barren and scarcely vegetated scree and dry prostrate dwarf scrub.

SADLEROCHIT SPRING SPECIAL AREA

Sadlerochit Spring and its surrounding area (approximately 4,000 acres), in the southern part of the 1002 area, west of the Sadlerochit River (pl. 1A) has been nominated as a National Natural Landmark (Bliss and Gustafson, 1981). The National Natural Landmark program was established to encourage the preservation of areas illustrating the diverse ecological and geologic character of the United States. Areas qualifying as National Natural Landmarks must be free of disturbance and capable of retaining and perpetuating their inherent natural qualities over time, as well as having exceptional scientific research and education values. Sadlerochit Spring is unique because of its large discharge and almost constant temperature, which maintains an open channel for nearly 5 miles downstream during the coldest part of the year. Located near the foothills on the coastal plain of the Arctic Refuge, it is one of the largest perennial springs on the North Slope of Alaska. It has a discharge ranging from 35 to 53 cubic feet per second (cfs) and warm waters of 50$^{\circ}$ to 58$^{\circ}$F, which support a dense population of tiny organisms (macro-invertebrates) (400 to 500 per cubic foot) and populations of arctic char and arctic grayling (Craig, 1977). Sadlerochit Spring is a fish-wintering area (pl. 1B); such areas are extremely limited on the 1002 area and are generally associated with the larger springs. Several plant and bird species not found anywhere else this far north are associated with this spring. Muskoxen also use the area throughout the year.

The Sadlerochit Spring Special Area, as designated by regulations for exploration in the 1002 area, encompasses an area within 1/2 mile of the spring outlet and extends 1/4 mile on each side of the stream downstream 5 miles to the aufeis field (50 CFR 37.32(g)). The spring and surrounding area have been identified as a special area primarily for their unusual plant communities and associated diverse wildlife (pl. 1A). Because of the spring's special values, exploration activities have been prohibited within this area. The Sadlerochit Spring area is used as a traditional subsistence-use area, particularly in winter, when people from Kaktovik camp at the spring and hunt and fish in the area (Jacobson and Wentworth, 1982).

## Coastal and Marine Environment

Coastal-marine habitats in the 1002 area include offshore, nearshore, open coast, delta, and barrier island/lagoon-mainland shore areas, and those parts of the coastal uplands directly affected by storm surges and marine saline intrusions. These areas provide essential shelter, staging areas, and other life support attributes to resident and migratory fish and wildlife populations. Beaches, spits, and bars occur throughout the area. Although permafrost probably underlies these sites, it does not enter into the soil taxonomy. The inland extent of coastal habitats, biologically defined as the maximum inland reach of storm surges, is identified in many areas by the "strandline" of large drift logs and other debris, and by the extent to which salt spray and ingress of saline water affects the vegetative cover along the coast.

The North Slope Borough (NSB), under the framework of the Federal Coastal Zone Management Act and the Alaska Coastal Management Act of 1977 (AS 44.19.891-894 and 46.40), has developed a Coastal Management Program approved by the State, April 17, 1985. However, the Federal Office of Ocean and Coastal Resource Management denied approval of this program on August 8, 1986. The NSB Coastal Management boundary includes State lands that are within the 3-nautical-mile offshore territorial limit, are inland approximately 25 miles, and State lands up certain streams to include anadromous fish spawning and fish overwintering habitat.

Concurrent with the Coastal Management Program, the NSB initiated planning programs and sociocultural and economic studies. The NSB Comprehensive Plan and Land Management Regulations became effective January 1, 1983.

Under section 307(c)1 of the Federal Coastal Zone Management Act, Federal activities directly affecting the coastal zone must be consistent with the approved State Coastal Management local program to the " * * * maximum extent practicable." The NSB Coastal Management Plan noted that the Hulahula, Okpilak, and Achilik Rivers within the 1002 area had values warranting special attention (NSB, 1984a).

Goals of the State-approved NSB Coastal Management Program relevant to government and economic activities in the area are described below under "State and Local Political and Economic Systems." Most applicable to the coastal and marine environment is the program goal of protecting the natural environment and its capacity to support subsistence activities.

## Fish and Wildlife Resources

Section 303 of ANILCA, which establishes additions to existing refuges, requires that the Arctic National Wildlife Refuge be managed "to fulfill the international treaty obligations of the United States with respect to fish and wildlife and their habitats * * *" [Section 303(2)(B)(ii)]. International treaties and agreements related to fish and wildlife species that are either resident, transient, or occasionally found in the 1002 area, include:

1. Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, October 12, 1940 (56 Stat. 1354, TS 081), Article VII, Migratory Birds.

2. Convention with the Union of Soviet Socialist Republics on the Conservation of Migratory Birds and Their Environment (TIAS 9073).

3. Protection of Birds and Their Environment, Convention between the United States of America and Japan (25 U.S.T. 3329, TIAS 7990).

4. Agreement on the Conservation of Polar Bears, November 15, 1973 (TIAS 8409).

5. International Convention for the Regulation of Whaling, Whaling Convention Act of 1949 [16 U.S.C. 916-916(1)]. Article III of the act established the International Whaling Commission.

6. Marine Mammal Protection Act of 1972 (16 U.S.C. 1361, 1362, 1371-1384, 1401-1407), Section 1378, International Program, provides for negotiations for the protection and conservation of marine mammals.

The fish and wildlife occurring on the 1002 area are discussed by species, in five categories: terrestrial mammals, marine mammals, birds, fish, and threatened and endangered species.

### TERRESTRIAL MAMMALS

#### CARIBOU

The Porcupine and Central Arctic caribou herds are found within the 1002 area during various times of the year. Each herd has specific distributions, movement patterns, and herd dynamics.

The Porcupine caribou herd (PCH) is an international resource, estimated by the Alaska Department of Fish and Game (ADF&G) at 180,000 animals in 1986. The herd is increasing and is one of the largest in North America (Whitten, 1986). Earlier population estimates for the PCH

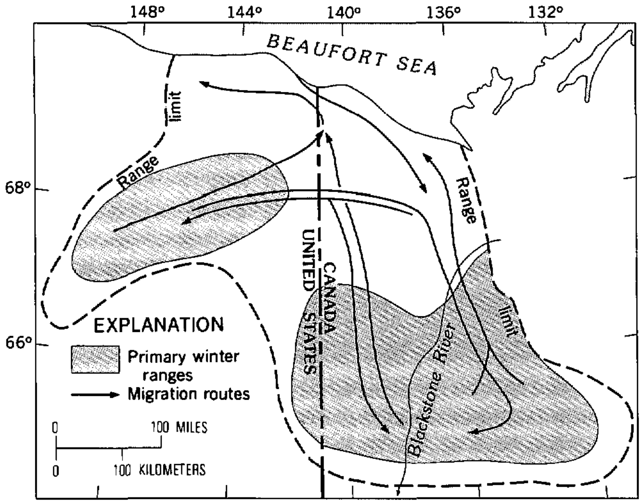


**Figure II-4.**--Migration routes and winter range of the Porcupine caribou herd.

were as low as 101,000 (LeResche, 1972). The lower levels of earlier estimates may reflect a truly smaller population, less accurate or less complete survey techniques, or a combination of these factors. Caribou populations appear to fluctuate unpredictably over the long term. The long-term maximum and minimum population of the PCH and the carrying capacity of the PCH are unknown.

The PCH ranges over 96,100 square miles of northeast Alaska and northwest Canada, and constitutes the largest population of large mammals shared between the two nations (fig. II-4).

The traditional calving grounds of the PCH extend throughout the Arctic foothills and coastal plain from the Canning River in Alaska to the Babbage River in Canada. Including the entire 1002 area, the calving grounds encompass an area of nearly 8.9 million acres (pl. 2A). From year-to-year, the distribution of caribou on these calving grounds varies considerably, with most calving usually taking place in the area between the Hulahula River and the Canadian border. During 1972-85 detailed observations were made of calving areas of the PCH. As a result of these studies, areas where caribou were present during calving at a density of at least 50 caribou/square mile were identified as concentrated calving areas. The core calving area is a location to which pregnant cows have shown a strong fidelity as traditionally favored calving habitat. Those concentrated calving areas used in at least 5 years during the 14-year study were identified as the core calving area. Of the 2.1 million acres identified as concentrated calving areas, 934,000 acres (44 percent) are within the 1002 area. An even greater proportion, 242,000 acres (78 percent), of the 311,000 acres of core calving area is within the 1002 area.

Spring migrations to the calving grounds start in May from winter ranges, which are usually south of the Continental Divide in Alaska and in central Yukon Territory and adjacent Northwest Territories in Canada (fig. II-4). Timing and routes of migrations vary annually depending on winter distributions, snow conditions, and the onset of spring weather. Most caribou migrate to reach the calving grounds of the 1002 area from Canada, moving westward along the northern foothills of the Brooks Range. In some years many caribou also pass through the first snow-free mountain valleys east of the Aichilik River in Alaska. As spring conditions progress, caribou in the foothills spread northward along a broad front, primarily following the major river corridors and associated terraces where snowmelt has advanced.

During years when snowmelt on the coastal plain is early, a broad zone north of the foothills is used for calving. In such years calving concentrations tend to be more northerly and scattered calving extends to the coast. When spring is late, calving is more southerly and easterly, followed by a distinct movement west and northwest. Once caribou have reached the calving grounds there is less directional movement. During and immediately after calving, foraging caribou use vegetated riparian habitats as well as tussock uplands. Riparian areas (pl. 2A) are used as travel corridors and important feeding areas in both spring and summer.

The percentage of PCH cows using the 1002 area for calving was estimated to be 74 percent in 1983 and 82 percent in 1985. In 1984, 35 percent of the cows calved in the 1002 area; 38 percent calved adjacent to the 1002 area, east of the Aichilik River. The latter group moved into the 1002 area within a week of giving birth and joined the cows already there (U.S. Fish and Wildlife Service, unpublished data). These estimates were extrapolations from locational data on radio-collared cows.

In arctic areas, caribou reproduction is highly synchronous. The majority of calving occurs within a 2- to 3-week period, when a single calf is born to most adult females (3 years old). Caribou calves are precocious, being able to stand and nurse within 1 hour following birth. They are capable of travel with adults within a week. The first 24 hours of life is critical, when a behavioral bond is formed between the calf and its mother. Disturbance of cow-calf groups on the calving grounds may interfere with bond formation and can increase calf mortality.

Usually caribou begin to arrive on the calving grounds of the Arctic Refuge during mid- to late May. The first calves are born during the last week of May; peak calving occurs during June 4-8. Although calving has been observed in a variety of terrains, most calves are born in snow-free areas of sedge tussock uplands, where the cows seek suitable vegetation. Predator densities are apparently less in these areas and, subsequently, calf survival is better in the northern parts of the calving grounds which become snow-free when snowmelt is early (U.S. Fish and Wildlife Service, 1982; Mauer and others, 1983; Whitten and others, 1984, 1985).

After calving, small bands of cows with newborn calves gradually merge into larger groups. Yearlings, barren females, and bulls occupying the southern and eastern periphery of the calving grounds begin to mix with the cows and calves, ultimately forming huge postcalving aggregations. By late June or early July aggregations of 80,000 or more caribou on the 1002 area are common. Postcalving movements show considerable annual variation.

Although rather small in proportion to the herd's entire range, the calving/postcalving area is an important, identifiable habitat that has been repeatedly used by the PCH during these critical life stages.

As the spring progresses, weather conditions promote the emergence of swarms of mosquitoes. Harassment by these insects drives the caribou into dense aggregations and results in their increased movement to areas of relief. The groups usually move rapidly toward the coast seeking relief on points, river deltas, mudflats, aufeis, large gravel bars, barrier islands, and in the shallows of lagoons (pl. 2A). Some groups also move to higher elevations in the mountains for relief. In other years there can be a gradual westward shift across the coastal plain and northern foothills.

The postcalving season is the low point of the annual physiological cycle when energy reserves of parturient cows are especially low. The stresses of winter, pregnancy, migration, birth, lactation, hair molt, antler growth, and insect harassment draw heavily upon this segment of the population (Dauphine, 1976; White and others, 1975). Access to insect-relief habitat and forage resources during this period may be critical to herd productivity. In early July the herds usually move east and south, vacating the 1002 area by mid-July. In certain years, residual groups numbering up to 15,000 animals have remained on the 1002 area and adjacent foothills and mountains through August. Occasionally, remnants of such groups (up to 2,000 animals) have wintered in northern mountains and foothills.

An international agreement for management of the PCH is currently being negotiated between the governments of the United States and Canada. The State of Alaska and Provincial governments as well as local users are participating in the negotiations.

Harvest of the PCH occurs in both the United States and Canada. The harvest by individual Native villages is highly variable, depending upon herd movements. Recent annual harvests from the PCH by Kaktovik, the only village adjacent to the 1002 area, have ranged from 25 to 75 animals (Pedersen and Coffing, 1984). Annual harvest of the PCH throughout its range was estimated at 3,000-5,000 animals (LeBlond, 1979). The harvest varies greatly from village to village and from year to year within the same village. The annual harvest at Arctic Village, Alaska, ranges from 200 to 1,000 (LeBlond, 1979). During 1963-85 annual harvest of the PCH within Canada averaged approximately 1,700 animals for the years in which data were available (Yukon Territory Wildlife Branch, unpublished data).

The Central Arctic caribou herd (CAH) has been increasing, and in 1985 numbered about 12,000 to 14,000. Its range is entirely north of the Continental Divide, from the Itkillik and Colville Rivers on the west to the Sadlerochit River on the east (pl. 2B). The TAPS, Dalton Highway corridor and Prudhoe Bay-Kuparuk oil fields lie within the herd's range. In July 1983 the herd comprised 46 percent cows, 21 percent calves, and 33 percent bulls (Hinman, 1985).

Females of the CAH wintering in the mountains and foothills near the western part of the 1002 area migrate north-northwest across the rolling uplands south of Camden Bay to the calving grounds on or near the Canning and Staines River deltas. A northward movement along the Canning River corridor also occurs.

CAH calving activity has been concentrated in two areas: the vicinity of the lower Kuparuk River and the Canning River delta. Most years as many as 1,000 females calve on the Canning River delta within the 1002 area (pl. 2B). Scattered, low-density calving extends as far east as the Sadlerochit River. Little or no calving has been observed in the TAPS-Prudhoe Bay oil field area since about 1973 (U.S. Fish and Wildlife Service, 1982; Whitten and Cameron, 1985).

After calving, some CAH caribou move southeastward, to the uplands south of Camden Bay. During the insect season (July) there is often a strong eastward movement along coastal habitats between the Canning River delta and Camden Bay. An estimated 2,000-3,000 caribou of the CAH use the 1002 area (Canning River delta and coastal habitats along Camden Bay) for post-calving and insect-relief (pl. 2B). During the summer, an additional 1,000 animals may be scattered west of the Sadlerochit River and north of the Sadlerochit Mountains. Riparian areas are used for travel corridors as well as important spring and summer feeding areas. In late summer and fall, CAH caribou are found scattered across the coastal plain south of Camden Bay, in foothills north of the Sadlerochit Mountains, and in uplands south of the Sadlerochit Mountains where they remain for the winter. During most winters, scattered groups of CAH caribou range throughout the 1002 area west of the Katakturuk River and adjacent uplands to the south. The number of wintering animals ranges from 100 to 1,000.

The annual harvest of CAH caribou by Kaktovik residents has most recently been estimated to be 25-75 animals (Pedersen and Coffing, 1984). This harvest occurs along the coast during the summer when residents can travel by boat and inland during the fall and spring when snowmachine travel is possible (pl. 2D).

MUSKOXEN

Muskoxen were exterminated from the North Slope by the late 1800's, so carrying capacity and past historic levels are unknown. In an effort to reestablish an indigenous population, 69 muskoxen were reintroduced to the Arctic Refuge in 1969 and 1970 (Roseneau and Stern, 1974). The muskox population has grown exponentially since 1974 (fig. II-5) because of high productivity and low mortality. In 1985, the postcalving refuge population was estimated at 476, more than triple the 1979 population.

Muskoxen are highly social, usually found in mixed-sex herds. Herd size of the 1002 area population varies seasonally, the smallest herds occurring during the rut in August. Many bull muskoxen do not remain with a mixed-sex herd for long periods of time, but move from herd to herd, associate with other bulls in small groups, or travel alone (Reynolds and others, 1985). In response to predators or other threats, muskoxen form a compact defensive formation.

Muskoxen have used the same areas along the Niguanak-Okerokovik-Angun, Sadlerochit, and Tamayariak-Katakturuk river drainages for the past several years with approximately 80, 160, and 230 animals using those drainages, respectively. Muskoxen using the Sadlerochit and Tamayariak areas seem to be part of the same subpopulation, whereas animals in the Okerokovik area seem to be a separate subpopulation. Many of the cows marked for the baseline study research in 1982-85 have remained in these areas (pl. 2C) and show a high site-specific fidelity. Riparian areas are important travel corridors and muskoxen regularly feed there year-round. Dispersal of mixed-sex herds into new areas on the Katakturuk River and drainages east of the Aichilik River is also occurring.

Though not migratory, muskoxen apparently move in response to seasonal changes in snow cover and vegetation. In summer and fall, they are often found in riparian habitats along major drainages, where they feed on willows and forbs. In winter and spring many animals move to adjacent uplands with less snow cover to feed on tussock sedges (Reynolds and others, 1985). Preliminary FWS data indicate that muskoxen apparently reduce both their movements and activity during winter, probably as an adaptation to conserve energy. Table II-2 and plate 2C show the extent of muskoxen habitat within the Arctic Refuge and 1002 area and delineate those seasonal or year-round use areas where muskoxen have been observed most frequently, year after year (1982-85).

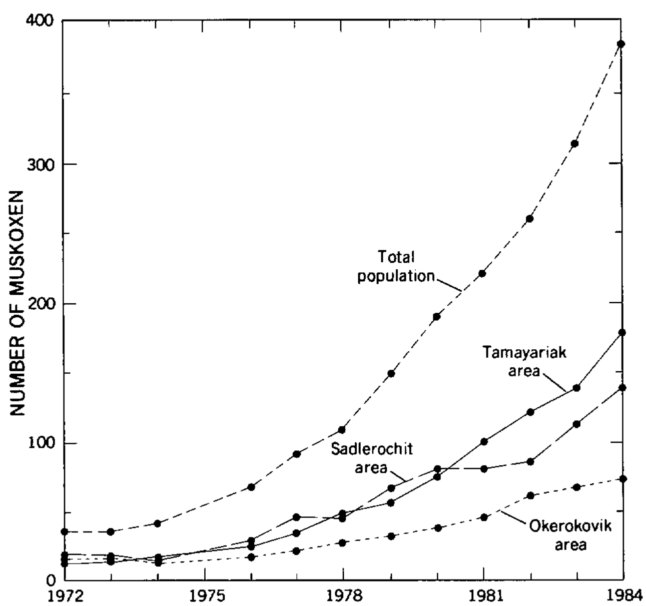


**Figure II-5.**--Estimated numbers of muskoxen in post-calving populations in the Arctic Refuge, 1972-84.

**Table II-2.**--Observed muskox range within the Arctic National Wildlife Refuge and within the 1002 area, 1982-85.

| | Within Arctic Refuge (acres) | Within 1002 area (acres) | Percent of total use area within 1002 area |
|---|---|---|---|
| High seasonal or year-round use with calving | 251,000 | 207,000 | 82 |
| High seasonal or year-round use "without calving" | 211,000 | 158,000 | 75 |
| Total observed range, including high-use areas | 1,116,000 | 760,000 | 68 |

Muskoxen hunting on the Arctic Refuge under permit from the Alaska Department of Fish and Game started in 1983. Five bull-only permits have been issued annually; the 1983, 1984, 1985, and 1986 harvests were 4, 5, 4, and 3, respectively.

MOOSE

Patterns of moose distribution north of the Brooks Range vary seasonally (pl. 1C). Winter concentrations occur south of the 1002 area where up to 158 and 239 moose have been counted in the Canning and Kongakut River drainages, respectively. A few moose are scattered in other river drainages (U.S. Fish and Wildlife Service, 1982; Martin and Garner, 1984, 1985).

In late May or early June small widely dispersed groups of moose move northward along riparian systems. Moose using the 1002 area have dispersed from populations to the south and use a variety of habitats in July and early August. The number of moose using the 1002 area at any one time probably does not exceed 25. In late August, moose begin to aggregate; the largest groups occur in October during the rut south of the 1002 area. Most moose using the 1002 area move southward to winter in valleys of the Brooks Range. Riparian willow species comprise a major part of the forage used by moose; mountain alder is an important winter food where available.

Subsistence hunters from Kaktovik take one or two moose annually (Jacobson and Wentworth, 1982). Other hunters harvest a few moose, generally less than 10 annually, from the North Slope of the Arctic Refuge. Most of this harvest is in the Canning River and Kongakut drainages, and nearly all outside the 1002 area.

## DALL SHEEP

Although the estimated total population of Dall sheep within the original 8.9-million-acre Arctic Refuge is approximately 6,800, Dall sheep are very rare on the 1002 area, because suitable habitat is lacking. The Sadlerochit Mountains contain an estimated 270 sheep, and constitute the northernmost extent of their range in North America (T.G. Smith, 1979).

Traditional summer range consists mainly of alpine slopes and meadows. Winter range, limited mostly by topography, consists of windblown slopes and ridges, usually south-facing. FWS surveys indicate that Dall sheep have used the lower foothill terrain near Sadlerochit Spring, mostly in winter; in summer, they cross this tundra area in moving to other habitats (D. Ross and M. A. Spindler, unpublished data, 1981).

## WOLVES

Wolves are found throughout Alaska's North Slope. On the 1002 area, the population density is lower than in areas farther south. Wolves occupy large home ranges. In winter wolves tend to congregate in areas of overwintering caribou and possibly moose or Dall sheep. Daily movement depends on availability of prey. Estimates of density for restricted geographic areas vary widely, but most fall within the range of 6 to 200 square miles per wolf (Mech, 1970). Mating occurs in March, and pups (usually 4-7 per litter) are born in dens 2 months later. Although the 1002 area appears to contain suitable denning habitat, no dens have been found. Dens that have been documented are in mountainous terrain, 10 to 40 miles south of the 1002 area. The number of wolves using the 1002 area on a seasonal basis is low and apparently does not exceed 5-10 animals annually.

Populations in or adjacent to the 1002 area were depressed in the late 1970's by an outbreak of rabies. A similar outbreak occurred in 1985 when six dead wolves, including four radio-collared animals, were found. Four of the animals were confirmed as rabid. Historical den sites on the Kongakut, Hulahula, and Aichilik Rivers were deserted in 1985. Death of breeding wolves from rabies was suspected as the reason. However, four new dens were found, three of them occupied by wolves which were remnants of earlier packs.

Wolves on the North Slope are known to prey on caribou, moose, sheep, ground squirrels, small rodents, and birds. Wolves are typically associated with drainage systems which they use as travel corridors. They are also attracted to riparian areas because of the abundance of prey, including ground squirrels. During the summer when prey species are most abundant, wolves are distributed throughout all 1002 area habitat types (U.S. Fish and Wildlife Service, 1982; Haugen, 1984, 1985; Weiler and others, 1985). Wolves are hunted and trapped by Kaktovik residents. Most of the harvest occurs in the Hulahula, Sadlerochit, and Okpilak River areas (Jacobson and Wentworth, 1982; Weiler and others, 1986). Generally, fewer than 10 wolves are harvested annually, usually south of the 1002 area.

## ARCTIC FOXES

Arctic foxes move seasonally between summer breeding habitats in wet tundra and winter habitats along the northern Alaska coast and onto the sea ice (Chesemore, 1967). They are limited in their range by habitat and interspecific competition with red foxes. Periodic outbreaks of rabies can reduce fox populations. Productivity of foxes is related to abundance of microtines (small rodents). Foxes regulate their food supply, despite fluctuating prey availability, by caching food in early summer when prey is abundant and utilizing food caches and carrion in late summer when fewer prey are available. At Demarcation Bay arctic foxes spent most of their time in medium-relief, low-center polygon and meadow habitats, preying on small mammals and bird nests (Burgess, 1984). In 1979 when rodents were at low population levels, foxes at Demarcation Bay depended mainly on birds and eggs. No pups were produced that year (Burgess, 1984).

Arctic foxes are trapped by Kaktovik residents in the winter for fur. The number taken annually fluctuates according to their abundance. In years of abundance more than 100 foxes may be taken. Most trapping is within 15 miles of the coast, mainly on or near Barter Island (Jacobson and Wentworth, 1982).

## WOLVERINES

Wolverines frequent all types of terrain found in Arctic areas, as evident from observations and tracks. Rivers and mountains are frequently associated with territorial boundaries. Snowdrifts are important for wolverine den sites, and, in the tundra, remnant snowdrifts in small drainages are used by females for rearing their offspring (Magoun, 1985).

A few wolverines inhabit the 1002 area. Accurate population figures are unavailable. A rough estimate of the 1002 area wolverine population can be made from the wolverine densities and assumptions used by Magoun (1985) for estimating the population in the Western Arctic. On Magoun's assumptions, the estimated density for the 1002 area is 90 wolverines. This figure may not be very accurate: Magoun's area and the 1002 area are not identical; Magoun studied a virtually unexploited population whereas wolverines in the 1002 area and environs are routinely harvested by Kaktovik residents. Furthermore, sighting records for the 1002 area are sparse; recent FWS studies have resulted in very few sightings.

Wolverines feed opportunistically and have been reported pursuing large ungulates such as caribou, moose, and Dall sheep, though they are more commonly scavengers than predators. In the Arctic, ground squirrels are an important food (Rausch and Pearson, 1972). Caribou are scavenged, particularly during May and June when they are numerous on the 1002 area. During June and July, wolverines also prey on birds and eggs.

Kaktovik residents hunt wolverines most frequently in the foothills and northern mountainous areas of the Sadlerochit, Hulahula, and Okpilak Rivers. ADF&G records indicate that an average of about one wolverine per year is harvested from the 1002 area; this may be an underestimate because of incomplete reporting. Magoun (1985) believed that harvest in Game Management Unit 26A (Western Arctic) was 2 to 10 times greater than reported. During the winter of 1980-81, seven wolverines were taken by Kaktovik residents (Jacobson and Wentworth, 1982). Wolverines are sometimes harvested by trappers near the village of Kaktovik. These animals are mostly subadults that may be dispersing onto the 1002 area from the foothills to the south. Information is lacking as to whether the 1002 area wolverine population is resident or transient.

## BROWN BEARS

Brown bears seasonally use the 1002 area. At periods of greatest abundance (in June) use is estimated at one bear per 30 square miles, or approximately 108 bears (Garner and others, 1984). Brown bears north of the Brooks Range are at the northern limit of their range. These populations are characterized as having low reproductive rates as a result of short periods of food availability, large individual home ranges (95 to 520 square miles), and habitats that provide little protective cover (Reynolds and others, 1976; Reynolds, 1979; Garner, Weiler, and Martin, 1983).

Brown bears appear on the 1002 area in late May and are generally most abundant during June and July when caribou are most plentiful. The bears breed during this same period. Brown bears are found throughout the entire 1002 area. There are two known high-use areas One, used by 50-70 adult bears and cubs, is in the southeastern section of the 1002 area where caribou calving is concentrated. The second, used by 15-20 bears, is a much smaller area along the upper reaches of the Katakturuk River (pl. 1D). Moderate-use (30-80 bears) is located between and around the high-use areas and are generally used for a shorter period (June-July). (Note that bear numbers from each use area cannot be added because they represent different times of residency. Each bear may use more than one or all areas delineated.) After caribou leave the 1002 area in early July, brown bears gradually move south into the foothills and mountains (Garner and others, 1983, 1984, 1985). Riparian areas are used as travel corridors. Brown bear habitat changes seasonally according to food availability (U.S. Fish and Wildlife Service, 1982). Spring foods include vegetation, carrion, caribou, ground squirrels, and rodents. River courses frequently contain abundant prey as well as preferred vegetation. During mid- to late summer, brown bears shift to eating horsetail, grasses, and sedges. In the fall, they eat wild sweetpea roots, crow- berries, blueberries, bearberries, and ground squirrels and other rodents (Phillips, 1984).

Denning occurs in late September and October, depending on soil conditions (the top soil must be frozen to support den excavation) and weather (Pearson, 1976; Reynolds and others, 1976; Garner and others, 1983, 1984, 1985). Cubs are born in the den in January and early February. Litters range from one to three cubs; the average litter for bears using the 1002 area is 1.9 (Garner and others, 1984). Most dens are located in the foothills and mountains south of the 1002 area. Six of 129 (4.6 percent) known den sites within the Arctic Refuge have been located on the 1002 area (Garner and others, 1983, 1984, 1985). Brown bears emerge from winter dens in late April through May. On the 1002 area the survival rate among cubs and yearlings ranges from zero to 100 percent. Causes of juvenile mortality on the 1002 area are not well known, but a major cause is probably the killing of juveniles by mature males such as occurs in other brown bear populations (Stringham, 1983).

Residents of Kaktovik harvest an average of 2 brown bears annually. The bears are taken opportunistically on the 1002 area or farther south in the foothills or mountains (Jacobson and Wentworth, 1982). The sport harvest within the Arctic Refuge north of the Brooks Range averages 2-4 brown bears annually. Virtually all sport harvest is south of the 1002 area.

## ARCTIC GROUND SQUIRRELS AND OTHER RODENTS

Arctic ground squirrels are found throughout the 1002 area in colonies restricted to well-drained soils free of permafrost. Ground squirrels hibernate from late September through May (U.S. Fish and Wildlife Service, 1982). Activity resumes in the spring, before the snow begins to disappear. Mating is followed by a 25-day gestation period. Young ground squirrels grow rapidly in preparation for winter hibernation.

Ground squirrels are a subsistence food for Kaktovik residents. They are also important in the diets of snowy owls, rough-legged hawks, brown bears, arctic foxes, red foxes, and wolves.

Other rodents found on the 1002 area include the collared lemming, brown lemming, and tundra vole. Red-backed voles and tundra voles may occur in the foothills in the southern part of the 1002 area. The brown lemming is the leading herbivore along the coast, and in high population years can account for more plant consumption than ungulates (Batzli and others, 1980). Impacts on the vegetation are cyclic and correspond to the brown lemming's 3- to 5-year population cycle. Lemmings and voles are active all year, grazing frozen plant material and breeding under the snow. Maximum population densities occur after successful winter reproduction. Shallow snow depths result in low temperatures under the snow, creating an energy stress that can reduce winter reproductive success.

## MARINE MAMMALS

Fourteen species of marine mammals may occur off the coast of the Arctic Refuge. Some of these--the spotted seal and walrus--are occasional visitors. Others such as the killer whale, gray whale, humpback whale, fin whale, narwhal, harbor porpoise, and hooded seal are only rarely seen because this part of the Beaufort Sea is at the extreme margin of their ranges. Five of the species were evaluated: polar bear, ringed seal, bearded seal, beluga whale, and the endangered bowhead whale.

### POLAR BEARS

Polar bears are closely associated with pack ice of the Arctic Ocean throughout most of the year. The Beaufort Sea population of polar bears is estimated to be 2,000. Some females move to coastal areas and occasionally farther inland during October and November to seek maternity den sites. Pregnant polar bears, and later their cubs, probably spend more time on the 1002 area than other segments of the polar bear population. Other groups of polar bears seasonally frequent the coastal periphery of the area. Recapture of polar bears marked by the FWS in recent years indicates that an influx of females accompanied by cubs as old as 20 months and subadult animals coincides with the fall ice-edge advance to the shoreline.

Polar bear dens have been found as far as 250 miles offshore and 32 miles inland. Eighty-seven percent of dens located in 1983-85 were offshore. The onshore area from the Colville delta to the Canadian border is within the area used by the Beaufort Sea population of polar bears for denning. However, the most consistently used land denning areas were on and adjacent to the 1002 area where 1-2 dens were found in 4 of the 5 years, between winter 1981-82, when the FWS began a continuing study of North Slope polar bears, and winter 1985-86 (Amstrup, 1986a). The ideal denning sites are riverbanks, draws, and the leeward side of bluffs where snow accumulation is sufficient to support den construction. At least 15 dens were located in the 1002 area, 1951-85 (pl. 1E). Another five dens have been located on ice near the 1002 area.

Three locations in the 1002 area (pl. 1E) have been delineated as confirmed denning areas, that is, areas in which polar bear dens and denning activity have been observed during more than one winter. Dens or denning activity has also been observed in other 1002 area locations, but data are inadequate to confirm recurrent use.

Female polar bears that den on land move onshore to seek out den sites in October and November, depending on ice movement and ice buildup in the fall (Lentfer and Hensel, 1980). Denning females give birth to 1 or 2 cubs in December or January, and bears emerge in late March or early April, depending upon weather conditions. The female and cubs generally remain near the den, making short forays for 1 to 2 weeks until the cubs gain strength and become acclimated to outside conditions. Soon thereafter, they move to the sea ice to feed on seals. Many females with new cubs concentrate their foraging on the shore-fast ice, which varies in width from a few feet to more than 30 miles.

When the nearshore ice breaks up in the spring, the bears move with the sea ice and many concentrate at the south edge of the pack ice. This position varies seasonally but usually is between the coast and latitude 72°N.

Except for a shore lead, the Beaufort Sea is ice covered year-round. Open water nearshore begins to freeze in September or October, and nearshore ice does not melt until May or early June. Male and nondenning female polar bears inhabit the sea ice throughout the winter. The distribution of polar bears is influenced by the availability of their major prey species, ringed and bearded seals, which concentrate in areas of drifting pack ice (Lentfer, 1971; Stirling and others, 1975). Ringed seals probably constitute 95 percent of the polar bear's diet (Burns and Eley, 1978).

Polar bears are protected under the provisions of the Marine Mammal Protection Act of 1972. An international agreement for the conservation of polar bears was ratified in 1976 by the governments of Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States of America. Article II requires that appropriate actions be taken to protect ecosystems of which polar bears are a part, especially denning and feeding sites.

Large numbers of polar bears may occur seasonally along the coast of the Arctic Refuge near the village of Kaktovik where whale carcasses can be scavenged (Amstrup and others, 1986). Each year many bears are available to local subsistence hunters, but in most recent years the kill has been small (FWS, unpublished data). Annual subsistence harvest of polar bears by local residents was as high as 23 to 28 in 1980-81; at least one polar bear was confirmed as being taken in each of the following 4 years, with three bears being taken in 1985-86 (Schliebe, 1985; Jacobson and Wentworth, 1982; FWS, unpublished data).

## SEALS AND WHALES

Ringed seals, bearded seals and, occasionally, spotted seals occur in the Beaufort Sea and along the coast north of the coastal plain, including the lagoons of the 1002 area (U.S. Fish and Wildlife Service, 1982). Although there is some evidence of ringed seals within the refuge in summer and fall, their primary habitats are generally outside the 1002 area. Ringed seals use stable, shore-fast ice as their primary pupping habitat (T.G. Smith, 1980). To improve chances of successfully rearing pups, older, more-dominant female ringed seals select and actively defend territories on stable shore-fast ice for pupping. Subadult and younger females are forced to construct lairs on active pack ice, increasing the chances of predation by polar bears. Bearded seals are chiefly associated with the pack-ice edge throughout the year. Primary breeding and pupping habitat is associated with the ice edge. A small number of bearded seals remain in northern ice-bound areas. The extent of active pack ice use by seals is not well understood within the 1002 area. However, seals in Canada do occupy active pack ice, a preferred hunting area for polar bears (T.G. Smith, 1980).

Kaktovik residents harvest spotted, ringed, and bearded seals for subsistence, though relatively few seals are taken (Jacobson and Wentworth, 1982).

Bowhead and gray whales are listed as endangered species. Gray whales are occasionally found in the Beaufort Sea, north of the 1002 area (U.S. Fish and Wildlife Service, 1982). The bowhead whale is known to inhabit waters offshore of the Arctic Refuge in September and October during its fall migration along the Beaufort Sea coast. The southern boundary of the bowheads' fall migration corridor is generally the 66-foot isobath, although they are occasionally seen in shallower water. Demarcation Bay east of the 1002 area is a feeding area for these whales; waters off the 1002 area may also be used (National Marine Fisheries Service, 1983). Belukha (beluga) whales also migrate through waters north of the 1002 area.

Bowhead whales are taken for subsistence by residents of Kaktovik. Subsistence whaling at Kaktovik began in 1964. During 1981-85 the annual harvest has averaged one whale, with an average of one additional whale struck and lost each year.

## BIRDS

One hundred eight species of birds have been recorded on the Arctic Refuge coastal plain (Garner and Reynolds, 1986a, b). The majority are migratory, present only from May to September. Six species are considered permanent residents--rock and willow ptarmigan, snowy owl, common raven, gyrfalcon, and American dipper. The common and hoary redpoll, ivory gull, and Ross' gull occasionally winter on the 1002 area. Twenty-one species occur offshore, mostly from late July to mid-September, with distribution generally limited to within 35 miles of shore. Sixteen offshore species breed locally on coastal tundra or barrier islands (Bartels, 1973). Greatest concentrations of summer resident waterbirds on the Arctic Refuge occur in two general habitats: shallow coastal waters and tundra wetlands (pl. 3A).

Birds begin using coastal lagoons when the snow melts in early June. During this period, river overflows cover lagoon deltas and provide the first open water of the season. Habitat use during the breeding season (mainly June and July) varies with bird species. Peak numbers of birds are often seen in August and September during staging and early migration. Smaller numbers are present until freezeup in late September or early October.

Lagoon areas are relatively high in productivity, and are important during all phases of the avian life cycle. More than 35,000 waterbirds of 20-25 species (primarily oldsquaw) may use the coastal lagoons during the open-water period (July-September). As many as 11,000 birds may be present in a lagoon at one time. Some birds move from terrestrial nesting habitats into shallow lagoons, bays, and sand spits to molt and for protection from predation during this flightless stage. The lagoon systems are also important feeding areas used by oldsquaw, eiders, scoters, and other ducks, loons, phalaropes, terns, gulls, jaegers, and black guillemots (Divoky, 1978).

Migratory birds are international in range; nesting and wintering grounds and migration routes may occur not only in different countries but on different continents. International treaties for the protection of migratory birds have been ratified between the United States and the Union of Soviet Socialist Republics, Japan, Canada, and Mexico. In addition, measures for the protection of migratory birds are contained in the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, an agreement to which the United States is a party.

Species-specific information follows, under five bird categories: swans, geese, and ducks; seabirds and shorebirds; raptors; ptarmigan; and passerines.

### SWANS, GEESE, AND DUCKS

Tundra swans are common breeding birds of the thaw-lake plains. Up to 150 nests and 400 to 500 adult swans have been counted on the 1002 area during annual surveys (Brackney and others, 1985a). Swans arrive in late May and early June and concentrate on the Canning-Tamayariak delta, the Hulahula-Okpilak delta, Barter Island lakes, Jago River wetlands, the Aichilik-Egaksrak deltas, and Demarcation Bay area lakes (pl. 3A). Spring surveys from 1982 to 1985 showed average densities of 1 swan per 0.67 square mile in concentration areas. These areas apparently offer highly desirable swan nesting and feeding habitat. Average density for the overall 2,960-square-mile area studied was 1 swan per 7.7 square miles. Swans depart the breeding grounds from late August to late September, those swans with young being last to leave (U.S. Fish and

Wildlife Service, 1982; Bartels and Doyle, 1984a, b; Bartels and others, 1984; Brackney and others, 1985a, b).

Four species of geese regularly use the 1002 area of the Arctic Refuge: Canada geese, black brant, greater white-fronted geese, and lesser snow geese. Canada geese and black brant may breed there each year; however, the size of the breeding population is unknown, and the coastal plain is not a major nesting area. Geese nest on islands and peninsulas associated with the drained-basin wetlands of the thaw-lake plains and river flood plains (pl. 3A). Canada geese with broods seek lakes and lagoons for protection shortly after they hatch. Brant breeding areas are usually found near the mouths of large rivers. In late June, nonbreeding and failed breeding pairs begin to molt. Some of these individuals may move west prior to molting (pl. 3B). Several hundred molting Canada geese and brant have been observed in late July and early August along the Arctic Refuge coastline.

Staging lesser snow geese congregate on the Arctic Refuge coastal plain in mid-August and may remain through late September (pl. 3B). These geese nest chiefly on Banks Island in Canada and, prior to fall migration, move westward into the 1002 area as far as the Hulahula River. Several hundred snow geese also use the Canning River delta during fall staging. More than 595,000 birds have been estimated for the entire staging area on the coastal plain in Alaska and the Yukon Territory, Canada (FWS, unpublished data). The maximum estimated for the Arctic Refuge coastal plain was 325,760 in 1976 (Spindler, 1978b), with an 11-year average of 136,000. The average number of geese using the 1002 area is 105,000, approximately 15-20 percent of the Banks Island population. Distribution of staging snow geese on the 1002 area is highly variable. Preferred staging areas shift annually among the Niguanak-Okerokovik area, the Jago-Bitty-Okerokovik area, the Jago-Bitty-Okpilak River area, and the lower Aichilik and Angun Rivers between the 400- and 1,000-foot contours. Staging geese move up to 225 miles west of their southward migration corridor on the Mackenzie River in order to take advantage of the food resources on the Yukon and the Arctic Refuge coastal plain. The geese feed heavily to accumulate fat reserves for the fall migration flight. Significant weight gains have been reported in fall staging snow geese on the North Slope (Patterson, 1974; Brackney, Masteller, and Morton, 1985a).

As many as 10,000 greater white-fronted geese and black brant have been found to use the Arctic Refuge coastal plain for fall staging and migration from late August through mid-September. The white-fronted geese congregate with snow geese and move east during migration (Martin and Moitoret, 1981), probably to the Mackenzie River. Coastal salt marshes and mudflats in the river deltas are especially important habitat for the westward-migrating black brant at this time (pl. 3B). During spring migration, reported arrival dates for geese range from mid-May to early June. Brant rely heavily on vegetated coastal mudflats during spring migration when the availability of suitable foraging areas is critical to ensure healthy arrival on the breeding grounds.

Several species of ducks use the 1002 area, the coastal lagoons, and nearshore Beaufort Sea waters during summer. Ducks arrive during spring migration in late May and early June. Early-arriving ducks are attracted to overflow water at river mouths until open water becomes available in nearby lakes and wetlands. Northern pintail, American wigeon, greater scaup, oldsquaw, common eider, and king eider breed on the 1002 area; the oldsquaw is the most numerous breeder (pl. 3A). Nesting density throughout the 1002 area is generally low; locally, nesting densities in wetland complexes around river deltas and other coastal areas may be higher.

Probably more important than breeding habitat, the 1002 area lakes and wetlands, coastal lagoons, and nearshore Beaufort Sea waters provide important molting and staging areas for several duck species. Oldsquaw are the vast majority of waterbirds using the 1002 area. As many as 33,000 postbreeding oldsquaw congregate in coastal lagoons, nearshore waters, and large open lakes during the midsummer molt period and remain throughout the summer. The movement of oldsquaw and common and king eider continues to late summer. Fall migration includes movement of females, juveniles, and late-molting individuals along the Beaufort seacoast. Many of the ducks that breed outside the 1002 area use coastal lagoons and nearshore waters as staging areas during molt and fall migration. In midsummer, scoters (especially surf scoters) and eiders (especially common eiders) move westward along shorelines and lagoons. At the same time, pintails migrate eastward over the coastal tundra.

Waterfowl and their eggs are taken for subsistence. The largest harvest occurs from May through early June, though birds are taken throughout the summer (Jacobson and Wentworth, 1982). Virtually all species of waterfowl are used, oldsquaw being the most abundant and geese the most prized.

SEABIRDS AND SHOREBIRDS

Seven species of seabirds are known to breed in the 1002 area: three jaegers (pomarine, parasitic, and long-tailed), two gulls (glaucous and Sabine's), arctic tern, and black guillemot. Jaegers are widely distributed over all habitat types, but their breeding population is comparatively small, except in years of high microtine populations. Likewise, glaucous gulls and arctic terns are widely distributed, reaching greatest densities in tundra wetlands near the coast, but they occur in limited numbers on the 1002 area. Sabine's gulls and black guillemots are highly localized. The only known nesting areas of the Sabine's gull in the 1002 area are on the Canning River delta. Black guillemots breed only on the coastal beaches. Gulls, terns, and jaegers feed and nest along the coastline and major coastal rivers. Jaegers feed on small birds and insects along the beaches, as well as on lemmings, the eggs and young of small birds, and carrion (U.S. Fish and Wildlife Service, 1982).

Shorebirds are present in the coastal plain from mid-May through the end of September in all habitats (pl. 3C). Sixteen species of shorebirds have been recorded as breeding on the coastal plain. Most abundant are pectoral and semipalmated sandpipers, lesser golden plovers, red-necked and red phalaropes, ruddy turnstones, and long-billed dowitchers. Other common breeders are Baird's, stilt, and buff-breasted sandpipers; dunlin; black-bellied and semipalmated plovers; and wandering tattlers. Occasionally snipes and whimbrels nest on the coastal plain. Along the coast, seasonal fluctuations in shorebird numbers are characterized by highs each year in mid-June (arriving birds), early July (nonbreeding transients), and late August (departing birds). More than 2 million shorebirds are estimated to be present on the coastal plain from mid-June to mid-July (U.S. Fish and Wildlife Service, 1982). Mudflats on river deltas, particularly the Canning, Okpilak/Hulahula, and Jago, and thaw-lake ponds along the coast are important stopping points for several species of migratory shorebirds.

RAPTORS

Rough-legged hawks, golden eagles, gyrfalcons, merlins, snowy and short-eared owls, as well as the threatened arctic peregrine falcon, are present on the coastal plain. Rough-legged hawks nest on river bluffs and near steep foothill slopes; golden eagles nest in the foothills and mountains of the Brooks Range; gyrfalcons nest on the cliffs along rivers or on isolated upland cliffs; and owls nest on the open tundra (pl. 3D). These birds use the coastal plain mostly as a feeding area. Raptors generally arrive on the 1002 area in mid-May, except for gyrfalcons which are resident and begin nesting as early as the first week of April. Raptors prey upon small rodents, ptarmigan, waterfowl, and other birds, and so their populations and distributions vary with the availability of prey. Snowy owl and short-eared owl population peaks are directly related to the microtine cycle. Concentrations of 25-75 golden eagles (mostly immature birds) occur on the calving grounds and postcalving areas of the PCH, where they prey on young calves and scavenge caribou carcasses (Mauer, 1985b).

PTARMIGAN

Willow ptarmigan and rock ptarmigan are common breeders and fairly common winter residents on interior parts of the 1002 area. Both species are less common near the coast than inland, but rock ptarmigan are more common than willow ptarmigan at coastal sites. Little is known of the wintering status of these species on the 1002 area, although they are present. A general northward migration of willow ptarmigan occurs in April and early May as flocks totaling several thousand birds move from the Brooks Range north toward the 1002 area. In the spring, ptarmigan are commonly observed in riparian willow or on exposed ridges and bluffs where the earliest snowmelt occurs; later they move elsewhere for nesting. Rock ptarmigan nest in nearly all 1002 area habitats except the very wet sites; willow ptarmigan prefer drier upland sites with moist sedge shrub or tussock habitat. In the postbreeding season, flocks and broods of both species usually move into riparian willow habitat.

Willow and rock ptarmigan are frequently hunted as subsistence food species by Kaktovik residents. In midwinter, willow ptarmigan are hunted on the 1002 area. Rock ptarmigan are hunted mostly in the spring (April-May).

PASSERINES

Many passerines, or perching birds, use the 1002 area during summer (pl. 3C). Erect riparian willow stands support the highest nesting density and diversity of passerine species. The common and hoary redpolls, white-crowned sparrows, yellow wagtail, and American tree sparrow are largely restricted to riparian willow thickets or adjacent riparian Dryas terrace or gravel bars which also support willow growth. Savannah sparrows use similar habitats, but are also found in uplands, tussocks, and coastal areas. Snow buntings seem to be limited to bluffs near the coast and around buildings. Lapland longspurs are the most abundant species nesting in all tundra types. Only two passerine species are resident, the common raven and the American dipper. Some raven nesting areas are shown on plate 3D. American dippers are probably restricted in winter to the only open water available which is near Sadlerochit and Shublik Springs.

## FISH

Fish resources in the Arctic survive because of extreme adaptations to a harsh environment. They have a limited period in which food is available to them and generally a limited area in which they can survive during the long winter. The result is populations of slow-growing fish that can be affected easily by changes in environmental factors.

Coastal waters of the Beaufort Sea in Alaska have been reported to contain 62 marine and anadromous species, including arctic char, arctic cisco, arctic flounder, arctic cod, boreal smelt, and fourhorn sculpin (Craig, 1984). Nearshore waters and the brackish lagoon systems provide migrational corridors for anadromous fish and are extremely important feeding areas for these species.

Marine nearshore waters are important spawning and overwintering areas for some marine fishes such as arctic cod, arctic flounder, and fourhorn sculpin. River deltas are also believed to be important overwintering areas. Suitability of deltas for overwintering depends largely on the salinity tolerances of species using the areas.

The Canning River has been studied more than any other fresh-water system in the 1002 area. Species reported include arctic char, arctic grayling, arctic cisco, arctic flounder, fourhorn sculpin, least cisco, round whitefish, broad whitefish, ninespine stickleback, chum salmon, and burbot. Lake trout are also found in several lakes within the Canning River drainage but outside the 1002 area. Other 1002 area streams (pl. 1B) that support fish populations are listed below.

Streams that support fish populations (excluding Canning River).

A: Arctic grayling. C: Anadromous arctic char.
B: Resident arctic char. D: Pink salmon.

| | A | B | C | D |
|---|---|---|---|---|
| Tamayariak River | X | | | |
| Itkilyariak Creek | X | X | | |
| Sadlerochit River | X | X | | X |
| Hulahula River | X | | X | |
| Akutoktak River | X | | | |
| Okpilak River | X | | | |
| Aichilik River | X | | X | |

These and many other smaller streams and coastal lakes have populations of ninespine sticklebacks. The other major streams in the 1002 area (Katakturuk River, Marsh Creek, Carter Creek, Jago River and tributaries, Niguanak River, Sikrelurak River, Angun River, and Kogotpak River) apparently do not support major fish populations. They may support fish locally and serve as summer feeding areas for a few fish but seemingly lack adequate overwintering habitat.

The drainages that originate in or transect the 1002 area range from small intermittent-flow tundra streams to the Canning River which has an estimated 50-year flood discharge of 13,500 cfs (Childers and others, 1977). The integrity of riparian areas is important for maintenance of water quality and fish stocks on the coastal plain. Most of the water present is a result of precipitation, surface permafrost-thaw processes, deep-lake drain, or springs. Peak flows are associated with snowmelt in early summer or with rainfall during late summer and fall. By late October, most rivers in the 1002 area have no measurable flow. As riffle areas freeze to the bottom, overwintering fish become isolated in deeper pools, spring areas, or brackish river deltas. Substantial movement from summer feeding areas to small overwintering areas has been recorded (West and Wiswar, 1985). Ice accumulation on Arctic rivers is thickest from late March through early May.

Available fish overwintering habitat, such as deeper pools, is greatly reduced in early spring. Although pool depth is important, several other factors affect suitability for overwintering. These factors, which ultimately affect dissolved oxygen concentration, include density of organisms in the pool area, species' physiological tolerances, volume of the pool, temperature, amount of organic matter, and the influence of springs. Overwintering habitat is probably the greatest limiting factor for Arctic anadromous and fresh-water fish populations (pl. 1B).

Springs supply most, if not all, of the free-flowing water in the 1002 area during late winter. The importance of springs for spawning, rearing, and overwintering arctic fish populations has been well documented in the Arctic Refuge and other Arctic areas. Macro-invertebrates (aquatic insects consumed by fish) are generally much more abundant and diverse in springs and spring-fed sections of stream channels than in other Arctic Refuge stream habitats (Glesne and Deschermeier, 1984).

Lakes are uncommon in the 1002 area. The few that exist are generally thaw lakes located along the coast. Lakes less than 6 or 7 feet deep generally lack fish over-wintering capabilities: they either freeze to the bottom by late winter or have poor water quality because of freeze concentrations of dissolved solids and low dissolved-oxygen levels. Lakes near the coast may be brackish, owing to saltwater intrusion or windblown ocean spray. In contrast to the more inland lakes, some shallow coastal lakes may be important summer feeding areas for anadromous and marine fish, depending on access.

Coastal lakes near the Canning River delta, sampled during summer, have contained arctic char, arctic grayling, arctic flounder, round whitefish, and broad whitefish (Ward and Craig, 1974). In deeper mountain and foothill lakes to the south of the 1002 area, arctic char, arctic grayling, and/or lake trout may be found. The best known and most widely used for recreation and subsistence are Lake Peters and Lake Schrader, in the headwaters of the Sadlerochit River. These lakes contain all three of the aforementioned fish species.

Most Native subsistence use of fish occurs along the coast. Arctic char and arctic cisco are the primary species caught during summer when they are present in large numbers in the Arctic Refuge lagoon systems. The arctic cisco is an international resource believed to originate in the Mackenzie River in Canada. Some subsistence use of arctic cod occurs in winter in apparent response to its increased abundance during that time. Arctic cod (Lowry and others, 1978) also constitutes more than 95 percent of the diet of ringed seals which in turn are the major prey of the areas's polar bears. Some winter subsistence fishing also occurs at fresh-water overwintering sites. The most notable of these are "Fish Hole One" and "Fish Hole Two" on the Hulahula River (pl. 1B) where arctic char and arctic grayling are caught from holes in the river ice.

Sport fishing is currently minimal in the 1002 area because of difficulty in access and seasonal limitations on fish abundance.

THREATENED AND ENDANGERED SPECIES

BOWHEAD AND GRAY WHALES

Bowhead and gray whales are listed as endangered under the Endangered Species Act of 1973, as amended. Both species migrate into or through the Beaufort Sea, north of the 1002 area, although sightings of gray whales are extremely rare. In-migrations of bowheads occur after spring breakup, and out-migrations take place before fall freezeup.

ARCTIC PEREGRINE FALCON

The arctic peregrine falcon is the only terrestrial threatened or endangered species known to occur in the 1002 area. In Alaska, most peregrine falcons nest on ledges of cliffs or bluffs along river courses. In the Arctic Refuge north of the Brooks Range, cliff habitat is not abundant. However, a few peregrines have been reported nesting there in past years (Cade, 1960; Roseneau and others, 1976; Amaral, 1985; Amaral and Benfield, 1985). Historically, peregrines were known to occupy eyries along the Canning, Katakturuk, Sadlerochit, Hulahula, Jago, Aichilik, and Kongakut Rivers (U.S. Fish and Wildlife Service, 1982). Among the eyries formerly or potentially occupied by peregrines within the Arctic Refuge, only two are within the 1002 area. These sites occur on bluffs along the Sadlerochit River near the spring and at Bitty Benchmark on the Jago River (pl. 3D).

Peregrine falcons are highly migratory and spend only a relatively short time in Alaska. Arctic peregrines generally arrive at their North Slope eyries between April 21 and May 7, egg-laying and incubation occur between May 15 and July 21, and young fledge (leave the nest) during August (U.S. Fish and Wildlife Service, 1982). Generally, the breeding season is defined as the period from April 15 to August 31.

There appears to be a significant movement of arctic peregrine falcons through the 1002 area from late August to mid-September (Martin and Moiteret, 1981; U.S. Fish and Wildlife Service, 1982). The number and timing of these observations strongly suggest that at least some North Slope arctic peregrines follow a coastal migration route along the Beaufort Sea. The lagoons, river mouths, and bays concentrate shorebirds and waterfowl, which are favored prey of the peregrine.

Documented nesting of peregrines in the Arctic Refuge north of the Continental Divide occurred in 1972-73 when three sites near the confluence of the Marsh Fork and Canning River 40 miles south of the 1002 boundary were occupied (Roseneau, 1974), and in 1984 and 1985, when pairs nested along the Canning and Aichilik Rivers, also outside the 1002 area. Several sightings during June and July have been reported from the 1002 area (U.S. Fish and Wildlife Service, 1982; Amaral, 1985; Amaral and Benfield, 1985; Oates and others, 1986). The significance of these observations is unclear, as the birds did not appear to be associated with nest sites. Yet the observations do indicate that in addition to those present during migration, a few scattered peregrines (possibly nonbreeders) can be found in the 1002 area during the breeding season.

## SOCIOECONOMIC ENVIRONMENT

### Population

The North Slope Census Region comprises the entire 88,281-square-mile northern coast of Alaska. The region is very sparsely populated, with a density of one person per 220 square miles. With the exception of Anaktuvak Pass, the population of the region lives on or near the coast. The majority of residents are Inupiat Eskimo; but about 6,200 nonresidents are employed in isolated, self-sufficient large to medium-sized industrial or military enclaves (NSB, 1984a).

Population figures for the Census Region are derived for several purposes and must be checked to see which data are used. For example, the U.S. Census 1980 population was 4,199 but it did not include workers at Prudhoe Bay as "residents;" the 1980 population including both residents and the nonresident workforce was 9,234 (NSB, 1984b). In comparison, the 1970 population of Prudhoe Bay was 217.

The NSB Comprehensive Plan uses an annual population growth rate of 2 percent and assumes a doubling of the Eskimo population for the region in 35 years (3,034 in 1980 to 6,000 by 2015).

Kaktovik is the only settlement near the 1002 area. The 1980 U.S. Census listed Kaktovik's population as 165, a 34-percent increase over the 1970 population. The 1983 population shows another increase, although counts differed: 185, according to an April 1983 population count by Pedersen, Coffing, and Thompson (1985), and 203 according to the North Slope Borough (1984b). Nearly 90 percent of the population is of Native Inupiat Eskimo descent. The population increase since 1970 has been primarily the result of residents formerly living in Barrow who have returned to the village because of improved housing and employment opportunities. Key features of the community are family and cultural ties, ties to the land, and the economic opportunity for both jobs and subsistence. Community growth will probably continue if current trends for services and other village improvements continue (U.S. Bureau of Land Management, 1978).

## Existing Land Use

SUBSISTENCE USE

Responsibilities for subsistence management and use on Federal lands are derived from Title VIII of ANILCA. Under section 803, "subsistence uses" are defined as "the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of nonedible byproducts of fish and wildlife resources taken for personal or family consumption; for barter, or sharing for personal or family consumption; and for customary trade."

Because of its location adjacent to the 1002 area, Kaktovik is the community of primary concern relative to subsistence land uses within the 1002 area. Residents of other villages at considerable distances from the 1002 area harvest migratory CAH and PCH caribou mainly when those animals are not on the 1002 area. These villages are Arctic Village (1980 population of approximately 125) on the south boundary of the Arctic Refuge, 120 miles south of the 1002 area; Venetie (1985 population of 132) and Fort Yukon (1980 population of 619), even farther away, being 150 and 170 miles, respectively, south of the 1002 area; and Old Crow, Yukon Territory, Canada (1973 population of 206) about 160 miles southeast of the 1002 area. Because this chapter focuses on 1002 area resources and uses of those resources within the 1002 area, these other villages are considered only generally.

The Alaska Department of Fish and Game Division of Subsistence recently completed a detailed investigation, begun in 1980, of Kaktovik subsistence land use (Pedersen and others, 1985). That study elaborated upon the previous work by Jacobson and Wentworth (1982) and Wentworth (1978). The 1981-82, 1982-83, and 1983-84 caribou harvest by Kaktovik residents was also reported by ADF&G (Pedersen and Coffing, 1984). Figure II-6 displays Kaktovik's subsistence species use by season.

Approximately 68 percent of Kaktovik's present subsistence land use is within the Arctic Refuge (Pedersen and others, 1985). This area extends as far south as the headwaters of the Hulahula River and includes the entire 1002 area (23 percent of the total subsistence land use area) (fig. II-7). The State lands along the coast west of the refuge are used during summer, often to Bullen Point and occasionally as far as Foggy Island Bay. Those and other State lands, though rather lightly used, account for 30 percent of the Kaktovik subsistence land use area. Kaktovik Inupiat Corporation (KIC) lands adjacent to Kaktovik are the remaining 2 percent.

Participation in subsistence activities is a major aspect of Kaktovik residents' life. In 1978, 20 percent of Kaktovik households obtained their entire food supply from hunting, fishing, and gathering; 65 percent obtained most of their food supply in that manner (J.W. Peterson, 1978). More recent studies, as summarized by Pedersen and others (1985), found that 80 percent of Kaktovik households consumed meats daily that were obtained from hunting and fishing.

Kaktovik residents depend mainly on caribou, Dall sheep, bowhead whales, fish, waterfowl, and other birds for subsistence (table II-3). Seals, polar bears, furbearers, and small game are also widely used, although they are not major components of the local diet. Brown bears and moose are occasionally taken. Many residents harvest berries, wild rhubarb, and roots. Driftwood is gathered from the beach and used as a supplementary heating source to oil, and willows are an important heating and cooking source when camping.

Subsistence activities are most intensive during spring and summer months--the time of long hours of daylight, relatively mild weather, and species abundance. During the snow-free months, usually mid-June through September, overland travel is difficult. Shallow water prevents access to inland areas by river; however, by early July, coastal areas are accessible by small motorboats. From October through May, snow cover and frozen ground greatly expand the area used for subsistence. Longer days combined with adequate snow cover and milder weather make April and May the best months for snowmachine travel. Travel then extends across the tundra of the 1002 area and to hunting camps along the Hulahula and Sadlerochit River drainages. During winter, foothills and mountain valleys are the most important places for subsistence activities.

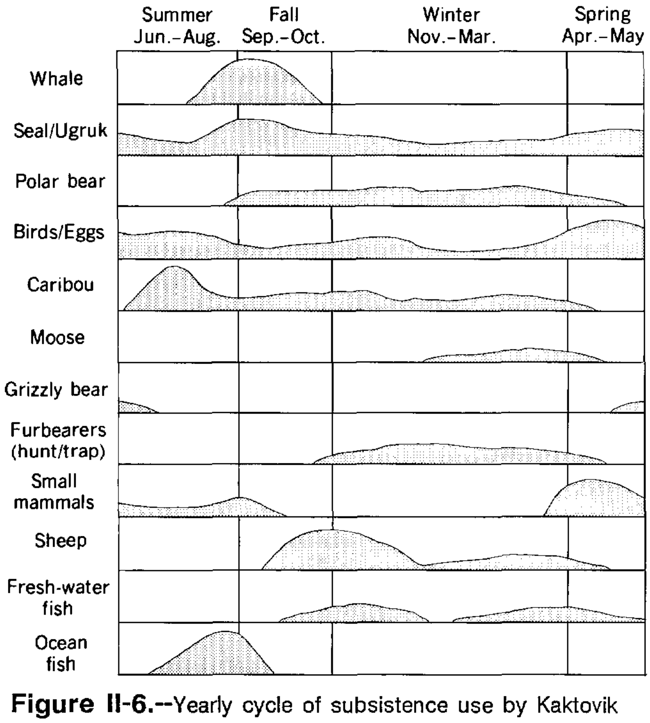


**Figure II-6.**--Yearly cycle of subsistence use by Kaktovik residents. Patterns indicate periods for pursuit of each species, based on abundance, hunter access, seasonal needs, and desirability. Modified from Jacobson and Wentworth (1982, p. 29).

Caribou is the staple land mammal in the Kaktovik subsistence diet. It is a source of fresh meat throughout the year, and is also frozen and dried. It is also important in holiday feasts. Caribou hides are used for garments, boot soles, and blankets.

Caribou hunting opportunities and harvest are usually greatest from early July to late August, when they are hunted primarily along the coast from outboard-powered boats (pl. 2D). Other major hunting periods are from late October to late November, when there is enough snow for overland travel by snowmachine and daylight is not yet too brief, and again from late February through March and April, when daylight is longer and weather conditions are better.

Availability of the PCH to local hunters is highly variable. During the summers of 1978-81, the PCH migrated past Barter Island and into Canada before breakup of sea ice allowed Kaktovik people to travel by boat. Caribou from the CAH in the vicinity of the Canning River delta are especially important during such years. For 1972-84 the annual harvest was estimated at 40-300 caribou total, from both herds. More detailed studies in recent years show an annual harvest level of about 100 animals. The proportions of harvested caribou from the two herds varies: in 1981-82, more than 80 percent of Kaktovik's caribou harvest was from the PCH; in 1982-83, about 70 percent was from the PCH; and in 1983-84, approximately half of the community's harvest came from each herd (Pedersen and Coffing, 1984; Coffing and Pedersen, 1985).

Most winter caribou hunting occurs in the mountains along river valleys. Occasional hunting occurs on the coastal plain, especially at favored locations such as Konganevik Point. The Hulahula River valley is one of the most intensely used areas for winter caribou hunting, and the Okpilak River and Okpirourak Creek drainages are also important winter-hunting areas. The Jago and Niguanak Rivers, the Niguanak Hills, and the Niguanak Ridge area immediately south are other winter-hunting areas.

In spring, caribou hunting continues along the Hulahula, Sadlerochit, Okpilak, and Jago Rivers. The greatest expanse of hunting territory is covered at that time. Some trips are made up the Okerokovik River and to the foothill country of the Aichilik River. Occasionally, in late winter or early spring, people travel to the Canning River in the vicinity of Ignek Valley and Shublik Island and hunt caribou as far upriver as the Marsh Fork.

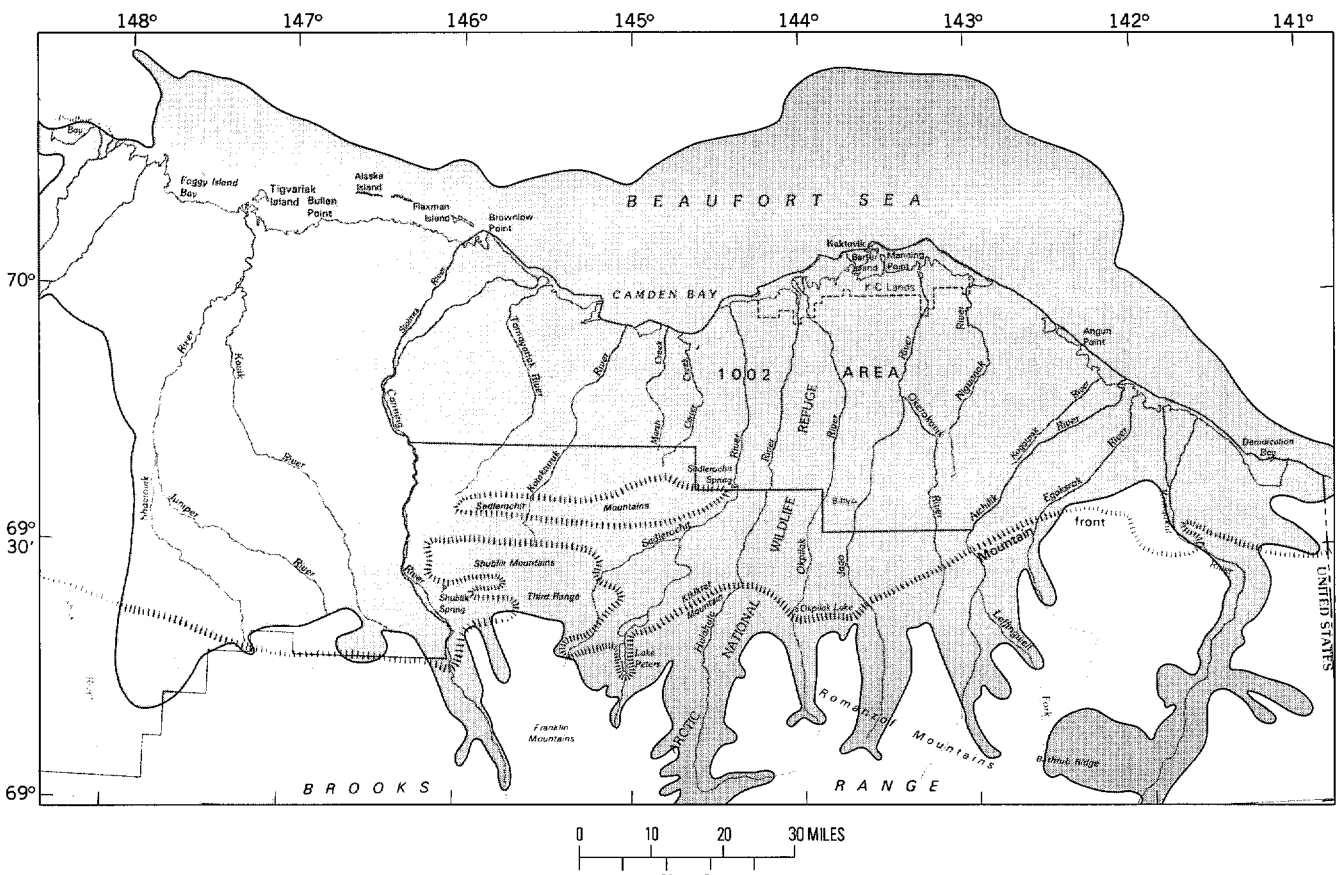


**Figure II-7.**--Extreme extent (patterned) of subsistence use by Kaktovik residents in the years 1923-83. Data from Pedersen, Coffing, and Thompson (1985).

**Table II-3.**--Kaktovik participation in subsistence use, according to resource harvested.

[Of Kaktovik's 46 households, 21 were surveyed. Ten of the households not surveyed were teachers, or short-term residents, or without active hunters. NA, not available. Adapted from Pedersen and others, 1985]

| Resource harvested | Participation (total 21) | |
|---|---|---|
| | Households | Percent |
| Fish | 21 | 100 |
| Caribou | 20 | 95 |
| Sheep | 20 | 95 |
| Wildfowl | 20 | 95 |
| Seals | 19 | 90 |
| Polar bears | 18 | 86 |
| Small mammals | 18 | 86 |
| Trapping furbearers | 16 | 76 |
| Moose | 16 | 76 |
| Vegetation | 15 | 71 |
| Whales | 14 | 67 |
| Hunting furbearers | 12 | 57 |
| Grizzly bear | 11 | 52 |
| Walrus | 6 | 29 |
| Wood, fuel, and structural materials | 5 | 24 |
| Invertebrates | NA | -- |

Harvest of caribou by villages other than Kaktovik depends on availability of animals near those villages. In some years caribou migration routes or wintering areas may not bring caribou near enough to a village to make hunting feasible. Still, a large amount of sharing and trading of resources occurs between villages. The two villages other than Kaktovik which are most dependent on caribou using the 1002 area are Arctic Village and Old Crow, Yukon Territory--inland villages having little or no access to marine resources. Caribou is the most important food source for Arctic Village and caribou from the PCH are often available from August to April. Fall hunting is conducted near the village; winter hunting occurs farther away because snowmachines can be used. In the 1970's, the harvest at Arctic Village, Alaska, was reported to be 200-1,000 animals (LeBlond, 1979).

Approximately half the food consumed by people in Old Crow comes from the land; of this, caribou is the most important resource. The major hunt for caribou is in the fall; some hunting occurs in winter and in spring depending on the year. In September, large numbers of caribou pass through the Old Crow flats and cross the Porcupine River heading for their wintering areas. At this time they can be taken on land or by boat. There is some caribou hunting in winter and in spring depending on the year. Annual harvest of the PCH from Old Crow and other Canadian villages averaged approximately 1,700 between 1963 and 1985 for the years in which data were available (Yukon Territory Wildlife Branch, unpublished data).

Venetie and Fort Yukon residents also take caribou when they are available. For 1980-81 the harvest for Venetie was reported as 200-300 caribou and the harvest for Fort Yukon as 80-100 caribou (Pedersen and Caulfield, 1981). Variations in annual harvest described here do not necessarily indicate a large variation in the quantity of subsistence resources consumed. The villages do much sharing and trading of resources.

Because they are rare within the 1002 area, Dall sheep are generally hunted outside the 1002 area, with hunting occurring from mid-October through March. The Hulahula River drainage within the mountains is used most extensively. Hunting begins at the river's exit from the mountains near the Second Fishing Hole and continues to the headwaters. The Sadlerochit River, creeks along the eastern sides of the Shublik Mountains and Third Range, and the Whistler Creek area at Lake Peters are other locations where sheep are occasionally hunted. During recent years there has been increased hunting in the upper Okpilak, Jago, and, especially, the Aichilik River drainages (Jacobson and Wentworth, 1982).

The number of sheep taken by Kaktovik hunters has fluctuated greatly; only a few were killed in some years and as many as 50 in other years. The harvest is closely tied to the success of the whaling season and the number of caribou available for harvest. Snow cover, weather, and travel conditions in the mountains are also important factors. During 1982-84, Kaktovik hunters took only about half the 50 sheep for which they could obtain permits (Pedersen and others, 1985), mainly because of their success in procuring other resources.

In the historic period, no whaling occurred at Kaktovik. Beginning in 1964, whales (particularly bowheads and occasionally belugas) have been actively hunted. Whaling is viewed as among the village's most important annual activities (Jacobson and Wentworth, 1982). It expresses the cultural values of large group cooperation and sharing of resources, and is a way of passing these values to the younger generation. The harvest quota for Kaktovik, as determined through the cooperative agreement between the Alaska Eskimo Whaling Commission and the National Oceanic and Atmospheric Administration, has never been exceeded. Kaktovik hunters filled their quota of 3 whales in 1981. In 1981-85 an average of one whale was harvested annually with an additional annual average of one whale struck and lost by the village. Approximately 22 whales were taken during 1964-81. Kaktovik's bowhead whaling season occurs during the westward migration of bowheads near the Beaufort Sea coast, from late August until early October. There is no spring whaling season in Kaktovik because the leads (open water channels) are too far from shore. Whales are generally hunted within 10 miles of land and sometimes as far as 20 miles offshore of Barter Island. After a whale is butchered, the meat and muktuk (blubber and skin) are divided among the captain, crew, and the rest of the village.

Kaktovik people hunt bearded, ringed, and spotted seals for oil, meat, and skins. Seals are hunted throughout the year, although relatively few are taken. Most seal hunting occurs by boat along the coast from July into September.

In recent years, most polar bears harvested were foraging on Barter Island, usually attracted by the remains of a beached whale or the Kaktovik landfill. They are actively hunted on the ice, seaward of the barrier islands. The main hunting area for polar bears extends from the Hulahula-Okpilak River delta on the west to Pokok Lagoon on the east. Hunting is often best near decaying bowhead carcasses. Harvest varies considerably from year to year; as many as 28 were taken in the 1980-81 season, but an average of one bear has been taken annually since then (Schliebe, 1985; Jacobson and Wentworth, 1982; U.S. Fish and Wildlife Service, unpublished data).

Arctic char is the fish species most extensively used by local people. In early July, sea-run char are caught all along the coast, around the barrier islands, and along the navigable parts of the river deltas. Arctic cisco, the most commonly caught whitefish species, is taken in the ocean by netting or seining. Cisco begin appearing in the nets about mid-July near the peak of the arctic char run.

Willow and rock ptarmigan are hunted year-round, with greatest success during April and May. Waterfowl are hunted along the coast, mostly in the spring from May through early June, although less intensive hunting continues through the summer and into September. People usually hunt black brant, common and king eider, snow and Canada geese, pintail, and oldsquaw. More oldsquaw are taken than any other species, usually incidental to other forms of hunting or when fishing nets are checked. A few bird eggs are collected each spring.

Winter is the season for trapping and hunting furbearers. Some Kaktovik residents hunt wolves and wolverines and trap for red foxes in the foothills, chiefly south of the 1002 area. Others concentrate on arctic foxes on or near the 1002 area. Furs are used locally in making parkas and ruffs or are sold to the Village Corporation or to furbuyers.

Brown bears are taken by villagers strictly on an opportunistic basis (Jacobson, 1980), recently about two for the entire village per year. One or two moose are also harvested each year by Kaktovik on an opportunistic basis. They are most often taken in the Sadlerochit Valley and in the foothills along Old Man Creek, Okpilak River, and Okpirourak River. Expanding muskoxen populations are a limited source of subsistence hunting. Arctic ground squirrels are hunted mainly from March through May along the banks and sandy mounds of the major rivers, especially the Jago, Okpilak, Hulahula, and Sadlerochit (Jacobson and Wentworth, 1982).

Several goals of the State-approved North Slope Borough Coastal Management Program (see "Coastal and Marine Environment") relate to subsistence resources. These goals are: (1) to protect the natural environment and its capacity to support subsistence activities; (2) to protect and enhance subsistence resources; (3) to preserve the Inupiat culture; and (4) to maintain and enhance access to subsistence resources.

## LAND STATUS

Land ownership within and adjacent to the 1002 area is a complex of Federal, State, and private interests. Federally owned land to the south and east is managed as the Arctic National Wildlife Refuge. Oil and gas exploration has occurred on State lands west of the Canning River. Lease sales have been proposed for January 1987 on nearly one-half million acres of State lands between the Canning and Colville Rivers.

The Kaktovik Inupiat Corporation has statutory entitlement to ownership of 92,160 surface acres within the Arctic Refuge north of the 1002 area. Subsurface ownership was conveyed by the United States to the Arctic Slope Regional Corporation under the terms of an August 9, 1983, agreement.

Submerged lands beneath the coastal lagoons in the area located between the mainland and the offshore barrier islands between Brownlow Point and the mouth of the Aichilik River (with the exception of lagoons north of KIC lands) were included within the area of exploration authorized by section 1002(b)(1). The United States and the State of Alaska dispute ownership of these lands and have presented their arguments to a Special Master appointed by the United States Supreme Court. A final decision has not yet been rendered. Until this decision is made, all activity on these submerged lands requires concurrent Federal and State approval.

The State of Alaska has solicited comments and is developing a preliminary analysis for State offshore oil and gas lease sales, including submerged lands. Approximately 127,000 acres immediately offshore of the 1002 area between the Canning and Hulahula Rivers has been identified for a May 1987 State sale; about 300,000 acres offshore from the Arctic Refuge between the mouth of the Hulahula River and the Canadian Border has been proposed for a May 1988 State sale.

Native allotments (described below) are scattered throughout the 1002 area.

NATIVE ALLOTMENTS

Within the 1002 area, the Federal Government has begun to process toward conveyances some 21 applications, involving 29 parcels for Native allotments. None of these parcels had been issued a certificate of allotment as of February 1986. In total, these applications cover approximately 1,985 acres. A Native allotment is a parcel of land, containing 160 acres or less, which can be conveyed to a Native based on that individual's use and occupancy of the land under the authority of the Native Allotment Act, May 17, 1906 (43 U.S.C. 270-1), as amended, August 2, 1956, and repealed by the Alaska Native Claims Settlement Act of December 18, 1971 (43 U.S.C. 1617).

Subsurface ownership under an allotment will be reserved to the government if it is determined that it may be valuable for coal, oil, or gas. The allotment owner would then be subject to the right of the government or its lessee to enter and use the lands for the development of the reserved minerals, subject to the duty to pay for damages to surface improvements and a bond to guarantee such payments. If the allotment area is known to be valuable for minerals other than coal, oil, and gas, the allotment is not granted.

INDUSTRIAL USE

The 1002 area has received no industrial land use other than oil and gas exploration under the 1002 program.

GOVERNMENT AND MILITARY USE

Arctic Contractors (PET-4 Contractor) established an exploration camp at Barter Island in 1947. It also supported the U.S. Coast and Geodetic Survey coastal surveying parties. Arctic Contractors constructed the airstrip in 1947.

The U.S. Air Force constructed a Distant Early Warning (DEW) Line Station (DEW Line Site BAR MAIN) on Barter Island in 1955, as part of a larger network of radar installations across the North American Arctic. In 1956 they built the DEW Line hangar adjacent to the airstrip. The establishment and expansion of the site forced the village of Kaktovik to relocate three times, but also brought employment opportunities to villagers. The site is located about 1/2 mile from the present village and is largely self-contained, functioning as a separate entity from the village. As many as 70 employees live at the site. Most DEW Line site employees are hired from outside the North Slope. The site currently employs three Inupiat and two non-Inupiat residents of Kaktovik. Modernization of the Bar Main DEW Line site is scheauled to start in 1986.

The Alaskan DEW Line also included intermediate sites at Camden Bay (POWD) and Beaufort Lagoon (Humphrey Point, BAR A), which were constructed for communications relays. Because of advances in communications technology, these sites were deactivated in 1963. The lands formerly withdrawn for the two sites (approximately 876 acres) became a part of the Arctic Refuge on December 28, 1982.

## State and Local Political and Economic Systems

Four levels of government operate within or affect the 1002 area: Federal, State of Alaska, North Slope Borough (NSB), and the village of Kaktovik. Two corporations, Arctic Slope Regional Corporation (ASRC) and Kaktovik Inupiat Corporation (KIC), have a major influence on private lands adjacent to the 1002 area. Many Native residents belong to and have direct input to the NSB, ASRC, KIC and Kaktovik Village.

The State (1) establishes laws and regulations governing certain local activities, (2) provides financial and technical assistance, (3) exercises certain police and regulatory powers such as hunting and fishing bag limits and subsistence and commercial harvest of natural resources, and (4) sets standards for water quality.

The NSB was organized in 1972; in 1973 it was converted to a home-rule charter--the strongest form of local government under Alaska law (NSB, 1984a). The NSB has an elected mayor and an elected seven-member assembly. It is responsible (among other functions) for borough-wide planning such as the coastal management program, and it oversees the capital improvements program.

Kaktovik was incorporated as a second-class city in 1972, and has a council-mayor form of government. The mayor is appointed from the elected seven-member council.

The ASRC is the regional profit-making Native organization formed in 1972 under the provisions of the Alaska Native Claims Settlement Act (ANCSA). It is responsible to nearly 4,000 Inupiat stockholders for management of 5.6 million acres and $75 million (ASRC, 1985; NSB, 1984b). ASRC owns the entire 5.6-million-acre subsurface and about 4.8 million surface acres scattered across the North Slope of Alaska.

KIC is a village corporation; it was formed under the provisions of ANCSA in 1972 to manage surface resources surrounding the village of Kaktovik transferred under the provisions of ANCSA and ANILCA.

Between 1970 and 1979, employment in the NSB increased from 977 jobs to 5,598. During 1979, total wage and salary employment for the North Slope Region was as follows: mining, including oil development, 47.9 percent; construction, 7.4 percent; State and local government, 22.3 percent; transportation, communication, and utilities, 6.3 percent; and services, 5.8 percent (NSB, 1984b). The majority of the jobs are held by non-Native workers, principally at Prudhoe Bay and the military enclaves. However, participation by Inupiats in the labor market has been encouraged through NSB and ASRC programs. Government employment in July 1980 totaled 1,171 workers.

The economy recently made a major transition from largely subsistence to a mixed subsistence and cash economy. Through local-hire policies, the NSB has provided at least some employment for more than 50 percent of the resident Inupiat adults and has contributed significantly to increased per capita income. A major factor contributing to increased Native employment is the capital improvement program. However, long-term Inupiat employment opportunities depend on: (1) NSB's continuing ability to provide jobs; and (2) ability and desire of Natives to work at sites away from their homes.

The region has been isolated from the periodic boom-and-bust economic cycles of forest/fishery/gold extraction typical of other parts of Alaska. Except for whaling it remained virtually unchanged until after World War II. The primary driving force then became national defense (research at the Naval Arctic Research Laboratory at Barrow, and Distant Early Warning radar sites along the coast). Today, the production of oil at Prudhoe Bay is the basic economic influence.

The State-approved NSB Coastal Mangement Program was described under "Coastal and Marine Environment." Of the program goals relating to economic and government activities those particularly pertinent to this report are:

Preserve opportunities for traditional activities and the Inupiat way of life in the North Slope, regardless of ownership and jurisdictional boundaries,

Increase economic opportunity in villages,

Create employment for NSB residents which provides flexibility for traditional Inupiat cultural and subsistence activities,

Develop new industries based on the Inupiat culture,

Protect life and property from natural hazards and phenomena,

Provide guidance and direction for present and potential resource development, onshore and offshore, including exploration, extraction, and processing activities and related facilities,

Cooperate and coordinate with private development,

Improve energy supply for local communities, and

Develop local energy resources.

## PUBLIC SERVICES AND FACILITIES

A detailed description of existing public services and facilities is in the NSB Coastal Management Program--Background Report (NSB, 1984b). New oil and gas facilities assumed to result from existing offshore Federal leasing are described in Oil Development Scenarios for Outer Continental Shelf Oil and Gas Lease Sale 97--Beaufort Sea Planning Area (Draft) (Roberts, 1985).

Air transportation is the single most extensive all-season form of travel in the region. Air facilities range from long, well-maintained paved runways to unimproved strips, sand bars, and local large lakes. During the winter oil and gas exploration operations are supported by artificially created ice strips. Commercial air transportation facilities are located at all communities in the NSB. Except for Barrow and Prudhoe Bay, most lack sophisticated navigation aids, lighting or snow-removal equipment. The only military air facility of significance to the 1002 area is at Barter Island (Kaktovik), and is shared by the NSB and U.S. Air Force (NSB, 1984b). Originally constructed by the military, airstrips located at Camden Bay, Demarcation Bay, Beaufort Lagoon, and Bullen Point have since been abandoned and remain unmaintained.

Marine transportation is controlled by ice conditions and shallow nearshore waters. Major port facilities important to the area are located at Prudhoe Bay. At Barter Island, shallow-draft vessels land directly upon the beach. Military sites have in the past been served by marine transportation. Most ports of embarkation are in Washington and California; only a small part of ocean freight is shipped from Alaska ports. The rivers in the 1002 area are too small and shallow for inland commercial navigation.

The Dalton Highway is an all-weather road connecting Prudhoe Bay to the Alaska highway system. No road network connects population centers in the NSB. Cross-country transportation to and from the 1002 area is limited to winter using special equipment on the snow or sea ice. Nearly every community and military site in the NSB has an internal gravel or dirt road system linking air or marine transportation facilities. Village residents use motorbikes, three-wheeled all-terrain vehicles, cars, or trucks in summer, and snow machines in winter.

The Trans-Alaska Pipeline connects Prudhoe Bay and associated oil fields to a marine tanker terminal at Valdez, Alaska. Recent offshore sales by Federal and State Governments have been based on the assumptions that feeder pipelines will connect any new commercial discoveries to the existing oil pipeline and that half those pipelines would be located onshore. Many factors including potential locations of production platforms and size of commercially developable fields are unknown. Possible offshore pipeline routes and landfalls include those suggested for Sales 71, 87, and 97. Of significance to the 1002 area is an assumed landfall at Bullen Point, west of the Canning River (Roberts, 1985).

The NSB provides water, sewage, sanitary, light-power-heating, public housing, education, health, and public safety facilities in Kaktovik. At Kaktovik the school complex consists of a two-room elementary school and a high school with four classrooms, library, gymnasium, swimming pool, and kitchen. A vocational education building was completed in 1981. Junior and senior high school enrollment for the 1984-85 school year was 36.

Kaktovik has a health clinic staffed by a health aide. Two NSB Department of Public Safety Officers are located at Kaktovik. Federal facilities include the Post Office, the Arctic Refuge field office, and the Bar Main DEW site.

## ARCHEOLOGY

Approximately 100 archeological sites are known to occur within the 1002 area (pl. 1A). Dated sites appear to be comparatively recent and of either Historic Inupiat (approximately AD 1838-present) or Western Thule (about AD 900-1838) origin. Several smaller sites--mostly scatters of lithic debris from the manufacture, maintenance, and use of stone tools--are not yet datable but may be considerably older.

Sites near the 1002 area are known to be as much as 6,000 years old (U.S. Fish and Wildlife Service, 1982). A fairly widely accepted date from the Old Crow area of the Yukon Territory (about 150 miles southeast of the 1002 area) indicates that people have been present in the general area for the last 27,000 years. Even though sites of such an early period are few, sites 5,000-6,000 years old may occur on the 1002 area, but are yet to be discovered.

In the 1002 area, archeological sites may occur almost anywhere. However, some areas are much more likely to have sites, especially coastal areas and offshore barrier islands. Most identified sites consist of the remains of sod houses, log cabins, burials, caches, lookout towers, and related features. Older sites may have become buried under considerable sediment.

Archeological sites are also likely along rivers and streams that cross the 1002 area from the Philip Smith Mountains. These rivers could have provided fishing areas and would have been natural travel routes between the coast and the foothills. Sites known from the river courses are chiefly tent rings, although there are two interior sites with sod houses. Points of particular interest are high, well-drained banks, especially near stream confluences.

Undiscovered sites may also be on high points of land that provide overlooks above the surrounding moist tundra; such spots are known to produce archeological sites throughout most of northern Alaska and Canada. There are relatively few such locations on the 1002 area, and sites identified in such locations are uniformly small scatters of lithic material.

Archeological sites are even less likely on the relatively stable sandy areas in river deltas. As with the overlook sites, material from blowouts in such deltas is currently limited to lithic remains.

The remainder of the 1002 area consists largely of flat to gently rolling tundra, now very wet. Such areas are least likely to contain sites, or to contain sites that are susceptible to discovery.

## RECREATION

Recreational use of the Arctic Refuge is varied and is related to wildlife or wilderness values. Types and amount of recreation are limited by the refuge's remoteness, harsh climate, and poor access. Fewer than 3,000 visits occur annually. Wet and moist ground conditions in the short summer season make surface travel difficult, and extended periods of cold and darkness during the winter reduce recreational uses at that time. Access to the refuge is almost exclusively by aircraft and is costly. Recreational use of the 1002 area is slowly increasing as it becomes better known and scheduled airline services to Barter Island improve.

The most common forms of recreation on the 1002 area are hunting, backpacking, and float trips on some of the larger rivers such as the Canning, Hulahula, and Aichilik. Other recreational pursuits are wildlife observation, photography, sightseeing, cross-country skiing, fishing, and nature study. Most recreationists involve themselves in a variety of these activities. Kaktovik residents also engage in snowmobiling.

In 1984, 13 hunting guides operated on the refuge, though none guided on the 1002 area. An additional 10 recreational guides conducted group float or backpack trips on the refuge. Four of these operated, at least in part, on the 1002 area. Float-trip groups average 6-12 people. Figures on nonguided recreationists are unavailable. But probably fewer than 100 unguided visits occur annually on the ground in the 1002 area. Several hundred visitors fly over the 1002 area annually for sightseeing or en route to other locations on the Arctic Refuge.

## WILDERNESS AND ESTHETICS

The Arctic Refuge is the only conservation system unit that protects, in an undisturbed condition, a complete spectrum of the various arctic ecosystems in North America. Approximately 8 million acres of the refuge is designated as wilderness by ANILCA section 702(3), and adjoin the 1002 area on the south and east. The eastern coastal plain, from the eastern 1002 area boundary to the Canadian border is designated wilderness.

Wilderness is described by the Wilderness Act of 1964 (Public Law 88-557) as ". . . an area of undeveloped Federal lands retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value." With the exception of the two abandoned DEW Line sites on the coast, the entire 1002 area could meet the criteria. The coastal plain in its present state has outstanding wilderness qualities: scenic vistas, varied wildlife, excellent opportunities for solitude, recreational challenges, and scientific and historic values.

Most of the major wildlife species occurring on the refuge (caribou, moose, brown bears, wolverines, wolves, muskoxen, polar bears, and numerous species of birds) use 1002 area habitats for all or part of their life cycles (calving, nesting, breeding, staging). The 1002 area is the most biologically productive part of the Arctic Refuge for wildlife and is the center of wildlife activity on the refuge. Caribou migrating to and from the 1002 area and the postcalving caribou aggregation offer an unparalleled spectacle. The area presents many opportunities for scientific study of a relatively undisturbed ecosystem.

Visual resources of the 1002 area encompass diverse ecotypes and landforms. The irregular coastline of the Beaufort Sea--characterized by its barrier islands, lagoons, beaches, submerged bars, spits, and river deltas--gives way to the south to the gently rising coastal plain. The backdrop of the steeply rising Brooks Range, with its deep river valleys and glacier-clad peaks, portrays the abruptness and rugged beauty of the area.

While the esthetic value of the 1002 area has been temporarily reduced as a result of seismic exploration, the area remains noteworthy. Recent botanical studies show that recovery on the 1002 area is starting with seismic trails less visible in the second year after disturbance (Felix and others, 1986a).

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# CHAPTER III

# ASSESSMENT OF OIL AND GAS POTENTIAL AND PETROLEUM GEOLOGY OF THE 1002 AREA

## INTRODUCTION

This chapter presents the assessment of the oil and gas potential of the 1002 area of the Arctic Refuge. This assessment and the discussion of the petroleum geology of the 1002 area are based on surface geology studies and seismic surveys conducted by industry and the Department of the Interior. Although all seismic work was conducted by industry for the Department, the analyses presented here are based on interpretations of that work by the U.S. Geological Survey (GS) and the Bureau of Land Management (BLM).

This chapter is organized as follows: first, significant results of the resource assessment are summarized; second, the geology of the 1002 area is briefly described, indicating the types of rocks and structures which might be present; third, the likelihood that oil and gas resources are present is assessed through the use of geological "play" analysis which leads to estimates of the amount of resource potentially located in nature beneath the surface of the 1002 area, without reference to its recoverability; fourth, the possibility of recovering these potential resources is assessed by including technological and economic considerations.

## SIGNIFICANT FINDINGS AND PERSPECTIVES

The 1002 area is potentially rich in oil and gas resources. Seven different "plays," areas with common geological characteristics favorable for oil and gas resource occurrence were identified. From these plays, in-place resources were calculated. According to these estimates, there is a 95-percent chance the 1002 area contains more than 4.8 billion barrels of oil (BBO) and 11.5 trillion cubic feet of gas (TCFG) in-place, and there is a 5-percent chance that the 1002 area contains more than 29.4 BBO and 64.5 TCFG in-place. The average of all the estimates made in this study, called the mean estimate, is 13.8 BBO and 31.3 TCFG in-pace.

Not all in-place resources are recoverable. To estimate the amount of the in-place resource which may be recoverable, 26 prospects were delineated and assessed (fig. III-1). These 26 prospects were subjected to technological and economic conditions to determine the degree to which their resources could be recovered, resulting in estimates of conditional economically recoverable resources. It is estimated, if there is economically recoverable oil present (the chance of which is estimated to be about 20 percent), that there is a 95-

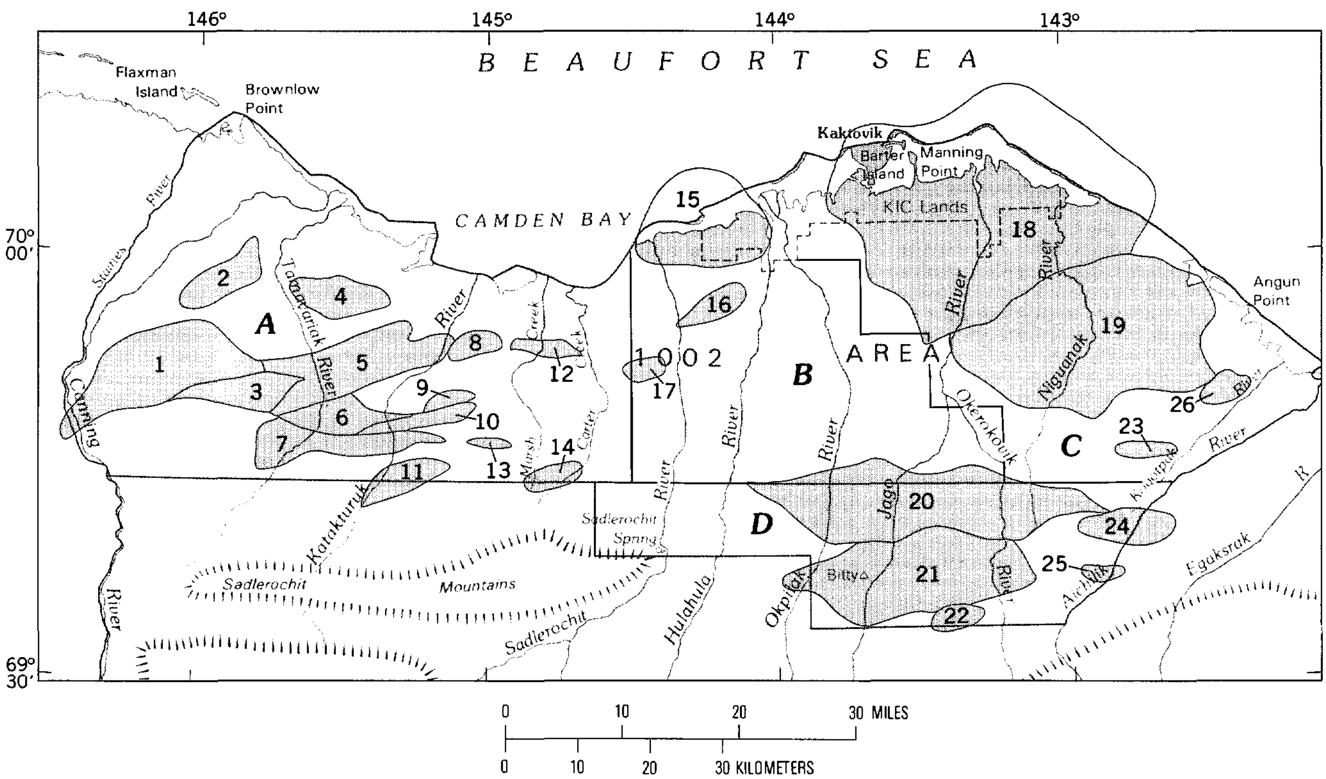



**Figure III-1.**--Seismically mapped prospects (1-26) and resource blocks (A-D) in the 1002 area.

percent chance for more than 0.6 BBO and a 5-percent chance for more than 9.2 BBO recoverable in the 1002 area as a whole. The average of all the estimates of the conditional economically recoverable resources, the mean, is 3.2 BBO.

Gas was not included in the calculation of economically recoverable resources. Gas resources are unlikely to be economic at any point in the time period being considered. Nevetheless, the amount of gas resource estimated to be in-place is considerable, and represents a major addition to the Nation's gas resources. At some time in the future, this gas resource conceivably could become economic and benefit the Nation.

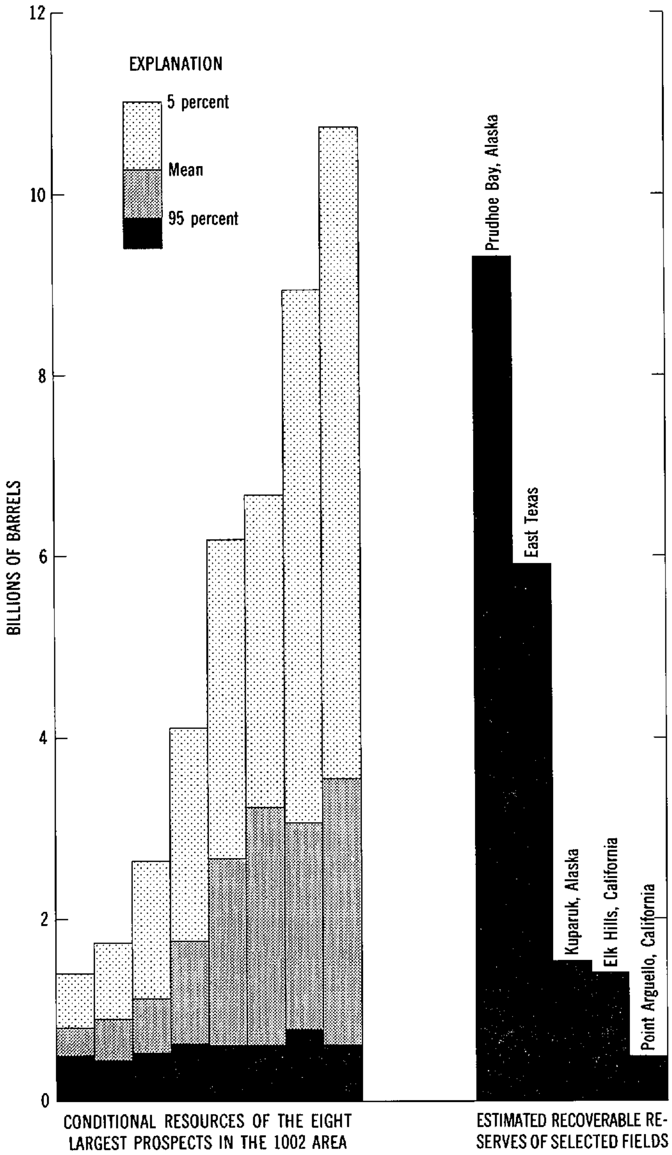



**Figure III-2.**--Conditional oil resources of the eight largest prospects in the 1002 area compared with estimated recoverable reserves of five known producing fields. Modified from McCaslin (1986, p. 318-319). M, mean.

Estimates of specific propects were also undertaken. If recoverable oil resources are present in the prospects, there is a 5-percent chance that the two largest prospects contain economically recoverable resources equivalent to those found at Prudhoe Bay (fig. III-2). There is also a 5-percent chance that the next two largest prospects contain recoverable resources rivaling the East Texas field. In addition, there is a 5-percent chance that the next four largest prospects contain recoverable resources exceeding fields such as Kuparuk, Elk Hills, and Point Arguello. Table III-1 shows the conditional economically recoverable resources estimated for the 1002 area and estimates made for parts of the Outer Continental Shelf. The 1002 area is clearly one of the most outstanding prospective oil and gas areas remaining in the United States.

**Table III-1.**--Estimates of undiscovered, conditional, economically recoverable oil resources in the 1002 area and elsewhere.

[In billions of barrels. Figures do not reflect the risk that economically recoverable oil resources may not exist in the planning area. Date for Outer Continental Shelf resources from U.S. Department of the Interior]

| Planning area | 95-percent case | Mean case | 5-percent case |
|---|---|---|---|
| 1002 area | 0.60 | 3.20 | 9.20 |
| Central Gulf of Mexico | .95 | 2.66 | 4.97 |
| Western Gulf of Mexico | .45 | 1.69 | 3.31 |
| Eastern Gulf of Mexico | .03 | .36 | 1.48 |
| Southern California | .61 | 1.26 | 2.08 |
| Northern California | .15 | .42 | .76 |
| Central California | .18 | .56 | 1.01 |
| Washington-Oregon | .04 | .18 | .54 |
| South Atlantic Ocean | .34 | .82 | 1.46 |
| Mid-Atlantic Ocean | .07 | .24 | .51 |
| North Atlantic Ocean | .10 | .26 | .43 |
| Florida Straits | .01 | .04 | .12 |
| Navarin Basin | 1.81 | 3.28 | 5.09 |
| Beaufort Sea | .11 | .65 | 1.66 |
| St. George Basin | .37 | 1.12 | 1.98 |
| Chukchi Sea | .96 | 2.68 | 4.88 |
| Gulf of Alaska | .12 | .49 | .86 |
| North Aleutian Basin | .08 | .36 | .76 |
| Norton Basin | .05 | .28 | 1.02 |
| Kodiak | .04 | .15 | .26 |
| Hope Basin | .13 | .17 | .40 |
| Shumagin | .05 | .05 | .09 |
| Cook Inlet | .03 | .18 | .40 |

## SUMMARY OF METHODS

Methods used in the estimation of in-place and recoverable oil and gas resources in the 1002 area rely on two related techniques utilizing similar components of the extensive geologic data base. Each assessment depends fundamentally upon recognition of potential petroleum traps (prospects) and description of their geologic and fluid characteristics. Particular care was employed to ensure consistent data treatment, honoring information from the geologic studies.

The separate methods employed meet specific requirements of the 1002 area study. First, the assessment of the natural endowment of hydrocarbon resources is met by an assessment of what is in-place, employing a broad-based view of what may be present, and is without economic constraints. Second, the assessment of resources for the development of the infrastructure, impact, and national need requires a site-specific evaluation of what may be a recoverable resource at a given prospect, taking into consideration questions of economics, technology, and transportation under various assumptions.

Assessment of in-place resources used a "play analysis" method whereby prospects (potential petroleum accumulations) are grouped according to their geologic characteristics into "plays" or natural associations having common characteristics. In the assessment of recoverable resources, a site-specific analysis of larger individual prospects was employed in order to model the elements which determine recoverability and determine exploration, development, production, and transportation at that level.

Generally, the assessment of in-place resources deals with prospects in the aggregate, whereas the recoverable resources assessment deals with separate assessments of the larger (or selected) prospects which are then aggregated. Estimation of in-place resources includes both identified prospects and those estimated to exist on the basis of geologic setting, and includes both structural and stratigraphic traps. However, estimation of recoverable resources was limited to those prospects (all structural) which can be identified and delineated with a reasonable degree of certainty, and which are physically large enough that they could reasonably be expected to contain commercial quantities of oil.

## PETROLEUM GEOLOGY

The 1002 area of the Arctic Refuge lies along the foothills and coastal plain north of the Brooks Range (fig. III-3). Much of this area is covered by soil or vegetation, and the few outcrops that are present are mostly of the younger part of the stratigraphic sequence. Our knowledge of the geology of the area is based on these few outcrops, extrapolating known geology of adjacent areas, and integrating this with the geophysical data (mainly seismic surveys) acquired within the 1002 area. This section reviews the overall geology, emphasizing those aspects that relate to petroleum geology. More detailed and technical discussions of the geology, geophysics, and assessment methods are contained in a GS Bulletin (Griscom, in preparation).

### Sedimentary Rocks

The area in and adjacent to the 1002 area is underlain by sedimentary rocks several tens of thousands of feet thick. These rocks range in age from Precambrian (greater than 570 million years old) to Quaternary (Bader and Bird, 1986). In northern Alaska, rocks prospective for petroleum (oil and gas) are mostly Mississippian to Tertiary in age and overlie folded and truncated pre-Mississippian rocks. These rocks are divided into two sequences: the Ellesmerian sequence of Mississippian to Early Cretaceous age, and the Brookian sequence of Early Cretaceous and younger age. Deposition of the Ellesmerian sequence occurred when the land area was to the north and the seaway was to the south. During deposition of the Brookian sequence, the geography was reversed--the land area was to the south (the ancestral Brooks Range) and the seaway was to the north, much as it is today. The differentiation of these two sequences is important in understanding depositional history, and in projecting trends of reservoir rocks. Furthermore, properties of the Ellesmerian sandstones are generally better than those of the Brookian sequence.

Figure III-4 is a generalized stratigraphic column of the rocks in the area showing oil-bearing formations west of the 1002 area, potential source rocks, and significant geologic events. The following discussion summarizes pertinent information on the sedimentary rocks relating to the oil and gas assessment and reviews their depositional history.

#### PRE-MISSISSIPPIAN ROCKS (BASEMENT COMPLEX)

Pre-Mississippian rocks in the mountains adjacent to the 1002 area consist of more than 20,000 feet of a variety of rock types such as phyllite, argillite, quartzite, chert, and volcanic and carbonate rocks, and are mostly of Pre-cambrian age. Because most of these rocks are weakly metamorphosed and are not prospective for petroleum, they are considered to be economic basement and are not discussed further. However, the carbonate rocks--limestone and dolomite--could have porous zones that may serve as reservoirs for oil or gas that may have generated in overlying younger rocks. These conditions apparently exist in the Exxon Alaska State F-1 and Sohio Alaska Island 1 wells on the barrier islands north of Point Thomson (fig. III-3), where oil and gas have been recovered from carbonate rocks in the basement. Similar situations may occur in the 1002 area, and these rocks are important to the petroleum assessment.

At least 6,500 feet of carbonate rocks, ranging in age from Precambrian(?) to Devonian and known as the Katakturuk Dolomite and Nanook Limestone, crops out in the Sadlerochit and Shublik Mountains. Unnamed carbonate rocks as much as 200 feet thick have been penetrated in a few wells in the Point Thomson area. Their distribution in the subsurface of the 1002 area is unknown, because they had been folded and eroded prior to deposition of Mississippian and younger strata. Seismic reflections beneath these younger strata are not adequate for mapping these older carbonate rocks without closer well control. Hence, their presence as possible reservoirs for petroleum is risked accordingly in the assessment.

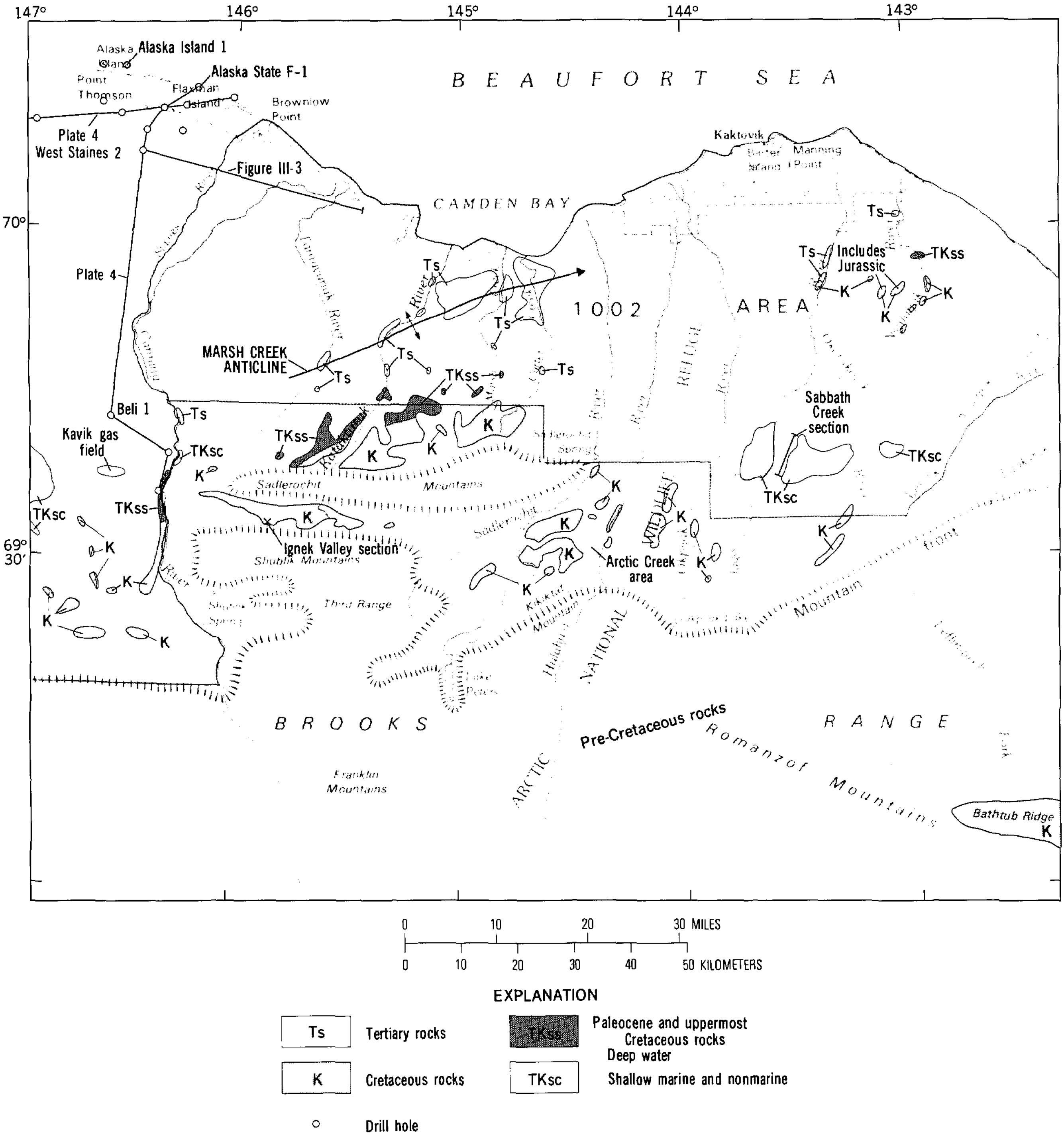



**Figure III-3.**--Map of the 1002 area and adjacent mountains showing locations of Cretaceous and Tertiary outcrops and lines of sections of figure III-8 and plate 4.

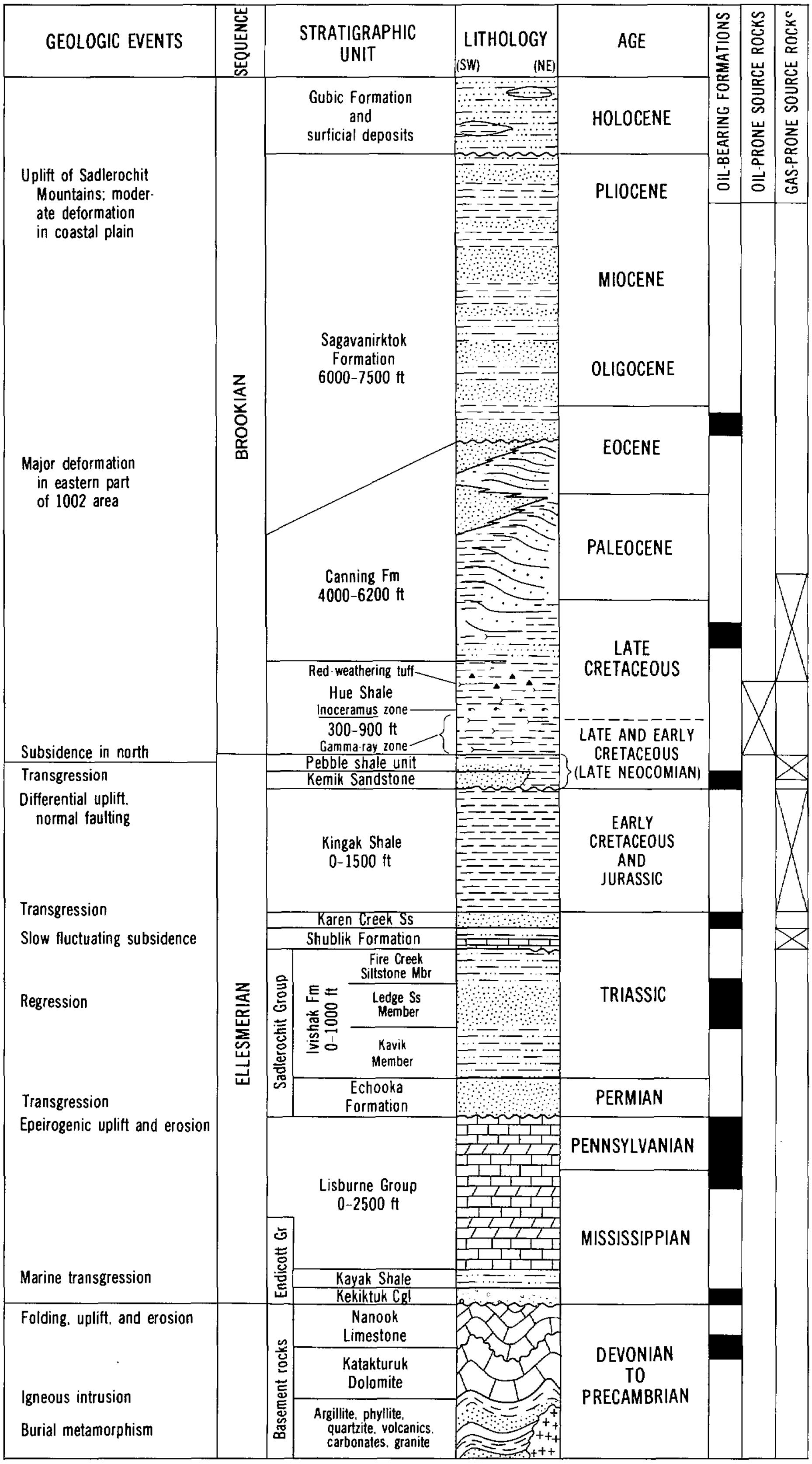



**Figure III-4.**--Generalized stratigraphic column for the northern part of the 1002 area showing significant geologic events, oil-bearing formations west of the Arctic Refuge, and potential source rocks.

ELLESMERIAN SEQUENCE

Rocks of the Ellesmerian sequence record marine and nonmarine deposition along a slowly subsiding continental margin in which the land area was to the north and the seaway to the south. These rocks consist dominantly of limestone, shale, and sandstone that range in age from Mississippian to earliest Cretaceous (fig. III-4), a time span of about 210 million years. All the oil production in the Prudhoe Bay-Kuparuk River field areas is from rocks of the Ellesmerian sequence. By far the greatest production is from the Ledge Sandstone Member of the Ivishak Formation, but almost all the sandstone units of the Ellesmerian sequence and some of the carbonates of the Lisburne Group are potentially productive in some fields (fig. III-4).

In and adjacent to the 1002 area, the Ellesmerian sequence ranges in thickness from a few hundred feet to about 5,000 feet. This wide range is due to a regional unconformity in the upper part of the sequence in which progressively more of the sequence had been removed by erosion in a north or northeastward direction prior to deposition of the uppermost part of the Ellesmerian sequence (fig. III-5; pl. 4). This unconformity is of great importance to the petroleum potential of the 1002 area because it controls the northern distribution of most Ellesmerian rocks. In addition, the porosity of reservoirs directly underlying the truncated surface may be enhanced owing to solution of calcite cement, and the shale overlying the unconformity may provide a seal and source rock for truncated reservoirs. Well control west of the 1002 area and seismic data indicate that most of the Ellesmerian sequence is missing in the northwestern quadrant of the 1002 area (fig. III-6), but seismic data suggest that a significant part of the sequence may be present in the eastern part of the area (pl. 5). The presence or absence of these rocks in that area greatly affects the petroleum potential because very large structures occur in that area; these rocks include the main oil-producing reservoirs in the Prudhoe Bay area. If most of the Ellesmerian rocks are missing in most of the 1002 area, the assessment number would be reduced considerably. Drilling one or two wells in critical areas would resolve this question.

Based on outcrop and well control, maps showing the known trends and thicknesses of three of the main Ellesmerian potential reservoir rocks of the 1002 area are shown in figure III-7.

DEPOSITIONAL HISTORY

Following a period of deformation (folding and faulting), uplift, and erosion of pre-Mississippian rocks, the Ellesmerian sequence was deposited on an erosion surface of slight relief. Initial deposits of sand, gravel, mud, and peat filled in low areas and built up on a coastal plain as the seaway advanced from the south. These deposits became the sandstone, conglomerate, shale, and coal of the rock unit called the Kekiktuk Conglomerate, which is

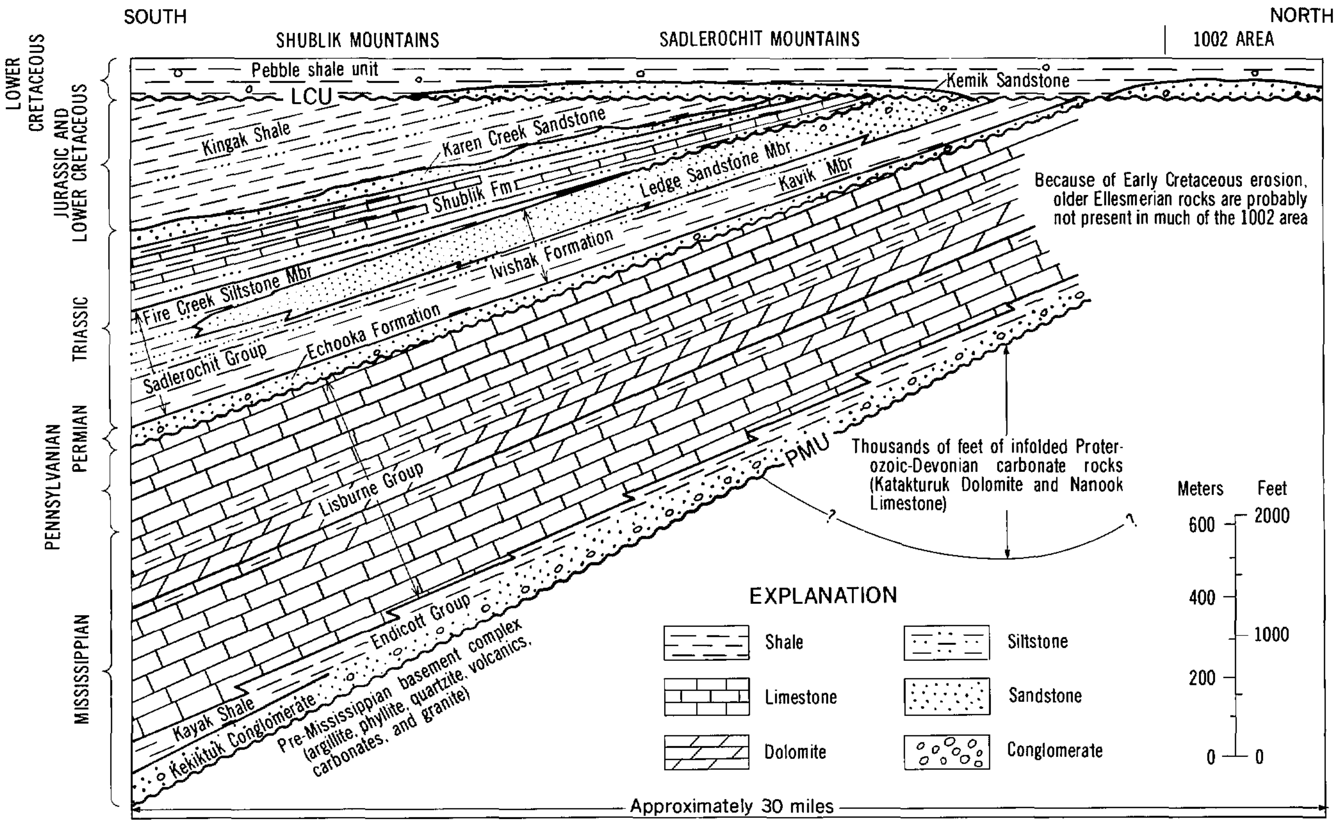



**Figure III-5.**--Diagrammatic section showing stratigraphic relations of the Ellesmerian sequence along the mountain front south of the 1002 area.

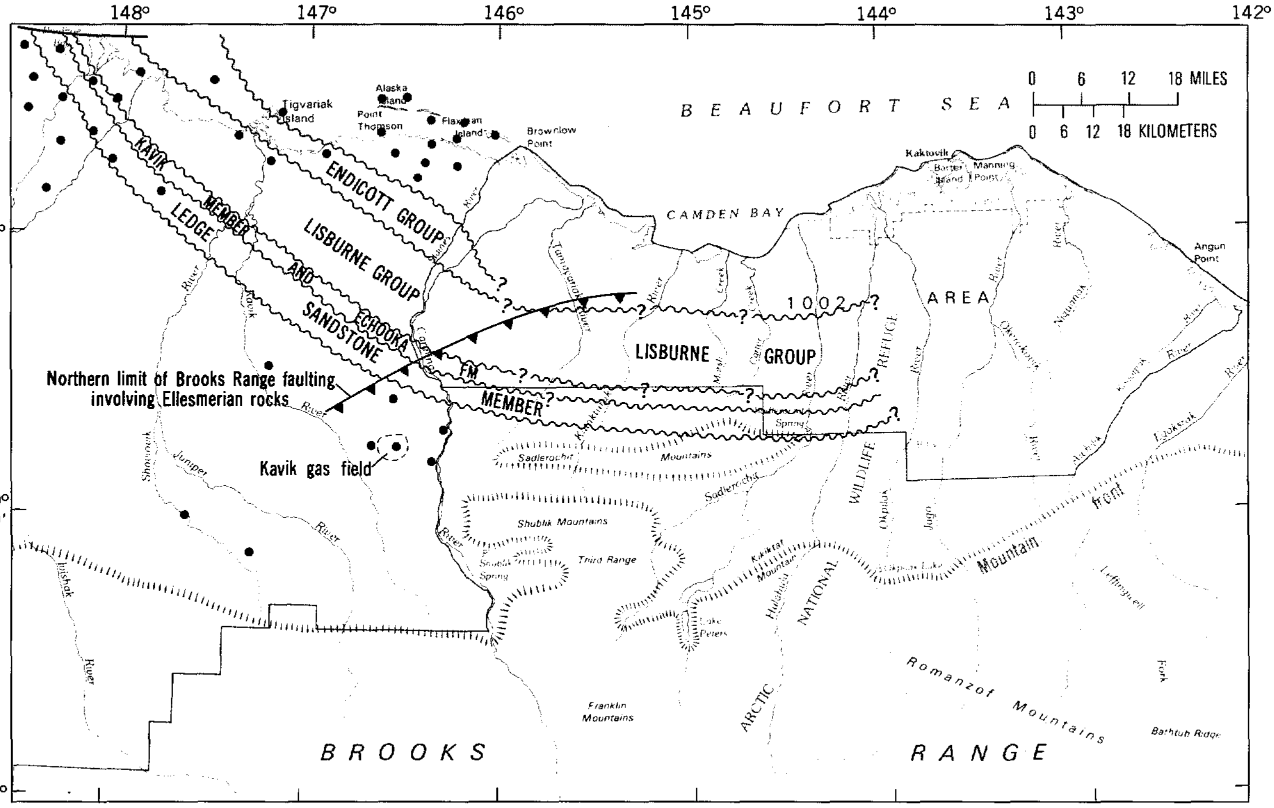


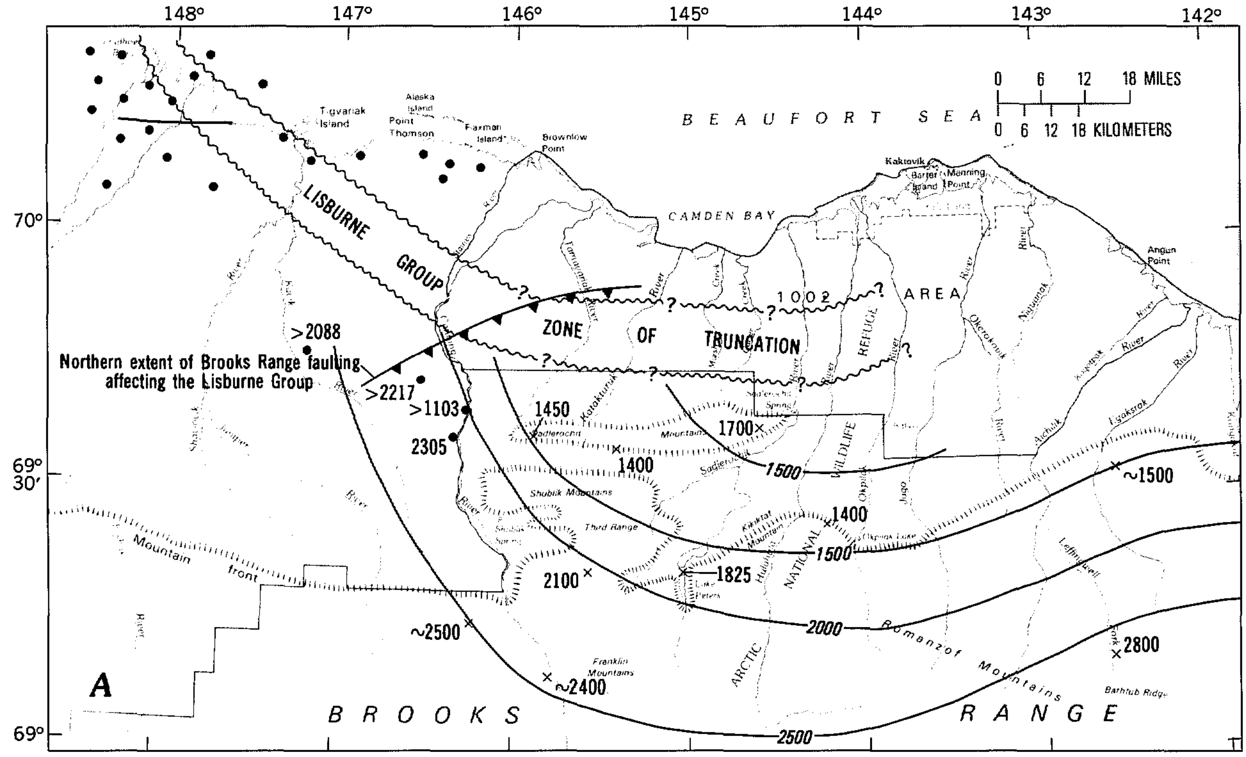

**Figure III-6.**--Map summarizing the northern limits of the Ellesmerian potential reservoir rocks preserved under the Lower Cretaceous unconformity. (Based on regional control.)

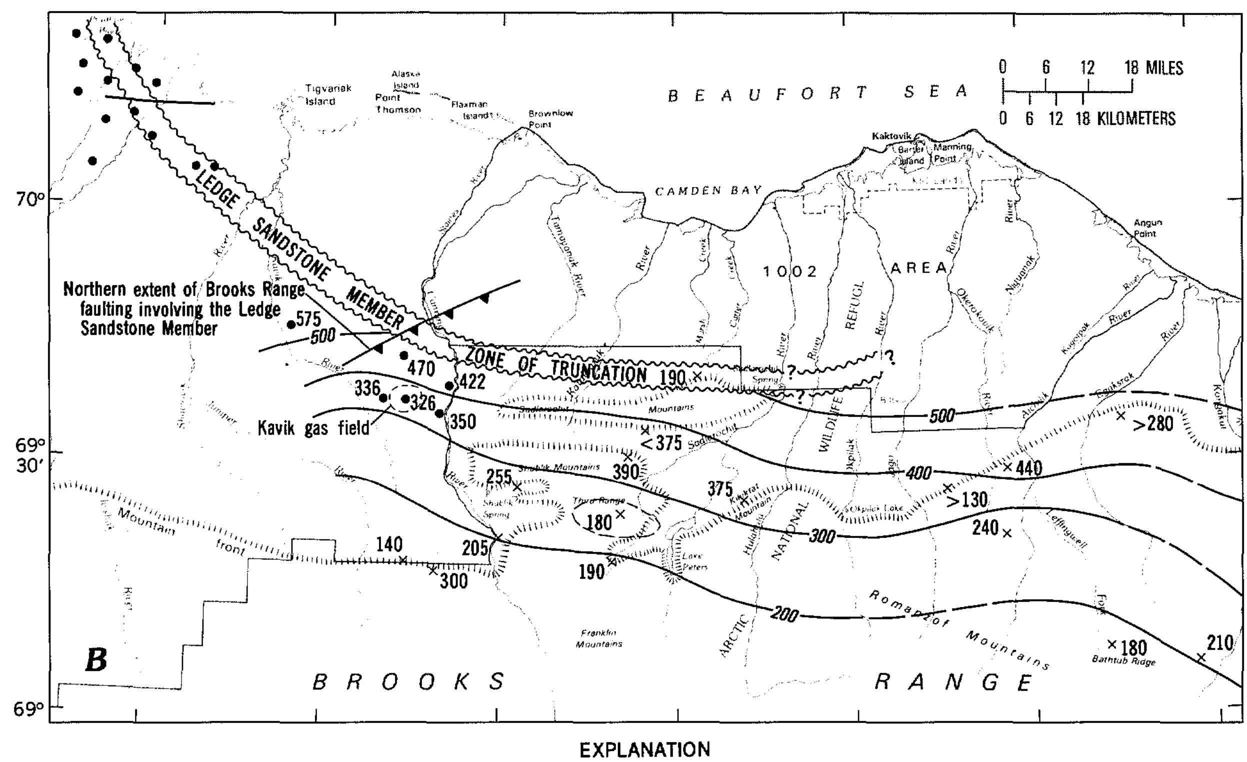
less than 400 feet thick in areas adjacent to the 1002 area. As the sea advanced northward, a few hundred feet of offshore muds accumulated that formed the Kayak Shale. As the sea advanced farther and the land area to the north subsided, less sand and mud washed into the seaway or basin. Lime muds and fragments from lime-secreting organisms then accumulated in substantial thicknesses to form the limestone and dolomite of the Lisburne Group. Then probably in Late Pennsylvanian and Early Permian time, the entire North Slope area was uplifted and subjected to erosion. In areas adjacent to the 1002 area, the remaining Lisburne Group is 1,500 to 2,000 feet thick.

In Late Permian time and continuing into the Early Triassic, the area was once again inundated by the sea while sand, gravel, and mud were washing into the sea from the rising northern landmass. Initially, sands and gravels were deposited along the shoreline of the advancing sea. These formed the Echooka Formation, which is 50 to 400 feet thick adjacent to the 1002 area. Later, as the sea advanced farther, offshore muds were deposited until deltaic and offshore shelf deposits of sands and lesser amounts of gravels filled in or pushed the seaway back again. Then either the northern source area was worn down or the sea advanced northward again and more offshore muds were deposited. All these deposits make up the Ivishak Formation, which is further divided (in ascending order) into the Kavik Member, a shale unit made up of the lower offshore muds; the Ledge Sandstone Member, formed from the deltaic and shelf sands; and the Fire Creek Siltstone Member, formed from the upper offshore muds. The Ledge Member is 200 to more than 400 feet thick and is the main producing reservoir at the Prudhoe Bay field. The Ivishak and Echooka Formations together make up the Sadlerochit Group.

Continued subsidence of the basin followed Sadlerochit deposition and offshore muds and chemical sedimentation predominated in a sea rich in organisms in Middle and Late Triassic time. This formed the black shales, siltstones, and dark phosphatic fossiliferous limestones of the Shublik Formation, which is 150 to 500 feet thick adjacent to the 1002 area. The Shublik is considered to be an important oil-source rock for Prudhoe Bay oil. A minor regression or increase in clastic input from the northern source area resulted in deposition of widespread silt and fine sand on a broad shelf, which formed the 10- to 125-foot-thick Karen Creek Sandstone.

Subsidence of the basin occurred during Jurassic and earliest Cretaceous time and thick deposits of mud accumulated on the shelf, basin slope, and basin bottom. These muds make up the Kingak Shale, which, after subsequent erosion, is 0-1,200 feet thick adjacent to the 1002 area. Parts of the Kingak are thought to contain enough organic matter to be a source rock for some of the Prudhoe Bay oil and gas.





EXPLANATION

Control points—Showing thickness in feet

•350 Well

×140 Outcrop

—400— Isopach—Showing thickness in feet. Dashed where approximately located

**Figure III-7.**--Maps (facing and above) summarizing regional and local geologic trends of the Lisburne Group (A), Ledge Sandstone Member of the Ivishak Formation (B), and Kemik Sandstone and Thomson sand (C).

Uplift of northernmost Alaska and the offshore area to the north in Early Cretaceous time resulted in removal by erosion of progressively more of the Ellesmerian section to the north. This was followed by subsidence of the area and northward inundation by the seaway again. Lenticular sands were deposited along the advancing shoreline and offshore shelf, and mud was deposited farther offshore. These deposits formed the Kemik Sandstone, as much as 100 feet thick, and the pebble shale unit, 200-300 feet thick. Deposition of the Ellesmerian sequence ended as the northern land area subsided and was never again a sediment source.

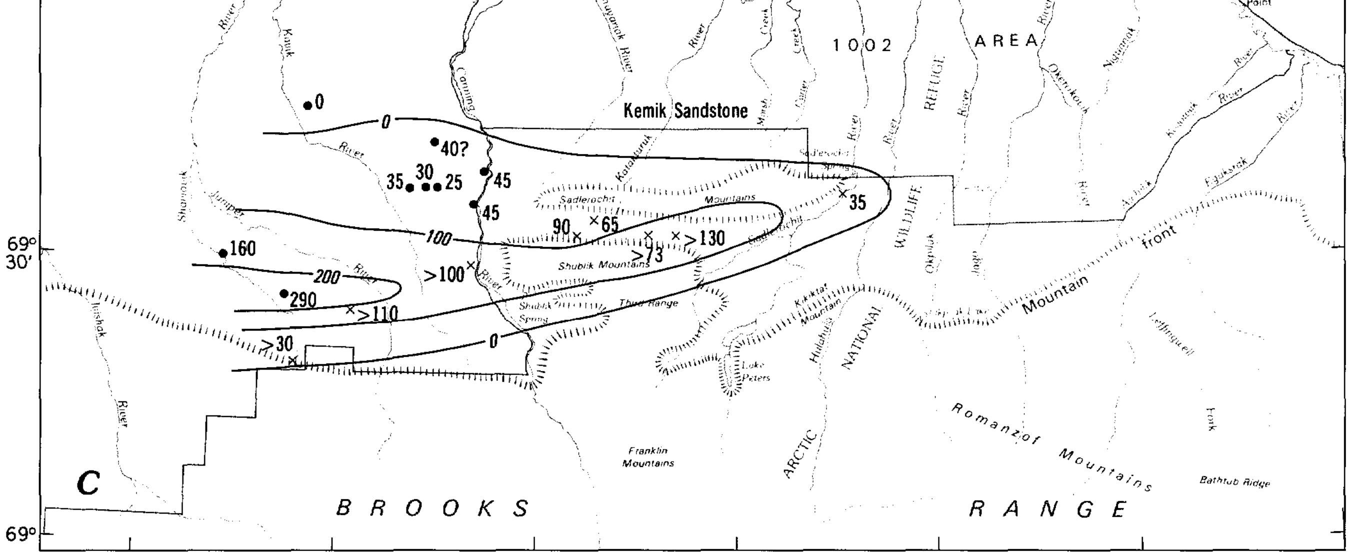
## BROOKIAN SEQUENCE

The Brookian sequence consists of thick northeasterly prograding basinal, basin-slope, and marine and nonmarine shelf deposits derived from the ancestral Brooks Range to the south and southwest. These deposits consist dominantly of shale, sandstone, conglomerate, and bentonite (consolidated volcanic ash) that range in age from late Early Cretaceous to Quaternary (fig. III-4), a time span of about 120 million years. In wells immediately west of the 1002 area, the sequence is as much as 13,000 feet thick (fig. III-8; pl. 4), but seismic data indicate that Brookian rocks may be as thick as 26,000 feet in the central part of the 1002 area. However, this thickening could be due in part to duplication caused by thrust faulting.

Potential reservoirs in the Brookian sequence would be primarily lenticular turbidite (deep-water) sandstone beds in the lower part of the Canning Formation. These beds are generally thin bedded, but locally thicker beds are present. They are potentially productive of oil and gas in several wells in the Point Thomson area west of the northwest corner of the 1002 area (pl. 4). Sandstones and conglomerates of the Sagavanirktok Formation also would be good reservoirs for petroleum. However, because of the dominance of sandstone in the section, effective petroleum seals for traps may be limited. Rich oil-prone source rocks occur in the lower half of the Hue Shale. These rocks are considered to be the main potential source rock for oil in the 1002 area.

### DEPOSITIONAL HISTORY

Mountain building of the ancestral Brooks Range may have started in Jurassic time, and the mountain belt was a dominant sediment source during earliest Cretaceous time. But, as the former land area to the north subsided, initial deposition from the rising mountain belt to the south and southwest was very slow in the 1002 area because a deep trough (the Colville trough of the central North Slope, fig. I-1) developed immediately north of the mountain belt (which then was much farther south than the present mountain front) had to be filled first. Consequently, initial Brookian deposition in the 1002 area consisted of clay and volcanic ash that settled out of suspension, probably in deep water. These deposits formed the Hue Shale, which is 500 to 1,000 feet thick. Because of poor circulation and low oxygen content of the bottom water during deposition of the lower half of the Hue Shale, pelagic organisms that



also settled with the clay were preserved in the sediments to eventually form an organic-rich shale, a good oil source rock.

Deposition became more rapid as delta-front deposits prograded into the area from the southwest. Initially, deep-water mud and sand that slumped or flowed down the basin slope as turbidity currents from the front of shallow-water deltas to the southwest were deposited at the base of the basin slope. Concurrently, thick deposits of mud were accumulating on the northeastward-prograding basin slope. These deposits formed the Canning Formation, which is 4,000-6,000 feet thick in wells adjacent to the 1002 area (fig. III-8; pl. 4). In much of the 1002 area, however, compressional forces folded and faulted the strata during late Paleocene and early Eocene time resulting in uplift and erosion of some earlier deposited Brookian sediments and more deposition in adjacent low areas. Deformation and associated deposition continued during middle and late Tertiary time in the eastern part of the 1002 area but the depositional patterns are poorly understood. In the southeastern part of the 1002 area, a 10,000-foot-thick section of nonmarine sandstone, conglomerate, and shale containing thin beds of coal, which is latest Cretaceous to Paleocene in age and is referred to as the Sabbath Creek unit, probably was displaced northward from a position farther south by thrust faulting.

Meanwhile, in the northwestern quadrant and areas to the west, after the thick deposits of prodelta or slope muds filled in deeper parts of the seaway, sand, mud, gravel, and peat were deposited along and adjacent to a deltaic shoreline as the sea oscillated back and forth across the area. These deposits make up the Sagavanirktok Formation, which is the youngest bedrock unit in the 1002 area and is 5,000-7,000 feet thick in areas to the west (fig. III-8; pl. 4).

## Structure

Seismic and surface data indicate that all but the northwestern quadrant of the 1002 area is complexly folded and faulted. This complexity is vastly different from the relatively simple structure that underlies the coastal plain west of the Arctic Refuge, such as the Prudhoe Bay area. The line of change in structural style from the simpler structure to the west and the complex structure observed in most of the 1002 area cuts across the northwest part of the 1002 area, approximately coinciding with the north flank of the Marsh Creek anticline (fig. III-3). This dividing line is important in separating the various types of prospects for assessment purposes.

Seismic data, which are of good quality in the northwestern quadrant of the 1002 area, show that the strata are little deformed except for a generally northeast gentle dip. One very low-relief structure, which is an oil and gas prospect, is mapped at the top of the pre-Mississippian surface (pl. 5). The remaining part (southeastern part of the 1002 area) is characterized by complexly folded and faulted structures. Lateral compressional forces have folded and faulted strata into what is called a fold-and-fault belt. The thrust faults move older strata over younger strata; in the 1002 area, the direction and amount of transport has been to the north several miles to tens of miles. The thrust faults originate in deeper layers and step upsection northward following structurally incompetent layers such as shales. In the mountains and foothills south of the 1002 area, these detachment surfaces (thrust faults) are in Jurassic and older rock. In the 1002 area, the detachment surfaces are mostly in Cretaceous and younger rocks, although the older rocks are also involved in thrusting. Several large oil and gas fields occur in this type of structural setting in western Wyoming, northern Utah, the foothills of the Canadian Rockies, and in other parts of the world.

The structural patterns produced by this type of deformation are very complex, and because the strata are highly folded and faulted, interpreting the seismic data is difficult. Nevertheless, a seismic reflection from the top of the pre-Mississippian basement (pl. 5), which was mapped over most of the area, shows several very large structural closures. These closures are discussed with the various prospects or plays later.

Seismic reflections, as well as outcrops of Cretaceous and Paleocene strata, indicate that these rocks have been much more deformed than the older strata. The reason is that these younger rocks are structurally weaker and yield more to the compressional forces. Seismic reflections are discontinuous and very difficult, if not impossible, to map for any distance. Hence, a structure map of a shallower horizon was not made except for the northwest quadrant of the 1002 area. Figure III-9 shows the near-surface structural trends in Brookian rocks.

The Eocene and younger strata are only moderately deformed in the northeastern part of the 1002 area. Seismic lines in that area show a discontinuity (an unconformity) between the more complexly folded Cretaceous and Paleocene rocks below and the gently deformed Eocene rocks above (pl. 5). This discontinuity indicates that the major deformation probably occurred in late Paleocene to Eocene time, before deposition of the younger Eocene rocks. Deformation continued, probably episodically, into the late Tertiary. Indeed, on the north flank of the Marsh Creek anticline (fig. III-3), the tilted Eocene strata dip 60° and overlying Pliocene strata dip 15°.

Twenty-six potential hydrocarbon traps have been seismically mapped at or near the top of the pre-Mississippian surface (fig. III-1). Generally, prospects occurring near this horizon have three or more objective reservoirs. Table III-2 summarizes the pertinent data for each prospect.

No prospects were adequately resolved within the detached and highly deformed Mesozoic and Tertiary rocks. However, figure III-10 shows the distribution of structural culminations in these deformed rocks. Structural analogs in

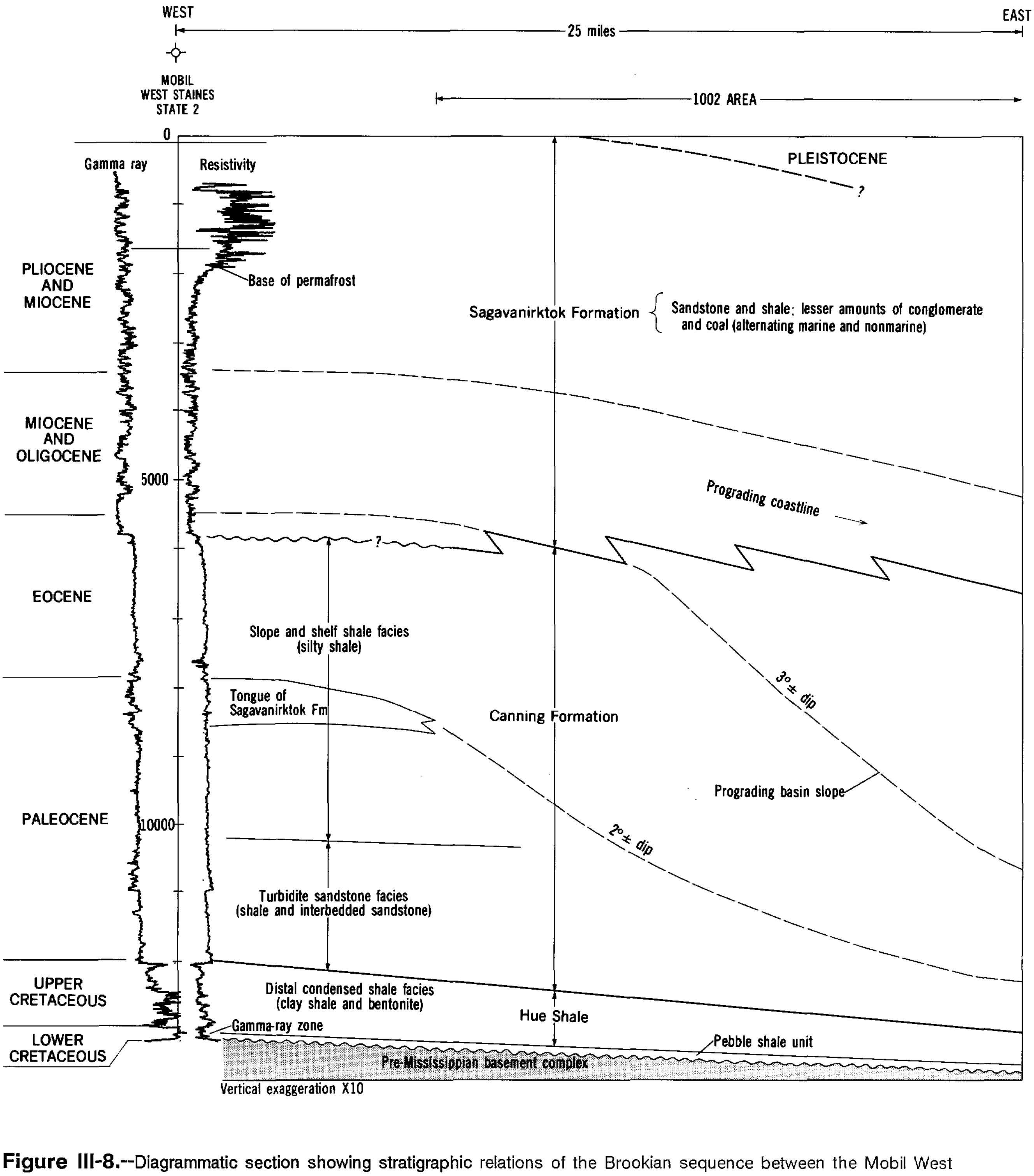



**Figure III-8.**--Diagrammatic section showing stratigraphic relations of the Brookian sequence between the Mobil West Staines State 2 well and the northwest corner of the 1002 area. Dashed lines represent time lines as inferred from seismic reflections. Depths on well logs are in feet. Ages based on micropaleontologic data correlated from wells to the west. See figure III-3 for location of section.

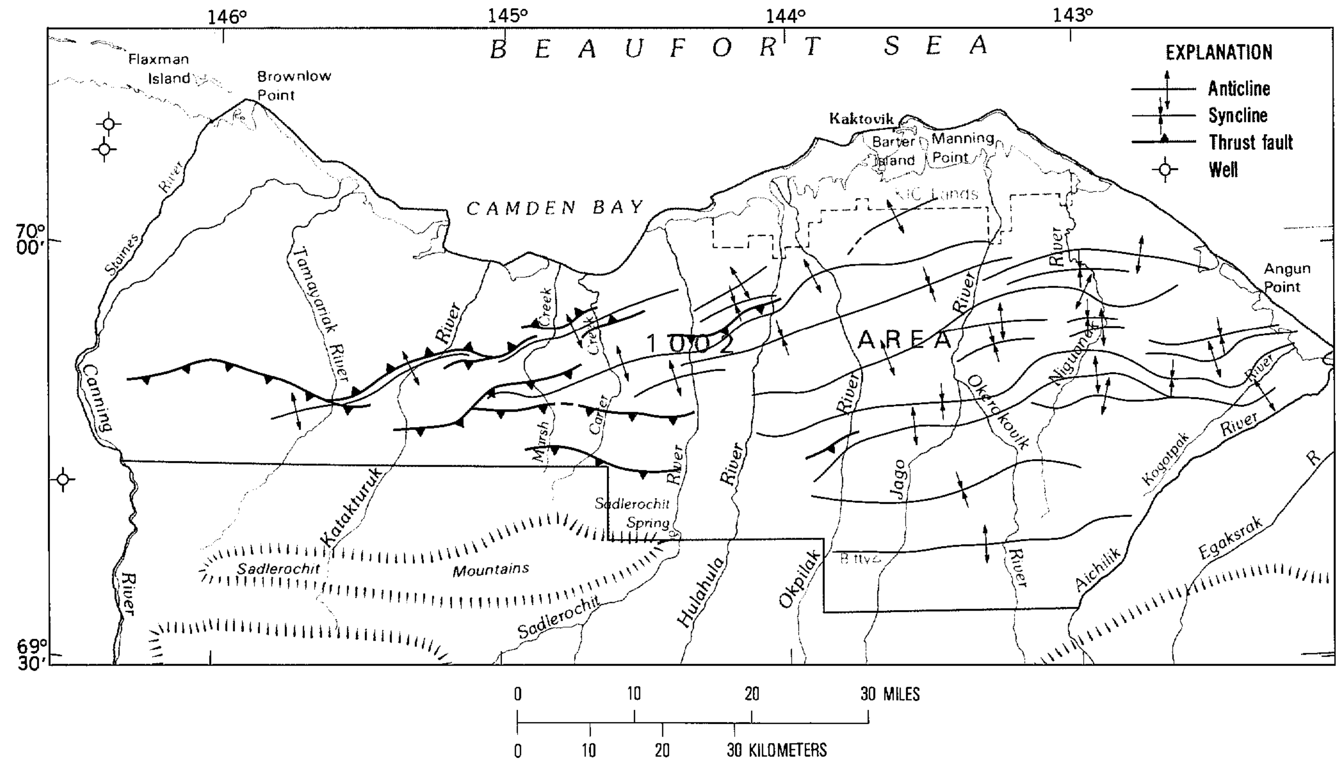



**Figure III-9.**--Generalized near-surface structural trends in Brookian rocks, based on seismic data. Because of structural complexity, not all features are shown, particularly in the east part of the 1002 area.

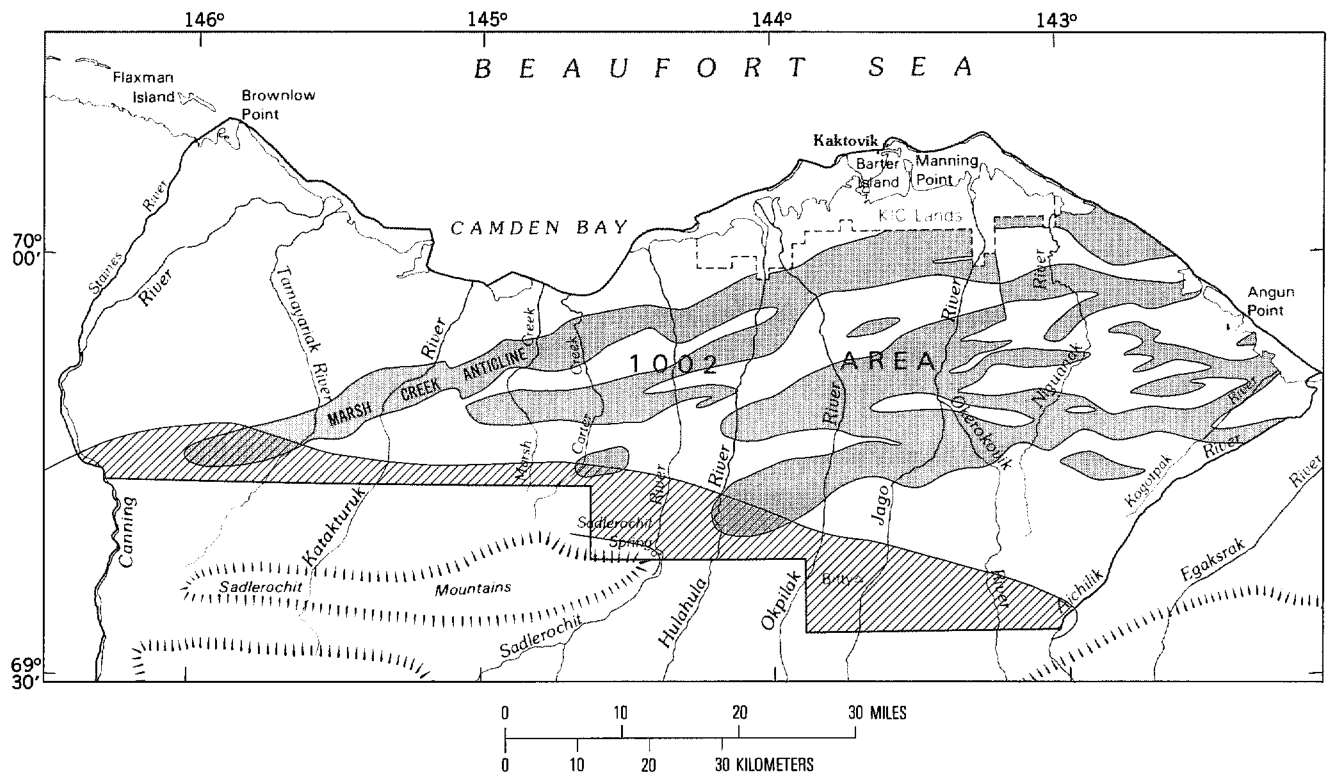



**Figure III-10.**--Trends of structural culminations in highly deformed Mesozoic and Tertiary rocks (shaded) and area of monoclinal north-dipping strata (line pattern) that may have petroleum potential in the 1002 area.

Canada--the Alberta disturbed belt--and in the Montana-Wyoming thrust belt suggest that the probability of traps occurring in the subsurface in this structural setting is high, although determining their location on the basis of existing seismic data is difficult. In addition, a narrow zone of north-dipping strata along the southern margin of the 1002 area (fig. III-10) may be interrupted by faults which could trap petroleum.

## PETROLEUM GEOCHEMISTRY

Petroleum geochemistry deals with (1) identifying and quantifying petroleum source rocks (which rock units contain sufficient organic matter and how much); (2) determining the type of source rock (oil prone versus gas prone); (3) identifying the specific source rock responsible for oil and gas from seeps, outcrops, and wells; (4) determining thermal maturity of the source rock (whether subjected to enough heat to convert organic matter to petroleum); and (5) determining the time of oil and gas

**Table III-2.**--Data on petroleum prospects in the 1002 area.

[Depths are below mean sea level. Potential objectives: 1, pre-Mississippian carbonate rocks; 2a, Ellesmerian clastic rocks; 2b, Ellesmerian carbonate rocks; 3, Thomson/Kemik sandstones; 4, turbidites; 5, lower Neogene(?) topsets]

| Prospect | Area (acres) | Size (miles) | Crestal depth (feet) | Lowest closing contour (feet) | Potential objectives | | | | | | Number of seismic lines |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2a | 2b | 3 | 4 | 5 | |
| 1 | 48,512[1] | 18 X 6 | 14,000 | 15,000 | X | X | X | X | X | -- | 5 |
| 2 | 11,793 | 8 X 3 | 14,820 | 15,000 | X | X | -- | X | X | -- | 2 |
| 3 | 13,120 | 12 X 3 | 13,000 | 14 | X | X | X | X | X | -- | 3 |
| 4 | 12,922 | 8 X 3.5 | 14,900 | 15,500 | X | -- | -- | X | X | -- | 4 |
| 5 | 34,234 | 16 X 4 | 12,700 | 15,000 | X | X | -- | X | X | -- | 6 |
| 6 | 11,940 | 10 X 3 | 11,500 | 13,800 | X | -- | -- | X | X | -- | 3 |
| 7 | 18,970 | 16 X 2 | 8,500 | 10,500 | X | X | X | X | X | -- | 6 |
| 8 | 4,880 | 4 X 2 | 16,300 | 17,000 | X | -- | -- | X | X | -- | 2 |
| 9 | 2,200 | 4 X 1 | 12,500 | 13,200 | X | -- | -- | X | X | -- | 1 |
| 10 | 6,291 | 11 X 1 | 11,900 | 12,500 | X | -- | -- | X | X | -- | 3 |
| 11 | 9,430[1] | 8 X 3 | 5,200 | 6,000 | X | X | X | X | -- | -- | 2 |
| 12 | 3,950 | 6 X 1 | 19,000 | 21,000 | X | -- | -- | X | X | -- | 2 |
| 13 | 1,344 | 4 X 0.8 | 10,900 | 11,500 | X | X | X | X | -- | -- | 1 |
| 14 | 4,915[1] | 5 X 2 | 5,640 | 6,000 | X | X | X | X | -- | -- | 1 |
| 15 | 42,500[1] | 13 X 10 | 22,500 | 23,000 | X | -- | -- | X | X | -- | 6 |
| 16 | 6,720 | 6.3 X 2.4 | 1,230 | 2,300 | -- | -- | -- | -- | X | X | 3 |
| 17 | 3,170 | 3 X 2 | 21,600 | 22,000 | X | -- | -- | X | X | -- | 1 |
| 18 | 226,822[1] | 27 X 15 | 13,500 | >24,000 | X | -- | -- | X | X | -- | 16 |
| 19 | 129,587 | 22 X 13 | 9,790 | 17,000 | X | X | X | X | X | -- | 10 |
| 20 | 79,738 | 30 X 7 | 11,900 | 17,500 | X | X | X | -- | -- | -- | 10 |
| 21 | 65,300[1] | 21 X 4 | 7,500 | 14,500 | X | X | X | -- | -- | -- | 7 |
| 22 | 4,560[1] | 5 X 2 | 11,600 | 12,000 | X | X | X | -- | -- | -- | 1 |
| 23 | 3,706 | 5 X 1.5 | 16,300 | 16,500 | X | X | X | -- | -- | -- | 1 |
| 24 | 11,872[1] | 8 X 3 | 10,400 | 12,000 | X | X | X | -- | -- | -- | 4 |
| 25 | 2,360[1] | 4 X 1 | 11,950 | 12,000 | X | X | X | -- | -- | -- | 1 |
| 26 | 4,954 | 5 X 3 | 16,500 | 17,000 | X | X | X | X | X | -- | 2 |

[1]Prospect area includes extensions or projections outside the 1002 area as shown in figure III-1.

generation and the direction in which it migrated. In the 1002 area (where there is no well control), most of these data come from surface samples and seismic shot-hole samples or must be projected from wells or outcrops in adjacent areas. Because of the different and complex structural history of most of the 1002 area compared with that of adjacent areas to the west, some of the projections are tenuous.

Analyses of different rock units throughout northeastern Alaska indicate that the Shublik Formation, Kingak Shale, pebble shale unit, Hue Shale, and shales in the Canning Formation may be potential oil or gas source rocks (fig. III-4). The first three units are considered to be the source for the oil in the Prudhoe Bay field. In or adjacent to the 1002 area, however, analytical data on a limited number of samples of some units indicate that all the above units except the Hue Shale are gas-prone source rock of fair to good quality and that the Hue Shale is a good to excellent oil-prone source rock. In addition, the distribution of the Shublik and Kingak is not known, and because of pre-pebble shale erosion, these rocks may not be present in much of the 1002 area.

Analyses of the oils collected from seeps and stained outcrops in or adjacent to the 1002 area, and of the different potential source rocks, suggest that the Hue Shale is the most likely source rock in the 1002 area. None of the sampled oils are similar to Prudhoe Bay oil.

Maturation studies indicate that in the outcrop belt south of the 1002 area, all potential source rocks are mature to overmature, the latter having been overheated by deep burial and so petroleum had already been generated and expelled. In wells in the Point Thomson area, where the rocks are now at or near their maximum burial depths, the Hue Shale and pebble shale unit are at the beginning of hydrocarbon generation. According to maturation data and downward-extrapolated temperature gradients from these wells, the maturity thresholds of oil, condensate, and thermal gas are about 12,000, 22,500, and 28,000 feet, respectively. These threshold values can be extrapolated into the northwestern quadrant of the 1002 area with a fair degree of confidence, but in the structurally complex area to the east, there are complications. Where the Hue Shale is at or near the surface, it is immature, but seismic data indicate that it could be as deep as 25,000 feet in nearby areas. Thus, depending on its structural position, the Hue Shale ranges from immature to mature or overmature.

In the deformed eastern part of the 1002 area, data are insufficient to determine the time of oil generation with respect to the formation of petroleum traps. It seems likely, however, the generation occurred before, during, and after formation of the traps because the Hue Shale, the main source rock, occurs in such a wide range of burial depths and maturation stages. The time range of oil generation was probably long enough for reservoirs in early-formed as well as late-formed traps to be charged by migrating petroleum.

## ASSESSMENT OF THE OIL AND GAS POTENTIAL

### In-Place Oil and Gas Resources

The method employed for estimating in-place oil and gas resources for the 1002 area is a modified version of the play analysis technique developed by the Geological Survey of Canada to assess Canada's oil and gas resources (Canada Department of Energy, Mines and Resources, 1977) and used in earlier assessments of the NPRA and the 1002 area (U.S. Department of the Interior Office of Minerals Policy and Research Analysis, 1979; Mast and others, 1980; Miller, 1981; Bird, 1984). But the present assessment uses a more efficient computer program (FASP), utilizing probability theory rather than Monte Carlo simulation (Crovelli, 1985, 1986).

In this method, geologic settings of oil and gas occurrence are modeled, risks are assigned to geologic attributes of the model necessary for generation and accumulation of petroleum, and ranges of values are assessed for the geologic characteristics of traps and reservoirs which control petroleum volumes within the modeled accumulations of each play. The volumes of petroleum in the hypothetical traps are determined using reservoir engineering formulas, and summed for the play as a whole. Consequently, a play can be viewed as an aggregate of prospects, which are conceived as having similar geologic characteristics and sharing common geologic elements. They are defined by a known or suspected trapping condition, which may be structural, stratigraphic, or combination in character.

In this appraisal method, geologists make judgments about the geologic factors necessary for formation of an oil or gas deposit and quantitatively assess those geologic properties which determine its size. The computer program (FASP) then does the resource calculation based on that information. This arrangement utilizes the geologist's expertise with geologic factors and the computer's facility in manipulation of numbers. The method provides for a systematic analysis and integration of the geologic factors essential for the occurrence of oil and gas, a thorough documentation of the analysis, and an assessment which provides information on the size, distribution, and number of petroleum accumulations as well as their sum.

In this assessment, seven plays were identified, encompassing Precambrian to Cenozoic rocks (fig. III-11), and for each play, in-place oil and gas resources were estimated. Estimates for each of the seven plays were aggregated using probability theory to produce estimates for the Arctic Refuge 1002 area.

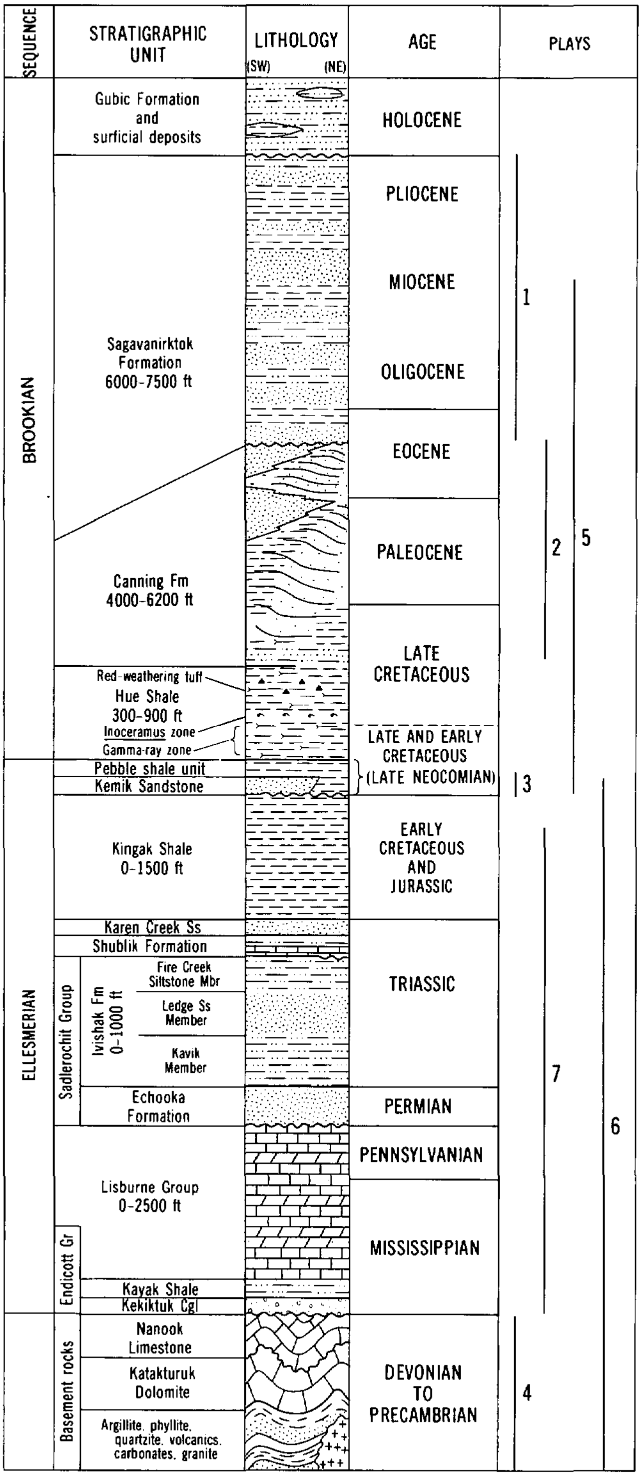



**Figure III-11.**--Generalized stratigraphic column for the northern part of the 1002 area showing intervals of assessed plays.

DESCRIPTION OF PLAYS

Brief descriptions of the seven plays follow, including maps and cross sections to show the play limits and geologic relations (fig. III-12). Some plays are similar or equivalent to oil and gas plays with known petroleum in adjoining areas. The plays are presented in the order that they were assessed rather than according to their estimated oil and gas potential.

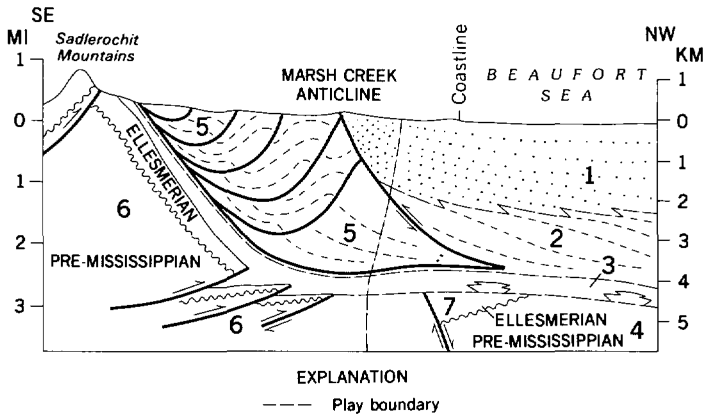



**Figure III-12.**--Schematic section showing the seven assessed plays in the 1002 area: 1, Topset; 2, Turbidite; 3, Thomson-Kemik; 4, Undeformed Pre-Mississippian; 5, Imbricate Fold Belt; 6, Folded Ellesmerian/Pre-Mississippian; and 7, Undeformed Ellesmerian.

TOPSET PLAY

The Topset play consists of stratigraphic traps in sandstone reservoirs of Tertiary age and includes those rocks represented on the seismic records in the topset position in a topset-foreset-bottomset sequence. This play is limited to the northwestern part of the 1002 area and is generally unaffected by Brooks Range folding and faulting (fig. III-13). The southeastern boundary is selected as the line marking the north flank of the Marsh Creek anticline. These rocks, on the basis of well penetrations immediately west of the 1002 area, are assigned to the Sagavanirktok Formation and consist of marine and nonmarine deltaic sandstone, siltstone, shale, conglomerate, and minor amounts of coal. A maximum thickness of 10,000 feet, estimated from the seismic records, occurs in the eastern part of the play; the sequence thins westward to about 7,000 feet in wells just west of the Arctic Refuge. Drilling depths range from 100 to 10,000 feet.

The reservoir rocks are composed of sandstone and conglomerate which may constitute as much as half the total thickness of the play interval, even though individual reservoir beds seldom exceed 50 feet. Fair to good reservoir continuity in sand bodies is expected parallel to depositional strike (northwestward), but marked changes may occur over short distances perpendicular to strike. Porosity of reservoir rocks is expected to be excellent, averaging 10-32 percent, and permeability is in the hundreds of millidarcies.

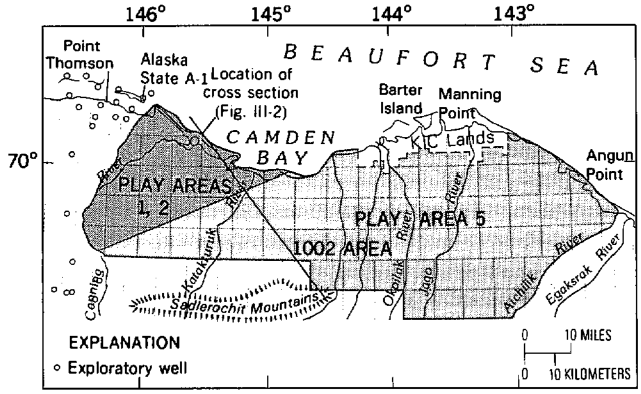



**Figure III-13.**--Locations of the Topset (1), Turbidite (2), and Imbricate Fold Belt (5) plays in the 1002 area.

Potential source rocks immediately associated with the reservoirs are deltaic shales and mudstones which are immature and probably biogenic gas prone. The underlying marine shales are both oil prone (Hue Shale) and gas prone (Canning Formation and pebble shale unit), and are mature below about 12,000 feet in the play area. As a consequence, oil accumulations in this play are likely to be the result of vertical migration along faults or inclined foreset beds in the underlying Canning Formation. Oil shows are reported in several wells in the Point Thomson area from the lower part of the rock sequence included in this play. The multi-billion-barrel heavy oil and tar accumulations just west of the Prudhoe Bay field (West Sak and Ugnu) and the small oil accumulations in northeastern NPRA (Simpson and Fish Creek) are considered to be analogs for potential accumulations in this play.

Postulated traps in this play are mostly stratigraphic, related to facies changes, or combination structural and stratigraphic traps formed against small-displacement normal faults. Faults, interbedded shales, facies changes, permafrost, and asphaltic petroleum are expected to provide only fair to poor seals. Poor seals--that is, barriers to petroleum migration--may have allowed preferential escape of gas, leaving mostly oil accumulations in this play.

TURBIDITE PLAY

The Turbidite play consists of stratigraphic traps in deep-marine sandstone reservoirs of Late Cretaceous and Tertiary age which occur in the foreset and bottomset units of the Canning Formation as shown by seismic reflectors. The play is limited to the northwestern part of the 1002 area that is generally unaffected by Brooks Range folding and faulting (fig. III-13). The southeastern play boundary is a line marking the boundary between folded and faulted rocks of the Marsh Creek anticline and the adjacent undeformed rocks. On the basis of well penetrations adjacent to the 1002 area, these rocks consist of relatively deep-marine shale, siltstone, and turbidite sandstone. A maximum thickness for rocks in this play is about 5,000 feet. Drilling depths range from 4,000 to 22,000 feet.

Reservoir rocks, which are turbidite sandstones, may occur anywhere within the play interval, but in wells adjacent to the 1002 area they occur mostly in the lower third as toe-of-slope or basin-plain turbidites. Sandstone bodies are expected to be laterally discontinuous and to have an aggregate thickness of several hundred feet, although individual beds are expected to be less than 50 feet thick. Abnormally high fluid pressures are expected in the lower part of the play interval as in wells west of the Arctic Refuge, and so porosities should be better than normally encountered for turbidite sandstones at these depths.

Potential source rocks include deep-marine shale adjacent to the reservoirs (the Canning Formation) and below the reservoirs (the Hue Shale and pebble shale unit). These shales are gas prone (Canning Formation and pebble shale unit) and oil prone (Hue Shale) and are mature below about 12,000 feet. Oil and gas have been recovered from turbidite reservoirs in several wells adjacent to the Arctic Refuge. The oil, generally 21° to 27°API gravity, but as high as 44° in one occurrence, has been recovered on drillstem tests at rates of as much as 2,500 barrels per day. Gas flows of 2.25 million cubic feet per day were also measured in the Alaska State A-1 well adjacent to the northwest corner of the 1002 area.

Postulated traps in this play are mostly stratigraphic and are related to facies changes or traps formed against small-displacement normal faults; three broad, low-amplitude structures have been identified seismically. Faults and the surrounding thick marine shales are expected to provide fair to good seals.

THOMSON-KEMIK PLAY

The Thomson-Kemik play consists of stratigraphic traps in sandstone reservoirs of Early Cretaceous (Neocomian) age in the Kemik Sandstone or the equivalent Thomson sand. This play is limited to the northwestern part of the 1002 area that is generally unaffected by Brooks Range folding and faulting (fig. III-14). The southeastern play boundary is a line marking the boundary between folded and faulted rocks of the Marsh Creek anticline and the adjacent undeformed rocks. Sandstone in this play overlies the Lower Cretaceous regional unconformity, was deposited under shallow marine to possibly nonmarine conditions, and is expected to be discontinuous. Drilling depths range from 12,000 to 25,000 feet.

The reservoir rock may range from a fine-grained, well-sorted quartzose sandstone (Kemik) to a detrital dolomite and quartz conglomeratic sandstone (Thomson). Thicknesses of as much as 345 feet have been penetrated by wells, but the distribution of sandstone is unpredictable and appears to be seismically undetectable. Average porosity is expected to be about 12 percent. Abnormally high fluid pressures are expected in this play as in wells west of the Arctic Refuge in these same units. Owing to abnormal pressures, porosities are expected to be better than normal for similar sandstone at these depths.

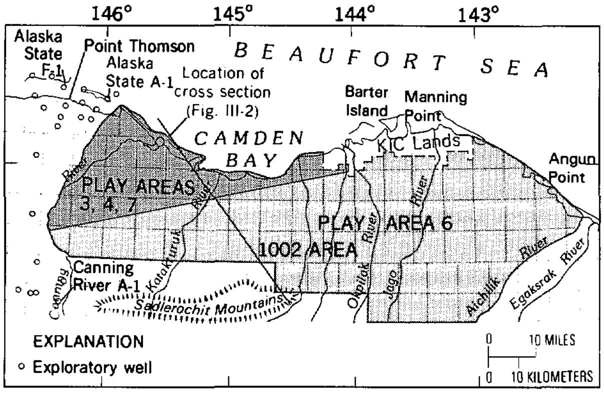



**Figure III-14.**--Locations of the Thomson-Kemik (3), Undeformed Pre-Mississippian (4), Folded Ellesmerian/Pre-Mississippian (6), and Undeformed Ellesmerian (7) plays in the 1002 area.

Potential source rocks include the overlying Canning Formation, Hue Shale, and pebble shale unit and, possibly, the Kingak Shale and Shublik Formation where these formations are present beneath the regional unconformity. Geochemical data indicate that the Hue Shale is oil prone and the other units are gas prone and, in the play area, may be marginally mature to mature. Both oil and gas are present in the Thomson sand in the Point Thomson field, which is reported by the Exxon Corporation to contain reserves of 5 trillion cubic feet of gas and 375 million barrels of condensate. Flow rates are reported to be as much as 13 million cubic feet of gas and 2,283 barrels of oil per day. Oil gravity generally ranges from 35° to 45° API, but some oil as low as 18° API has been reported.

Postulated traps in this play are mostly stratigraphic and are related to facies changes or traps formed against small-displacement normal faults; three broad, low-amplitude structures have also been identified seismically. Faults and the overlying thick marine shales are expected to provide fair to good seals.

UNDEFORMED PRE-MISSISSIPPIAN PLAY

The Undeformed Pre-Mississippian play consists of stratigraphic traps in carbonate or sandstone reservoirs in the pre-Mississippian basement complex. In this play, it is critical that the reservoir rocks be charged and sealed by source rocks in the overlying Ellesmerian or Brookian sequences. Pre-Mississippian rocks were metamorphosed, folded, faulted, uplifted, and eroded prior to deposition of younger rocks. The occurrence of reservoir rocks in the basement complex is unpredictable. This play is limited to the northwestern part of the 1002 area that is unaffected by Brooks Range folding and faulting (fig. III-14). The southeastern play boundary is a line marking the boundary between folded and faulted rocks just north of the Marsh Creek anticline and the adjacent undeformed basement rocks. Drilling depths are expected to be 12,000-25,000 feet.

Potential reservoir rocks may be dolomite, limestone, and sandstone. Dolomites may be vuggy as observed in the Katakturuk Dolomite in outcrops. Sandstone may also be present. Under favorable conditions, leaching of calcareous cements may have improved the reservoir character. Although carbonate rocks may locally have porosity of as much as 25 percent, the average porosity is expected to be less than 10 percent. Fractures are expected in these rocks and should enhance the observed low matrix permeabilities. Flow rates from basement rocks in the Alaska State F-1 well were about 3 million cubic feet per day and 150 barrels of 35°API gravity oil per day. Salt water was recovered from the Alaska State A-1 well at a rate of 6,800 barrels per day and fresh water was recovered from the Katakturuk Dolomite in the Canning River A-1 well at a rate of 4,800 barrels per day. Abnormally high formation pressures are present in the basement rocks in some Point Thomson wells.

Source rocks within the pre-Mississippian basement are unlikely because of the regional metamorphic character of these rocks. Hence, juxtaposition of younger (Cretaceous or Tertiary) source rocks with basement reservoir rocks is critical for petroleum accumulations in this play. The Hue Shale is expected to be a mature oil-prone source rock, and the Canning Formation and pebble shale unit, gas-prone source rocks. Possible asphaltic petroleum is described from the Katakturuk Dolomite in the Canning River A-1 well, and oil and gas have been recovered from Point Thomson wells.

Postulated traps in this play are stratigraphic and are located in areas where truncation placed Cretaceous or Tertiary source rocks in contact with reservoirs in the basement.

IMBRICATE FOLD BELT PLAY

The Imbricate Fold Belt play consists chiefly of structural traps in sandstone reservoirs of Cretaceous and Tertiary age. Structural traps are the result of Brooks Range folding and faulting. This play encompasses that part of the area southeast of a line marking the limit of deformation of rocks along the north flank of the Marsh Creek anticline (fig. III-13). Rocks included in this play are bounded below by a major structural detachment zone, which in the area of the Sadlerochit Mountains lies within the Kingak Shale, and in the subsurface to the north is believed to cut stratigraphically up-section and eventually to die out within rocks of the Marsh Creek anticline.

Sandstone reservoirs in this play may include the Kemik Sandstone, Canning Formation turbidites, and Sagavanirktok Formation deltaic deposits. Drilling depths in this play range from 100 to about 26,000 feet. The turbidite reservoirs are expected to be most prospective in this play. Distribution of the Kemik is expected to be unpredictable as in the Thomson-Kemik play. Deltaic sandstones are generally expected to have the same excellent reservoir but poor sealing characteristics as described in the Topset play; also included are the very poor reservoir sandstones and conglomerates that crop out along Igilatvik (Sabbath) Creek east of the Jago River in the southeastern part of the area. The distribution of this thick section of rocks (Sabbath Creek unit) beyond the area of surface exposure is unknown.

Potential source rocks include the Kingak Shale, pebble shale unit, Hue Shale, and Canning Formation. These shales may be present within this play or below the detachment zone in the subjacent Folded Ellesmerian/Pre-Mississippian play. The Canning Formation is expected to be a poor, submature source rock, whereas Cretaceous and Jurassic shales are expected to be fair to good source rocks in the submature to mature range. Oil seeps at Manning Point and Angun Point are thought to be from rocks assigned to this play. In addition, oil-stained sandstone is known from many surface exposures of these rocks.

Traps in this play are mainly structural and area expected to consist of relatively small but numerous fault-cored anticlines. Stratigraphic traps, such as updip pinchouts on the flanks of anticlines, may also be present. Shales within the play are expected to provide fair to good seals for these traps, although faulting and related fracturing may reduce their effectiveness.

## FOLDED ELLESMERIAN/PRE-MISSISSIPPIAN PLAY

The Folded Ellesmerian/Pre-Mississippian play consists mostly of structural traps in sandstone or carbonate reservoirs of earliest Cretaceous to pre-Mississippian age. The structures are the result of Brooks Range folding and faulting. This play underlies nearly the same area as the Imbricate Fold Belt play. The play area lies southeast of a line marking the approximate northern limit of deep basement faulting which lies just north of the surface trace of the Marsh Creek anticline (fig. III-14). Rocks in this play lie beneath the major structural detachment zone which marks the base of the overlying Imbricate Fold Belt play, and reservoirs consist mainly of Ellesmerian and pre-Ellesmerian rocks. Depending on the stratigraphic level of the main structural detachment zone, some Brookian rocks may also be included.

Reservoir rocks in this play consist of both carbonate and sandstone. Potential carbonate reservoirs include the Katakturuk Dolomite, Nanook Limestone, other unnamed pre-Mississippian carbonates, the Lisburne Group, and Shublik Formation. Potential sandstone reservoirs include pre-Mississippian sandstone, Kekiktuk Conglomerate, Echooka Formation, Ivishak Formation, Karen Creek Sandstone, Kemik Sandstone, and possibly turbidite sandstones in the basal part of the Brookian sequence. The most important sandstone reservoir is expected to be the Ivishak Formation (Ledge Sandstone Member) and the most important carbonate reservoirs, the Lisburne Group and Katakturuk Dolomite. The areal distribution of reservoirs in this play is uncertain. The uncertainty is caused by the Lower Cretaceous regional unconformity in which erosion has removed an undetermined amount of underlying strata. The Ivishak Formation and Lisburne Group can be projected eastward from the Sadlerochit Mountains into the subsurface of the southernmost part of the 1002 area with a relatively high degree of confidence. North of this area, the character of seismic reflections offers the possibility of their presence. However, their northern extent depends on several factors, such as the rate of truncation on the unconformity, the amount of northward transport by thrust faulting, and the possible existence of downdropped fault blocks north of the truncation edge, about which we have little direct information. Drilling depths range from 2,000 to 25,000 feet.

Potential source rocks include marine shales in the Kayak Shale, Ivishak Formation, Shublik Formation, Kingak Shale, pebble shale unit, and possibly the Hue Shale. The Hue Shale is expected to be the best oil-prone source rock where it occurs at depths shallower than the thermal gas threshold (about 22,000 feet). The other shales are all apparently gas-prone source rocks. They are generally mature to possibly overmature. As with reservoir rock described above, truncation is expected to reduce the areal extent of all pre-pebble shale unit source rocks by an unknown amount.

Traps in this play are mostly structural and are expected to consist of a relatively few large, broad anticlines and fault traps. A significant number of structures smaller than the present 3- by 6-mile seismic grid is also expected to be present. Stratigraphic traps related to truncation by the Early Cretaceous unconformity are also possible. The pebble shale unit and younger shales are expected to provide good to excellent seals.

Within this play area, two extremely large structures were seismically identified (prospects 18 and 19 shown on figure III-1 and table III-1). These two structures were each assessed independently from the other structures composing this play, and special consideration was given to their position relative to the Ellesmerian truncation edge and the relationship of trap fill to petroleum column height.

## UNDEFORMED ELLESMERIAN PLAY

The Undeformed Ellesmerian play consists of stratigraphic traps in carbonate or sandstone reservoirs in the Ellesmerian sequence. The play is limited to the northwestern part of the area that is unaffected by Brooks Range folding and faulting (fig. III-14). The southeastern play boundary is a line marking the boundary between folded and faulted rocks and adjacent undeformed Ellesmerian rocks. This boundary coincides with the northwest boundary of the Folded Ellesmerian/Pre-Mississippian play. A wedge of Ellesmerian rocks is seismically mapped beneath the Lower Cretaceous unconformity only in the southwesternmost corner of the play area. Elsewhere in the play area, there may be one or more fault-bounded, downdropped blocks which preserve

Ellesmerian rocks. Such fault-bounded blocks are well known in the Prudhoe Bay area but have not been identified thus far on the seismic data in the 1002 area. Drill depths to Ellesmerian rocks are 12,000-25,000 feet.

Potential reservoirs consist of both sandstone and carbonate rocks. The most important reservoirs are expected to be dolomite in the Lisburne Group and sandstone in the Ledge Sandstone Member of the Ivishak Formation. Reservoir properties may be improved by proximity to the unconformity, as at Prudhoe Bay. Average carbonate porosity is expected to be about 4 percent and average sandstone porosity, about 15 percent.

Potential source rocks include marine shales within the Ellesmerian sequence (Kayak Shale, Ivishak Formation, Shublik Formation, Kingak Shale) and the overlapping pebble shale unit. These shales are expected to be submature to mature. The Shublik, Kingak, and pebble shale unit are expected to be gas-prone source rocks.

Postulated traps in this play are stratigraphic and depend for seals on the pebble shale unit or younger shales.

## ESTIMATES AS DISTRIBUTIONS

The estimates of in-place oil and gas resources included in this report are in the form of complementary cumulative probability distributions, as shown in figure III-15. These distributions summarize the range of estimates generated by the FASP computer program as a single probability curve in a "greater than" mode. Because of the uncertainty attached to the many geologic variables, no single answer is possible to the question of how much oil and gas are present; instead, an infinite number of answers are possible, each with its own confidence level. In nature, only one real value exists and the curve is an expression of the uncertainty about its size. The degree of uncertainty is expressed in the "spread" or variance of the distribution. The curve for in-place oil is read as: there is a 50-percent chance that the resource is greater that 11.9 billion barrels, and there is a 5-percent probability that the resource is greater than 29.4 billion barrels. Large quantities correspond to lower probabilities--that is, there is less confidence that those quantities are present. Our estimates are reported at the mean and at the 95th and 5th probability levels, considered by us to be "reasonable" minimum and maximum values. In addition, other central values are discussed.

## ESTIMATED IN-PLACE RESOURCES

In-place oil and gas resources contained within the 1002 area of the Arctic Refuge are estimated to range from 4.8 billion to 29.4 billion barrels of oil (BBO) and from 11.5 trillion to 64.5 trillion cubic feet of natural gas (TCFG), at the 0.95 and 0.05 probability levels, respectively (fig. III-15). Though indicating a relatively high degree of uncertainty regarding the true value, this wide range of values does

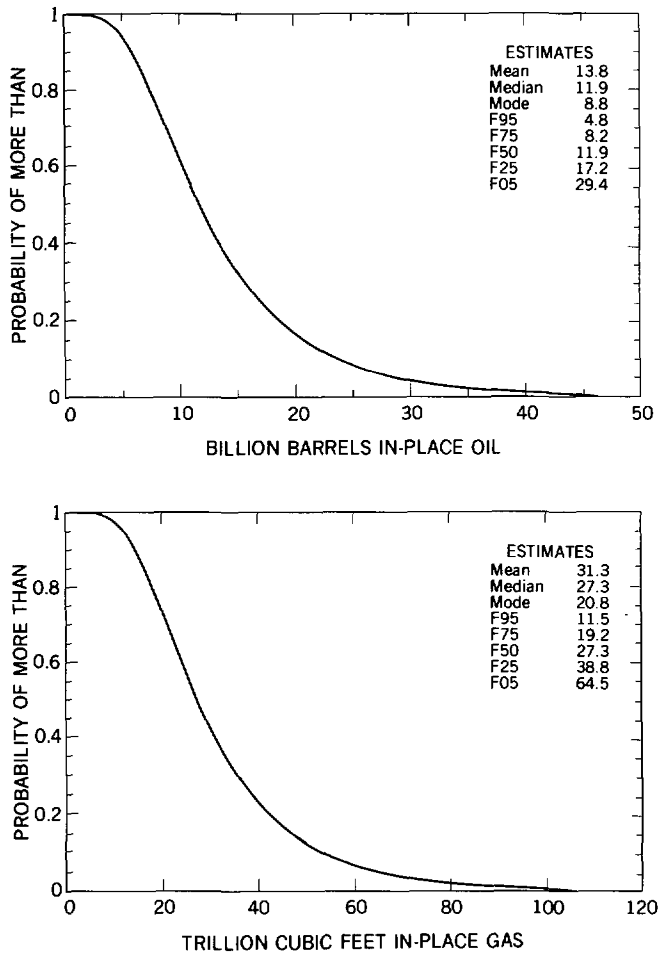
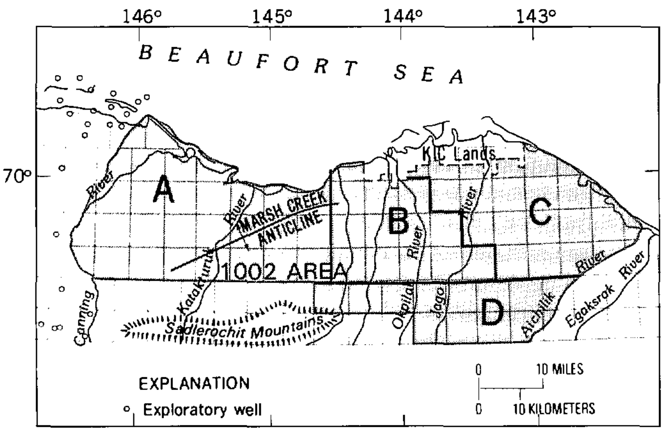



**Figure III-15.**---Probability curves showing the estimated in-place oil and total gas resources of the 1002 area. Oil in billions of barrels; gas in trillions of cubic feet. F, fractile.

indicate the potential for unusually large resources, or the possibility that there may be no exploitable petroleum resources in the 1002 area. For perspective, the Prudhoe Bay field is calculated to have initially contained about 23 BBO in-place and more than 35 TCFG in-place in Triassic reservoirs. Furthermore, an area similar in size and shape to the 1002 area, centered at Prudhoe Bay, encompasses 10 oil and gas accumulations, both economic and subeconomic, with nearly 60 BBO and 45 TCFG in-place. Mean estimates for the 1002 area are calculated to be 13.8 BBO in-place and 31.3 TCFG in-place; these mean values have probabilities of 40 percent or less of being exceeded.

To facilitate weighing of land-use values within the 1002 area, the mean values of in-place oil and gas resources were assessed for four separate geographic blocks as shown in figure III-16.

This assessment of oil and gas in-place represents those deposits which constitute the resource base without reference to recoverability. Included are accumulations




| | MEAN ESTIMATE | |
|---|---|---|
| | OIL IN PLACE (BBO) | GAS IN PLACE (TCFG) |
| BLOCK A | 5.5 | 12.7 |
| BLOCK B | 1.5 | 2.9 |
| BLOCK C | 5.1 | 11.5 |
| BLOCK D | 1.6 | 4.2 |

DISTRIBUTION OF GAS IS VERY SIMILAR TO THAT OF OIL

APPROXIMATE DISTRIBUTION OF IN-PLACE OIL

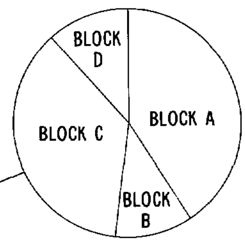



**Figure III--16.**--Resource blocks A-D of the 1002 area (shaded) and the approximate distribution of mean values of in-place oil and gas resources.

estimated to range in size from very small (far less than 1 million barrels of oil in-place or equivalent) to very large (greater than 1 billion barrels in-place). Included are both stratigraphic traps and structural traps, not only traps unequivocally identified and measured by seismic data, but also traps inferred to exist on the basis of framework geology. Clearly, this in-place resource includes many deposits well below any economic size limit which may currently be assumed for the Arctic, and includes deposits which have reservoir characteristics that preclude them from being economic (see section on Economically Recoverable Oil Resources).

Estimated in-place resources of individual plays are shown in figures III-17 and III-18. The most significant play in terms of contribution is the Folded Ellesmerian/Pre-Mississippian play, containing approximately 50 percent of the area's estimated in-place oil and 60 percent of the estimated total gas. This play has several unusually large structural prospects and is estimated to contain large accumulations. Next in order of decreasing importance are the Imbricate Fold Belt play and the Turbidite play. However, in these and several other plays, the estimated accumulation sizes, though perhaps substantial, are often of such size as to be of little or not current economic interest if occurring singly, and are often mapped with great difficulty. If occurring above deeper and larger deposits or close to them, such accumulations may be of interest.

## Economically Recoverable Oil Resources

Conditional estimates of economically recoverable oil resources were calculated for use in environmental analyses and to assess the potential contribution of the 1002 area to the Nation's domestic energy resource supply. These estimates are conditional upon the occurrence of at least one economic size oil accumulation in the area, the probability of which is about 19 percent. The estimates are reported as a range of values, which reflects the uncertainty inherent in such estimates. The conditional mean estimate was used to provide a single point value for the indicated purposes.

Natural gas is not expected to be economic during the time period considered.

### METHODS

The estimate of economically recoverable oil resources for the 1002 area is the result of a prospect-specific analysis using the computer simulation model PRESTO II. PRESTO is an acronym for Probabilistic Resource Estimates--Offshore, developed and currently used by the U.S. Minerals Management Service for generating petroleum resource estimates for Outer Continental Shelf planning areas. The PRESTO process is described by Cooke (1985).

PRESTO II uses prospect-specific geological and geophysical volumetric input data for identifiable prospects and produces prospect-specific and areawide resource estimates. The uncertainty in a frontier area is addressed by allowing the user to input geologic risk factors and a range of values for each volumetric input parameter. The PRESTO model also allows for input of a minimum economic field size. Any field smaller than this economic field size is not counted in the prospect or area conditional resource estimates.

PRESTO uses a "Monte-Carlo" random sampling technique. The model repetitively simulates an exploratory drilling program for the area, "finding" various combinations of prospects and various combinations of values for volume parameters in the prospects for each simulation "pass." This process, if repeated enough times, results in a range of values which represents all possible combinations of subsurface conditions that affect hydrocarbon volumes. Similar models and the Monte-Carlo method are described more fully by Newendorp (1975).

After all input information is entered, PRESTO starts its drilling simulation, drilling each prospect in the area based on prospect and area risks. After the area has been "drilled" a sufficient number of times, PRESTO then computes the prospect-specific resource volumes for each trial where a prospect was found to be economically productive, by sampling from the input distributions. The average of these productive trials for each individual

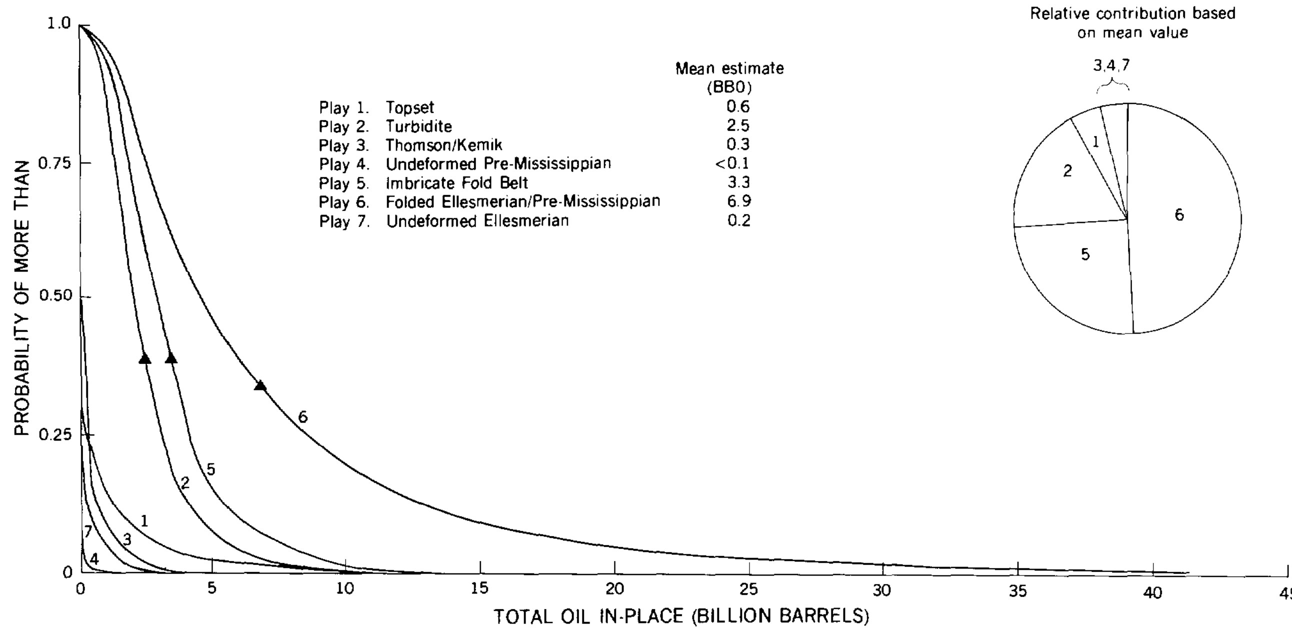



**Figure III-17.**--Estimated in-place oil for plays in the 1002 area, showing individual probability curves and relative contributions of the plays. Triangles show mean values on principal distribution curves.

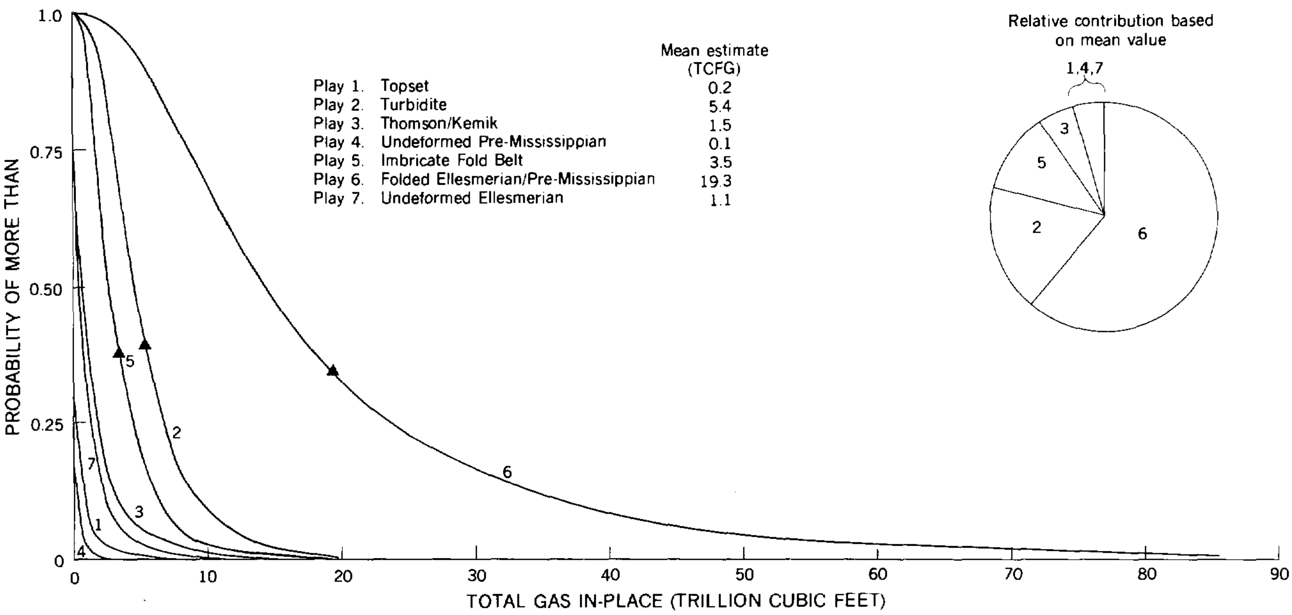



**Figure III-18.**--Estimated in-place total gas for plays in the 1002 area, showing individual probability curves and relative contributions of the plays. Triangles show mean values on principal distribution curves.

prospect is the conditional mean prospect resource. For each trial where a prospect is found to be productive, prospect resources are added to give areawide resources for that trial. The area conditional mean is the average of these trials. The results of all the productive trials are then arranged in ascending order to give the cumulative frequency of the conditional area resources, that is, the percentage chance of finding resources greater than a given value. The results of all trials (including zero, non-economic, and productive trials) are used to generate risked resource estimates and an economic risk factor (Cooke, 1985, p. 11).

## PRESTO MODEL INPUTS

The PRESTO model requires the development of user input values in much the same way as described for the in-place resource assessment. The major difference is that volumetric parameters and risk factors are developed for specific, identified prospects, and that technological and economic factors affecting recoverability are considered. Specific variables are discussed in this section.

### PROSPECTS

Twenty-six structural prospects, identified and delineated as a result of interpretation of seismic data, were considered in the 1002 area recoverable resource assessment. The minimum (areal) size of prospects is a function of the seismic grid density and the resolution (quality) of the data on seismic record sections, which is variable within the area. A large volume of additional, possibly economically recoverable resources in small structural traps and stratigraphic traps, may also be present, as reflected in the in-place resource assessment.

### ZONES

Each prospect is modeled as having one or more prospective reservoir zones. For the purpose of the 1002 area recoverable resource assessment, the number and geologic characteristics of zones within prospects were based on the areal distribution of the equivalent geologic plays used for the in-place assessment. The major part of the economically recoverable estimate is modeled as occurring in Ellesmerian clastic and carbonate reservoirs.

### VOLUMETRIC PARAMETERS

Each reservoir zone in a prospect requires input of hydrocarbon volumetric parameters, including the productive area, zone pay thickness, and a barrel/acre-foot oil recovery factor. Gas recovery factors and the associated gas input parameter (gas-oil ratio) were "zeroed out" for purposes of the 1002 area assessment. All volumetric parameters are ranges of values, with an associated probability distribution, to account for uncertainty. The ranges and distributions used for recovery factors were derived directly from equivalent parameters developed for the in-place resource assessment. See table III-3.

### GEOLOGIC RISK

The probability of occurrence of hydrocarbons in an area or prospect is normally expressed as a geologic risk factor which is the complement of the probability of occurrence (1 minus probability of occurrence). It is the probability that hydrocarbons will not be found.

The PRESTO model requires user input of unconditional risk factors for the area and for each prospect and each zone being assessed. At the prospect and zone levels, these risk factors are internally adjusted by the model to a conditional basis, and these conditional risk factors control the frequency with which prospects and zones are found productive during a PRESTO "run" (Cooke, 1985, p. 9). This sampling frequency determines the relative contribution of each prospect to the area resource estimate.

For the 1002 area, the areawide prospect geologic risk level used was approximately 90 percent (1 chance in 10 of a discovery). This prospect risk level is generally consistent with the industry standards for significant (not necessarily commercial) rank wildcat success rates. The abundant direct evidence of hydrocarbons (oil and gas seeps, oil staining) within the 1002 area and the existence of commercial oil deposits to the east and west argue for use of this level of unconditional prospect risk even for some of the very large prospects modeled in this analysis, which, statistically, would ordinarily be considered very rare occurrences. Unconditional prospect risk was assessed at the conditional mean (expected) resource level, rather than at the threshold (near minimum) level. This is necessary to remain consistent with subsequent, more detailed analyses, such as economic evaluations, required for various purposes.

Unconditional risk factors on specific prospects were assessed within this framework on the basis of prospect-specific characteristics, such as confidence in the seismic interpretation, which is a function of data quality and coverage. Well-defined, structurally simple prospects have lower risk factors, whereas more complex structures would have higher risks.

Reservoir zone risks were assessed on a relative, or "conditional" basis, often using the conditional risk analyses jointly (GS/BLM) conducted for use in the in-place resource assessment.

Area risk was derived from the array of prospect risks in the area, using the "state of nature" conditional mean field size as the primary criterion. Simply put, the area geologic risk is based on the probability of occurrence of at least one field large enough to meet the economic requirements for commercial production in the 1002 area. No geologic dependencies were assumed among the prospects selected for this purpose.

**Table III-3.**--Reservoir volume parameters used in estimating recoverable resources.

["Hydrocarbon saturation" range and probability distribution are based on equivalent range and distribution currently built into the GS FASP Model for carbonates and sandstone reservoirs.
"Recovery efficiency" is based on reported or projected estimates published for North Slope reservoirs in industry trade publications or State of Alaska reports. Proven primary and enhanced recovery technology (water flood, gas injection) are considered implicit in these estimates.
The "yield" is the estimate of technically recoverable oil at reservoir conditions, not corrected for a formation volume factor. The formation volume factor is depth dependent and, therefore, prospect specific]

| Zone equivalent | | Porosity | Hydrocarbon saturation | Recovery efficiency | Yield BBL/acre-ft) |
|---|---|---|---|---|---|
| Topset | Minimum | 0.100 | 0.350 | 0.200 | 54 |
| | Most likely | .250 | .730 | .250 | 354 |
| | Maximum | .320 | .950 | .350 | 825 |
| Turbidite | Minimum | .030 | .350 | .250 | 20 |
| | Most likely | .135 | .730 | .320 | 245 |
| | Maximum | .300 | .950 | .400 | 884 |
| Thomson-Kemik | Minimum | .030 | .350 | .250 | 20 |
| | Most likely | .110 | .730 | .320 | 199 |
| | Maximum | .300 | .950 | .400 | 884 |
| Ellesmerian clastic | Minimum | .030 | .350 | .250 | 20 |
| | Most likely | .170 | .730 | .300 | 289 |
| | Maximum | .300 | .950 | .500 | 1106 |
| Ellesmerian carbonate | Minimum | .030 | .350 | .100 | 8 |
| | Most likely | .045 | .750 | .250 | 65 |
| | Maximum | .150 | .950 | .350 | 387 |
| Pre-Mississippian carbonate | Minimum | .030 | .350 | .100 | 8 |
| | Most likely | .055 | .750 | .250 | 80 |
| | Maximum | .150 | .950 | .350 | 387 |

ECONOMIC INPUTS

The economics of petroleum development for the area and for each prospect are applied in the PRESTO analysis. This is accomplished by means of an estimate of the volume of recoverable resources that would be required for a prospect to be economically successful. This estimate, referred to as the minimum economic field size (MEFS), is based on estimated development, production, and transportation costs, and various forecasts and estimates of future economic factors, such as oil prices, inflation, and discount rates. Pertinent assumptions used in the derivation of MEFS for prospects in the 1002 area are shown in table III-4 and are discussed at greater length in an unpublished paper by Young and Hauser (1986).

Under the most likely case economic scenario, the minimum economic field size for the 1002 area as a whole is about 440 million barrels of technically recoverable oil. For individual prospects, the MEFS varies, depending on prospect-specific characteristics, such as drilling depths, well spacing, and pipeline distance. The areawide minimum is equal to the MEFS for the prospect with lowest development costs.

Minimum economic field sizes were calculated using alternative, more optimistic economic assumptions. Under these assumptions, the areawide minimum economic field size (that is, least costly prospect) is about 155 million barrels of technically recoverable oil. This is referred to as the "optimistic case MEFS."

PRESTO ANALYSIS RESULTS

Economically recoverable estimates of oil resources were calculated using two economic scenarios. The results are shown in table III-4, along with economic variables which significantly affect the estimate of the minimum economic field size.

The optimistic case resource estimate was made to assess the effects of different economic conditions or projections on the estimate. Except for economic inputs (the minimum economic field size), all other input variables were held constant. On a conditional basis, the area resource estimate is lower because the prospect resources contributing to the area resource are lower. The range of values for each prospect modeled is truncated at a lower level by the lower minimum economic field size. This results in a wider range of conditional values containing lower values. This is offset by the increased probability of occurrence associated with the wider range of values, because prospects and the area are found economic more often during the Monte Carlo simulation (Cooke, 1985, p. 11).

To assess the effect of variations in geologic risk, PRESTO runs were made at different levels of unconditional risk. These runs produced no significant variations in the conditional area resource estimate.

RESOURCES BY BLOCK

To provide a basis for assessing the consequences of resource management decisions in terms of the oil resource potential of the 1002 area, the unconditional resource potential for the area was allocated on a percentage basis to the blocks shown in figure III-16. This allocation is based on the unconditional resource potential of the individual prospects contained in each block. See table III-5. A similar resource allocation, by percentage, was made to "activity areas" in the Sec. 105B Economic and Policy Analysis for the National Petroleum Reserve-Alaska.

**Table III-4.**--Undiscovered, conditional, economically recoverable oil resources in the 1002 area.

[BBO, billion barrels of oil]

| | Greater than | Economic scenario: Most likely case | Economic scenario: Optimistic case |
|---|---|---|---|
| **Conditional, economically recoverable oil** | | | |
| Probability | 99% | 0.49 BBO | 0.18 BBO |
| | 95% | 0.59 | 0.23 |
| | 75% | 1.12 | 0.67 |
| | 50% | 2.21 | 1.49 |
| | 25% | 4.24 | 3.67 |
| | 5% | 9.24 | 7.85 |
| | 1% | 17.19 | 15.73 |
| Maximum simulated oil | | 22.34 | 22.34 |
| Mean (arithmetic average) | | 3.23 | 2.66 |
| Marginal probability[1] | | 19.0% | 26.0% |
| Minimum economic field | | 0.44 BBO | 0.15 BBO |
| **Significant economic assumptions** | | | |
| Crude oil market price (1984 dollars/ barrel in year 2000) | | $33.00 | $40.00 |
| Annual inflation rate | | 6.0% | 3.5% |
| Discount rate: | | | |
| Real | | 10.0% | 8.0% |
| Nominal | | 16.6% | 11.78% |
| Federal royalty rate | | 16.67% | 12.5% |
| Development cost multiplier | | 1.0 | 0.75 |

[1]The marginal probability is the probability of occurrence of economically recoverable oil somewhere in the 1002 area.

**Table III-5.**--Distribution, by block, of estimated unconditional mean recoverable oil resources in the 1002 area.

| Block | Location in 1002 area | Resource distribution (percent) | Number of prospects in block |
|---|---|---|---|
| A | West | 9 | 14 |
| B | Central | 3 | 3 |
| C | East | 63 | 4 |
| D | South | 25 | 5 |

## Natural Gas Economics

For this analysis, crude oil is assumed to be the only potentially economic hydrocarbon in the 1002 area which would attract development interest in the early to mid-1990's, and which could be explored for, developed, and marketed at expected costs and prices. Given (1) the projected high costs of North Slope natural gas at market, (2) uncertainties associated with development of a natural gas transportation system to a viable market for proven North Slope natural gas reserves located at Prudhoe Bay, (3) the additional costs of moving potential gas resources from the 1002 area to a major transportation system near Prudhoe Bay, and (4) the quantity of proven reserves likely to be developed prior to any gas reserves found in the 1002 area, it is assumed here that there would not be a demand for acquiring acreage in the area in the early to mid-1990's for the purpose of finding and producing natural gas.

It is assumed that any gas resources discovered through oil exploration activities will remain undeveloped or will be used locally. This is not to say that potential gas resources in the 1002 area are without value. At some future time, national or international economic conditions or technological advances may warrant exploration for and development of potential natural gas resources in the 1002 area. For a detailed discussion of the alternatives and issues affecting development of potential natural gas resources in the 1002 area see Young and Hauser (1985).

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# CHAPTER IV
# DEVELOPMENT AND TRANSPORTATION INFRASTRUCTURE

## INTRODUCTION

Section 1002(h)(3) requires an evaluation of the effects of further oil and gas exploration, development, and production, should it be permitted on the 1002 area. Section 1002(h)(4) requires a description of oil and gas transportation facilities. To meet these requirements, scenarios were needed to describe possible oil and gas development within the Arctic Refuge coastal plain, and transportation of the oil and gas to processing facilities. The scenarios in this chapter are based on general concepts germane to oil development, and production in an arctic environment. Determining the possible magnitude of such development in the 1002 area required an estimate of the amount of potentially recoverable hydrocarbon resources. Chapter III describes how these recoverable resource estimates were derived, and the limitations connected with their use.

Gas was not considered in the recoverable resource assessment; at present crude oil is assumed to be the only potentially economic hydrocarbon which would attract leasing interest if the 1002 area were opened to leasing. Conceivably, at some future date, gas as well as oil could be economically produced from the Arctic Refuge. Therefore, a general discussion of gas development and transportation is presented at the end of this chapter.

For this chapter and Chapter VI, the recoverable estimates used are those attributed to the mapped structures (fig. III-1). This is not to imply that these are the only areas of oil and gas potential on the 1002 area. It merely provides a less speculative tool from which to project potential development activity and from which to evaluate possible environmental impacts. Areas without mapped structures may prove to be of greater, lesser or equal potential. Without exploratory drilling as a confirmation and delineation tool, all estimates must be considered uncertain.

## EXPLORATION, DEVELOPMENT, AND PRODUCTION

The exploration and development of an oil field on the North Slope of Alaska and the transportation of oil to markets entail several activities and the construction of many types of facilities. The various activities include seismic exploration; drilling of exploration, confirmation, delineation, and production wells; and the planning, engineering, and construction of field production facilities, support facilities, and transportation systems. Following is a general description of the activities and facilities that would normally be required to bring North Slope oil from the 1002 area to markets. The exploration, development, and construction scenarios presented herein are general concepts and must not be considered to be final engineering solutions for the 1002 area, if developed for oil and gas production. Specific locations and sources of water and gravel for exploration and development activities have not been identified; and it is understood that these resources, especially water, are not readily available on the 1002 area.

### Exploration

#### ADDITIONAL GEOLOGICAL AND GEOPHYSICAL EXPLORATION

Additional surface geology work would probably occur prior to drilling exploratory wells. This would consist of hand sampling of rock and further study and measurements of geologic sections. Access would be by helicopter, and actual time on the ground would be only a few hours for each survey.

Additional seismic exploration would also take place to obtain more detailed information on subsurface geology. Use of vibrator equipment would probably be the preferred method, based on the results of seismic activities already conducted in the 1002 area. Although the total line miles of new surveys might not differ much from the cumulative total of about 1,300 line miles already collected, more crews may be on the area for two reasons: (1) different companies have different ideas as to where to concentrate detailed surveys (closer grid spacing); and (2) different types of data and parameters are useful to companies in their interpretations of subsurface geological structures or style. Thus, there could be requests for authorizations to run "3-D surveys," which use closely spaced, parallel survey lines.

#### EXPLORATORY DRILLING

Exploratory drilling is a large-scale operation using heavy equipment, but it is usually confined to a localized area. For environmental, engineering, and economic reasons, exploratory drilling on the North Slope is typically conducted during the winter. If the exploratory drilling operations, including construction, drilling, and testing, can be completed within approximately 170 days, the well can probably be completed in a single winter season (Mitchell, 1983b). On the North Slope, exploratory wells to a depth of approximately 12,000 feet can usually be drilled in a single season. It is possible that many wells would require two seasons.

A single-winter-season operation involves the mobilization of construction crews and equipment, followed by the mobilization of the drilling rig. After the rig and support equipment are delivered to the site and assembled, drilling begins, and continues until desired depth is reached. After drilling, testing, and suspension or abandonment of the well, the rig, support equipment, and camp are demobilized and the pad area is rehabilitated.

Heavy construction equipment is used to prepare the wellsite for the drilling operation and to prepare an airstrip large enough for Hercules C-130 aircraft. The drilling rig and the ancillary equipment are massive, usually requiring 110 to 180 C-130 loads, depending on the size of the rig. Drilling an exploratory well requires 500,000-800,000 gallons of fuel. That is about 115 C-130 tanker loads or, if supplied by overland tanker truck and trailer, 115 truck loads.

Construction equipment is hauled cross-country by low-ground-pressure vehicles to the exploratory well site. Once the equipment and crew arrive on site, construction begins for ice roads, an ice airstrip, and the drilling pad. The drilling pad can be constructed of ice, material excavated for various purposes such as reserve pits, gravel-foam-timber, or other possible combinations.

The drilling pad is large enough to hold the rig, camp, and support equipment, and to provide storage for drilling supplies (drillpipe, casing, drilling mud, cement, etc.). A typical pad (including reserve pit) is about 600 feet by 700 feet, and covers approximately 10 acres of ground surface. The construction and drilling camps contain sleeping and eating accommodations, communication equipment, power generator units, storage space, shops, and offices. A construction camp contains facilities for 50-75 people and the drilling camp for 50-60 people. The actual number of people varies with the type of activity.

A reserve pit is excavated at the edge of the pad immediately adjacent to the well. The purpose of a reserve pit is twofold: (1) to contain fluids that might be ejected during an "upset" such as when high-pressure natural gas forces part of the column of drilling mud to the surface, or in the unlikely event of a "blowout" when uncontrolled crude oil reaches the surface, and (2) to contain the used drilling muds and "cuttings" from the well.

Reserve pits are generally about 200 feet wide and 300 to 400 feet long (parallel to the drilling pad); and are 10 to 20 feet deep. A small (50-foot-square) flare pit is excavated at the corner most distant from the drilling rig, in case it is needed for gas flaring during testing. The ice-rich material excavated from the reserve and flare pits is used to level the drill pad and provides a cover of approximately 2 feet over the tundra surface. Because of uneven ground, the pad-cover thickness may range from 6 inches at one edge to 3-5 feet at the opposite edge.

The drilling pad is connected to the airstrip and the camp water source by ice roads. Initially a source of water sufficient for ice-road and airstrip construction and camp and drilling uses must be located. On the 1002 area, obtaining the water needed for drilling, and more particularly for ancillary needs such as ice roads and airstrip construction, poses the major engineering problem. Water in the 1002 area is confined to surface resources, and there are few lakes of appreciable size within the area. The water requirements for drilling an exploratory well are approximately: (1) 1.7 million to 2.0 million gallons for the drilling operations and domestic use, (2) 1.2 million to 1.5 million gallons per mile for construction and maintenance of ice roads, and (3) 7 million to 8 million gallons for construction and maintenance of an airstrip on the tundra, if required. Therefore, as much as 15 million gallons of water may be needed to drill one exploratory well.

Three possible scenarios despite water shortage are:

1. Exploratory wells drilled reasonably near the coast could be constructed on shorefast sea ice, in areas protected from ice ridging by projecting land points or nearby barrier islands. Construction could be done early in the season in shallow water. If water from shallow ponds in the area of a proposed wellsite is inadequate for constructing an ice road between the airstrip and the wellsite, rolligons could be used with care to transport heavy drilling-rig components, drilling supplies, and fuel to the wellsite. By using a series of parallel paths, such transport would be analogous to the use of "winter trails" by the seismic crews. The fresh water required for domestic purposes, and especially for drilling could be obtained from shallow ponds. When these ponds freeze to bottom, a snow or ice melter could be used for melting snow scraped from the surface of the ponds or ice ripped from those ponds. Melters with sufficient capacity to handle these requirements have been successfully used on the NPRA (W. T. Foran Test Well 1).

2. For exploratory wells drilled near lakes that are on the KIC lands or near the band of small lakes east of the Jago River, if the appropriate permissions were granted, airstrips could be constructed partially on the lake ice and continued on the adjacent flat-lying tundra. Depending on the overall availability of water, rolligon and snow-melter techniques might be necessary.

3. The same innovative effort (obtaining water, snow, or ice from wherever it can be found, without disrupting the biological environment) would be required for exploratory drilling elsewhere in the 1002 area.

If a suitable water source can be found, ice roads would probably be constructed, typically by applying a layer of water over snow cover along the desired route with specially designed water trucks. This process is repeated until an ice layer of sufficient thickness is created. One mile of ice road generally requires about 1.5 acre-feet of water. Ice airstrips are usually placed on nearby lakes if they are of sufficient size; otherwise, the airstrip is constructed on level tundra similar in manner to an ice road except with a minimum ice thickness of 12 inches. The airstrip may be as long as 5,000-6,000 feet and about 150 feet wide, usually to accommodate Hercules C-130 aircraft.

Drilling operations begin by augering a hole for the conductor casing, typically 50-100 feet. Then the drilling rig is placed on the pad. To prevent differential settling during drilling, the rig is placed on pilings or timbers. The conductor casing is run and cemented in place and the well is spudded. Drilling begins and the hole is drilled to a competent geologic formation, usually to a depth of about 2,000 feet. Test logs are run and the surface casing is run into the hole and cemented with a special arctic cement. This casing passes through the entire permafrost zone and provides an anchor for blowout-prevention equipment until the next casing string is set. Drilling continues to the next casing point where the well is logged and intermediate casing is run and cemented. Drilling continues until the target zone is reached and tested. After the final testing and logging, the well is suspended or abandoned by placing several cement plugs in the well bore and casing.

Usually demobilization of the drilling rig and camp starts immediately after the well is abandoned. Within several weeks, the equipment and most of the debris will have been removed or the equipment made secure for movement to the next wellsite. A final-cleanup crew returns to the site in the summer to pick up any remaining debris or garbage and to check on the rehabilitation.

For wells that cannot be completed in a single winter season two options exist: (1) year-round drilling or (2) interrupted drilling during two or more winter seasons (Mitchell, 1983a). Year-round exploration drilling uses the same facilities as the winter method, but the pad, roads, and airstrip are usually constructed with gravel instead of ice. Therefore, a source of gravel for construction material must be available.

Multi-winter drilling is similar to single-winter drilling, except that the drilling pad is constructed with enough gravel (usually about 35,000 cubic yards) to provide a stable and suitable surface on which to store the drilling equipment and camp during the summer. Gravel sources for drilling pads and other facilities are discussed under the following section on roads. Also the well is arctic packed and suspended. At the beginning of the second or subsequent winter drilling seasons, the roads, airstrip, and drilling pad are rebuilt to the extent necessary with ice, the nonfreezing fluid in the upper part of the well is removed, and the drilling is resumed.

## Development

Following a discovery of oil from exploration drilling, a confirmation or delineation well is drilled during the next drilling season. This well tests the same prospect and is drilled in a similar manner as an exploration well. If the well results are positive, further delineation drilling occurs during subsequent drilling seasons. The purpose for the delineation drilling is to determine the size of the discovery and the geologic characteristics of the reservoir. Delineation drilling continues until enough information has been collected to determine whether or not the reservoir could be produced economically. The actual number and scheduling of delineation wells are tailored to each reservoir. The drilling method is similar to that for discovery and confirmation wells except that two or more wells might be drilled during the same winter. So, the airstrip and roads for support of the drilling rigs would be shared. If the discovery is significant and appears to be economically developable, some of the roads and delineation-drill pads may be constructed with gravel so they could be used during production.

From time of discovery through delineation, evaluation, and engineering, the lessee or lessees conduct environmental studies and plan for the development and production of the reservoir. Once the studies and plans are completed, the lessee's plans for construction, development, and production are submitted to appropriate Federal and State agencies for review, possible modification, and approval.

Assuming that the decision is to proceed with development and that plans of operation are approved, the first on-the-ground activity is establishment of a temporary construction camp for workers. This camp provides the necessities for living and working on the North Slope and may house as many as 1,500 workers during peak construction and development. Gravel extraction and construction of roads, drilling pads, and airstrip are priorities, because these facilities receive immediate and continuous use. First to be constructed is the airstrip to handle the heavy supply loads. With connecting roads, such an airstrip could serve more than one oil field, were they to be discovered nearby. Next would be gravel roads to planned drilling pads, and then all-season pads. Construction would begin at the main camp area, again with an all-season gravel pad. Once each drilling pad is completed, drilling rigs can be moved on location and production drilling can begin.

The buildings and engineering equipment for the permanent camp and most of the production facilities are usually constructed as large modular units elsewhere (lower-48 States, Anchorage, etc.). The modules, often several stories high, are sent by barge on an annual sealift during the open water season to a suitable port site with large-scale dock facilities. From there, they are either trucked or moved by tracked vehicles to the project location. On-site the modules are assembled and functionally tested. The actual years of construction may depend on the overall scope of the field development and is usually a continuing operation. For example, construction was begun on the Prudhoe Bay field during the early 1970's, yet major construction supported by annual sealifts has continued into the 1980's with expansion of the initial production field and improved technology for extraction of additional petroleum resources. Construction may continue for many more years.

Construction of a hot-oil transmission pipeline presumably to TAPS Pump Station 1 at Prudhoe Bay would proceed concurrently with construction of production facilities (see "Transportation options for oil and gas production," this chapter).

Once the major production facilities, including gathering pipelines and main pipeline, are in place, production begins. The initial production rate depends upon the number of production wells drilled and connected to production facilities; peak production is probably attained in 2 to 5 years, and expected to be 5-10 percent of total recoverable resources annually. Production may remain at that level for 3-8 years and then decline 10-12 percent per year. The productive life of an oil field is usually 20-30 years (National Petroleum Council, 1981). Although this has not yet occurred on the North Slope, after production from the reservoir is no longer economic, the field would presumably be abandoned. Most facilities, buildings, structures, equipment, and above-ground pipelines would be removed to permit rehabilitation of the surface.

The time period from lease acquisition to initial oil production from a new reservoir on the North Slope is difficult to determine. Even under optimum circumstances, about 10 years will elapse before production starts from a new lease.

## Production

The physical characteristics (size, shape, and depth) and performance (well-production rate and spacing) of a field determine the number and location of surface facilities needed for development and production.

The size and shape of the productive field roughly define the areal extent of surface disturbance from production-related facilities. The lateral dimensions of the reservoir, when projected to the surface, would typically encompass all or most of the production facilities, such as drilling pads, reserve pits, infield roads, and gathering lines. The camp, airstrip, or other facilities not directly related to actual production could be positioned to best suit environmental and engineering concerns.

For environmental or technical reasons, it may be desirable to shift the location of the drilling pad. Directional drilling allows multiple wells to be drilled from a single surface location (fig. IV-1). This typical North Slope practice reflects economics, engineering considerations, and

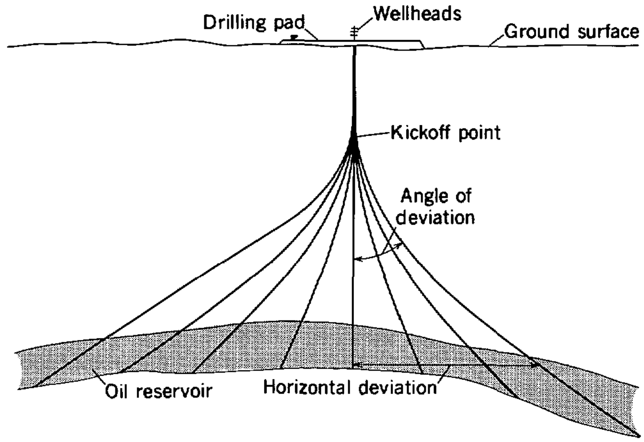


**Figure IV-1.**--Directional drilling from a single drilling location.

environmental impact mitigation. A vertical hole is drilled to a predetermined "kickoff" point where it begins a controlled deviation (drift) from vertical. The angle of deviation increases with depth until it reaches the necessary angle for the well to reach a specific bottom-hole location in the producing geologic horizon. The horizontal deviation (horizontal distance between surface and bottom-hole locations) depends upon the angle of deviation and the vertical depth of the hole. The amount of horizontal deviation that is possible for a group of wells drilled from a single pad determines the degree of flexibility in choosing the surface location of that drilling pad. Increased true vertical depth of a reservoir increases the degree of flexibility in pad location.

Unless advances in technology dictate otherwise, most development wells for the 1002 area would likely be drilled with an angle of deviation between $0^{\circ}$ and $45^{\circ}$ from an assumed kickoff point of 2,000 feet. The actual kickoff point depends upon geologic conditions and reservoir depths. From the kickoff point, the hole can be deviated $3^{\circ}$ per 100 feet of hole drilled. The maximum practical angle for directional drilling on the North Slope is now about $60^{\circ}$, with the horizontal deviation reaching a possible distance of over 12,000 feet in some of the deeper reservoirs (that is, deeper than 10,000 ft.) (U.S. Army Corps of Engineers, 1984).

Reservoir depth also influences the number of drilling pads required for development and production. A deep reservoir can be produced from fewer drilling pads because more wells can be drilled from a single pad (fig. IV-2). Conversely, a shallow reservoir requires more drilling pads, because fewer wells can be drilled from each pad.

Reservoir type and performance influence the spacing of production wells, which in turn affects the number of drilling pads required for development and production. The

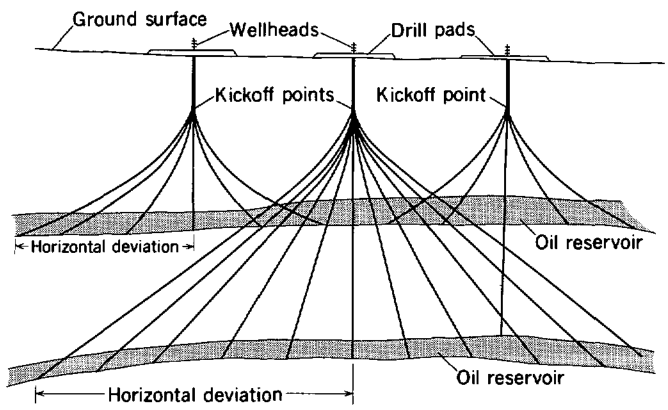


**Figure IV-2.**--Horizontal deviation versus well depth.

well spacing for a producing field is designed to effectively drain a specific area surrounding the well bore. On the North Slope, well spacing, or well density, ranges from 50 acres to 320 acres, depending on production performance and needs (Williams, 1982; Petroleum Information Corporation, 1985).

Production drilling on the 1002 area is assumed to be on 160-acre spacing, the present practice in portions of producing fields on the North Slope and the spacing herein assumed for the development scenarios and the minimum economic field size determinations. Each production well would then drain 160 acres. This spacing is "reservoir spacing" in the subsurface and should not be confused with surface well spacing. Also, if gas were to be eventually produced, reservoir spacing would probably be greater (320 or 640 acres). Injection wells are required for fluid disposal, gas reinjection for storage and pressure maintenance, and waterflooding for pressure maintenance.

Infrastructure for any oil production on the 1002 area requires many facilities, like those for the Kuparuk River and Prudhoe Bay oil fields (U.S. Army Corps of Engineers, 1984; Andrews, 1984). These major facilities include central production facilities (CPF's), drilling pads, roads, airstrips, pipelines, water and gravel sources, base camps, construction camps, storage pads, powerlines, powerplant, support facilities, and possibly a coastal marine facility. All would be of permanent construction and have a useful life of 20-30 years. The airstrip, roads, pads, and dock facilities would typically be constructed of gravel mined from nearby upland sites, terraces, or streambeds. Most structures and production facilities would be built off-site as modules and transported to and assembled on location.

## CENTRAL PRODUCTION FACILITY

The central production facility (CPF) is the primary operation center for production activities and may possibly be the headquarters for each field. Typically the CPF includes: production facilities; living quarters and administrative office center; workshops, maintenance buildings, and garages; fuel and water storage; electric-power-generation unit; solid-waste and water-treatment facilities; and a crude-oil topping unit.

If the field being developed is small, all facilities may be located on a single gravel pad. However, field sizes in the 1002 area may be on a scale similar to Prudhoe Bay or Kuparuk River. This would require locating some facilities on separate pads, and additional CPF's could be necessary. Pad size varies according to the magnitude of the field, good arctic engineering practice, and environmental concerns. Each pad would be about 5 feet thick and could cover 20-100 acres, requiring 180,000-900,000 cubic yards of gravel. Actual pad thickness depends on the amount of insulation necessary to protect the permafrost from thawing, but a 5-foot thickness should provide the needed insulation for most of the 1002 area. Structures would be built on pilings and elevated above the pad surface to ensure foundation integrity for the project life.

Living quarters must provide sleeping accommodations, kitchens, food storage, dining areas, sanitary stations, and recreation facilities for all production, maintenance, and administrative personnel at the CPF, about 200-500 people depending on the magnitude of operations. Support services, administration, engineering, communications, and project management would be housed in an adjacent administrative office center. The workshop, maintenance center, and main garage would be located nearby, for fire, safety, and oil-spill equipment as well as parts and supplies.

Production facilities include the equipment necessary to process hydrocarbons from the producing wells, beginning with a series of three-phase separators which result in three products--oil, gas, and water. Each product is run through additional separators until the required separation is obtained. Oil is piped through a sales meter and then to the pipeline pump station. The gas is available for on-site fuel requirements or is used for producing additional oil (enhanced oil recovery or gas lift). In gas lift, gas is the medium for lifting fluid from a well. The separated gas is compressed and returned to the production well and injected into the space between the casing and tubing, where gas enters the tubing through a gas-lift valve. The oil in the tubing mixes with the gas and is raised to the surface by the expanding gas (American Petroleum Institute, 1976). Any excess gas is injected back into the reservoir through gas injection wells to maintain reservoir pressure (enhanced oil recovery).

The produced water is pumped to water injection wells for subsurface disposal or reservoir waterflooding. A waterflood system for secondary oil production would probably be necessary for developing a reservoir in the 1002 area. Waterflooding involves the injection of large amounts of water into the reservoir (400,000 barrels per day for the Kuparuk River field, and up to 2 million barrels per day for the Prudhoe Bay field), and serves to sweep the oil toward producing wells and to maintain reservoir pressure (Lynch and others, 1985). This process increases the recoverable reserves of the reservoir.

Sea water is the likely choice for a waterflood project if sufficient quantities of produced water are not available. A sea-water waterflood system includes a sea-water-intake structure and treatment plant, an insulated pipeline from the plant to each CPF, and heat generators spaced at intervals along the pipeline to prevent the water from freezing. The sea-water-treatment plant facilities probably would be located at the coast as in Prudhoe Bay (Williams, 1982). For the Prudhoe Bay facility the entire plant was built in a single barge unit towed up during the open-water period and grounded at the prepared coastal site. The sea-water treatment pipeline would be routed to the CPF where additional pumps would increase the pressure to meet injection needs. The treated sea water would then be piped to the appropriate drilling pads for injection.

Fresh water for camp use is normally obtained from various sources--lakes, water-filled gravel pits, or by desalination of sea water. Requirements for camp use could be as much as 10,000 gallons per day, and drilling water requirements could be as high as 30,000 gallons per day per well. Water for drilling and production requirements may be difficult to obtain in sufficient quantities on the 1002 area, as previously discussed, so combinations of several or all sources may be necessary.

Data from water-availability studies for the proposed Alaska Natural Gas Pipeline are shown in table IV-1. The data were obtained 12-27 miles inland, approximately in the middle of the 1002 area, and suggest that in winter rivers in the 1002 area are not a potential source of water for industrial use. Note that water depths beneath ice do vary throughout the length of these rivers.

**Table IV-1.**--Winter water depths at selected locations on the 1002 area.

[Data from U.S. Department of the Interior, 1976, p. 99]

| River | Date sampled/ observed (1973) | Thickness of ice (ft) | Water depth (ft) | Approximate straight-line distance (mi) upstream |
|---|---|---|---|---|
| Canning | 4/18 | 7.54 | 0 | 19.8 |
| (downstream) | 11/05 | 1.15 | 0 | 14.0 |
| Tamayariak | 11/07 | 0 | 0 | 14.0 |
| | 11/07 | 0 | 1.15 | 13.0 |
| Katakturuk | 11/07 | 0 | 0 | 11.8 |
| Sadlerochit | 11/07 | .03 | 0 | 18.9 |
| Hulahula | 4/18 | 0 | 0 | 21.7 |
| | 11/08 | 0 | .82 | 19.2 |
| Jago | 4/18 | 0 | 0 | 26.7 |
| | 11/07 | .85 | 0 | 26.7 |
| Okerokovik | 11/07 | 0 | .66 | 25.7 |
| Aichilik | 11/07 | 2.16 | 0 | 19.8 |

Water sources may include non-fish-bearing streams, rivers, and lakes year round. Water may be removed from fish-bearing waters, except in winter, provided that water removal meets Alaska Statute Title 16 requirements, is within terms of other necessary State and Federal permits, and does not impede fish passage or otherwise measurably degrade aquatic habitats.

Desalinated sea water and snow melting are also options, particularly for domestic use and exploratory drilling operations. These sources may not be economically feasible for ice roads and airstrips. Material sites may also function as water reservoirs and, where possible, could be positioned and designed to fulfill both gravel and water needs. Potable water for camp use would be stored at the CPF in insulated tanks. Additional water and sewage treatment facilities are normally placed at each CPF.

The fuel-storage area would hold diesel and other necessary refined petroleum products and would be diked to contain any spills. A crude-oil topping plant could provide all the field's needs for arctic diesel and jet fuel. An electric generating plant, fueled with produced gas, would provide power for each field. Backup diesel power would be available at all sites for use in power outages.

## DRILLING PADS AND WELLS

Each drilling pad would support drilling activities until all the production and injection wells had been drilled. Production from the pad could begin before all wells are completed, so production and drilling may occur simultaneously. The layout of a pad during drilling activities typically includes the following: drilling camp, fuel and water storage, one or two drilling rigs, drilling supplies, reserve pits, production facilities and equipment, gathering facilities, and flare stack.

The drilling pad is normally constructed with gravel and covers 20-35 acres. A pad thickness of 5 feet requires 160,000-285,000 cubic yards of gravel. The drilling camp is similar to the camp facilities at the CPF, but smaller and temporary. Housing is required for approximately 50 people per drilling rig, and support staff and some maintenance workers for the production wells. Once drilling is complete, the drilling camp is disbanded and remaining personnel are housed at a CPF. Drilling supplies at the pad would include well tubulars, drill bits, drilling mud and chemicals, cement, wellheads, and other assorted equipment.

The wells on the pad are customarily arranged in a straight line; adjoining wells may be as close as 10 feet (U.S. Army Corps of Engineers, 1984). Spacing between wells depends on pad-size restrictions and the number of wells required for each pad. Producing-well design depends upon well-production rates, geologic conditions, and drilling depth. A design example is shown in figure IV-3.

Drill cuttings and used drilling muds for the well are usually stored in a reserve pit on the drill pad until final disposal. Pumpable liquids are generally pumped into a mud disposal well. Solids must be removed to a government-approved site, such as an abandoned gravel pit or an offshore dump. A flare stack, located near the drilling pad, is used for routine and emergency gas flaring.

The number of pads required to develop and produce an oil reservoir depends upon reservoir size and depth, the production-well spacing, and number of wells on a pad. These factors cannot be determined until site-specific engineering studies are completed. However, as an example, a relatively deep field of 35,000 productive acres developed on 160-acre production-well spacing may require approximately 220 production wells and 90 injection wells. If the wells drilled from a single pad could effectively drain 5,000 acres, seven drill pads would be necessary; 40 to 50 wells could be drilled from each pad.

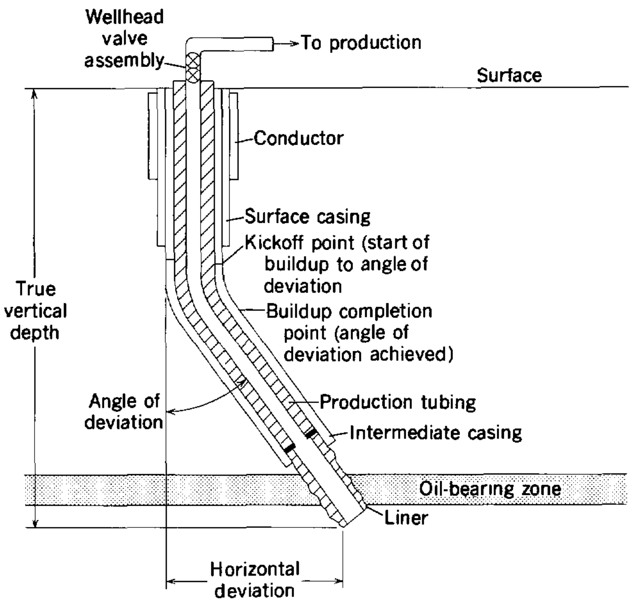


**Figure IV-3.**--Production-well design.

AIRSTRIP

An airstrip to support each major field development and production area in the 1002 area would be a permanent, year-round structure used for the entire lifetime of that field. The airstrip(s) would be designed to accommodate all types of fixed-wing aircraft and helicopters, and have a length of 5,000-6,000 feet and a width of 150 feet. The airstrip(s) would cover approximately 20 acres each; the adjacent taxiway, apron, terminal, and other airport support facilities could require another 10 acres. Airstrip(s) and pad(s) for support facilities would be constructed of gravel and be about 5 feet thick. The estimated gravel requirement for each is approximately 250,000 cubic yards.

FIELD ROADS AND PIPELINES

Gravel roads would connect all permanent facilities in the field, that is, all drilling pads, CPF's, airport complex, water and gravel sources, and waterflood and marine facilities. These roads would have a crown width of approximately 35 feet and a thickness of 5 feet. Each mile of road occupies about 5 acres and requires approximately 40,000 cubic yards of gravel. The number of miles of roads constructed would depend upon the size and physical setting of the field.

In-field pipelines or gathering lines would run from each drilling pad to the CPF. Parallel pipelines carry gas and water from the CPF to the drilling pads for fuel, injection, or disposal. The pipelines would probably be 8-16 inches in diameter and be built parallel to the roads connecting the drilling pads and the CPF. They are commonly placed on steel vertical support members (VSM) elevated at least 5 feet. Pipelines, pump stations, and the VSM's are discussed in more detail later in this chapter.

MARINE FACILITY

Construction of a marine facility to service development of the 1002 area would be necessary because long hauls across the tundra from Prudhoe Bay are impractical. The facility built on the coast would take into consideration the locations of the proposed developments and environmental and engineering concerns. As needed, detailed engineering studies would be prepared for the marine facility size, design, and location.

The facility would contain water-treatment facilities and various supporting operations. It would be designed to receive barges loaded with the annual sealift of supplies, other cargo, and production/support modules used in the oil field's development and production. Barging these goods with an annual sealift is the most economical method of transportation and the only practical method of delivering very large modules to the North Slope. Barge routes and timing would be similar to the current annual sealift used by North Slope operators.

The facility would require one or more docks and sufficient acreage in storage pads to facilitate orderly and timely unloading of barges. A temporary camp and associated support facilities would be required during unloading periods if the main camp were too distant to provide necessary living quarters for marine facility workers. A transportation corridor would be required to connect the marine facility with the development site.

Because more than one marine facility may be necessary to economically develop and produce oil resources from the 1002 area, two locations along the coast of the 1002 area were selected for the analysis. The Camden Bay area could serve the western and central part of the 1002 area, and a site near Pokok Lagoon could serve the eastern part. These potential locations were used in creating prospect-specific development scenarios to identify and assess possible wildlife conflicts with oil development and production.

Both locations seem to be suitable, although there may be other potential sites. They both appear to have sufficient water depths seaward of the site so as not to require dredging. They also have open ice periods similar to those at Prudhoe Bay (Arctic Environmental Information and Data Center, 1983). These potential sites were not selected on the basis of detailed engineering studies and the locations may prove less desirable after such studies are conducted, should the area be opened for development.

## TRANSPORTATION OPTIONS FOR OIL AND GAS PRODUCTION

This section assesses the technology involved in the major elements of oil transportation methods. Pipelines are emphasized as the most reasonable transportation method because the Trans-Alaska Pipeline System (TAPS) is in place and operating. As production of the Prudhoe Bay oil field declines, TAPS should have adequate capacity to accommodate the Arctic Refuge oil by the 1990's. However, if TAPS capacity (about 2.2 million barrels per day, according to W. Witten, Alyeska Pipeline Service Company, Jan. 9, 1986) were inadequate, capacity might be increased by looping or by improving pipeline hydraulics. The ultimate method to increase transmission capacity significantly is to construct a second pipeline parallel to TAPS between Prudhoe Bay and Valdez. Major elements of other systems are also described and evaluated. Gas transportation is considered separately, later in this chapter.

Because of the existence of TAPS, the most probable method is assumed to be transportation of crude oil produced on the 1002 area by pipeline to TAPS pump station, thence to the ice-free port of Valdez on the southern coast of Alaska.

Prior to TAPS, little was known about constructing oil pipelines in an arctic environment. Design and construction techniques used during TAPS construction (1974-77) and in the ensuing years of development of the Prudhoe Bay and Kuparuk River oil fields have advanced the state of the technology and have proved that hot-oil pipelines can be constructed, and reliably and safely operated.

Because of ice-rich permafrost conditions throughout the area, an elevated pipeline is the most probable system for transporting oil produced from the 1002 area west to TAPS Pump Station 1. To prevent thawing, elevated pipelines supported by VSM's placed into the frozen ground are most effective.

Experience from the operation and maintenance of TAPS has shown that unacceptable settling and stress in buried pipe may occur despite systematic geotechnical investigations. Even in soils thought to be thaw stable, ice may be present and go unnoticed during construction, and it may cause problems in later years as the ice melts, causing differential settling in the pipelines.

The hot-oil, 24-inch pipeline from the Kuparuk River field to Pump Station 1 is entirely elevated on VSM's and support beams. A minimum 5-foot clearance is provided for caribou crossing; varying terrain features allow greater clearance in places. Also, caribou ramps (relatively short sections of gravel fill placed over the pipe) are provided. The Kuparuk River field pipeline support beams are constructed to carry more than one pipe.

A concept used in the Kuparuk River field pipeline, but not incorporated in TAPS, was construction of only one road for use as both a main transportation artery and a pipeline-maintenance road. A temporary ice road was used during construction of the pipeline, eliminating the need for a construction work pad. That construction placed the pipeline on the uphill side of the gravel road fill, enabling the road to act as a dam in the event of an oil spill. Cross drainage for water was provided by culverts, which could be quickly plugged if an oil spill occurred. Insofar as possible, a similar design could be proposed across level terrain in the 1002 area. Where the terrain is irregular, engineering and environmental constraints would require adjustments so the pipeline could be continued in a straight line but the road could follow the contours of the land.

### Pipelines

Several alternative pipeline routes for transporting crude oil from the 1002 area to processing facilities were considered:

1. An elevated pipeline following an east-west inland route from the 1002 area, across State lands, to TAPS Pump Station 1.
2. An elevated east-west pipeline (onshore) from the 1002 area along the Beaufort Sea coast to TAPS Pump Station 1.
3. A marine pipeline east-west (offshore) along the Beaufort Sea coast to TAPS Pump Station 1. This pipeline would require north-south feeder lines from producing fields on the 1002 area to the coastal site.
4. An elevated east-west pipeline from the 1002 area across State lands to TAPS Pump Station 1, then a new pipeline paralleling TAPS to Valdez.
5. An inland pipeline from the 1002 area east to the Canadian border, thence southeastward through the Yukon and Northwest Territories, to connect with the existing oil pipeline systems in the Province of Alberta.

The most probable route for a pipeline was determined to be an inland route, which roughly bisects the 1002 area from east to west (fig. V-1) and is the route used for the assessment of environmental effects (Chapter VI of this report). The exact route would be determined primarily by the location of hydrocarbon discoveries, and would be adjusted to minimize impact to surface resources, and to meet engineering requirements. The existing TAPS is believed to have the capacity to carry oil produced from the 1002 area by the earliest date production would start. Figure IV-4 shows a typical pipeline installation, in cross section. The pipeline could be designed like the Kuparuk River field pipeline, with support beams large enough to accommodate additional pipelines, depending on future needs for oil or gas, or possibly water. A road constructed on at least a 5-foot gravel fill would be needed to supply the oil-field facilities and give access for pipeline maintenance. Unless otherwise necessary for minimizing impacts on caribou migration or to accommodate engineering constraints, the pipeline could be built close to the upslope shoulder of the road to preclude an additional maintenance road. Access to valves, which require frequent maintenance, would probably call for a special work road connecting the valve site to the main road. In critical caribou habitat, the pipeline and main road might require separation. If so, a gravel maintenance work road might have to be constructed along the pipeline for segments where the pipeline and road are separated.

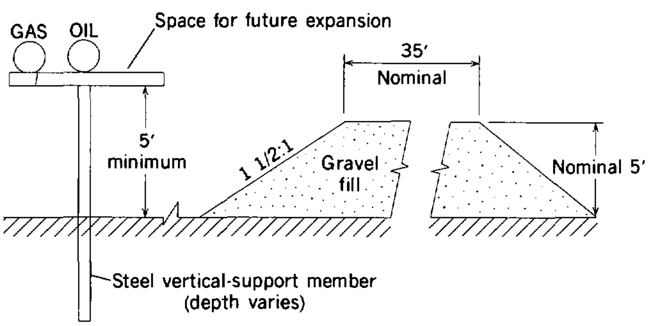


**Figure IV-4.**--Typical cross section of pipeline and road development. No scale.

Figure IV-5 shows pipeline diameters required for various pumping rates. A pump station is required every 50 to 100 miles depending on desired pumping rate and topography. Therefore, two to three pump stations probably would be required for an inland route across the 1002 area. The first would be located near the oil field or fields and the second and third between the oil field(s) and Pump Station 1. Each pump station would contain pumping, oil-storage, power, pipeline equipment and repair, and communication facilities, living quarters for about 30 people, and environmental-support systems; the station would be constructed on about a 7-acre gravel pad. Other related facilities are described below (Mechanics Research, Inc., 1977).

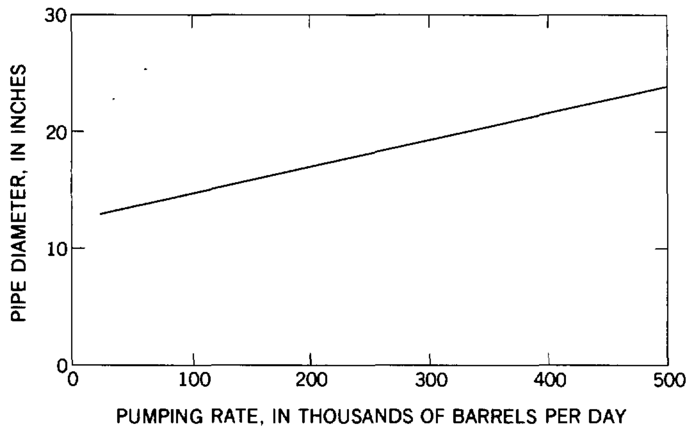


**Figure IV-5.**--Land-pipeline pipe diameter versus pumping rate. Modified from Han-Padron Associates (1985, fig. 7.2-1).

## SURGE AND STORAGE TANKS

Pipeline hydraulic design analyzes normal hydraulic gradients and also the effects of pressure surges and their control by means of suction and discharge relief protection at each pump station. Tanks at each station collect oil that is discharged through relief valves when surges occur; the collected oil is later returned to the pipeline.

## VALVES

Federal regulations (49 CFR 195.260) provide criteria for the locations and number of valves required for pipeline systems. For example, valves must be placed on each side of a water crossing more than 100 feet wide. A mainline valve system can be used to reduce the potential size of an oil spill. Valve locations are selected so that a spill at any point is limited to a predetermined maximum quantity (50,000 barrels on TAPS).

On TAPS, remotely operated gate valves close rapidly under emergency conditions to protect pump stations and environmentally sensitive areas. Check valves are used where the terrain slope allows the valve to effectively stop reverse oil flow and block potential oil spills.

## COMMUNICATIONS

Maintaining continuous control of the pipeline from the Arctic Refuge to Prudhoe Bay would require a complex communication system. The primary system could be a series of permanent microwave stations which link all pump stations, remotely controlled gate valves, and pipeline-maintenance centers with a control center. Each remote station typically includes a self-supporting steel antenna tower, two small buildings, and 2 to 4 fuel tanks, a heliport, backup generators, and a battery system. Such stations, if patterned after TAPS, could be backed up by a satellite system and would be located on relatively high ground about 40 miles apart. Also, common-carrier circuits, telephone, and mobile radio systems would be incorporated into the overall pipeline communication system.

## ROADS

As noted previously, a road would roughly parallel the pipeline across the 1002 area and continue across State lands to Pump Station 1. This permanent all-season gravel road would be built in accordance with accepted arctic engineering practices on 5-foot gravel fill, with a 35-foot-wide driving surface, and would support construction of the pipeline and link central production and marine facilities. The pipeline could be constructed during winter from a snow pad or ice road. If snow or water is not available in sufficient quantities, a gravel work road could be built. Gravel access roads would connect the main road to pump stations, valves, and maintenance stations. Emergency access to the pipeline during the summer would be accomplished by rolligon or similar vehicles. The availability of adequate gravel supplies on the 1002 area is uncertain. Gravel could be mined from inactive streambeds, but additional pits would have to be opened to obtain the large quantities of gravel required for roads, pump stations, airports, and maintenance-support facilities. Gravel might have to be mined from upland sites, river terraces, streambeds, lagoons, or other potential sites. Site selections would be based on environmental and engineering considerations as well as availability. No gravel would be removed from the active stream channels of major fish-bearing rivers or from barrier islands. All gravel removal will follow the guidelines for arctic and sub-arctic flood plains (Woodward Clyde Consultants, 1980a, b). Sites would be designed to provide fish and wildlife habitat after they are abandoned. For example, gravel-removal sites may be designed to fill with water and provide islands for migratory-bird nesting and resting habitat, littoral zones for migratory bird and fish feeding, and deep water for fish overwintering. Thus, these gravel pits can also be potential water reservoirs. Bridges and culverts would be designed and constructed to provide cross drainage for roads in a manner that prevents erosion or adverse effect to the fishery resources.

## AIRFIELDS FOR CONSTRUCTION CAMPS

Airfields may be required at pipeline construction camps and pump stations or airstrips may be shared with oil development facilities. The typical airfield for these camps would be similar to those supporting air development, that is, 5,000-6,000 feet long and 150 feet wide and 5 feet thick.

## CONSTRUCTION CAMPS FOR ROADS AND PIPELINES

Camp buildings would be portable module structures, self-contained and equipped with functional furnishings for sleeping, eating, recreation, and with sanitation facilities. A typical camp houses 150-300 people. To minimize surface disturbance, these temporary camps should be collocated with the permanent pump station sites. Production and transportation on the 1002 area would probably require two or three pump stations. Therefore, two or three camps would occupy the pump station sites; two additional temporary camps might be required. These sites could be used for 2 years and would be rehabilitated after construction or used for road maintenance camps.

## OIL-SPILL CONTINGENCY, INCLUDING LEAK DETECTION

The first lines of defense against spills are design and operational procedures (including personnel-training programs), properly designed and maintained equipment, adequate alarm systems, and strict adherence to industry and State and Federal government codes and regulations in construction and operation. It must be recognized, however, that even with the most comprehensive precautions, oil spills will occur. Operators of a pipeline across the 1002 area would be required to have an oil-spill contingency plan that, as a minimum, included provisions for oil-spill control, which consist of (1) leak-detection systems; (2) methods for locating, confining, and cleaning up spills; (3) notification procedures for local, State, and Federal agencies; (4) corrective action for the affected area; (5) various types of oil-spill equipment; and (6) site-specific cleanup techniques.

A leak-detection system would include automatic instrumented detection systems and periodic ground and aerial surveillance. For best visual ground surveillance, the road should be close to the pipeline if there is no gravel work road next to the pipeline. Aerial surveillance by helicopter or fixed-wing aircraft covers the greatest amount of area in the shortest time, but could be restricted by weather, length of daylight, and wildlife considerations.

## PIPELINE ROUTING

The 1002 area's widely diversified local environments require numerous engineering constraints regarding location and routing of pipelines, roads, and airstrips. This applies particularly to stream and ravine crossings where, to minimize environmental problems, cutbanks and braided stream areas must be avoided, especially by road crossings.

### INLAND ROUTES

The southern part of the 1002 area provides more feasible stream crossings, relatively more stable soils, better drainage, and more sources of gravel than a route nearer the coastline. The actual availability of gravel is unknown, but at least 16 borrow pits located in active flood plains were identified by the Alaskan Arctic Gas Pipeline Company as possible sources of about 2.4 million cubic yards of sand and gravel for the ANGTS (Alaska Natural Gas Transportation System--U.S. Department of the Interior, 1976, p. 10).

An inland pipeline from the 1002 area east into Canada was discussed in the TAPS and ANGTS reports (U.S. Department of the Interior, 1972, 1976). Construction of the pipeline would require a cooperative agreement between Canada and the United States, as well as Congressional authority to cross the designated wilderness area east of the Aichilik River.

## COASTAL ROUTES

A coastline route would cross more ice-rich permafrost than an inland route (U.S. Department of the Interior, 1976, p. 491). More of the route would be on thaw-unstable material; such material and the braided stream crossings would complicate pipeline construction and could compromise pipeline integrity. A coastal route would have fewer stream crossings, but more of the route would be on active flood plains and cross wider delta areas. Work pads and roads in that flat, poorly drained area could result in water-ponding problems. Construction costs of an elevated oil pipeline would be expected to be slightly higher for a coastal onshore route than for an inland route because of (1) extra length, (2) higher gravel requirements, (3) poor drainage, and (4) poorer soils for construction. The earlier ANGTS study (U.S. Department of the Interior, 1972) for a buried natural gas line along coastal and inland routes also estimated slightly higher costs for the coastal onshore route.

## SUBSEA MARINE ROUTES

For the past 15 years, the petroleum industry has been actively engaged in research and development of technology for the design and construction of subsea oil pipelines in the Arctic. Large-diameter marine-pipeline construction in the Beaufort Sea is considered to be technically feasible by some authorities (Han-Padron Associates, 1985). However, to date no marine pipelines have been constructed in the Arctic.

In general, the continental shelf of the Beaufort Sea of the Alaska coast is not more than 50 miles wide, and breaks at a water depth of 225 to 250 feet. The average duration of open-water conditions, during which a pipeline could be constructed, is approximately 50 days. A marine pipeline presents significantly higher environmental risks than does an onshore pipeline. Wherever a hot-oil pipeline is buried in permafrost, differential settling is to be expected. Any significant settling could rupture the pipe, causing an oil spill. Repair and maintenance of a marine pipeline under ice would impose almost impossible engineering problems for much of the year.

Critical environmental factors affecting the design and construction of marine pipelines include ice and weather conditions, their effect on construction equipment and the length of the construction season, the nature of the seabed soil, seabed ice scouring, and, in the permafrost zones, prevention of permafrost degradation. Marine-pipeline design, installation, and cost considerations are described below.

A major consideration in designing a marine pipeline for Arctic waters is placement of the line with regard to ice and permafrost. Shorefast ice includes all types of ice, broken or unbroken, attached to the shore, beached, stranded, or attached to the bottom in shallow water. The fast-ice zone of the 1002 area extends from shore outward to water depths of approximately 10 to 66 feet. Intense interaction between moving pack ice and shorefast ice forms a shear zone of ice ridges, which often ground on the seabed. The keels of these ice pressure ridges and occasional pieces of ice islands scour deep gouges in the subsea floor during subsequent movement of the ice. Grounded ridges may extend outward to a depth of approximately 150 feet. From shore to 50-foot seabed depth, ice scour is frequent but relatively shallow. Scour is greatest at seabed depths of 65 to 100 feet. The deepest recorded scour is 18 feet at a seabed depth of 125 feet.

In nearshore areas, ice-bonded permafrost will probably be present and must be considered in the design of an offshore pipeline (Heuer and others, 1983). But nearshore ice-wedge permafrost under shallow water, particularly along a rapidly receding coastline, is even more critical for design. A hot-oil pipeline placed in areas of ice-bonded or ice-wedge permafrost must be heavily insulated to limit thawing of permafrost and pipeline settling. The best location for an offshore pipeline is at water depths of 6.5-65 feet, to minimize ice gouging. Beyond the 6.5-foot water depth the top of the ice-bonded permafrost generally is below the surface of the seabed. Inshore of the 18-foot bottom-depth contour, ice gouging is typically less than 1.6 feet (Mellor, 1978).

An arctic marine pipeline must be laid in a trench to ensure that the top of the pipe is below maximum ice-gouging depth. Several subsea trenching methods are available but have never been used in the Arctic. Because the construction season is short, fast-moving cutter-suction dredges or subsea plows would be required. Under development are self-propelled seabed plows, rippers, or cutting devices.

Automatic block valves at intervals along the pipeline would minimize oil spillage in the event of a rupture. The only way to assure continuous operation is to have a loop line (a second pipeline parallel to the existing line) or similar built-in redundancy. Maintenance and repair work on a marine pipeline in the Arctic would not be feasible during the ice season (normally October through July).

Marine pipelines must be waterproofed and weighed down with a concrete coating to give negative buoyancy. They also must be cathodically protected from corrosion by sea water, in accordance with industry standards.

## Tankers

Transportation of petroleum products by icebreaker tanker in the Beaufort Sea has been considered for more than 15 years. However, no offshore loading terminals suitable for the area exist. Nor do designs exist for such icebreaker tankers, their support vessels, or loading terminals. Presumably, icebreaker tankers would transport crude oil to an ice-free transshipment terminal in the Aleutian Islands or on the Alaska Peninsula. Several other concepts have been considered, with or without internal storage capacity (Han-Padron Associates, 1985, p. 7-30). Greater knowledge of ice conditions and ice dynamics north of the Bering Strait is needed before the requirements and risks of operation in the Chukchi and Beaufort Seas can be adequately appraised.

A study on using submarine tankers, prepared by a team headed by the Newport News Shipbuilding and Drydock Company (NNSDC, 1975) for the U.S. Marine Administration, was updated by Han-Padron Associates (1985, p. 7-53). Han-Padron escalated the capital and operating costs in order to be able to compare transportation costs for submarine tankers with those for icebreaker surface tankers. A submarine tanker designed to operate under the Arctic icepack is limited as to propulsion methods and overall size. Current technology limits the power source to a nuclear reactor, although fuel-cell powerplants might propel smaller submarines. The original study (NNSDC, 1975) indicated that no existing shipyard could construct or maintain a submarine of sufficient size (200,000-300,000 tons deadweight) to be efficient in such an operation. The updated study suggests that the unit-transportation cost of a submarine tanker would not differ significantly from that provided by an icebreaker tanker of similar capacity. Technical problems associated with loading, construction, and operation have yet to be solved.

## Other Transportation Methods

Several other transportation systems have been proposed and discussed in detail (U.S. Department of the Interior, 1972, 1976). Only a few are discussed here, as none is a realistic alternative to a pipeline in terms of safety, economics, and environmental impact. The reader should refer to the cited reports for further information.

Two rail routes have been considered for transporting North Slope oil. The shorter, in terms of new railroad construction, is an extension of the Alaska Railroad. This railroad is State-owned and has 470 miles of track from Seward to Fairbanks. The extension would be northward across the Yukon River and the Brooks Range to the North Slope oil fields near Prudhoe Bay. The other route crosses Alaska and Canada from Prudhoe Bay to Whitefish, Montana, via Dawson, Yukon Territory. Either route would encounter major construction constraints and operational problems in accommodating, handling, loading and unloading, marshaling trains, and maintaining track and rolling stock. Potential environmental impacts are air and noise pollution, oil spills, and degradation of fish and wildlife habitat caused by roadbed construction through mountainous terrain.

Possible, but not practical, is operating a large fleet of trucks to haul oil to a southern Alaska port, for transshipment to West Coast ports, or to the north-central United States via a trans-Alaska-Canada route. High operating costs, air and noise pollution, and the high potential for oil spillage make truck transport impractical. The existing TAPS haul road (Dalton Highway) would not be adequate for such high-volume traffic, which, considering round-trip travel, would require almost bumper-to-bumper trucks.

### NATURAL GAS TRANSPORTATION SYSTEM

Since the early 1970's, industry has given serious consideration to developing a transportation system to deliver Alaskan North Slope (ANS) natural gas to the market place. Gas produced at Prudhoe Bay is currently used on-site for power generation, enhanced oil recovery, or is reinjected, inasmuch as it is not yet economical to produce for marketing.

In December 1981, the Secretary of the Interior issued a right-of-way to the Northwest Alaska Pipeline Company to construct a large-diameter, chilled, buried gas pipeline and related facilities from Prudhoe Bay to domestic markets in the lower-48 States. However, by 1985 the project sponsors had temporarily reduced their efforts to complete the Alaska Arctic Gas Pipeline until market conditions for ANS natural gas improved. A timeframe for remobilizing the project has not been identified.

In 1984, the Yukon Pacific Corporation (YPC) applied to the BLM for Federal permits to construct and operate a buried gas pipeline from Prudhoe Bay to a tidewater liquid natural gas (LNG) terminal in south-central Alaska (an area such as Valdez). That pipeline project, called the Trans-Alaska Gas System (TAGS), would export ANS natural gas to markets in Pacific Rim nations, such as Japan and Korea. Export of natural gas (or oil) outside the United States would require approval of the President of the United States, pursuant to the Mineral Lands Leasing Act of 1970. The YPC project was also suspended. But in January 1986, YPC requested the BLM to resume processing its 1984 application.

Accordingly, it is likely that a gas delivery system from Prudhoe Bay would provide ready market access for any gas discovered in the 1002 area, should it become economically recoverable.

The environmental impact statement for the Alaska Arctic Gas Pipeline project (U.S. Department of the Interior, 1976) described the overall effects that would result from construction and operation of a gas pipeline transportation system through the Arctic National Wildlife Refuge. This pipeline system proposed construction of a buried, chilled gas pipeline through the coastal plain of Arctic Refuge to the Canadian border, to facilitate production of gas from the Mackenzie delta region of Canada. However, for purposes of this report, it is presumed that commercial quantities of natural gas discovered in the 1002 area would be processed and transported west to Prudhoe Bay using shared facilities with oil development and transportation on the 1002 area. Ideally, the vertical support mechanisms for the oil delivery system to TAPS could be designed so that construction, operation, and maintenance of both oil and gas systems could be collocated. It is also assumed that gas production and transportation systems would not be constructed until after a natural gas transportation system was operational between Prudhoe Bay and markets outside Alaska, now speculated not to occur before the middle to late 1990's.

Construction of an oil transportation system from Arctic Refuge would have a higher priority than a gas transportation system due to the anticipated decline in oil from Prudhoe Bay which would make available oil capacity in the TAPS during the late 1990's. Therefore, construction of the oil and natural gas transportation systems would be sequential on the Arctic Refuge. The timing for the natural gas transportation system would depend upon the final design and delivery capability of the gas pipeline system south from Prudhoe Bay, combined with the consideration of economic factors in both domestic U.S. and foreign natural gas markets.

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# CHAPTER V

# ALTERNATIVES

## ALTERNATIVE A--FULL LEASING OF THE 1002 AREA

Under the alternative of full leasing, it is assumed that Congressional action would allow all Federal subsurface ownerships of the 1002 area to be available for development through a leasing program administered by the Department of the Interior. This action would also open to oil and gas development and production the private lands within the refuge. The exact terms of the leasing program would be developed in response to specific legislation passed by the Congress. If the Congress chooses to authorize leasing in the entire 1002 area, the legislation would probably contain the important elements of the Mineral Leasing Act and the NPRA legislations, with special provisions to meet the unique needs of the Arctic Refuge.

Presumably, major portions of the 1002 area would be leased and additional geophysical exploratory work would take place on all leased areas before exploration wells are drilled. Leaseholders would likely focus first on those areas and geologic structures believed to have the highest probability of containing commercial quantities of oil. It is feasible for phased development to occur.

The 1002 area contains a combination of identified potential petroleum prospects having a mean conditional estimated total of 3.2 billion barrels of economically recoverable oil under current and foreseeable economic conditions (Chapter III). These prospects are grouped into 4 geographic areas (blocks) of the 1002 area to facilitate an analysis of the effects of oil development on the environment. These blocks are depicted in Chapter III (fig. III-16).

Alternative A assumes that:

1. Although both oil and gas would be leased, initially only oil will be developed and transported to market. Associated gas will be reinjected and/or used for field operations in the manner similar to other North Slope fields, until it becomes economical and adequate markets are identified.

2. Oil production will start about the year 2000.

3. Development will be unitized within the 1002 area and on privately owned subsurface resources in the vicinity of Kaktovik.

4. A single trunk oil pipeline will transport oil from Federal leases and from any private lands in the 1002 area to Pump Station 1 of the Trans-Alaska Pipeline System (TAPS).

5. Development, production, and transportation of oil from the 1002 area are considered to be independent of any offshore production; however, infrastructure could be shared.

6. The State of Alaska will allow a trunk oil pipeline to cross State lands between the western boundary of the 1002 area and Pump Station 1 at Prudhoe Bay (a distance of about 50 miles).

7. Once the Congress approves leasing, but prior to lease sales, industry will be allowed to conduct additional geophysical and surface geological exploration work.

8. Surface occupancy for oil and gas purposes will not be permitted within areas formally designated by the Congress as Wilderness.

According to the size, number, and characteristics of prospects described in Chapter III, and production and transportation scenarios described in Chapter IV, the number and types of facilities likely to be required for development and production of oil resources in the 1002 area are listed in table V-1. Figure V-1 shows a conceptual placement of production and transportation facilities based on typical North Slope prospect characteristics for three localities within the 1002 area.

Actual placement of oil production facilities and marine facilities on the 1002 area, or location of the trunk pipeline from producing fields to TAPS Pump Station 1, depends upon site-specific geotechnical, engineering, environmental, and economic data that can be determined only after a specific prospect has been drilled, and a discovery made and confirmed.

Chapter IV describes the types and numbers of facilities that might be necessary for oil production in the 1002 area. Typically, these include for each developed prospect: central processing facility (CPF) and initial pump station for the oil pipeline, all-weather airfield, consolidated production and reinjection well pads, and an internal network of roads and gathering lines connecting pads and the CPF. A trunk oil pipeline would connect the CPF to Pump Station 1. From Pump Station 1, oil from the 1002 area would move through the existing TAPS to Valdez and then by tanker to market. Depending on the amount of final through-put, one or several additional pump stations may be required.

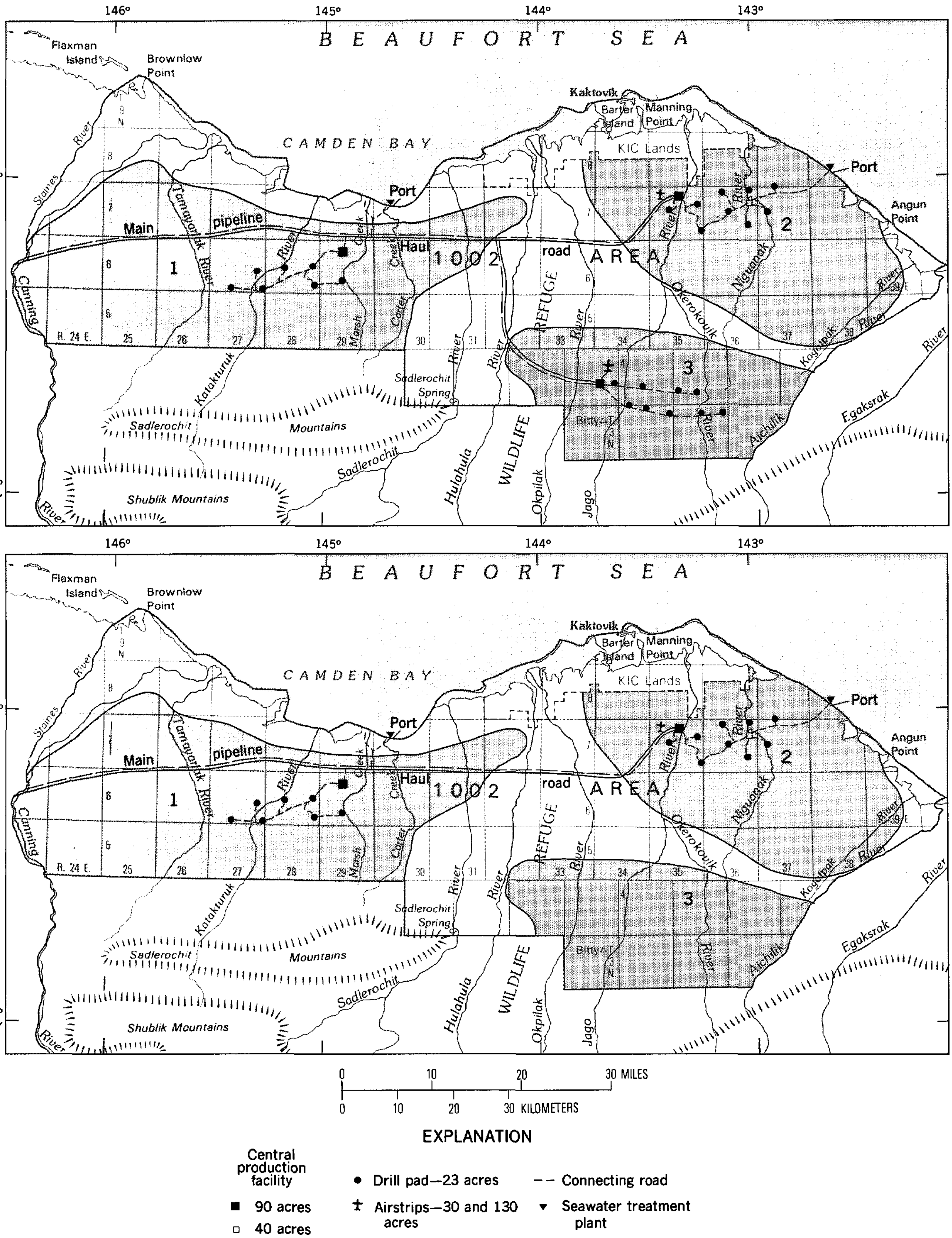


**Figure V-1.**--Hypothetical generalized development of the 1002 area under full leasing (upper) or limited leasing (lower) if economic quantities of oil are discovered. Numbers indicate three localities (shaded) having typical prospect characteristics.

**Table V-1.**--Number and area of in-place oil-related facilities assumed to be associated with development of estimated mean conditional recoverable oil resources made available by full leasing or limited leasing of the 1002 area.

[mi, miles; cu yds, cubic yards; ac, acres]

| Facility | Approximate units[1] | |
|---|---|---|
| | Full leasing | Limited leasing |
| Main oil pipeline within the 1002 area[2] | 100 mi (610 ac) | 80 mi (490 ac) |
| Main road paralleling main pipeline and from marine facilities[2] | 120 mi (730 ac) | 100 mi (610 ac) |
| Spur roads with collecting lines within production fields | 160 mi (980 ac) | 120 mi (730 ac) |
| Marine and salt water treatment facilities | 2 (200 ac) | 2 (200 ac) |
| Large central processing facilities | 7 (630 ac) | 6 (540 ac) |
| Small central processing facilities | 4 (160 ac) | 3 (120 ac) |
| Large permanent airfields | 2 (260 ac) | 2 (260 ac) |
| Small permanent airfields | 2 (60 ac) | 1 (30 ac) |
| Permanent drilling pads | 50-60 (1,200-1,600 ac) | 30-40 (700-1,000 ac) |
| Borrow sites | 10-15 (500-750 ac) | 8-13 (400-650 ac) |
| Gravel for construction, operation, and maintenance | 40 million-50 million cu yds | 35 million-40 million cu yds |
| Major river or stream crossings | Maximum 25 | Maximum 15 |

[1]Figures given in miles refer to linear miles of the facilities. Areas were calculated on the basis of 50-foot widths each for the main oil pipeline and main road, totaling a 100-foot right-of-way for the main transportation corridor. A 50-foot right-of-way was assumed for spur roads with collecting lines. The numbers of nonlinear units are also provided.

[2]The distance from the 1002 western boundary to TAPS Pump Station 1 is approximately 50 miles, across State of Alaska land. This 50 miles is not included in the mileage estimates.

## ALTERNATIVE B--LIMITED LEASING OF THE 1002 AREA

This alternative discusses a leasing program that would develop if the Congress chose to pass legislation, based on environmental considerations, that would limit the amount of the 1002 area available for leasing. There would be no leasing, exploration, development, or transportation of oil from or through the traditional core calving area of the Porcupine caribou herd (Chapter II and pl. 2A). The remainder of the 1002 area would be offered for leasing; presumably, all potentially economic prospects would be leased, explored, and developed. The assumptions in this alternative are the same as for full leasing, including the opening of the KIC and ASRC lands. Approximately 2.4 billion barrels (800 million barrels less than in Alternative A) of economically recoverable oil are estimated as the mean conditional resource which might be available for development under this alternative.

A conceptual placement of production and transportation facilities under the limited leasing alternative is also shown on figure V-1.

Production and transportation facilities were described in the full leasing alternative. Under limited leasing, facilities would not be constructed in the core caribou calving area. All other facility requirements would be virtually the same (table V-1).

## ALTERNATIVE C--FURTHER EXPLORATION

Under this alternative, the Secretary would recommend additional exploration, to include exploratory drilling, to permit acquisition of more data to aid the Secretary and the Congress in their decision of whether or not to authorize leasing of the 1002 area. Acquisition of additional data could be by the Government, or industry, or both.

Section 1002 of ANILCA has afforded the Department of the Interior the opportunity to acquire a substantial amount of exploration data in the 1002 area. During two winter field seasons, private industry obtained 1300 line miles of seismic data on a 3x6-mile seismic grid over a large part of the 1002 area. A substantial amount of gravity, magnetic, geochemical, paleontological, and shallow stratigraphic data was also collected. The BLM and GS acquired additional data through in-house research and field investigations over several field seasons.

Analysis of the available geological and geophysical data has revealed that the 1002 area is a very complex geological terrane, and additional geological and geophysical data might provide a basis for a more defined assessment of the oil and gas potential of the 1002 area. Additional seismic data could better define some of the more complex geologic structures that have been identified. It is expected that if a decision was made to allow leasing of the 1002 area, industry would want to obtain more detailed seismic data over particular areas of interest in order to make a more accurate determination of oil and gas potential prior to a lease sale. These data would also be made available to the Department for its use in determining the fair market value of tracts to be leased.

The location and size of geologic structures have been generally defined. However, the nature of the rocks present remains virtually unknown, owing to a lack of deep stratigraphic, paleontological, and geochemical data specific to the 1002 area. Therefore, only indirect inferences based on surface and near-surface geological data and on well data outside the 1002 area can be made as to the nature of source and reservoir rock and the type of hydrocarbon present. A program to drill off-structure test wells would provide subsurface geological information on the 1002 area and eliminate some of the uncertainties in the oil and gas assessment such as the probability of the occurrence of adequate source and reservoir rocks, and also the probable mix of hydrocarbons. This type of information might better define the more prospective parts of the 1002 area that should be considered for leasing.

Four deep test wells could be drilled off-structure similar to the stratigraphic test wells (COST wells) drilled in the Outer Continental Shelf. These wells would provide more definitive data on the stratigraphy, paleontology, geophysics, and geochemistry of the rock formations present. Core samples would be taken to determine the quality of the source rocks, the characteristics of the reservoir rocks, and the availability of seals to trap hydrocarbons. Possible locations for stratigraphic test wells are:

1. East of the Canning River in the northwest block (Block A, fig. III-16) to test primarily for geologic conditions similar to those of the Prudhoe Bay field.

2. Near the Hulahula River between the Marsh Creek anticline to the west and larger mapped geologic structure to the east (Block B, fig. III-16 and fig. III-9).

3. In the northeastern part of the 1002 area north of the large mapped geologic structure and south of the Kaktovik lands (Block C, fig. III-16, and fig. III-9).

4. Near the large mapped geologic structure in the southern foothills (Block D, fig. III-16, and fig. III-9).

## ALTERNATIVE D--NO ACTION

This alternative describes the probable future management of the 1002 area if the Congress chose to take no further legislative action regarding the 1002 area of the Arctic Refuge. According to the provisions of sections 1002 and 1003 of ANILCA, an act of the Congress would be prerequisite to leasing or other development leading to oil and gas production on the Arctic Refuge. If the Congress chose instead to designate all or part of the 1002 area as wilderness, that too would take legislative action. If instead, the Congress chose to allow the management of the 1002 area to continue under existing legal authorities guided by the Arctic Refuge comprehensive conservation planning (CCP) process outlined by section 304(g) of ANILCA, no additional Congressional action would be required.

The management goals of the Arctic National Wildlife Refuge, until further defined by the CCP process, are to maintain the existing availability and quality of refuge habitats with natural forces governing fluctuations in fish and wildlife populations and habitat change; provide the opportunity for continued subsistence use of natural resources by local residents, in a manner consistent with sound natural resource management; and provide recreational and economic opportunities compatible with the purposes for which the refuge was established.

Section 304(g) of ANILCA mandates that management of the 16 National Wildlife Refuges in Alaska, including the Arctic Refuge, be assessed through the CCP process. This process requires that the plan: (1) designate areas within the refuge according to their respective resources and values; (2) specify the programs proposed for conserving fish and wildlife and maintaining the values for which the refuge was established; and (3) specify uses which may be compatible with the major purposes of the refuge. The preferred alternatives identified in this process would establish the long-term basic management direction for each refuge. This planning process allows for the evaluation of a range of alternatives for refuge management and consultation with the appropriate State agencies and Native Corporations. The FWS is using the environmental impact statement (EIS) process to implement the CCP's. Following a series of public scoping activities and a comment period on a draft EIS, a preferred alternative would be chosen by the Alaska FWS Regional Director, described in a final EIS, and documented by a Record of Decision.

Currently, the CCP process for the Arctic Refuge is in the first or scoping and data-collection phase and calls for completion of the CCP by the spring of 1988. The 1002 area has been deleted from this planning process, pending the decision of the Congress as to its future management. If this no-action alternative were selected by the Congress, the 1002 area would be added to the planning process as an integral part of the Arctic Refuge. Depending on the stage of planning, at least the CCP, and perhaps some step-down management plans, would need to be amended or supplemented to include management of the 1002 area.

Under section 1008 of ANILCA, a policy was established to permit certain oil and gas activities, including leasing and development, on Alaska refuges in areas where such activities are deemed to be compatible with the major purposes for which a particular refuge was established. Because of the provisions of sections 1002 and 1003, section 1008 does not apply to any part of the Arctic Refuge. Selection of Alternative D would preclude production of oil and gas from the Arctic Refuge, and leasing or other develoment leading to oil and gas products.

Step-down management plans for the Arctic Refuge would be developed for specific activities once the CCP was completed. These management plans might address activities such as public use, wildlife inventories and other scientific research, wild and scenic rivers, wilderness management, and fire management. Harvest of fish and wildlife would generally be conducted in accordance with the State of Alaska Department of Fish and Game regulations, and subsistence use of the refuge would continue.

The Arctic Refuge would be managed under the legal authorities found in ANILCA and the National Wildlife Refuge System Administration Act of 1966 (Public Law 89-669). Other laws and their amendments that affect the management of the 1002 area and the Arctic Refuge in general include but are not limited to the Migratory Bird Treaty Act, Endangered Species Act, Antiquities Act, Clean Air Act, Clean Water Act, Coastal Zone Management Act, Fish and Wildlife Act of 1956, Marine Mammal Protection Act, National Environmental Policy Act, National Historic Preservation Act, Refuge Recreation Act, Refuge Revenue Sharing Act, and the State of Alaska Fish and Game Regulations. Provisions of the Wilderness Act would apply to those 8 million acres of the Arctic Refuge outside the 1002 area.

Activities proposed for the 1002 area would be subject to a compatibility determination as required by ANILCA section 304(b) and the Refuge Administration Act. Permissible activities could include hunting, fishing, subsistence harvest, river trips, hiking, photography, and certain other forms of recreation and compatible scientific research. Guiding for recreational activities, trapping, and other commercial activities determined to be compatible with refuge purposes also would be allowed. These commercial activities could conceivably include activities as diverse as onshore support and transportation facilities for offshore oil and gas activities. Any proposed activity would be reviewed for compatibility before it could be permitted. Because compatibility determinations are very site-specific, and the list of probable activities long and speculative, effects of specific activities are not assessed in Chapter VI.

The establishment of aids to navigation and facilities for national defense would be authorized under ANILCA section 1310. Weather, climate, and research facilities could also be permitted.

Title XI of ANILCA governs access on Federal lands in Alaska. Authorized forms of access on the Arctic Refuge include snowmachines (during periods of adequate snow cover), aircraft, motorboats, and other means if found compatible.

Refuge management could include activities such as wildlife surveys, reintroduction of native fish and wildlife species, fisheries management, prescribed burning for habitat enhancement, and construction of public use facilities where appropriate. Although these activities are allowed by law, their actual implementation and the extent of implementation would be decided through the CCP process and the subsequent management plans.

Implementation of Alternative D would preclude the development of estimated oil resources, as discussed in Chapters III and VII.

## ALTERNATIVE E--WILDERNESS DESIGNATION

Under this alternative, the Congress would designate the 1.55-million-acre 1002 area as wilderness, within the meaning of the 1964 Wilderness Act (Public Law 88-577).

No further study or public review is necessary for the Congress to designate the 1002 area as wilderness. Previous studies and public debate have sufficiently covered the issue. A wilderness review of the Arctic Refuge was conducted in the early 1970's pursuant to the provisions of the Wilderness Act. A draft report was prepared in 1973; however, the draft was never made final nor was public comment obtained.

The issue of wilderness designation for all of the Arctic Refuge, including the 1002 area, was debated extensively by the Congress and the public in widely held hearings from 1976 through 1980 during the development and passage of ANILCA (Eastin, 1984). The House of Representatives generally favored designation of the 1002 area as wilderness, whereas the Senate generally did not. The Senate view was that designating the area as wilderness was premature until a resource assessment of the oil and gas potential was completed and reviewed by the Congress. The Senate view prevailed and became the section 1002 portion of Title X of ANILCA.

The draft report resulting from the original wilderness study recommended that all of the original 8.9 million acres of the Arctic Refuge be designated as wilderness, with the exception of 74,516 acres consisting of tracts at Camden Bay (456 acres), Beaufort Lagoon (420 acres), Demarcation Point (10 acres), Lake Peters (10 acres), the village of Kaktovik (141 acres), the military withdrawal on Barter Island (4,359 acres), and land in the vicinity of Barter Island that was to be selected by the Kaktovik Inupiat Corporation (KIC) under the Alaska Native Claims Settlement Act (ANCSA) (69,120 acres). Section 702(3) of ANILCA ultimately designated approximately 8 million acres of wilderness on the Arctic Refuge which encompassed all of the pre-ANILCA refuge with the exception of the 1002 area.

This alternative considers wilderness designation of the entire 1.55-million-acre 1002 area, except for the abandoned DEW line sites at Beaufort Lagoon and Camden Bay, native allotments, and land owned by KIC. The 1002 area would still be included in the CCP process, as described in Alternative D, but would be managed as wilderness under the provisions of the Wilderness Act, the National Wildlife Refuge System Administration Act, and ANILCA.

Permitted uses in wilderness include hunting, fishing, backpacking, river trips, and photography. Commercial activity would be restricted to commercial guiding for such activities. These activities may be restricted or eliminated if necessary in designated wilderness areas under the provisions of other laws or regulations. Motorized equipment would generally be prohibited. Exceptions would include operation of aircraft, including landing. Wilderness designation would not affect the air space over the area. The use of motorboats and snowmachines (during periods of adequate snow cover) would be authorized for traditional activities--for example, subsistence uses or for access to inholdings such as native allotments. Cabins could be constructed in wilderness areas if they were necessary for subsistence trapping, public safety, or administration of the area.

In contrast to the "no-action" alternative, use of motorized equipment by the FWS in administering the area would only be allowed consistent with the minimum-tool concept. (Minimum-tool concept is use of the minimum action or instrument necessary to successfully, safely, and economically accomplish wilderness management objectives.) Situations for which motorized access might be used include emergencies involving public health or safety and search-and-rescue operations. Landing of aircraft would be permitted. Other government agencies (local, State, and Federal) would also be allowed to use motorized equipment in carrying out legitimate activities in wilderness consistent with the minimum-tool concept. An example would be the use of helicopters by the Department of the Interior to carry out the ANILCA section 1010 Alaska Mineral Resource Assessment Program (AMRAP). Management activities such as wildlife control, prescribed burning, habitat rehabilitation, predator control, reintroduction of native fish and wildlife species, and wildlife surveys would be permissible, though not necessarily practiced, in the designated wilderness area. The appropriateness of these activities would be addressed in the CCP.

As in the "no-action" alternative, placement and maintenance of navigation aids, communication sites and related facilities, and facilities for national defense could be permitted (ANILCA section 1310). Facilities for weather, climate, and fisheries research could also be permitted.

Implementation of this alternative precludes the development of estimated oil resources, as discussed in Chapters III and VII.

## REFERENCE CITED

Eastin, K. E. 1984, Wilderness review for Arctic National Wildlife Refuge's 1002 area: U.S. Department of the Interior, Office of the Solicitor, 21 p.

# CHAPTER VI

# ENVIRONMENTAL CONSEQUENCES

## INTRODUCTION

This chapter analyzes and discusses the potential environmental effects of activities that could occur from implementing any of the alternatives described in Chapter V:

Alternative A: Full Leasing
Alternative B: Limited Leasing
Alternative C: Further Exploration
Alternative D: No Action
Alternative E: Wilderness Designation.

The impacts of Alternatives A through E are summarized and compared at the end of this chapter.

Development, if it occurs, may differ somewhat from the scenarios assessed here. However, the magnitude and types of effects should be reasonably comparable. The analysis of oil development is based on best available information as to possible location and size of mappable prospects delineated by the seismic surveys. Additional exploration would further refine these data. Oil and gas may be discovered in other parts of the 1002 area or the areas now delineated may be nonproductive; the magnitude and types of effects should not change significantly. If the area is opened to leasing, this will be subject to reassessment at appropriate stages as the development proceeds.

The environmental effects described in this chapter are based on scenarios developed for the mean estimated recoverable resource figure of 3.2 billion barrels of oil. There is a 5-percent chance that 9.2 billion barrels of oil could be recovered. The environmental effects associated with this 5-percent case would likely result from the extended development of 2 or 3 of the largest prospects if they contain a much larger volume of oil than expected. The effects would not increase proportionally with increased production.

Based on development of the large field at Prudhoe Bay, well spacing for prospect(s) contributing to the 9.2-billion-barrel recoverable estimated would be assumed at the 160-acre average, the same as that for the 3.2-billion-barrel case, and field life would be expected to remain at about 30 years. The majority of any additional surface impacts would be due to expansion and modification of the infrastructure used to develop the individual oil fields. This could mean construction of additional drilling and production pads, and additional production facilities and connecting lines. These facilities would still be concentrated within the boundaries of the field, so impacts would be largely confined to the same surface area as assessed at the 3.2-billion-barrel mean recoverable case.

The additional production from the 5-percent case is not likely to significantly change the impacts of a main oil pipeline, haul road, airstrips, ports, and their supporting roads and infrastructure from that required to develop the mean estimated case. A larger diameter oil pipeline could be used to accommodate increased oil production. Additional disturbance and displacement might occur due to increased or prolonged traffic on the roads and at the port sites. The roads and port facilities anticipated for the mean case development should be capable of handling that increased traffic.

Whether or not the development of potential gas resources becomes economic, gas development and the infrastructures to support it would be expected to share oil development and transportation facilities to the extent possible. Therefore, no appreciable increase in environmental impacts is anticipated. Development of gas would require separate approval and would be subject to appropriate environmental review prior to such approval.

### Developing the Assessment

To determine the potential environmental consequences of the various alternatives, a Fish and Wildlife Service (FWS) environmental assessment team was formed in February 1985. This team of biologists met with Bureau of Land Management (BLM) and Geological Survey (GS) scientists to determine the scope and probable surface modifications required for effects of oil development on the 1002 area. Maps of fish and wildlife use areas (pls. 1-3) were overlaid with full and limited development scenarios (fig. V-1). This allowed measurement of direct habitat loss or alteration. Determinations were then made as to the nature and magnitude of direct and indirect habitat losses, disturbance, mortality, and other potential effects. Effects are characterized as either major, moderate, minor, or negligible (table VI-1) for the physical, biological, and socioeconomic features of the 1002 area that would be affected. Effects that could likely persist 20 years or more were considered "long-term" and those likely to persist less than 20 years were considered "short-term."

The scenarios for development in Alternatives A and B depict hypothetical infrastructures based on a projected hydrocarbon potential at the mean economically recoverable resource estimate. As mentioned earlier, if the 5-percent-probability production occurs, the effects remain basically the same. In Alternative A, three portions of the 1002 area --western, eastern, and southern--are all predicted as being developed, and the assessment considers all three areas as developed concurrently. In fact, however, development would likely occur sequentially. Therefore, the analysis and consequences may represent a higher level of development than may actually occur at any specific time if the area were opened to leasing. This factor was recognized and, because any prediction as to the various stages of development at any given time on the 1002 area would be highly speculative and perhaps misleading, the FWS chose

**Table VI-1.**--Definitions of environmental effects.

[Long-term, 20 years or more. Short-term, less than 20 years]

| Effect level | Definition |
|---|---|
| | Physical resources |
| Major | Widespread modification of considerable severity in landforms, surface appearance, or distribution of physical resources, or contamination of those resources, lasting several tens of years. Modifications could occur during development/production phase. |
| Moderate | Local modification of considerable severity in landform, or surface appearance, or contamination of physical resources, lasting several tens of years; or widespread modification of lesser severity in surface appearance or other characteristics of physical resources, lasting from a few years to several tens of years. Modifications could occur during the exploration phase. |
| Minor | Localized, relatively isolated change lasting from less than 1 year to no more than 10 years, with no observable residual modification in surface appearance, distribution, or other characteristics of physical resources. |
| Negligible | Little or no change in the surface appearance, distribution or other characteristics of physical resources. |
| | Biological resources |
| Major | Widespread, long-term change in habitat availability or quality which would likely modify natural abundance or distribution of species using the 1002 area. Modification will persist at least as long as modifying influences exist. |
| Moderate | Widespread, short-term change in habitat availability or quality which would likely modify natural abundance or distribution of species using the 1002 area; or local modification in habitat availability or quality which would likely modify natural abundance or distribution at least as long as modifying influences exist. |
| Minor | Short-term, local change of species abundance, distribution, habitat availability, or habitat quality. |
| Negligible | Little or no change in population, habitat availability, or habitat quality. |
| | Socioeconomic resources |
| Major | Requires substantial changes in governmental policies, planning, or budgeting, or is likely to affect the economic or social well-being of residents of the area. |
| Moderate | Requires some modification of governmental policies, planning, or budgeting, or may affect the economic or social well-being of residents of the area. |
| Minor | Requires marginal change in governmental policies, planning, or budgeting, or may marginally affect the economic or social well-being of residents of the area. |
| Negligible | Not sufficient to have any measurable effect on governmental policies, planning or budgeting, or any measurable effect on the economic or social well-being of residents of the area. |

to perform the analysis as if concurrent development were to take place.

A high degree of interest and concern for effects on the Porcupine caribou herd exists. Because of the general lack of relevant information concerning probable reactions of that specific herd to oil development, the assessment team consulted with caribou biologists from the State of Alaska, the oil industry, universities, Canada, and within the FWS itself. In November 1985, a meeting with 14 biologists was held to specifically address the potential effects of oil development within the 1002 area on the Porcupine and Central Arctic caribou herds and to compare the experiences gained from oil development at Prudhoe Bay and its effect on the Central Arctic herd. These experts evaluated a scenario approximating the magnitude of development likely to occur from developing prospective areas identified by the BLM and GS in their preliminary studies. The location of development in that scenario was modified to prevent disclosure of any proprietary data. On the basis of their studies of the Porcupine and Central Arctic caribou herd biology, and of caribou reactions to arctic oil development and other disturbances, these experts assisted the assessment team by providing information and ideas on the types and magnitude of possible effects. Recommendations on appropriate mitigation were developed during the workshop and a report of the proceedings was prepared (Elison and others, 1986).

## Fish and Wildlife Service Mitigation Policy

Many potential effects of development can be avoided or minimized through mitigation. The FWS Mitigation Policy (46 F.R. 7644-7663, January 23, 1981) guided the assessment team in identifying appropriate measures for mitigating avoidable adverse impacts so there would be no unnecessary adverse effects. The policy is focused especially on losses of habitat value.

The mitigation policy lays out a process based on the Council on Environmental Quality's definition of mitigation: "(a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and (e) compensating for the impact by replacing or providing substitute resources or environments" (40 CFR, Part 1508.20[a-e]).

The FWS would emphasize early and continuous consultation and coordination with leaseholders, permittees, and State and Federal agencies at the start of planning. Performance standards would be developed for safety and environmental requirements rather than adherence to highly specific design or operational procedures. This flexibility would encourage development of improved technology while maintaining high environmental and safety standards. Site-specific mitigation measures, including design and construction techniques, would be addressed early in the planning. These measures can be instituted in contracts and stipulations required by the FWS in special-use permits or other authorizations. If development or further exploration is authorized, addressing mitigation concerns early in the planning should benefit all parties, resulting in environmentally responsible development with no unnecessary adverse effects.

The five elements of this definition--avoiding, minimizing, rectifying, reducing or eliminating, and compensating impacts--represent the sequence of steps in the mitigation process. At whatever point the mitigation goal is achieved, the step-down process ceases.

In developing this assessment the first four elements were used for recommending mitigation for avoidable effects of the alternatives. Mitigation is considered in terms of current technology and standard requirements on previous oil developments in the Arctic. This includes safety and environmental stipulations that conform with available technology and industry practice. It should be noted that advances in technology by the time any development takes place might result in changes in the amount or type of mitigation that would be recommended.

Recommendations for mitigation vary depending on the fish and wildlife species being considered and the planning goals. The mitigation policy calls for the selection of important fish and wildlife species (evaluation species) to function as indicators of habitat quality. Selection of evaluation species has an important role in determining the extent and type of mitigation necessary. Five evaluation species were selected in the 1002 area (table VI-2). These species all have high public interest or ecological values, and are the focus for impact analysis, including mitigation recommendations, in this chapter. However, effects to all other species and resource concerns described in Chapter II are also considered and generally assessed, and additional mitigation needs are identified as appropriate.

**Table VI-2.**--Evaluation species for the 1002 area resource assessment.

| Common name | Scientific name |
|---|---|
| Caribou | Rangifer tarandus granti |
| Muskox | Ovibos moschatus |
| Polar bear | Ursus maritimus |
| Snow goose | Chen caerulescens |
| Arctic char | Salvelinus alpinus |

The mitigation policy also has four resource categories with corresponding mitigation planning goals to ensure that the level of mitigation recommended is consistent with the fish and wildlife resource values involved (table VI-3). Designation of resource categories and

**Table VI-3.**--Resource categories and mitigation goals.

[FWS Mitigation Policy: FR, v. 46, no. 15, January 23, 1981. Habitat value: a measure of the suitability of an area to support a given evaluation species]

| Resource category | Designation criteria of habitat to be affected | Mitigation planning goal |
|---|---|---|
| 1 | Habitat of high value for evaluation species. Unique and irreplaceable on a national basis or in the ecoregion. | No loss of existing habitat value. |
| 2 | Habitat of high value for evaluation species. Relatively scarce or becoming scarce on a national basis or in the ecoregion. | No net loss of in-kind habitat value. |
| 3 | Habitat of high to medium value for evaluation species. Relatively abundant on a national basis. | Minimize loss of in-kind habitat value. No net loss of value. |
| 4 | Habitat of medium to low value for evaluation species. | Minimize loss of habitat value. |

consequent determination of mitigation goals is based upon the habitat values assigned to specified evaluation species. This habitat value is a measure of the suitability of the area to support a given evaluation species.

The mitigation policy recommends that legally designated or set-aside areas, such as National Wildlife Refuges, be given special consideration as either Resource Category 1 or 2. As described in Chapter II, high-value habitat for each of the five evaluation species exists within the 1002 area. The Porcupine caribou herd (PCH) core calving area is considered unique and irreplaceable. Habitat in this area has been designated Resource Category 1 (pl. 2A) because of its high fish and wildlife values, particularly for PCH caribou. The remainder of the 1002 area has been designated Resource Category 2.

The FWS normally recommends that all losses of Resource Category 1 habitat be prevented, as these one-of-a-kind areas cannot be replaced. Insignificant changes that do not result in adverse impacts on habitat value may be acceptable, provided they will have no significant cumulative impact.

### Assumptions

Assumptions used in the physical, biological, and socioeconomic assessments include:

1. The Secretary of the Interior, through the FWS, would retain authority to issue refuge special-use permits for activities in the 1002 area, and to provide site-specific stipulations for all necessary authorizations.

2. Planning, design, construction, operation and maintenance, and rehabilitation would be accomplished using the most current available technology and practices. It is assumed that the 32 mitigation measures summarized at the end of this chapter, or measures as least as effective, will be included in development, construction, and operation plans, and will be implemented.

3. Any authorized operations and related activities would comply with all applicable Federal and State laws and regulations, as well as with any special laws and regulations the Congress or the Secretary of the Interior promulgate to govern activities on the 1002 area.

4. The environmental protection standards governing the seismic exploration program on the 1002 area (50 CFR 37.31-33) and the land-use stipulations for exploration drilling on the KIC/ASRC lands (August 9, 1983, agreement between ASRC and the United States) would continue to be in effect for oil and gas activities in the 1002 area. This would include special protections for terrestrial and aquatic environments and cultural resources, and designation of special areas such as Sadlerochit Spring. These regulations and stipulations may duplicate some of the mitigation measures recommended in this analysis, but also include specific references to the handling and disposal of garbage, combustible and noncombustible solid wastes, used equipment, sewage and gray water, fuel and hazardous or toxic materials, and provision for hazardous substances control and contingency plans.

## ALTERNATIVE A--FULL LEASING

### Effects on Physical Geography and Processes

Potential and probable impacts to the physical environment of oil development resulting from a full leasing program on the 1002 area are considered in four phases, each having progressively greater impact: geological and geophysical (principally seismic) exploration; exploratory drilling; development drilling; and construction of all-season roads, oil transmission pipelines, and marine and production facilities.

CONSEQUENCES OF GEOLOGICAL AND GEOPHYSICAL EXPLORATION

Additional geological surveys or studies during the snow-free months would not be expected to affect the physical environment on the 1002 area. These surveys are brief: the investigators arrive by helicopter, study and measure geologic sections, perhaps take a few hand-sized samples of rock, and, at most, remain on the ground for a few hours. The principal effect is noise generated by the helicopter during arrival and departure.

Effects of additional seismic exploration would be similar to effects of the seismic surveys during the winters of 1983-84 and 1984-85. Although the total line miles of new surveys might not differ much from the 1300 line miles run previously on the Arctic Refuge, more crews may be on the area. Different companies have different ideas as to where to concentrate detailed surveys (closer grid spacing); and different types of data and parameters are useful to companies in their interpretations of subsurface geological structures or style. Additional crews could increase the overall impact, mainly from increased mobilization to and demobilization from the 1002 area.

Effects of seismic exploration generally result from overland travel of seismic trains. The effect is to the tundra which, if broken or scarred, can cause thawing of the upper ice-rich permafrost during the succeeding summers. Such thawing in flat areas will cause ponding at the junction of the ice-wedge polygons, altering the appearance of the tundra landscape. However, if the thawing occurs on sloping ground, erosion can occur. If that erosion and its products terminate at a stream, local silting may result.

Surface effects of seismic surveys can be minimized by confining operations to the winter after the active layer is frozen to a depth of at least 12 inches and the average snow depth is about 6 inches. Seismic trains are generally routed through terrain where it is easier to move equipment, so potential for surface damage is minimized even though the routing may not provide the shortest travel distance. Gently sloping banks would be selected for the entry and exit to all stream crossings, to reduce equipment strain and avert bank damage which could cause erosion and stream siltation. This is very important on the 1002 area where, even though the topographic relief is not great, streambanks are steep along many drainages.

The effect of seismic operations on water resources would be negligible. Seismic trains use about 2,000 gallons of water per day for domestic purposes. Crews obtain water from lakes that do not freeze to bottom, where available. When such lakes are not available, a small snow or ice melter is used to obtain domestic water supplies. Minor amounts of local noise and air pollution result from equipment operation; these effects are brief and transitory. Minor fuel spills could also occur.

No ice roads or airstrips would be constructed to support seismic operations. Light, fixed-wing aircraft would be used for resupply and would land on 2,000-foot-long ice airstrips scraped on the nearest lake or pond. Occasionally, ski-equipped aircraft that can land on the snow-covered tundra can be used if there are no lakes nearby.

CONSEQUENCES OF EXPLORATORY DRILLING

Exploratory drilling requires heavy construction equipment to prepare the wellsite for the drilling operation and to prepare an airstrip large enough for Hercules C-130 aircraft. The drilling rig and the ancillary equipment are massive, usually requiring 110 to 180 C-130 loads, depending on the size of the rig. Drilling rigs must be set on a firm foundation, usually piles, not susceptible to differential settlement.

On the 1002 area, obtaining water for drilling and ancillary needs such as ice roads and airstrip construction could be a serious problem and the greatest potential for effects on the physical environment. Water in the 1002 area is confined to surface resources, and there are few lakes of any appreciable size within the 1002 area. A few shallow thaw lakes occur near the coast east of the Canning River and a few are found east of the Hulahula-Okpilak delta. However, the latter are on private lands outside the 1002 area. A few small, shallow thaw lakes also are found in a north-south band east of the Jago River. Of all the lakes, only the two near the Canning River are larger than 1 square mile, or long enough to accommodate a C-130 airstrip entirely on lake ice. The rivers on the 1002 area, for much of their lengths, are dry or virtually dry during the winter, and where they do have water, fish populations may overwinter.

As much as 15 million gallons of water may be needed to drill one exploratory well. Taking this amount of water from the water-deficient 1002 area could have a major adverse effect.

Ice roads constructed on the NPRA had virtually no effect on tundra. The longest road was 38 miles, with an average minimum thickness of 6 inches to keep from breaking under heavy loads. Ice airstrips on the NPRA were built with a minimum thickness of 12 inches for safety. Ice airstrips have been constructed in the same place a second season, with virtually no effects on tundra.

The area disturbed by activity at the wellsite is usually about 10 acres, including the area for the reserve (mud) pit.

When drilling is completed, the reserve pit will contain well cuttings; muds containing barite, bentonite, and some traces of oils used during drilling to "slicken" up the drill bit; chemical residues, principally the chlorides of salts used during the drilling process; fillers such as ground walnut shells; and water from snow that has blown into the pit during the winter.

The FWS has undertaken investigations into the effects of reserve pit fluid discharges on water quality and the fresh-water macro-invertebrate community of tundra ponds. The aquatic macro-invertebrates studied were resident species, sensitive to local environmental change. They were also known to be sensitive indicator organisms for a wide variety of environmental pollutants, and an important food source to the approximately 150 species of waterfowl, seabirds, shorebirds, raptors, and passerines using the North Slope for nesting, rearing, molting, and feeding.

Preliminary results of those investigations show gradients of increase in pH, salinity, alkalinity, turbidity, and sediment loads from control ponds to ponds adjacent to reserve pits (R. L. West and E. Snyder-Conn, unpublished data). Trends of increase in the vicinity of reserve pits were also shown for heavy metals such as aluminum, barium, chromium, zinc, and arsenic, as well as for certain hydrocarbons. Moreover, there were concomitant decreases in oxygen levels, total taxa, taxa diversity, and invertebrate abundance in tundra ponds associated with reserve pits. West and Snyder-Conn postulated that increased turbidity interfered with filter feeding and respiration, decreasing the overall primary productivity of affected waters. Detrimental physical changes in the sediment may be due to the fineness of barite, which physically smothers benthic organisms as well as benthic stages of other organisms. In summary, these results indicate deterioration in water quality that appears related to reserve pit fluid discharges into tundra ponds as a result of breaching, leaching, or overtopping of the pits. Along with deteriorations in water quality, the quality and quantity of organisms used as food by North Slope bird species may be decreasing.

There are two approaches to abandoning an exploratory well reserve pit:

1. Leave it as is. The muds at the bottom of the pit remain in place because of the permafrost. But there is always the chance that runoff water flowing into the pit may breach the downslope side, carrying some of the salts in the overlying fluid onto the tundra. If the chloride content is sufficiently high, this overflow can kill plants over a few square yards to perhaps an acre. Revegetation may occur naturally. The pit itself would become a somewhat rectangular pond, lasting decades or more.

2. "Button up" the reserve pit; that is, reinject unfrozen fluid at the time drilling is completed, and fill in the reserve pit with enough soil (usually gravel) so the drilling mud and frozen fluid becomes a part of the permafrost. On the North Slope at least 5 feet of cover material is required. Excavated material from construction of the reserve pit, even if not used for leveling the pad, would not provide nearly enough fill even if the contained ice did not melt. Therefore, this method requires remobilizing construction equipment, opening a gravel pit elsewhere, and hauling in material to fill in and "mound up" over the reserve pit area. Experience on the NPRA shows this to be a questionable mitigation technique, because it leaves a mound of material at the wellsite that is difficult to revegetate, a new borrow site that may be difficult to revegetate, and another ice road between the borrow site and wellsite.

The unavoidable physical consequences of drilling one exploratory well during the winter-only season would be:

1. Denuding of a 10-acre area of tundra for 10 years or more, and the long-term (many tens of years) creation of a 2- to 3-acre rectangular-appearing pond.

2. Temporary minor contamination of the tundra in the depression(s) where the treated gray water and/or the effluent is discharged from the camp's waste treatment plant.

3. The almost unavoidable minor oil leaks and spills from operating equipment, which are dispersed over the area within which operations would be conducted. Human error and mechanical breakdown in a rigorous environment create the potential for accidental oil spills which would contaminate the tundra and, possibly, the aquatic environment as further described in subsequent sections on "Vegetation" and "Fish."

4. Gaseous and particulate emissions which temporarily reduce air quality in the locale.

5. Short-term (one or two winter seasons) noise effects associated with operations, and the visual effect of the drilling rig, construction camp, and transportation activities.

From a technical and economic standpoint, industry may prefer to drill exploratory wells deeper than 15,000 to 17,000 feet on a year-round basis, not during the winter only. The impacts of year-round drilling would be similar to those for development drilling (discussed next) but would be more widespread throughout the 1002 area.

## CONSEQUENCES OF DEVELOPMENT DRILLING

Usually several million cubic yards of gravel are required to develop an oil field. In a tundra environment, adverse effects can be minimized by obtaining gravel from exposed and unvegetated river bars. As long as the removal is limited to gravel exposed above the river ice or above the streambed (in those cases where the stream runs dry in winter), the watercourse would remain unchanged and no silting would occur because the gravels tend to be clean. In addition, the rivers in the 1002 area completely flush during the spring runoff. The next least disruptive places are gravel terraces immediately adjacent to the river bed, if carefully mined using a ripper blade. Finally, gravel may also be removed from cutbanks of a river with minimal disruption. The most disruptive and the most visually displeasing (for thousands of years) places from which to obtain gravel are the upland areas. Gravel, but mostly sand in the absence of gravel, was obtained from river bars, river terraces, and cutbanks, in that order, during the construction of the permanent airstrips and access roads for the deep exploration wells on the NPRA. Today, the untrained observer can scarcely find those borrow sites.

The large quantities of water required for development drilling on the 1002 area are not available. The most obvious, and probably only feasible, solution relates to gravel sources: carefully mining gravel from streambeds to create elongated deep pools (up to 40-50 feet deep, depending on the depth of available gravel) which, after spring runoff, can supply water year-round. Excavations could be within the river channel, or immediately adjacent but connected to the channel.

The infrastructure required to develop the economic prospects of the 1002 area is described in Chapter IV. The unavoidable effects of such a program could be:

1. Possible mining and use of as much as 50 million cubic yards of gravel from within the 1002 area.

2. As a result of the gravel mining operations, the possible creation of 20 to 30 elongated deep pools for water storage within, or immediately adjacent to, river beds that now run dry during the winter months.

3. Construction of as many as four or five year-round 5-foot-thick gravel C-130 airstrips on the 1002 area.

4. Construction of multiple (15-55) 5-foot-thick drilling pads, and 200-300 linear miles of all-season gravel roads within several oil fields, assuming discovery of multiple commercial grade oil fields within the 1002 area. Total number of pads and miles of road depends on fields developed. Approximately 110 miles of road would be necessary east from the Canning River to the Pokok marine facilities.

5. Minor erosion in connection with culverts for in-field roads crossing minor drainages, and some ponding upslope of airstrips, roads, and pads.

6. Almost unavoidable minor oil leaks and spills from operating equipment, and from storage facilities, dispersed over the operational areas.

7. Dust associated with traffic on the roads, airstrips, and pads which temporarily degrades the air quality, but also affects nearby water and vegetation as it settles.

8. Gaseous and particulate emissions, other than dust, which temporarily degrade local air quality.

9. Noise generated by aircraft operations, drilling operations (especially that arising from power generation) and traffic.

CONSEQUENCES RESULTING FROM CONSTRUCTION OF ROADS, PIPELINES, AND MARINE AND PRODUCTION FACILITIES

Chapter IV describes many of the siting and construction aspects of a pipeline to transport oil from the 1002 area to TAPS Pump Station 1. An above-ground oil pipeline would not be as topographically confined in its routing as would the main road, and would be expected to be as straight as possible while minimizing the lengths of the spur lines to central production facilities (CPF). Thus, the distance between the pipeline and the work road could vary and occasionally the two might even cross, as with TAPS and the haul road (J. W. Dalton Highway) when they pass through similar topography. It is further assumed that the pipeline might cross some streams on vertical support members; in other instances the pipeline might be attached to the road bridge over the stream. A pump station would be required at each CPF; an additional one or two booster pump stations would be positioned somewhere within the 1002 area, all of which are described in Chapter IV.

CPF's, marine facilities, pump stations, and power-generation facilities to heat water lines running treated sea water to the CPF's would all be constructed on 5-foot-thick gravel pads. Pad areas would vary considerably, depending on the planned use, but consequences to the physical environment would vary mainly in degree.

Unavoidable effects on the physical environment from the construction of an all-season road, transmission pipelines, and production facilities would be similar to those described for the support facilities for development drilling, with these additional consequences:

1. Construction of permanent road bridges over several rivers, with possible ponding, washout, and drainage problems.

2. Construction of the elevated pipeline, and the potential for oil leaks from that line.

3. Construction of a solid-core causeway at the marine facilities stretching into sufficiently deep water so that heavy loads (up to several hundred tons per load) can be put ashore safely. This could result in changes in nearshore currents and would require breaching to permit fish passage, as necessary (see "Coastal and Marine Environment," this section).

### Effects on Biological Environment

Although this analysis treats species individually, the dynamic interrelationships existing among species and between species and their environments is recognized. Vegetation is a key component of the environment; it provides food, cover, and water essential to all wildlife. Therefore, a thorough discussion is first presented under "Vegetation, Wetlands, and Terrain Types" regarding the effects from full development to that foundation of wildlife habitat. This forms the basis for later discussions of effects to individual species.

## VEGETATION, WETLANDS, AND TERRAIN TYPES

Effects on the vegetation, wetlands, and terrain of the 1002 area are described for each sequential phase of oil development, similar to the assessment of the physical environment.

More detailed seismic surveys would create a closely spaced (2-mile by 2-mile or closer) network of generally temporarily visible trails over parts of the 1002 area. The effects of winter seismic trails would be similar to those from the 1984 and 1985 seismic operations in the 1002 area. These would include decreases in plant cover, patches of exposed peat and mineral soil, destruction of hummocky microrelief, compression of the vegetative mat, deepening of the active layer, and surface depression on trails (Felix and Jorgenson, 1985; Felix and others, 1986a, b). The trails through wet graminoid tundra and moist prostrate shrub scrub vegetation will appear greener due to compression of standing dead leaves which normally give the tundra a tawny appearance. Green trails may persist as a result of increased plant productivity and nutrient levels in future years (Challinor and Gersper, 1975; Chapin and Shaver, 1981; Envirosphere Company, 1985; Felix and others, 1986a, b). On heavily disturbed trails, surface depression of tracks could occur due to compression of the moss mat and possibly some subsidence. Standing water may be present on these trails, making them highly visible. In moist graminoid tussock tundra or other vegetation types with hummocky microrelief, moundtops could be scraped or crushed exposing small patches of peat and sometimes mineral soil. Trails here appear brown because of the exposed peat or increased litter from dead plants. The thin vegetation mat on dry prostrate shrub river terraces is easily disturbed, and large decreases in plant cover would be expected. Traffic through riparian areas could break shrubs, nearly to ground level at some sites. The most severe impacts occur on narrow trails with multiple vehicle passes, and occur more often on trails made by mobile camp units and fuel- or dynamite-supply sleighs.

Because of the potential of permanent damage from significant decreases in plant cover, increased exposure of peat and mineral soil, surface subsidence, and long-term moisture and species composition changes on summer vehicle trails (Bliss and Wein, 1972; How and Hernandez, 1975; Chapin and Shaver, 1981; Everett and others, 1985), summer seismic exploration has not been allowed on the coastal plain. It is not currently permitted on Alaska State lands. It has been assumed for purposes of this analysis that the restriction would continue.

Spills of diesel fuel, oil, and antifreeze would be expected to affect hundreds of small areas of vegetation (possibly extending out 30 feet in diameter). Diesel fuel is highly toxic and kills all plants on contact; it may penetrate deeply into soil, killing roots and rhizomes and remaining toxic for decades (D. A. Walker and others, 1978; Lawson and others, 1978; Mackay and others, 1980).

The effects on vegetation from ice roads and airstrips are not well-documented, although it is generally thought that properly built ice roads protect vegetation from adverse impacts. Ice roads delay plant growth in the first year after use, and may appear as green trails for several years. Higher sites, common in vegetation types on the 1002 area, may be scraped during road construction or during use if the ice is not sufficiently thick (Adam, 1981). On Alaska State lands, ice roads are not allowed in the same location 2 years in a row to avoid compounding vegetation impacts. Repeated passes of vehicles moving drilling rigs and supplies results in severe decreases in plant cover, destruction of microrelief, and subsidence unless ice roads are sufficiently thick and properly constructed. (Kerfoot, 1972; Lambert, 1972; Hernandez, 1973).

Well pads may be built of ice, gravel-timber-insulation, or gravel. Of these, ice well pads have the least impact on vegetation, similar to that for ice roads and airstrips. Gravel-timber-insulation pads use timber and insulation in place of some of the gravel needed for proper insulation and often use reserve pit materials for any remaining gravel needs, minimizing the need for gravel borrow sites and, thus, loss of vegetation. Rehabilitation is more successful for these pads. When the timber and insulation are removed, a much thinner layer of material remains, often containing soil as well as gravel. Pioneer species are slow to colonize gravel pads because of limited nutrients, limited water availability, and lack of fine-grained materials (Everett and others, 1985).

Reserve pit fluids may kill surrounding vegetation from overflow spills, breaching of pit walls, or leaching through the pit wall (French and Smith, 1980). Drilling muds may contain diesel fuel, soluble salts, heavy metals, and ethylene glycol, all of which can be toxic to vegetation (D. W. Smith and James, 1980). Closure of reserve pits can result in future leaks or erosion (French, 1980). Subsurface disposal of drilling muds by reinjection, a method currently being used in some Alaskan oil fields, provides permanent disposal of contaminants, eliminates the need for large reserve pits, and reduces the possibility of negative effects on vegetation.

Inasmuch as exploratory drilling requires large amounts of fuel, spills of much greater magnitude than those that occur during seismic exploration could occur. Leaks of crankcase oil, antifreeze, and hydraulic fluid from vehicles may occur, as they did during the 1984 and 1985 seismic exploration program on the 1002 area. The extent of vegetation damage that occurs depends on the time of year, type of material, size of spill, and vegetation type.

Diesel is the fuel most toxic to plants as previously described. Lawson and others (1978) found that an area of 30-year-old diesel spills in northern Alaska showed little recovery. Spills in the winter are less toxic than summer spills: winter spills are easier to contain and clean up, do not penetrate the soil as deeply, and lose some of their toxicity by evaporation.

Crude oil can cause severe decreases in vegetative cover but may not kill all vegetation, even in heavily saturated areas (Johnson and others, 1981). Mackay and others (1980) noted that crude oil degraded much faster than diesel, especially if it had not penetrated deeply into the soil, and revegetation sometimes began in less than 3 years. Areas where oil had penetrated deepest (20-30 mm) remained toxic for more than 4 years. Large spills inhibited recovery by altering the physical properties of the soils, making them drier, thus reducing or preventing seed germination and vegetative growth. Deep spills may also resurface in later years with toxic effects on the vegetation. Because oil penetration is related to soil moisture, wet vegetation types suffer less initial damage than vegetation on dry sites because standing water or saturated soils prevent fuel from penetrating to the roots or rhizomes. Wet sites usually recover faster. In addition, those species most resistant to oil spills (sedges and deciduous shrubs) are also the best recolonizers following disturbance (Walker and others, 1978). Direct contact with oil often results in immediate damage to above-ground vegetation. Injury to the root system may not be immediately obvious and can cause a slow deterioration of plants and a high degree of winter kill in future years (Deneke and others, 1975; Mackay and others, 1980).

If the entire 1002 area was leased, subsequent oil development, production, transportation activities, and associated infrastructure could result in approximately 5,000 acres of vegetation being covered by gravel for roads, pipelines, airstrips, and other facilities (table V-1). Physical disturbances such as erosion and sedimentation, thermokarst (caused by the melting of ground ice and settling or caving of the ground surface so that pits, hummocks, depressions, and small ponds result), impoundments, clearing, gravel spray, dust, snowdrifts, and pollution incidents would alter the habitat values of many more acres. Properly designed snow or ice pads used for construction and transportation activities are effective in protecting vegetation; however, gravel debris from those activities could smother additional vegetated areas (Johnson and Collins, 1980; Brown and Berg, 1980).

Culvert design would need to ensure that slumping from roadcuts and erosion did not occur. Altered drainage patterns caused by roads and pads would result in some ponding and a generally wetter environment on the nearby upslope side of a road or pad, and a drier environment on the nearby downslope sides. Impoundments caused by blocking drainages could cause changes in plant species composition or eliminate some plants depending on the depth and duration of flooding. Impoundments occur more frequently in aquatic and wet graminoid tundra vegetation in the Thaw Lake Plain terrain type (Walker and others, 1984), and in the Foothills type where complex drainage patterns occur due to the network of water tracks (Brown and Berg, 1980). Also thermokarst, which commonly occurs on the edges of roads and pads, extends the area of impact off the actual facility site and causes long-term changes in moisture conditions and plant species composition.

Gravel, dust, and changes in snow accumulation patterns would affect areas surrounding petroleum development facilities. As summarized by Meehan (1986): 1) gravel spray may be deposited as far as 100 feet on either side of roads; 2) heavy dust may be deposited within 80 feet and some dust up to 250 feet out from heavily traveled roads; 3) some dust will be deposited within 160 feet of lightly traveled roads; and 4) snowmelt will be early where dust is deposited adjacent to heavily traveled roads but generally later on the west side of highly traveled roads due to snow deposition by winter winds. On the basis of this information, secondary effects from gravel and dust spray were assumed to extend 100 feet on each side of all roads. Impoundments and altered snowmelt patterns were also assumed to occur within this same 100-foot area. Similar modifications would be expected adjacent to drill pads and other facilities. Therefore, approximately 7,000 acres of existing vegetation could be modified by these secondary effects.

An additional 500 to 750 acres may be mined for gravel at as many as 15 different locations, or by creating 20 to 30 deep holes for use as water reservoirs. The effects of gravel mines on vegetation depend on the location of the borrow sites, amount of gravel removed, and the vegetation type. Vegetation would not be directly affected if gravel were mined from unvegetated riverbars, unvegetated coastal beaches, coastal lagoons, or lake bottoms. Borrow pits on partially vegetated river bars or vegetated river terraces would cause losses of alluvial deciduous shrub and dry prostrate shrub river terraces, which cover only a small part of the 1002 area. In upland areas, vegetation would be lost in the area of the borrow site, the area covered by overburden, and any area affected by erosion. Gravel removal in upland areas would be the most visually disruptive and would be extremely difficult to rehabilitate to pre-project natural conditions.

Accidental spills of crude oil and refined petroleum products are an inevitable consequence of oil field development. Although diesel fuel is most toxic, crude oil is also toxic to vegetation. Throughout the operation of Prudhoe Bay, the very large spills, on the order of at least 10,000 gallons, have been of crude oil, gasoline, and diesel. Larger spills not only cover a larger area, but they also penetrate deeper into the soil than smaller spills. Since 1972 some 23,000, mostly small, spills have been reported to the Alaska Department of Environmental Conservation. The largest spill of 658,000 gallons was the result of sabotage in 1978. A spill of over 200,000 gallons near Atigun Pass in 1979 was caused by improper pipe bedding which resulted in permafrost thawing and a ruptured pipe.

An indication of the frequency and volume of potential spills is provided by recent records for Prudhoe Bay. According to 1985 records, the first full year of computerized oil-spill data, there were 521 reported spills totaling 82,216 gallons (Alaska Department of Environmental Conservation, Fairbanks, unpublished data). Diesel and crude oil were the most commonly spilled products, comprising nearly half of the reported spills, with other petroleum products accounting for fewer spills. Most spills were small; 51 percent of spills were no more than 10 gallons yet those spills equaled only 1 percent of the volume spilled in 1985. The most common causes of spills were leaks, ruptured lines, and tank overtopping. Effects have generally been localized. To date, the cumulative effect of spills has not been significant.

Pipelines may transport sea water from coastal marine facilities inland for waterflood or other purposes. The effects of sea water spills on tundra vegetation are poorly understood, but depend on the spill size, season of occurrence, moisture, pH level of the site, and vegetation type. Sea water spills affect dry sites more severely than wet sites. Sea water rapidly penetrates dry soil, resulting in high salt concentrations near the rooting zone. Recovery can take many years to recover (Simmons and others, 1983). Sea water would be diluted and more rapidly flushed away at wet sites. Also, many wetland sedge and grass species are salt tolerant. Large sea water spills that inundate the tundra could severely disturb vegetation, even in wet tundra sites. It has been shown that major storm surges have killed all vegetation on flooded sites (Reimnitz and Maurer, 1979).

A plant species of special note is Thlaspi arcticum, currently under review to determine if it qualifies as a threatened or endangered plant (category 2 candidate--45 FR 82480). The widest known distribution of Thlaspi arcticum in the Arctic Refuge is along the Katakturuk River (pl.1A), adjacent to potential economic prospects in Block A. Careful siting of petroleum exploration and development facilities and activities would be required to prevent disturbance of Thlaspi arcticum plants and their habitat. Some indirect plant loss might result from dust deposition.

Mitigation

Consolidating facilities to the maximum extent possible would minimize effects on vegetation. Snow pads and ice roads, of appropriate thickness and areal extent to protect vegetated areas, should be used as much as feasible to construct pipelines in order to reduce the need for gravel. An overall loss of approximately 5,650 acres (0.4 percent of the 1002 area) of existing vegetation could result, based on the estimated facility needs for developing the entire 1002 area. Habitat values would be lost when these habitats are covered by pads, airstrips, roads and other support facilities.

Additionally, at least 7,000 acres could be modified by the secondary effects of gravel spray and dust deposition, altered snowmelt and erosion patterns, thermokarst, impoundments, and pollution incidents. Habitat values would decrease. Some of these secondary effects would be reduced by appropriate facility design and operation, including traffic speed controls and reinjection of drilling muds and other fluids, as well as careful construction to prevent toxic spills. Appropriate containment procedures and absorbent pads must be used to minimize and clean up any fuel, sea water, or other spills which do occur. It is assumed that summer seismic exploration and ice road placement, in the same location 2 years in a row, would continue to be prohibited.

Further study to better define the locations and numbers of Thlaspi arcticum plants occurring on the 1002 area in conjunction with careful siting of pads and routing of collecting lines and associated roads in Block A would avoid most impacts to that species. Environmental briefings by FWS would include information on the characteristics and location of the candidate plants.

Conclusion

The expected modification of approximately 12,650 acres (0.8 percent of the 1002 area) would be a moderate effect (table VI-1) on area vegetation and wetlands. Many localized areas will be affected on a permanent, or at least very long term, basis.

## SADLEROCHIT SPRING SPECIAL AREA

Within the 1002 area, the approximately 4,000-acre Sadlerochit Spring (pl. 1A) and surrounding area are the only National Natural Landmark nomination and the only area which was closed year-round to exploration activities during the previous exploration program. This special recognition is due to the spring's continuous flow of warm water, the only major flow of warm water in the 1002 area during the winter. Prohibiting surface occupancy and certain other activities in the Sadlerochit Spring Special Area would prevent most negative effects from oil development.

The increased transient and permanent population expected under full leasing could increase use of the Sadlerochit Spring area, particularly by workers from adjacent Block D. The resulting increase in disturbance could cause muskoxen to avoid the area (pl. 2C) or could affect birds. In winter, the open water in the Sadlerochit Spring area provides habitat for the American dipper, one of only two passerine species resident year-round on the 1002 area (pl. 3C). Fishing pressure in the area could also increase, causing competition with and disturbance to Native subsistence users in the Sadlerochit Spring area (pl. 1B).

Mitigation

Before any water withdrawal in the Sadlerochit Spring Special Area, studies would be required to determine the quantity of water that could be removed, when, and by what methods, without seriously affecting fish, wildlife, and habitat that rely on the spring. However, the existing "no surface occupancy" restriction for oil exploration and development is assumed to remain in effect. This precludes surface development and disturbance, maintaining the area's physical features and important fish, wildlife, and subsistence resource values.

Conclusion

Development as a result of fully leasing the 1002 area would have negligible effects on the Sadlerochit Spring Special Area under current protective management regulations.

## COASTAL AND MARINE ENVIRONMENT

Petroleum development and production in the 1002 area and associated transportation at both onshore and offshore sites would have a variety of effects. Docks and causeways can affect dispersion, nutrient transfer, temperatures, salinities, invertebrate abundance and diversity, fish passage, and other uses of those areas by fish and wildlife. Disruption of natural nearshore currents can result in sea water intrusions into lagoons causing lower water temperatures and higher salinities. Salinity and temperature changes could alter invertebrate abundance; decreases in invertebrates would mean lower coastal area values to fish and wildlife. Such intrusions may also alter fish movements by reducing existing favorable habitat conditions in nearshore zones.

Noise created by construction and other operations in coastal areas could be a disturbance factor, sufficiently reducing the quality of the coastal and marine habitats to cause avoidance by some marine birds and mammals.

Debris washing ashore from transport and offshore activities could increase with increased human activities in the area. The driftline is used for nesting habitat by several species of waterfowl and seabirds (pl. 3A, B, C). Disruption and physical alteration of the driftline from activities associated with oil development could affect bird nesting success by disturbing nesting birds or altering their nests. Debris and disruption of driftlines would also affect esthetics. Occasional fish and wildlife mortalities could occur where animals become entangled in or ingest debris.

Any spill of oil or other hazardous materials along the coast could severely affect coastal and marine habitats and fish and wildlife. For example, decreased invertebrates result in decreased food for fish and wildlife. Sea ducks, such as oldsquaw which heavily use this coastal area, could be displaced, and direct mortality could occur. Level of impact would relate to the volume of oil spilled, location, effectiveness of cleanup, time of year, and fish and wildlife species present.

Mitigation

Experience gained from construction and operation of docks and causeways for Prudhoe Bay should be used to plan and construct docks and causeways for the 1002 area so that those facilities do not affect longshore water transport and lagoon water chemistry or impede fish movements. Release of fuels and other hazardous substances to the environment should be minimized by developing and implementing control, use, and disposal plans for such substances.

Conclusion

Overall, the effect of full leasing is anticipated to be minor on coastal and marine habitats. However, there is a small probability of major adverse effects depending on the extent and duration of future cumulative developments or in the event of a catastrophic offshore or coastal oil spill.

## TERRESTRIAL MAMMALS

### CARIBOU

Caribou use the 1002 area during the summer months for two important activities, calving and seeking relief from insect harassment. During that period, 3,000-4,000 caribou from the 12,000-14,000 member CAH use the 1002 area. Up to 82 percent of the calving caribou in the PCH calved on the 1002 area in recent years (1972-85) and the entire 180,000-member PCH may use the area in some years, mainly during the late June/early July insect-relief period. Concentrations of caribou are generally absent from the 1002 area in winter, except for as many as 1,000 animals (7 percent) of the CAH scattered between the Sadlerochit Mountains and Camden Bay.

Exploration

Winter seismic programs in 1984 and 1985 on the 1002 area, and exploratory drilling on adjacent Kaktovik Inupiat Corporation (KIC)/Arctic Slope Regional Corporation (ASRC) lands in the winters of 1985 and 1986, resulted in no apparent conflict with CAH or PCH activities. Similar results were found during both seismic and exploratory drilling work in the NPRA and on State lands within the range of the CAH (U.S. Bureau of Land Management, 1983; Fancy, 1983). Winter oil exploration, including exploratory drilling, would likely have a negligible effect on PCH caribou since they are generally absent from the area. Disturbance, resulting in displacement, could occur to the CAH. Disturbance and displacement to both the CAH and PCH from the short-term, scattered and local activities of summer surface geology programs would be almost negligible.

Production, Transportation, and Development

Effects on caribou from petroleum field development, production, and transportation would occur from direct habitat modification, indirect habitat loss (displacement, barriers to movement which reduce access to insect-relief and other habitats, and disturbance/harassment), and direct mortality (e.g., hunting, collisions with vehicles, or other accidents). Analogies comparing the effects of current oil development on the CAH and effects of potential 1002 area development on the PCH must be drawn with caution. Movements, density, and traditions of the PCH differ from those of the CAH (Chapter II). Because of the greater density of PCH on their calving grounds, the PCH would interact with oil development much more extensively and intensively than the CAH has interacted with oil development in the Prudhoe Bay area.

Caribou calving in the Prudhoe Bay area was reported by Gavin (1971), Child (1973), and White and others (1975), when development of the Prudhoe Bay oil field was beginning. Later studies (Cameron and Whitten, 1979, 1980; Cameron and others, 1981; Whitten and Cameron, 1985) indicate an absence of calving near the coast at Prudhoe Bay during 1976-85, possibly due to avoidance of the activity area by calving caribou. Two centers of concentrated calving activity were identified; (1) west of Prudhoe Bay in the vicinity of the Kuparuk and Ugnuravik Rivers (including recent oil development in the Milne Point and Kuparuk areas); (2) east of Prudhoe Bay, primarily in the Bullen Point to Canning River delta area (Shideler, 1986). Surveys in 1981 indicate that the Canning River delta area may support more calving caribou than the Kuparuk area (Whitten and Cameron, 1985). Table VI-4 compares calving in the Prudhoe Bay area and population of the CAH with development of the Prudhoe Bay oil field. The apparent herd increase has been attributed to high calf production and survival as well as relatively light hunting pressure (Whitten and Cameron, 1983).

Even more tenuous are parallels between caribou activities and population trends on NPRA with those which might result from oil development on the 1002 area. Although NPRA has been extensively explored, no oil production or infrastructure development has occurred.

Approximately 242,000 acres of the 1002 area used as a core calving area by the PCH has been determined Resource Category 1 habitat in accordance with the FWS mitigation policy. More than 50 caribou/sq mi have been present during calving in at least 5 of 14 years (1972-85) for which detailed data exist (pl. 2A); nearly 80 percent of the total core calving area for the 180,000 member PCH occurs in this portion of the 1002 area (table VI-5). The remaining approximately 1,304,000 acres, considered Resource Category 2 habitat, includes areas used year-round by up to 4,000 CAH caribou and for concentrated and scattered calving, postcalving aggregations, and insect-relief habitat by the PCH.

If the 1002 area's anticipated oil and gas resources were developed across the entire area, direct modification of caribou habitat could total approximately 5,650 acres. East of the Sadlerochit River about 3,650 acres used by the PCH, of which about 1,300 acres are Resource Category 1

**Table VI-4.**--Central Arctic caribou herd population, calving in Prudhoe Bay area, and Prudhoe Bay development activities, 1969-85.

[Information from Shideler (1986); some variation exists in calving areas surveyed. Long-term investigations of the CAH begun in 1974 by ADF&G. N.A., not available]

| Year | Total CAH population | Number cows and calves | Development activities |
|---|---|---|---|
| 1969-70 | ([1]) | ([1]) | Oil discovered. |
| 1972 | N.A. | 13 | Deadhorse airport, road system, several drill pads developed. |
| 1973 | N.A. | 42 | |
| 1974 | N.A. | 51 | Construction of TAPS; rapid area growth in roads, facilities, and drill pads. |
| 1976 | N.A. | ([2]) | Oil production begins. |
| 1978 | 6,000 | ([3]) | Drill sites and road connecting Kuparuk with Prudhoe Bay developed. |
| 1981 | 9,000 | N.A. | Kuparuk pipeline connecting to TAPS completed. |
| 1983 | N.A. | 0 | Expansion of Kuparuk oil field. |
| 1985 | 12,000-14,000 | N.A. | Pipeline to Milne Point constructed. |

[1]Reports of area used for calving by the 3,000 or so caribou residing in Prudhoe Bay area, early 1970's.

[2]A handful.

[3]About 10.

habitat, would be affected. West of the Sadlerochit River some 2,000 acres, predominantly used by the CAH, would be affected. Slightly more than 0.3 percent of all Resource Category 2 habitat would be directly modified. Most of the reduction in habitat value would result from covering feeding and calving habitat with gravel.

Because insects are easily blown off somewhat elevated, unvegetated areas by wind, some positive effect might occur in the form of increased insect-relief habitat (Curatolo and others, 1982; Elison and others, 1986). However, it is generally during the oestrid fly (nose bot and warble flies) harassment period from late July to early

**Table VI-5.**--Porcupine caribou herd calving area potentially affected by development under full leasing or limited leasing, assuming an approximately 2-mile sphere of influence.

| | Concentrated calving area[1] | Core calving area[2] |
|---|---|---|
| Total calving area within 1002 area (acres) | 934,000 | 242,000 |
| Area (acres) potentially influenced by development: | | |
| Full leasing | 357,000 | 78,000 |
| Limited leasing | 261,000 | 10,000 |
| Percent of 1002 calving area potentially influenced by development: | | |
| Full leasing | 38 | 32 |
| Limited leasing | 28 | 4 |
| Total calving area (acres) in U.S. and Canada | 2,117,000 | 311,000 |
| Percent of total U.S. and Canada area potentially influenced by development: | | |
| Full leasing | 17 | 25 |
| Limited leasing | 12 | 3 |

[1]At least 50 caribou/square mile during calving, in 1-4 years, 1972-85.
[2]At least 50 caribou/square mile during calving for at least 5 years, 1972-85.

August that caribou seek relief on unvegetated gravel roads, well pads, or the shade of pipelines and buildings on those pads (Curatolo, 1983; Fancy, 1983). Insect harassment of PCH on the 1002 area generally results from swarms of mosquitoes early in the summer season. The PCH usually leaves the 1002 area prior to the emergence of oestrid flies.

Secondary modification of habitat due to changes in surface water flow, snow accumulation, roadside dust deposition, gravel spray from vehicle movements, and pollution incidents would reduce the habitat value of additional acreage. These changes in vegetation, and thus food availability, could occur on approximately 7,000 acres, of which nearly 1,800 acres is in Resource Category 1 (1 percent). Total modification of caribou habitat attributable to direct and secondary changes would occur on about 12,650 acres, or 0.8 percent of the 1002 area, and 1.3 percent of the core calving area (Resource Category 1 habitat).

Major indirect losses of habitat and additional reductions in habitat value would be widespread throughout the 1002 area. The habitat value losses from these indirect effects would result from behavioral avoidance of development areas; decreased accessibility to undeveloped areas (insect-relief habitats along the coast) due to physical barriers and disturbances such as pipelines, traffic, or facilities; and other disturbances or harassment by oil development activities and personnel during sensitive caribou life stages.

Disturbance to caribou is unavoidable if oil development occurs on the 1002 area. Historically the entire area has been used by PCH caribou at varying levels of intensity. Disturbance can result from a variety of sources including presence of pipelines and roads, aircraft operations, general construction, routine operation of the oil field, presence of people, and hunting. Reactions depend upon several factors, including caribou age and sex, herd size, presence of calves, season, and type and distance of the disturbance.

Behavioral avoidance of development areas displaces caribou from preferred habitats of traditional use. It is generally believed to result from human activity (noise, vehicle movements, presence of people, and odors), instead of the mere presence of roads, pipelines, and buildings. Avoidance of oil development and other human activity by caribou has been reported by numerous investigators (Dau and Cameron, 1985; Cameron and others, 1979; Whitten and Cameron, 1983; Fancy and others, 1981; Urquhart, 1973; Wright and Fancy, 1980). The reported extent of displacement varies. Displacement of the CAH from historic calving grounds in response to oil development at Prudhoe Bay has been documented (Dau and Cameron, 1985; Cameron and Whitten, 1979). Whitten and Cameron (1985) found consistently low numbers of caribou and generally low percentages of calves in the Prudhoe Bay oil field from their annual surveys of the CAH calving grounds, 1978-82, with caribou being displaced to adjacent areas already used for calving. Mean densities of caribou in five other regions of the calving grounds were 2 to 18 times higher than at Prudhoe Bay. Dau and Cameron (1985), in what may be the most systematic study of caribou displacement by oil development, reported that maternal caribou groups showed measurable declines in habitat use within approximately 2 miles on either side of the Milne Point road in the central Alaskan arctic.

Caribou select calving areas because of favorable weather causing early snowmelt, advanced emergence of new vegetation, relative absence of predators, proximity to insect-relief habitat, absence of disturbance, or some combination of these and other factors. Maternal cows and their calves are most sensitive to disturbance during calving and immediately thereafter (Calef and others, 1976; Miller and Gunn, 1979; Elison and others, 1986).

Displacement of the PCH from a core calving area to a less desirable area would be expected to reduce caribou productivity. Loss of important habitat has been shown to directly impact ungulate populations (Wolfe, 1978; Skovlin, 1982). But no recognizable, long-term effect upon the CAH as a result of displacement by oil development in the central Alaskan Arctic has been demonstrated to date. In considering the effects of displacement of the CAH from traditional calving grounds, Whitten and Cameron (1985) contend that the CAH has not experienced a reduction in productivity or consequent population decline because: (1) the CAH has been displaced from only part of its calving grounds; (2) suitable alternative high-quality habitat appears available for caribou displaced from Prudhoe Bay; and (3) overall density of CAH caribou on their calving grounds is much lower than that of other arctic herds in Alaska. Although the CAH and PCH calving grounds are roughly equal in size and the Western Arctic herd calving ground is about 50 percent larger, the population of the PCH is about 15 times larger and that of the Western Arctic herd is about 18 times larger than the CAH (based on 1982 population estimates).

Both absolute (number of caribou, including calves, on the calving grounds divided by area of calving grounds) and effective (allowing for the length of time a herd uses its calving grounds each year) densities of the CAH are a fraction of PCH and Western Arctic herd calving ground densities. As described by Whitten and Cameron (1985), absolute density for the PCH is nearly 14 times, and for the Western Arctic herd nearly 15 times greater than for the CAH. The difference in effective densities is even greater, particularly for the PCH, which are found at approximately 24 caribou per square kilometer as compared with approximately 5 caribou per square kilometer for the CAH. Effective density of the Western Arctic herd is 15 caribou per square kilometer.

With the CAH calving density remaining low compared to other herds, despite a recent population increase, overcrowding and consequent habitat stress that might result in reduced productivity have not yet occurred, nor have caribou been displaced to areas of reduced habitat value or areas where they might be exposed to increased predation. Unlike the Western Arctic or Porcupine caribou herds, the CAH has been exposed to minimal predation in recent years. With the influx of workers and use of the haul road for Prudhoe Bay development, the wolf population in the Central Arctic area decreased in the mid-1970's because of hunting. At that time CAH numbers began increasing. The wolf population has remained low and brown bears, which also prey on caribou, are only moderately abundant in the area.

The lack of observable adverse effects from displacement exhibited by the CAH would be unlikely for the PCH. The PCH is much more crowded in its calving habitats, and a substantially greater proportion of important calving habitats would be involved with development that included their core calving area. Furthermore, predators are more abundant adjacent to their core and concentrated calving areas. For example, preliminary analysis of radio-relocation data indicate that brown bears shift habitat use patterns to coastal areas in June and early July (pl. 1D) to coincide with occupancy of those habitats by calving and postcalving caribou (Garner and others, 1985).

Biologists participating in the FWS workshop all agreed that displacement from areas of human activity related to oil and gas activities would occur (Elison and others, 1986).

Plates 2A and 2B show the substantial overlap of potential oil development facilities with PCH calving areas and smaller overlap of such areas with CAH calving areas. Calving caribou of the PCH and those CAH caribou using the 1002 area are the most sensitive segment of those herds. They would annually encounter oil development during one of the most, if not the most critical time in their yearly cycle. Based upon the work of Dau and Cameron (1985), caribou are displaced approximately 2 miles out from development. This is most applicable during calving and immediately postcalving, which coincides with the greatest caribou use of the 1002 area. Within this approximately 2-mile area of influence are about 357,000 acres (38 percent) of the total concentrated calving grounds in the 1002 area.

For this analysis, core calving areas for the PCH are defined as concentrated calving areas used by at least 50 caribou/sq mi in 5 or more of the last 14 years (Chapter II and pl. 2A). Development in these areas is of particular concern. Seventy-eight percent of the PCH's core calving areas is within the 1002 area and is designated as Resource Category 1 habitat. An approximately 2-mile displacement of caribou out from petroleum facilities would include loss of 32 percent of the most critical PCH core calving areas (table VI-5). The mitigation goal for Resource Category 1 habitat is no loss of existing habitat value. The projected displacement from preferred calving habitat would represent a complete loss of habitat values. Measuring the probable population decline from complete loss of habitat values in calving areas is impossible and the ultimate effects of displacement are unknown.

Barriers to caribou movements are another source of indirect habitat loss. Roads without activity generally present little problem to free movement of caribou. Depending upon design pipelines may create a barrier, those adjacent to or close to active roadways would probably most impede free movement (Elison and others, 1986). Several investigators have described where passage of caribou through oil or other development areas has been inhibited because of linear oil-development facilities and associated activities (Curatolo and others, 1982; Smith and Cameron, 1985a, b; Klein, 1980). This is of particular concern in the 1002 area because the probable pipeline/haul road route would bisect the area.

Barriers to caribou movements could result in decreased calving success by reducing access to preferred calving areas, compounding the displacement from calving areas which could result from disturbance as discussed previously. A greater concern, relative to the location of potential barriers under the full leasing scenario, would be inhibiting movements for the large postcalving aggregations which annually occur on the 1002 area as they move between inland feeding areas and coastal insect-relief habitats. In years when ice breakup is late and more of the PCH calving occurs east and southeast of the 1002 area, there is a strong westward movement following calving. Virtually the entire PCH gathers on the 1002 area for foraging and insect relief, with large portions of the herd tending to remain on the 1002 area later into July and August during the years of late breakup (Roseneau and Stern, 1974; U.S. Fish and Wildlife Service, 1982; U.S. Fish and Wildlife Service, unpublished data). The insect season is a period of extreme natural harassment and one of the primary driving forces in the annual caribou cycle. This harassment follows closely behind the critical calving period. Insect harassment can have a pronounced negative effect on caribou survival. Helle and Tarvainen (1984) reported that insect harassment reduced growth in reindeer calves in Finland and contributed heavily to increased mortality the following winter. Insect harassment also affected the body size at maturity. Insect harassment and the avoidance actions of caribou put considerable energy stress on caribou (Reimers, 1980; White, 1983). Davis and Valkenburg (1979) reported several dead and sick calves in the Western Arctic caribou herd, all with heavy infestations of nose bot larvae. Reduced access to insect-relief habitat would result in greater energy stress with possibly reduced survival.

Numerous investigators have reported on the varying successes of caribou in crossing roads and pipelines associated with Prudhoe Bay facilities (Fancy, 1982, 1983; Curatolo, 1984; Curatolo and Murphy, 1983; Smith and Cameron, 1985a, b). Crossing success depends on several factors including traffic and human activity levels, pipeline design, season, and type and amount of insect harassment. Caribou crossing success is generally greatest at buried pipelines and then decreases for roads without traffic, to elevated (at least 5 feet above ground) pipelines adjacent to roads without traffic, to pipelines adjacent to roads with traffic. Large mosquito-harassed groups do not readily cross beneath elevated pipelines (Curatolo and Murphy, 1983; Smith and Cameron, 1985b); deflections of up to 20 miles during which caribou trotted or ran have been observed in the central Alaskan Arctic. During the oestrid fly season, caribou crossing success was markedly increased. In summarizing their 1981-83 studies of caribou crossings at roads and pipelines in the Prudhoe Bay and Kuparuk oil fields, Curatolo and Murphy (in press) attributed the lower crossing frequencies at pipeline/road sites to the combined stimulus of vehicular traffic and a pipeline.

After evaluating caribou responses to pipelines, roads, and pipeline/road complexes in the Kuparuk oil field, Curatolo and Murphy (1983) suggested that caribou movements could be facilitated by separating pipelines from heavily traveled roads and constructing ramps at strategic locations over elevated pipelines. Other researchers have concurred that roads should be separated from pipelines as a means of improving caribou passage through development areas (Curatolo and others, 1982; Robus and Curatolo, 1983; Elison and others, 1986). The optimum separation between roads and pipelines depends upon terrain; preliminary information indicates that a separation of at least 400-800 feet improves caribou crossing success (Curatolo and Reges, 1986).

Where Curatolo and Murphy (1983) and Smith and Cameron (1985a, b) documented reduced crossing success in areas of oil-related development, it has been for caribou exposed to major oil and gas development for extended periods annually in the central Alaskan Arctic since the early 1970's. Because some habituation would presumably have occurred, animals in the CAH may be more likely to cross an oil-field development than the PCH which would encounter such developments for only 2 or 3 months each year.

Eighteen percent (294,000 acres) of the 1002 area, including KIC/ASRC lands, used for insect-relief and other purposes by the PCH lie north of the proposed pipeline/road corridor. Use of this area by the PCH could be affected by two possible factors. If caribou refuse to cross through any development areas, then 294,000 acres would be unavailable as habitat. That area encompasses 52 percent of total insect-relief habitats and over 80 percent of coastal insect-relief habitats. This would mean that all coastal insect-relief habitats within the 1002 area, except for a small area in the eastern portion, would become unavailable under full development. The second factor is to assume the approximately 2-mile sphere of influence for oil development used previously. Under that assumption, caribou crossing through the development area would avoid using approximately 72,000 acres or 29 percent of identified coastal insect-relief habitat within the 1002 area and KIC/ASRC lands (Pank and others, 1986). Failure to obtain relief from insect harassment from either factor could shorten foraging time, leading to poorer physical condition and subsequently to increased susceptibility to predation and reduced overwinter survival.

Notwithstanding the limited sample size and timeframe covered, the satellite telemetry work of Pank and others (1986) provides an indication of the extent to which 1002 area caribou could interact with facilities and infrastructure necessary for full leasing. Their preliminary analysis of the potential interaction between PCH and CAH caribou and the oil development scenario used in this report involved 10 caribou radio-collared on winter range in the Arctic Refuge, two from the CAH and eight from the PCH. An interaction was defined as whenever a caribou point location, or any segment of a line connecting two point locations calculated for the same caribou on adjacent days, was within approximately 2 miles of a road, pipeline, drill pad, airfield, or other development facility. Point locations for the five caribou from the PCH which entered the 1002 area in summer 1985 can be examined to indicate the extent of time caribou usually spend within the development area. Of the 232 point locations, 51 (22 percent of the time) were within approximately 2 miles of the infrastructure for full development. Moreover, 34 percent of caribou routes between locations on adjacent days were also within the approximately 2-mile area influenced by development. The two CAH caribou encountered the development scenario to a much greater extent than did the collared PCH caribou: 413 (32.7 percent) of 1264 point locations and 83 percent of routes were within the approximately 2-mile interaction area.

Effects of disturbance might also include injury by trampling during stampedes, particularly calves; energy stress, possibly critical during times of low energy reserves such as winter and postcalving; and inability to reach insect-relief habitat which also increases energy loss. Miller and Gunn (1979) and Northwest Territories Wildlife Service (1979) noted that major physiological responses to harassment may occur in the absence of visible behavioral changes.

Aircraft activities are another cause of disturbance; numerous instances involving caribou have been documented. For example, Calef and others (1976) reported that helicopters which hazed caribou from the rear caused the most severe panic reaction. Large herds of up to 60,000 animals could be herded by flying at altitudes of up to 2,000 feet above ground level (AGL). Calves were more sensitive than other age classes and caribou on calving grounds were most reactive.

Recommendations for aircraft restrictions differ. According to Calef and others (1976), flight elevations of 500 feet AGL would prevent most injurious caribou reactions and altitudes of 1,000 feet AGL would avoid mild escape responses. These investigators recommended that aircraft maintain altitudes of 1,000 feet AGL during caribou calving, caribou rut, and early winter. Davis and Valkenburg (1979) also noted an inverse relationship between the altitude of aircraft and severity of the caribou's reaction. They recommended altitudes of 2,000 feet AGL from May to August. The Peary caribou herd in Canada reacted similarly to helicopters (Miller and Gunn, 1979); altitudes of 2,000 feet AGL were recommended for May to November and 1,000 feet AGL at other times.

Davis and Valkenburg (1979) reported that caribou may respond more to people on the ground than to flying aircraft. They recommend that people and vehicles maintain a minimum distance of 3,000 feet from caribou during calving. Curatolo and others (1982), Miller and Gunn (1979), and Elison and others (1986) have all reported that traffic, people, or general activity is more disturbing to caribou than merely the presence of roads or structures. No agreement on effects, and sometimes even causes, of disturbance exists. For example, Bergerud and others (1984) have a dissenting, though widely disputed, view. For review of the effects of various human developments on the demographics of seven North American caribou herds and one wild Norwegian reindeer herd, they postulated that caribou can withstand periodic severe disturbance without adverse effects on productivity and survival. They discounted the effects of much of the disturbance associated with development activities, concluding instead that increased hunting along transportation corridors through several herd ranges was responsible for distributional changes.

One of the more significant effects on caribou as a result of better human access to their habitats has been increased harvest (Bergerud and others, 1984). Obviously, hunting directly reduces the number of caribou in a population. More important, it reinforces the negative stimulus in surviving animals to associate human activity and development with danger. This negative stimulus increases the intensity and duration of disturbance and displacement. It also reduces habituation which, over time, could otherwise offset some displacement. Habituation of caribou to structures and activity occurs more readily in unhunted than hunted populations (Klein, 1980).

Legal harvest outside developed areas would be expected to increase moderately as workers could conveniently travel to adjacent areas to hunt caribou in season. The State of Alaska as lead, in cooperation with the FWS, sets seasons and bag limits for the 1002 area. Closing the oil development area to hunters should reduce illegal take to a minor level. Still, law enforcement in such a remote area is often difficult. For example, notwithstanding the fact that a 5-mile corridor along either side of the Dalton Highway from the Yukon River north to Prudhoe Bay, the gravel TAPS haul road, has been closed to firearms since 1975, State Fish and Wildlife Protection Officers and Alaska Department of Fish and Game (ADF&G) biologists are discovering increasing numbers of people hunting illegally within the corridor and outside the corridor through illegal access using all-terrain vehicles. The ADF&G has been monitoring the kill; their biologists estimate that as many as 800 caribou were taken in Game Management Unit 26B (Central Arctic) during fall and winter 1985-1986. All but 82 came from along the approximately 200 miles of the haul road between Prudhoe Bay and Atigun Pass (K.R. Whitten, ADF&G, unpublished data). The majority of this harvest is illegal because hunters either lacked a road permit where necessary or illegally used all-terrain vehicles for access. While the prohibition on discharging firearms extends to all users, including subsistence users, subsistence take is not considered a significant factor in the total harvest because of the distance of subsistence users from this area. State protection officers have found it difficult to assign staff to such remote areas to enforce existing laws and regulations.

Based upon experience with TAPS and Prudhoe Bay, mortality as a result of vehicle collisions, entanglement and other accidents should be minor (R.D. Cameron and K.R. Whitten, unpublished data).

Mitigation

The following measures would help avoid and minimize habitat value losses in the 1,304,000 acres of Resource Category 2 caribou habitat. Mitigation of the loss of caribou habitat in Resource Category 1 (242,000 acres of core calving area) is not possible.

For exploration activities, all environmental protection measures required during the previous 1002 coastal plain exploration program (50 CFR 37.31) and the drilling of an exploration well on KIC/ASRC lands (August 9, 1983, Agreement between Arctic Slope Regional Corporation and the United States of America, Appendix 2, Land Use Stipulations) will maintain most habitat values. Oil exploration, with the exception of surface geology studies, should be limited to the period of winter conditions, generally November 1 to May 1.

For oil development, the success of various stipulations designed as mitigation will ultimately determine the degree to which oil development actually affects caribou using the 1002 area. Measures previously used with success for Arctic oil development as well as other measures which should further help to reduce negative effects on caribou include:

1. Bury all pipelines where possible (Cameron and Whitten, 1979; Elison and others, 1986). Because of permafrost, opportunities for pipeline burial will be few. Where burial is not feasible:

    A. Place ramps over structures in areas of natural crossings or where development tends to funnel caribou (Curatolo and Murphy, 1983; Robus and Curatolo, 1983; Elison and others, 1986).

    B. Elevate pipelines (the most common practice) to allow free passage of caribou in areas without ramps (Elison and others, 1986).

2. Reduce disturbance from vehicle activity by limiting use of development infrastructure to essential industry and agency personnel on official business (Elison and others, 1986).

3. Close the area within 5 miles of all development and associated infrastructure to hunting and trapping, as well as to discharge of firearms, so as to reduce disturbance to caribou and to protect people and equipment (Elison and others, 1986; Carruthers and others, 1984).

4. Site nonessential facilities outside calving areas and major movement zones (Cameron and Whitten, 1979; Elison and others, 1986).

5. Separate roads and pipelines as necessary in areas used for crossing to improve crossing success (Curatolo and Murphy, 1983; Curatolo and others, 1982; Robus and Curatolo, 1983; Elison and others, 1986; Curatolo and Reges, 1986).

6. Acquire authority to establish time and area closures or restrictions on surface activity to minimize disturbances during calving or in concentrated use areas (Cameron and Whitten, 1979; Curatolo and others, 1982; Robus and Curatolo, 1983).

7. Establish time and area closures and minimum altitude restrictions for aircraft operations of 1000 feet AGL (Aug. 16 through May 19) and 2000 feet AGL (May 20 through Aug. 15). Altitude and time restrictions may be modified after further study.

8. Monitor the effects of oil development on caribou.

9. Annually monitor herd size, productivity, movements, distribution, and general health. If greater or additional adverse effects are found to occur than those initially predicted, additional mitigation or protective management actions would be implemented upon the recommendation of the FWS, in conjunction with the State where effects extend beyond the boundaries of the 1002 area. Additional mitigation could include further seasonal area closures, surface or air traffic restrictions, phasing of field development, or state-of-the-art measures.

10. Protect insect-relief habitat and facilitate free movement and access for caribou by reducing surface occupancy in the zone from the coast to 3 miles inland (Elison and others, 1986). Occupancy would be restricted to marine facilities and infrastructure necessary to move inland beyond the restricted zone.

11. Protect riparian and adjacent areas by placing permanent production facilities outside the areas within 3/4 mile of the high-water mark on both sides of identified watercourses (pl. 2A) and by limiting crossings of transportation facilities.

Conclusion

Surface geologic exploration and study conducted throughout the year would be controlled by specific time and area closures to avoid conflicts with caribou calving and movements during the insect-relief period. Seismic activity would be confined to winter work only. Based upon experience from the 1983-1985 exploration program in the 1002 area, only negligible effects would occur. Localized avoidance and disturbance of a minor nature may occur in the area of exploration wells if caribou entered the area while well drilling activities were underway. Because human activity would be low, effects would most likely result from some avoidance and displacement around well pads.

The expanding population trend for the CAH in the past decade would indicate that the CAH is not at carrying capacity (the number of healthy animals that can be maintained by habitat on a given unit of land). However, the point at which cumulative effects and expanding developments all modify suitable displacement habitat is unknown. Also unknown is carrying capacity of the PCH. Given the geography of the calving areas and current densities in those areas, the availability of suitable alternative habitats is not apparent.

A major change in distribution as an adverse result of displacement of both that portion of the CAH using the 1002 area as well as the entire PCH could occur if the 1002 area were fully developed. The main oil pipeline would bisect the 1002 area between the western and northeastern boundaries. Disturbance would occur from the presence and activities of up to 6,000 people, hundreds of vehicles, and major construction and production activities scattered throughout the 1002 area, including sensitive caribou calving areas. Use of approximately 25 percent of the total PCH core calving area and 29 percent of the coastal insect-relief habitat could be reduced or eliminated. Potentially a much larger portion, nearly 80 percent of coastal insect-relief habitat, could be affected if development proves to be a barrier to caribou movements. Loss of calving habitat, barriers to free movement causing reduced access to insect-relief and other areas, disturbance, stress, and other factors would cumulatively reduce both available habitat and habitat values on remaining areas, resulting in caribou population declines.

These changes in habitat availability and value, combined with increased harvest, could result in a major population decline and change in distribution of 20-40 percent, based on the amount of calving and insect-relief habitats to be adversely affected. Because of the many variables involved and lack of relevant experience in estimating impacts on this herd and because of the difficulty in quantifying impacts, this estimate is uncertain.

For the CAH, a moderate change in distribution or decline in that portion of the CAH using the 1002 area could occur. The effect on the entire CAH population throughout its range may also be moderate. Those effects on the segment of the CAH within the 1002 area would be similar to those on the PCH that occur from disturbance, displacement and barriers to free movement. The population decline or distribution change would be 5-10 percent for the CAH throughout its range.

MUSKOXEN

Recently reintroduced to the Arctic Refuge, muskoxen are rapidly expanding and pioneering new areas. From the 69 muskoxen introduced between 1969 and 1970 the population has grown to 476 in 1985. Carrying capacity has apparently not been reached.

Experience in the Arctic Refuge from winter seismic exploration in 1984 and 1985 and summer surface exploration in 1983, 1984, and 1985, indicates that these activities have only minor disturbance effects upon Arctic Refuge muskoxen. Harassment may result in a net energy drain if it occurs during the critical winter period, and can thereby reduce survival. Reynolds and LaPlant (1985) reported no long-term or widespread changes in distribution or use of traditional areas in response to disturbance by seismic exploration. In response to seismic activity, one herd did move 2.8 miles and another herd moved 1.9 miles within 24 hours. Jingfors and Lassen (1984) found that muskox disturbed by seismic vehicles either ran or gradually moved away. Other investigators (Carruthers, 1976; Russell, 1977) reported similar responses by muskoxen from winter seismic exploration in Canada.

Potentially economic prospects in blocks A, C, and D occur partially in year-round high-use areas, including calving areas (pl. 2C). Direct loss of muskoxen habitat from oil development could total approximately 2,700 acres.

Disturbance caused by routine oil field operation and associated infrastructure may exclude or reduce muskoxen use of preferred habitat. Muskox reaction to helicopters depends on sex and age of animals, group size, number of calves in a group, the position of the sun and wind direction relative to the disturbance, what the animals are doing at the time of disturbance, and terrain (Miller and Gunn, 1979). In their extensive study of the reaction to helicopter disturbance of muskoxen on Banks Islands, Northwest Territories, Canada, Miller and Gunn (1979) reported that: cows and calves and solitary bulls were the most responsive to disturbance; the reaction of muskoxen to disturbance was similar to their response to a predator; and the degree of reaction to disturbance was generally inversely related to the distance of the disturbing stimuli. The presence of people on the ground in association with helicopters that had landed increased the disturbance. Although muskoxen disturbed by helicopters usually moved less than 0.2 mile, Miller and Gunn (1979) recommended minimum altitudes of 2,000 feet AGL during May-November and 1,000 feet AGL during December-April.

Muskoxen may also be disturbed by seismic surveys. One herd was reported to have run at least 0.6 mile after being disturbed by seismic vehicles 1.9 miles away (Reynolds and LaPlant, 1985). Temporary displacement of up to 2 miles has been observed on both sides of seismic lines (Russell, 1977). While oil field development and operation would be much more intrusive and sustained than seismic exploration, the increased disturbance may be partially offset by habituation which has been observed by Miller and Gunn (1979) during experimental helicopter harassment.

Muskoxen are present on the 1002 area throughout the winter when most exploration and construction activities would take place. Muskoxen daily activity may decrease during winter (Reynolds, 1986) as part of their behavioral strategy for energy conservation. Repeated disturbance causing increased or prolonged activity during the winter results in energy drain which may adversely affect survival of individuals or productivity of pregnant females.

The effects on muskoxen from habitat loss or stress due to disturbance have been difficult to measure. Miller and Gunn (1979) concluded that lack of visible response does not necessarily mean the absence of physiological changes or energy drain which may have a major effect on the population over time. Muskoxen, as residents on the 1002 area, will be exposed to year-round activity. As described in the previous section on caribou, loss of important habitat has been shown to have major negative effects on ungulates. Muskoxen, like caribou, presumably select wintering and calving areas because of factors favorable to herd productivity and survival: availability of preferred forage, better weather or snow conditions, relative absence of predators, lack of disturbance, or some combination of these and other factors. Displacement from calving areas would have a negative effect on muskoxen production. The magnitude of that effect is difficult to accurately predict, particularly in view of the expanding nature of the population and refuge management objectives to allow continued population expansion. The effect on production would likely be related to the magnitude and duration of displacement.

No information is available on the reaction of muskoxen to sustained oil development and production activities. From the reports of Russell (1977) and Reynolds and LaPlant (1985), a 2-mile sphere of influence was assumed in calculating the range which could be affected by full leasing. Table VI-6 shows that habitat values could be lost or greatly reduced throughout about one-third (256,000 acres) of the muskox range within the 1002 area. Habitats used for high seasonal or year-round use, including calving, would be disproportionately affected; muskoxen would be displaced from approximately 53 percent of those habitats. Habitat values could be lost on nearly 75 percent of the high use habitats in which calving occurs. Such a high percentage of loss in valuable calving habitat could have a major negative influence on herd productivity.

Direct mortality could result from hunting, vehicle collisions, and other accidents associated with development. Muskoxen are highly vulnerable to hunting, and direct mortality would be expected to increase over time as access into previously undeveloped areas increased. Increased hunting regulation and enforcement would be required to reduce illegal harvest. With adequate enforcement of season and bag limit restrictions, the number of animals killed would be expected to permit only a minor effect on the population.

Mitigation

Negative effects to muskoxen could be mitigated by standard stipulations prohibiting disturbance, implementing necessary time and area closures, and requiring on-site monitoring. Continued monitoring of the population's growth, distribution, and movements would detect changes and determine what, if any, additional mitigation may be needed. Because riparian areas are favored habitats, those stipulations for caribou that close valuable riparian areas to siting of permanent facilities and limit crossings of those areas by transportation facilities would minimize potential interactions and disturbance, which would reduce effects on muskoxen as well (pl. 2C).

**Table VI-6.**--Observed muskox range potentially affected by development under full leasing or limited leasing, assuming a 2-mile sphere of influence.

| | High-use range seasonally or year-round | | Other range | Total range |
|---|---|---|---|---|
| | Without calving | With calving | | |
| Total muskox range (acres) within Arctic Refuge | 251,000 | 211,000 | 654,000 | 1,116,000 |
| Area (acres) within development sphere of influence: | | | | |
| Full leasing | 46,000 | 112,000 | 98,000 | 256,000 |
| Limited leasing | 46,000 | 110,000 | 98,000 | 254,000 |
| Percent of Arctic Refuge range influenced by development: | | | | |
| Full leasing | 18 | 53 | 15 | 23 |
| Limited leasing | 18 | 52 | 15 | 23 |
| Total muskox range (acres) within 1002 area | 207,000 | 158,000 | 395,000 | 760,000 |
| Percent of 1002 area influenced by development: | | | | |
| Full leasing | 22 | 71 | 25 | 34 |
| Limited leasing | 22 | 70 | 25 | 33 |

Conclusion

Major negative effects upon the muskoxen population from oil development could occur, considering the present management objectives for continued population growth of the herd under natural regulation and the displacement from habitat likely to occur. Muskoxen could be displaced from up to 71 percent of their high-use, year-round with calving, habitats within the 1002 area. This, coupled with direct mortality, and the unavoidable disturbances would cause the population to decrease and its distribution to be altered. Effects would be most pronounced on the subpopulation using the Niguanak-Okerokovik-Angun River area. This subpopulation is the smallest (approximately 80) and has the least amount of interchange with other subpopulations. Consequently the likelihood of immigration offsetting population-depressing forces on this subpopulation would be very limited.

Predicted population changes resulting from petroleum development are speculative. There are no references in the literature to analogous activities in other muskoxen ranges. However, considering the large extent (158,000 acres, 43 percent) of all high-use muskoxen habitats within the 1002 area, as well as more than 33 percent of the population's high-use habitats throughout the Arctic Refuge which could be affected under full leasing, a change in distribution or decline affecting 25-50 percent of the population may occur.

MOOSE

The 1002 area is not high-quality moose habitat. Peak use by moose is during the summer when the 1002 area population probably is less than 25; during the winter, moose are rare on the area. The portion of the total refuge population represented by this figure is not known.

Direct loss of habitat is expected to be about 140 acres out of the 96,000 acres of the 1002 area identified as moose-use areas. Affected areas are low-density habitats (less than one moose per 26 square miles), mainly in Block D (pl. 1C).

Moose adapt readily and habituate to the presence of human activity; they are not easily disturbed (Denniston, 1956; Peterson, 1955). Moose have expanded their range in North America at the same time that human disturbance has spread (Davis and Franzmann, 1979). On the Kenai National Wildlife Refuge in Alaska, helicopter-supported winter seismic surveys using explosives did not modify moose distribution patterns, movements, or behavior (Bangs and Bailey, 1982). Most studies have dealt with moose in forested areas. The response of moose to disturbance in tundra areas has not been demonstrated.

Increased human development on the Kenai Peninsula, Alaska, has resulted in increased moose mortality from hunting, vehicle collisions, poaching, and other causes (Bangs and others, 1982). Moose mortality on the 1002 area could occur as a result of hunting or accidental death, especially vehicle collisions. Because so few moose use the area and because of the area's open nature, the number killed would probably be very low.

Moose populations south of the 1002 area would come under increased hunting pressure due to the influx of workers to the area. Declines in the population age structure and average antler size would probably occur. Moose concentrate in riparian habitats south of the 1002 area where they are highly visible and vulnerable to hunting.

Mitigation

None would be needed beyond those general measures for caribou such as limiting use of transportation corridors and closing the area within 5 miles of project facilities to the discharge of firearms. Moose harvest on Arctic Refuge would be regulated by the State of Alaska in cooperation with the FWS, and should consequently be kept within sustainable limits by modifying harvest seasons and bag limits.

Conclusion

Effects on the regional moose population from habitat loss and mortality due to oil development in the 1002 area would be minor.

DALL SHEEP

Dall sheep are rarely found north of the Sadlerochit Mountains in the 1002 area, although they are common in the Brooks Range, south of the 1002 area. Increased hunting pressure, air traffic, and harassment by sightseers could adversely affect Dall sheep.

Mitigation

More restrictive hunting regulations could be required if increased harvest affects the health of Dall sheep populations or reduces the quality of hunting and associated recreational use.

Conclusion

Indirect effects on sheep outside the 1002 area would be minor. Full leasing would have a negligible effect on Dall sheep in the 1002 area; average age and, consequently, horn size of rams may decline somewhat as a result of increased hunting pressure.

WOLVES

Five to ten wolves seasonally use the 1002 area (Weiler and others, 1985), mainly in the summer for hunting when prey is most abundant. Wolf dens have not been documented in the 1002 area. Wolves have denned infrequently on the coastal plain east and west of the 1002 area. Although wolves occur throughout the Arctic Refuge, their numbers are not known.

The effects of direct habitat loss to wolves would be negligible. Reduction of prey species (primarily caribou) caused by oil development could reduce wolf vigor and, consequently, productivity. The abundance of wolves is ultimately determined by the biomass of ungulate prey (Keith, 1983). Harrington, Mech, and Fritts (1983) reported a positive correlation between prey availability and survival of young wolves. Ability of adults to readily provide food is a key determinant in wolf-pup survival (Van Ballenberghe and Mech, 1975). Reduction of prey species would be greatest in the area east of the Hulahula River where caribou activity and, consequently, wolf use have been the greatest.

Development activity is not expected to cause wolves to avoid the area. During construction of the Dalton Highway and TAPS, instances of wolves becoming habituated to human activity were recorded. In some cases, wolves readily accepted handouts from construction workers (Eberhardt, 1977; Follmann and others, 1980).

Shooting or trapping, which may be the most likely causes of direct mortality to wolves, could increase with increased human access to the 1002 area. Zimen and Boitani (1979) and Mech (1970) reviewed the drastic reduction in the former range of wolves, not just in North America but throughout the Northern Hemisphere. The decline in wolves has largely been a result of human efforts to reduce wolf populations.

#### Mitigation

Measures designed for prey species such as caribou will also help reduce adverse effects to wolves. Enforcement of existing regulations by the State and the FWS would reduce potential effects of hunting. A few wolves might be killed for public safety (to combat rabies), with a minor effect on the population. Strictly enforcing prohibitions against feeding wildlife and providing adequate garbage handling would prevent wolves from becoming nuisances around camps, decreasing the probability of these animals being shot or trapped.

#### Conclusion

A moderate decline of the wolf population using the 1002 and surrounding area could result from the cumulative effects of direct mortality and reduced production or survival of young, caused by reduced prey availability.

### ARCTIC FOXES

Arctic foxes are common and widespread on and around coastal areas. Winter fox habitat is primarily along the coast and on the sea ice outside the 1002 area; denning occurs up to 15 miles inland. Habitat loss associated with oil development would be negligible. Experience across the North Slope has demonstrated that foxes are not greatly displaced. One fox den was reported abandoned when a seismic camp parked next to it (Eberhardt, 1977), but foxes readily used culverts and other construction materials around active TAPS construction camp sites for denning.

Direct mortality as a result of shooting and trapping would cause a minor population reduction. Regulations would limit most of this effect. Shooting some foxes for public safety reasons (rabies) would also occur. Once habituated to people, foxes become very bold which may increase their susceptibility to shooting or trapping. Accidents such as road kills would annually claim a few individuals. Improper garbage handling and illegal feeding of foxes could provide an unnatural supplementary food source which could enhance over winter survival and production of young. Arctic foxes regularly fed in dumps around construction camps during construction of TAPS (Eberhardt, 1977). Foxes have high fecundity rates which are directly influenced by food availability. MacPherson (1969) reported an average litter size of 10.6 young at Demarcation Bay. Under natural conditions production and survival of arctic foxes are directly linked to oscillations in rodent abundance (Speller, 1972). Consequently, arctic fox populations can increase rapidly when rodents are abundant. The effect of increased artificial feeding may result in increased density and, subsequently, increased exposure to rabies and other diseases.

#### Mitigation

No mitigation beyond that already outlined is recommended.

#### Conclusion

The effects on the arctic fox population are uncertain. Population could increase because of the potential for increased artificial food supplies, or decrease as a result of direct mortality from shooting, accidents, or rabies. Any effect is expected to be minor.

### WOLVERINES

The wolverine population is scattered throughout the 1002 area at low density (Mauer, 1985a). Recent wolverine observations on the 1002 area (Mauer, 1985a) relative to levels reported at other sites on the North Slope (Magoun, 1979), suggest that current 1002 area wolverine numbers may be at a low level in relationship to habitat quality. Data regarding wolverine use at specific areas within the 1002 area are lacking as are population estimates for the entire Arctic Refuge.

Throughout their circumpolar distribution, wolverines occur exclusively in remote regions where human activity is low (van Zyll de Jong, 1975; Myhre, 1967). The wolverine has been displaced from southern portions of its historic range in Eurasia and North America (Myhre, 1967) and is known to be cautious and wary of humans (Krott, 1960). Wolverine distributions and movements on the 1002 area would be altered by the presence of human activity associated with oil development. Displacement of wolverines from local areas of development on the 1002 area is very likely. In considering potential population effects to wolverines from the proposed Susitna hydroelectric project, Whitman and Ballard (1984) thought that local avoidance of work camps would not significantly influence wolverine movements or productivity.

Because wolverines are primarily scavengers, their abundance is related to the biomass and turnover of large herbivore populations (van Zyll de Jong, 1975). Thus, the magnitude of anticipated effects on populations of caribou, muskox, and moose upon which wolverines depend will directly affect the degree of effects on wolverines. Major effects have been projected for caribou and muskox populations, minor effects for moose. Magoun (1985) stated that successful management of wolverines in Game Management Unit 26A on the North Slope was directly related to successful management of the Western Arctic and Teshekpuk Lake caribou herds. She further stated that a decline in these herds could result in a decline in wolverine productivity. Whitman and Ballard (1984) believed that a decrease in the populations of moose and other prey as a result of the proposed Susitna hydroelectric project could eventually affect wolverine densities, population size, and movements. Reduction in abundance of the primary predators (wolves and brown bears for which moderate and minor effects are predicted, respectively) could also decrease the abundance of prey carcasses available for scavenging by wolverines.

During the winter wolverines on the tundra are vulnerable to hunting from snowmobiles and aircraft. Increased hunting and trapping could occur on the 1002 area as a result of the greatly improved access provided by the roads, trails, and airstrips associated with oil and gas development, and the increased human populations in the region. Hornocker and Hash (1981) found that trapping was the primary cause of wolverine mortality. Van Zyll de Jong (1975) felt that human predation was the factor most likely to affect wolverine numbers.

#### Mitigation

Measures designed for prey species such as caribou, muskox, and moose will also benefit wolverines. Control of access and harvest to minimize direct mortality would be the most important determinant of effects. This control is recommended as mitigation for effects on several species.

#### Conclusion

The cumulative effects of displacement/avoidance and reduced food resources could result in localized, long-term changes (a moderate effect) in wolverine distribution. Inadequate controls on access and harvest could possibly reduce by half or more the 1002 area wolverine population. If this occurred, it would result in a major effect.

### BROWN BEARS

Brown bears are common on the 1002 area during May-September when they forage and range widely. The 1002 area contains habitat used seasonally by bears at moderate or high density (pl. 1D). Habitat use and populations throughout the Arctic Refuge have not been similarly delineated.

Under full leasing, direct loss of brown bear habitat would total about 3,500 acres. Oil-field activities would take place throughout approximately 17 percent of high and moderate brown bear use areas within the 1002 area. Quantifying the number of animals involved is difficult. Seasonal density of bears on the 1002 area averages one bear/30 square miles, but local densities can range from one bear/18.5 square miles to one bear/2,200 square miles.

Brown bears use the 1002 area mainly for feeding from late May through July when caribou are present. The potential decline in caribou population and change in distribution probable with full leasing (major for the PCH and moderate for the CAH) could cause a decline in an important brown bear food source. This could result in decreased bear productivity and survival of young in years when alternate food sources, such as small rodents, are scarce.

Brown bears are not readily displaced by human presence or activity. Brown bears along the TAPS corridor became so habituated to development activity that they occasionally entered occupied buildings in search of food (Follmann and others, 1980), routinely fed at garbage dumps, and waited along roads and other activity areas for handouts. Electrified fencing successfully eliminated problems with both brown and black bears in two summer camps of 100 people each in the Brooks Range (Follmann and Hechtel, 1983).

Disturbance to brown bears denning on the 1002 area could occur, particularly from winter seismic exploration because such activity occurs after brown bears have denned and den sites may not be known. Disturbance of denning bears, once development is complete, should be negligible since bears would likely avoid denning in areas where activity was occurring. Hanley and others (1981) found that brown bears in their dens were disturbed by seismic blasting 1.2 miles away, as demonstrated by movement within the den, but no negative effect such as den abandonment was documented. Reynolds and others (1983) reported that seismic vehicles or shot detonation resulted in increased heart rate and movement in the dens of instrumented brown bears. Harding and Nagy (1980) reported brown bears successfully wintering within 1-4 miles of active oil exploration camps. Conversely, they also reported a den being abandoned when a seismic vehicle drove over it, and den destruction during gravel mining. Quimby (1974) reported that 5 of 10 brown bears apparently abandoned dens in early October after being followed to their dens by helicopters.

Only 6 of 129 (4.7 percent) den sites documented during the Arctic Refuge baseline studies were located on the 1002 area (Garner and others, 1984, 1985). Therefore, the potential to disturb denning habitat and disrupt denning activities of the regional brown bear population from oil exploration and development would be low, and impacts would be expected to be minor.

Aircraft disturbance of bears is unavoidable. Doll and others (1974) and McCourt and others (1974) reported variable reactions by bears to aircraft disturbance at 1,000 feet AGL or less. Douglass and others (1980) reported bears reacted strongly to hazing by vehicles and aircraft.

Direct bear mortalities from accidents or being shot in defense of human life and property will occur. Drug-induced death of bears occasionally occurs when nuisance bears are immobilized for relocation. Accidents, such as vehicle collisions, could also reduce bear numbers. Follmann and others (1980) reported 13 brown bears killed in conjunction with TAPS construction and operation during 1971-79. The BLM (1983) estimated that oil development on NPRA in an area of bear density similar to the 1002 area would produce a loss of one bear annually as a result of confrontation between bears and oil development personnel. The rate of mortality would presumable be similar on the 1002 area. Most deaths would probably result from bears' being attracted by improper garbage or food handling, or illegal feeding.

Bears that seasonally use the 1002 area are part of the same regional population inhabiting the mountains and foothills of the Brooks Range. Hunting pressure on this population could increase if oil workers remained on the 1002 area during off-duty periods to pursue recreational activities. Increased harvest of bears occurred during construction of TAPS (Follmann and Hechtel, 1983). Schallenberger (1980) similarly reported an increase in bear harvest as a result of increased human presence associated with oil development. Further regulation of hunting by the State and the FWS would probably be required.

#### Mitigation

In addition to those measures listed earlier in the chapter, strictly enforcing prohibitions on feeding wildlife, adequate food storage, control of harvest, and control of aircraft flight altitudes and corridors would lessen adverse effects of development resulting from full leasing. An active monitoring program for brown bears during seismic exploration, construction, and other development activities would help avoid disturbing denning bears. Buffer zones of at least 1/2 mile would be established around any known dens as required for previous exploration in the 1002 area [50 CFR 37.32 (c)].

#### Conclusion

A moderate decline in brown bear numbers or change in distribution could result from the additive effects of direct mortality, decreased prey availability, harassment, and disturbance in denning areas.

### ARCTIC GROUND SQUIRRELS AND OTHER RODENTS

Arctic ground squirrels are commonly found throughout much of the 1002 area. Moderate effects would result from localized habitat alterations such as placing gravel pads over squirrel colonies. Minor effects would be expected as a result of road kills.

Other rodents, primarily lemmings and voles, are naturally cyclic in abundance but can be expected to be affected somewhat by development on the 1002 area. Some effects may be positive--structures and debris would provide protective cover from hawks, owls, or other predators. Negative effects could include localized destruction of nesting sites and increased mortalities from entrapment and traffic.

#### Mitigation

None additional to that already outlined is recommended.

#### Conclusion

Developing oil resources throughout the 1002 area would cause minor to moderate effects on squirrel populations because of habitat loss and alteration. Effects on lemmings and voles should be minor.

## MARINE MAMMALS

Though 14 species of marine mammals may occur off the coast of the Arctic Refuge, only 5 species were evaluated: polar bear, ringed and bearded seals, and beluga and bowhead whales.

### POLAR BEARS

Polar bears are one of the few large mammal species present on the 1002 area during winter.

Polar bears are particularly sensitive to human activities during the denning period. Belikov (1976) reported that females will usually abandon their dens prematurely if disturbed. Early den abandonment can be fatal to cubs unable to fend for themselves or travel with their mother. Development of potential petroleum prospects in Block C could have a moderate adverse effect on the continued suitability of the eastern portion of the 1002 area for denning polar bears, substantially decreasing the habitat values of this area. At least eight polar bear dens were located within this area between 1972 and 1985 (pl. 1E).

Factors that may influence responses of denning female polar bears to disturbance include: frequency and level of disturbance, distance of the disturbance from the den, and the stage of denning when disturbance occurs.

Pregnant females beginning to den in the fall are especially vulnerable. A radio-collared female polar bear denning in the 1002 area emerged from her den in early February 1985 (Amstrup, 1986b), as the suspected result of repeated disturbance from motorized exploration support equipment within 1,600 feet of the den site. The bear was suspected of being pregnant when she entered her den, even though no cubs were later observed.

Pipelines and roadways may prevent female polar bears from moving to and from inland denning areas (Amstrup and others, 1986; Lentfer and Hensel, 1980). Disturbance from oil exploration, construction, and production in the immediate vicinity of polar bear dens could cause the bears to abandon dens. Production activities could create disturbances that would likely keep bears from returning to those preferred denning areas.

Locating petroleum resources, with resultant development and production facilities, in confirmed coastal denning areas could produce a major reduction in the availability of 1002 area denning habitat. Although the number of bears returning each year varies depending on ice, snow, and weather conditions, some researchers believe female polar bears show fidelity to birth sites and try to reach areas previously used for denning (Lentfer and Hensel, 1980). Recent analyses suggest that mortalities of female polar bears are now about the maximum the Beaufort Sea population can sustain (Amstrup and others, 1986) without a decrease in population levels. Thus, preserving undisturbed onshore denning habitat each year is very important for the 12 to 13 percent of females denning on land rather than offshore ice. Moreover, if there is an especially significant area for denning on land in Alaska, it is on and adjacent to the 1002 area (U.S. Fish and Wildlife Service, unpublished data).

Additional habitat value losses would result from development of marine facilities. The Pokok port site is located in a confirmed coastal denning area; polar bears were known to have denned within approximately 1 mile of the site in 3 of the last 5 years. The Camden Bay area has also been used by denning polar bears.

The effects of oil development on nondenning segments of polar bear populations are not well known. These segments of the population generally inhabit the pack ice throughout the year, although in the fall a number of animals, primarily family groups composed of females and juveniles, are seen along the coast (Amstrup and others, 1986). Potential adverse effects to bears inhabiting pack ice could be caused by shipping traffic and its concomittant disturbance of water and ice or from an accidental oil spill from a ship or loading facility. Disturbance alone may not greatly affect nondenning bears. Direct effects of oil contamination are not well known. Initial results of a study conducted in Canada (Hurst and others, 1982) indicate that bears forced to enter an oil slick and then subjected to cold temperatures and wind will die; that study did not determine if polar bears will voluntarily enter an oil slick.

Polar bears are attracted by garbage dumps and could become a nuisance or threat to personnel in camps. Because bears are attracted to the Barter Island area to scavenge on whale carcasses, nearby oil facilities could experience a higher occurrence of nuisance bears than other facilities report.

Mitigation

Some adverse effects to polar bears could be reduced by documenting den locations and use areas so that oil-development activities avoid them to the maximum extent possible. Avoiding suitable denning habitat is most important. To prevent disturbance which could cause early den abandonment, buffer zones of at least 1/2 mile should be established around known dens, such as the zones described for brown bears [50 CFR 37.32 (c)]. Activities along the coast during the late October-early November period when bears come ashore to den should be minimized. Where possible, orienting seismic lines, pipelines, and roads at right angles to the coast in coastal areas could further minimize interference with denning bears. Also, ice quality and movement data collected by industry should be made available to the FWS to augment research attempts to understand polar bear movements and behavior. Such data would be invaluable in learning how to predict and minimize adverse effects of industrial activities on polar bears.

If attracted by garbage, polar bears could become a nuisance or threat to personnel and would need to be relocated. Proper garbage control and fencing of camps would reduce this problem. Because killing polar bears by anyone except Alaskan Natives is prohibited under the Marine Mammal Protection Act of 1972, nuisance bears would have to be trapped and relocated.

Conclusion

Although only a few polar bears use the 1002 area, the exclusion of only one or two bears from areas consistently used for denning would be a moderate impact on that segment of the Beaufort Sea population because some decline in the reproduction rate could result. Given the apparently stable Beaufort Sea population of approximately 2,000 polar bears, such exclusion and decline in natality would likely not affect the species' overall survival, so long as similar intensive developments did not occur along the entire northern coast of Alaska and Canada. Biologists believe that the Beaufort Sea population can sustain little, if any, increase in mortality of females because population surveys and calculations show that the number of animals dying each year is approximately equal to the population increase from reproduction (Amstrup and others, 1986).

SEALS AND WHALES

Oil-development activities with the greatest potential for affecting seals and whales would be those occurring along the immediate coast or just offshore. Under full leasing any oil-development and production would probably occur far enough inland to have no direct effect on either seals or whales. Marine and air support facilities could affect some marine mammals, because noise producing activities generally disturb marine mammals.

Major sources of noise are low-flying aircraft or equipment that produces high-frequency, high-pitched sounds. Low-flying aircraft are known to panic hauled-out seals. If the disturbance is frequent during molting, successful regrowth of skin and hair cells can be retarded, increasing physiological stress on seals during a normally stressful period (U.S. Minerals Management Service, 1984). Another source of noise is vehicular traffic on coastal ice roads. This source of disturbance is of concern because noise transmitted through the ice may be loud enough to displace denning and pupping ringed seals to a degree sufficient to reduce reproductive success (U.S. Minerals Management Service, 1984). Underwater noise from aircraft flying at altitudes of less than 2,000 feet, as well as from boats, has been recorded (Fraker and Richardson, 1980; Greene, 1982; Ford, 1977; Fraker and others, 1981). Such noise may disturb or alarm marine mammals, causing them to flee.

Fraker and others (1978) reported a startle response by beluga whales and flight from barges and boats traveling through a whale concentration area. Flight or avoidance could displace whales from important habitat areas. However, monitoring of beluga behavior and distribution for 10 years did not show any long-term or permanent displacement of whales from Mackenzie delta development areas (Fraker, 1982).

Vessel operations (boats, barges, icebreakers) would increase with development of marine facilities at either Camden Bay or Pokok. Noise and disturbance associated with the increase would be the activity most likely to affect bowhead whales in the area. Preliminary field experiments on bowhead whales showed statistically significant differences in behavior as a result of nearby boat activity, including decreased time spent at the surface, decreased number of blows per surfacing, increased spreading out of grouped animals, and significant changes in directional orientation (Fraker and others, 1981). Bowheads in summer feeding locations have been observed to move away from boats when approached to within 0.6 mile, and sometimes to within 1.9 miles (Fraker and others, 1982). There was no evidence that bowheads abandoned any area where they have been disturbed by a boat; their flight responses seemed to be brief. Whether frequent or continuous boat operations would ultimately cause bowheads to vacate an area or would lower their reproductive fitness is unknown (Fraker and others, 1982). Conclusive evidence of effects from boat traffic on bowhead migration patterns or behavior during migration does not exist. East of Barrow, traditional spring migration of bowheads is seaward from the coastline. If icebreaking vessels are used to support 1002 area development supply needs, artificial leads may be created. These leads could alter migration chronology, encouraging early movement into northerly areas before safe ice conditions exist.

Short-term behavioral modification in marine mammals could occur near proposed marine facilities: changes in migrational routing, decreased time spent at the surface, concentration or dispersion of aggregations, or changes in swimming speeds. These changes would probably not preclude successful migration. But, the ultimate effect of disturbance may be abandonment of a particular area, and possibly reduced productivity and population size. Long-term behavioral effects from noise and vessel disturbance have not been demonstrated or measured.

Dredging activities and gravel deposition during construction could affect marine mammals through disturbance, habitat alterations, and changes in availability of food sources. Noise and other disturbances from dredging, causeway construction, and support traffic could displace marine mammals up to approximately 2 miles from the activity site during operations (U.S. Minerals Management Service, 1983). Dredging and gravel deposition could also temporarily disrupt or remove prey species for several miles downstream of dredging sites and near the port construction sites. Short-term, site-specific increases in turbidity would not be expected to adversely affect seals, whales, or their habitats in the coastal area. Sediments associated with causeway construction would be less than, but additional to, that naturally occurring during spring breakup or storms (Lowry and Frost, 1981).

#### Mitigation

No mitigation beyond that already outlined for other species is recommended.

#### Conclusion

The continued presence of dolphins, porpoises, and seals in coastal marine habitats with high levels of industrial activity and continuous marine traffic strongly suggests that at least some marine mammals are able to adjust to manmade noise and disturbance (U.S. Minerals Management Service, 1984). Knowledge of marine mammal behavior in association with industrial disturbance elsewhere suggests that any behavioral changes in animals using the Arctic coast would be minor as a result of petroleum development on the 1002 area.

### BIRDS

Factors that may directly affect birds using the 1002 area include shoreline alteration; facility siting; gravel mining; dredge and fill operations; contaminants from reserve pits, drill muds, and fluids; pipeline and road construction; and associated developments. The responses of birds to human disturbances such as road traffic, aircraft flights and other development-related activities are highly variable and depend on factors such as species; physiological or reproductive state; season; distance from disturbance; and type, intensity, and duration of disturbance.

Adverse effects on birds from further exploration are likely to be minor. Habitat modification and disturbance will have their greatest effect during oil field development and production. Of primary concern would be permanent habitat loss from facility sitings, roads, and pipelines. Approximately 5,650 acres of tundra habitat would be destroyed and at least an additional 7,000 acres would be modified due to dust and gravel spray, different rates of snowmelt, and changes in water drainage. Effects of habitat modification and disturbance are discussed in terms of the five bird categories used in Chapter II: swans, geese, and ducks; seabirds and shorebirds; raptors; ptarmigan; and passerines.

SWANS, GEESE, AND DUCKS

Disturbance associated with exploration and development, especially from air traffic near nesting waterfowl, could reduce productivity of waterfowl and may cause abandonment of important nesting, feeding, and staging areas. Studies in the Arctic indicate that black brant and common eider had lower nesting success in disturbed areas (Gollop, Davis, and others, 1974). Schweinsburg (1972) reported that snow geese were particularly sensitive to aircraft disturbance during pre-migratory staging. Conversely, studies by Ward and Sharp (1973) and Gollop, Goldsberry, and Davis (1974) indicate the unlikelihood of long-term displacement or abandonment of important molting and feeding areas by oldsquaw from occasional aircraft disturbance.

A small increase in direct waterfowl mortality would be possible. Road kills of hens and flightless broods could occur as well as some aircraft-bird collisions. Several investigators (Sopuck and others, 1979; Blokpoel and Hatch, 1976; Cornwell and Hackbaum, 1971; Anderson, 1978) have reported mortalities when waterfowl strike manmade objects, particularly powerlines. Some poaching could also occur.

Nest predation appears to be a significant source of natural mortality for waterbirds on the North Slope. Should raven, gull, or arctic fox populations increase as a result of poor housekeeping practices at facility sites (uncontrolled garbage dumps or feeding), predation on waterfowl nests and young could increase. Wright and Fancy (1980), studying the effects of an exploratory drilling operation at Point Thomson, Alaska, found that a large proportion of waterfowl nests were lost to predators at both the drill site and the control area. At least 50 percent of loon nests failed prior to hatching and five of eight waterfowl clutches were taken by predators, mostly arctic foxes. Disturbance that causes adults to temporarily abandon their nest or young can also increase predation.

Oil and other contaminant spills could kill waterfowl, particularly in lagoons where waterfowl congregate in large numbers. The effect to 1002 area populations could be major if a spill occurred in lagoons during peak molting, staging or migration periods. Effects could also extend to other bird populations which migrate along the Arctic Refuge coast.

The alteration of habitat and food chains by oil or other contaminant spills may affect birds through direct ingestion or contact. These effects are apt to be more subtle and prolonged. Because most breeding and many nonbreeding birds depend on invertebrate food sources during at least a portion of their stay on the North Slope, pollution-induced depression of invertebrate populations may influence survival and reproduction.

Oil spills can affect invertebrates through direct mortality by smothering, contact toxicity, toxicity of soluble compounds, destruction of sensitive eggs and larvae, and sublethal effects such as destruction of food sources, reduced tolerance to stress, interference with behavioral and integrative mechanisms, and concentration of carcinogens or other toxic compounds in the food chain (Percy and Mullin, 1975). A closer examination of sublethal effects upon physiological functioning shows that such sublethal effects may cause death of an organism over an extended period (Percy and Mullin, 1975). Mortality may result from a combination of behavioral and physiological disfunction, reduced feeding and stress, increased predation, and long-term increases in metabolic rate (Percy and Mullin, 1975).

In their study of major oil spills, Teal and Howarth (1984) concluded that the effect on aquatic invertebrates ranged from massive kills and total eradication of microbenthos communities to elimination of only the sensitive species. Effects on phytoplankton populations included changes in species dominance, depression of biomass, or increased biomass brought about by the reduction of zooplankton grazers. In some cases, invertebrate populations were still depressed 6 to 7 years after the spill. In other spills, recovery occurred within a year. Recovery of aquatic systems in Arctic waters would be much slower (Percy and Mullin, 1975).

An experimental spill of Prudhoe Bay crude oil by Barsdale and others (1980) on a tundra pond eliminated several invertebrate species from the pond for at least 6 years. These included fresh-water aquatic invertebrates utilized by breeding tundra birds.

The effect on North Slope bird populations from changes in water quality of tundra ponds as a result of reserve pit discharges has not been studied. However, along with deteriorations in water quality, as discussed previously, the quality and quantity of aquatic organisms used as food by waterfowl may be considered as also decreasing, thereby reducing habitat values (R.L. West and E. Snyder-Conn, unpublished data).

Sources of direct waterfowl mortality would include: shooting; strikes with towers, transmission lines, antennas, and other structures (particularly during the frequent foggy weather); predation; and environmental contaminants. The annual loss would be highly variable, depending on the number of waterfowl using the area and weather.

Tundra swans concentrate in the 1002 area in the Canning-Tamayariak delta, Hulahula-Okpilak delta, Aichilik-Egaksrak-Kongakut delta, and Jago River wetlands (Brackney and others, 1985a). Up to 100 nests have been found and 400 to 500 swans have used the Arctic Refuge coastal plain; most of this use is on the 1002 area.

Direct loss of tundra swan habitat would be relatively limited (pl. 3A). An area of low-density swan use could be affected by development in Block C. Marine facilities at Camden Bay or Pokok would also adversely affect swan habitat. Transportation corridors would have little effect on tundra swan nesting and staging areas, because they are sited away from coastal areas where most nesting occurs. Repeated disturbance from air or surface traffic, or other activities associated with development, might cause nest abandonment where nests and those activities occur in the same area. Nevertheless, swan nests and use areas have been observed less than 2 miles from the village of Kaktovik (Brackney and others, 1985a).

Snow geese would experience a direct loss of over 2,900 acres of their historically used staging habitat in Blocks B, C, and D (pl. 3B). Nearly 2,000 acres is considered preferred staging habitat that is used by approximately 75 percent of the snow geese using the 1002 area in any given year. Because this habitat represents less than 1 percent of the total preferred staging habitat available in the 1002 area, direct loss of habitat values would result in minor effects. Moreover, staging snow geese are highly mobile.

Disturbance resulting in indirect habitat loss could have a greater effect on snow geese. They are highly sensitive to aircraft disturbance. Studies in northeast Alaska and northwest Canada reported that snow geese flush in response to fixed-wing aircraft and helicopters passing by at 100-10,000 feet AGL and distances of 0.5-9 miles (Salter and Davis, 1974; Davis and Wiseley, 1974; Barry and Spencer, 1976; Spindler, 1984). Spindler (1984) found that fixed-wing aircraft flying at low-altitudes produced less disturbance than when flying at higher altitudes. He attributed this to reduced lateral dispersion of sound. Davis and Wiseley (1974) reported limited habituation to aircraft disturbance; after several passes with a helicopter flushing distance decreased. Flight distance of the geese decreased after several passes of a fixed-wing aircraft.

Disturbance by vehicle traffic, drilling, human presence, or other causes could extend up to 3 miles from the source. Gollop and Davis (1974) reported that the noise from a gas-compressor-simulator disturbed staging snow geese 3 miles away from the source at Komakuk Beach, Yukon Territory, Canada. Some birds, however, eventually returned to within 1.5 miles of the noise. Wiseley (1974) reported similar noise disturbance which displaced snow geese within 0.5 mile. Hampton and Joyce (1985) reported that snow geese were disturbed by general activity associated with oil-development at Prudhoe Bay. Wiseley (1974) did report limited habituation to disturbance over time.

Existing data on the degree of displacement are inconclusive. Table VI-7 shows the amount of habitat that could be affected by development resulting from full leasing, assuming snow geese are displaced 1.5 and 3 miles as observed by Gollop and Davis (1974). Habitat values could be lost on up to 45 percent of the preferred staging area on the 1002 area and 27 percent of the total preferred staging area in the Arctic Refuge with an assumed 3-mile displacement. A 1.5-mile displacement would result in lost habitat values on nearly 31 percent of the preferred staging area within the 1002 area and up to 18 percent of the total preferred staging area within the Arctic Refuge.

An average of 105,000 snow geese (15 to 20 percent of the Banks Island population) stage on the 1002 area, building energy reserves prior to their southward migration. During some years, as many as 325,000 snow geese have staged on this part of the 1002 area. Patterson (1974) reported an increase of 7.2 ounces of fat and 1.7 ounces of muscle (wet weight) in juvenile snow geese while they were on the 1002 area. Brackney (unpublished data) found an average daily gain of 0.6 ounces and 0.7 ounces of fat (dry weight) for adult male and female snow geese, respectively. Juveniles gained an average 0.5 oz/day. Reduced time spent feeding and lost habitat in which to feed would result from petroleum development, adversely affecting accumulation of the energy reserves essential for migration. Davis and Wiseley (1974) estimated that staging juvenile snow geese unable to adjust to aircraft disturbance accumulated 20.4 percent less energy reserves due to lost feeding time. Energy reductions of this magnitude could reduce the survival of migrating geese.

Mitigation

Measures outlined for other species also apply to waterfowl: careful facilities siting, as well as controls on surface activities, air transportation, and hunting. Reserve pit fluid discharges and other contaminants should be adequately controlled. Powerlines should be designed to minimize losses from bird strikes by burying or attaching to pipelines or otherwise eliminating the need for poles. Increased hunting from workers in the area will occur but will be kept to a minimum level by the assumed prohibition of discharging firearms around development areas. The judicious placement of transportation corridors south of coastal nesting areas would be particularly important for tundra swans.

Conclusion

A decline in waterfowl use on the 1002 area could occur. Indirect mortality would result from the cumulative loss of nesting and feeding habitat, persistent disturbance

**Table VI-7.**--Snow goose staging habitat potentially affected by development under full leasing or limited leasing, assuming 1.5- and 3-mile spheres of influence.

[Preferred staging is defined herein as the area used by approximately 75 percent of the staging snow geese on the refuge in any given year. Peripheral staging is defined herein as the area used by staging snow geese, excluding the preferred staging area.]

| | Preferred staging | Peripheral staging | Total staging area |
|---|---|---|---|
| Staging habitat within the Arctic Refuge (acres) | 888,000 | 460,000 | 1,348,000 |
| Staging habitat within 1002 area (acres) | 529,000 | 307,000 | 837,000 |
| Assuming a 1.5-mile sphere of influence: | | | |
| Staging habitat affected (acres) | | | |
| Full leasing | 162,000 | 101,000 | 263,000 |
| Limited leasing | 95,000 | 67,000 | 162,000 |
| Percent of staging habitat within 1002 area | | | |
| Full leasing | 31 | 33 | 31 |
| Limited leasing | 18 | 22 | 19 |
| Percent of staging habitat within Arctic Refuge | | | |
| Full leasing | 18 | 22 | 20 |
| Limited leasing | 11 | 15 | 12 |
| Assuming a 3-mile sphere of influence: | | | |
| Staging habitat affected (acres) | | | |
| Full leasing | 236,000 | 155,000 | 391,000 |
| Limited leasing | 135,000 | 104,000 | 239,000 |
| Percent of staging habitat within 1002 area | | | |
| Full leasing | 45 | 50 | 47 |
| Limited leasing | 26 | 34 | 29 |
| Percent of staging habitat within Arctic Refuge | | | |
| Full leasing | 27 | 34 | 29 |
| Limited leasing | 15 | 23 | 18 |

from development activities, and spills or contaminants from reserve pits and other facilities. Direct mortality from road kills, aircraft, bird strikes with structures, and poaching is expected to be minor. With effective implementation of mitigation and use of recent knowledge about previous oil development on the North Slope, the overall effect is expected to be minor for ducks, tundra swans, and geese other than snow geese. Operational needs, weather, and safety of equipment and personnel may limit the effectiveness of aircraft altitude and corridor restrictions as well as some time and area closures.

A major reduction or change in distribution of snow geese using the 1002 area could occur through the cumulative effects of direct habitat loss, indirect habitat loss due to disturbance, and direct mortality. Disturbance will cause subsequent loss of feeding areas and feeding time, as well as energy drain, and would be the single largest negative force causing losses in habitat value. Based upon past historical use of the 1002 area by some of the Banks Island, Canada, snow goose population and the assumed displacement of these geese from 45 percent of their preferred staging habitat, a reduction in the Banks Island population or change in distribution of an average of 5-10 percent could occur. The average number of snow geese annually staging on the 1002 area could be reduced by almost 50 percent. Because of highly variable annual use of the 1002 area, actual effects could vary widely from year to year.

SEABIRDS AND SHOREBIRDS

Development in the 1002 area would have widely varying effects on seabird and shorebird species, depending on time of year, location, and type and intensity of disturbance. Nesting seabirds are likely to be more susceptible to development activity than nonbreeders and can be expected to avoid nesting close to areas with visual or noise disturbances. Nesting attempts in disturbed areas may be less successful, as has been observed with Arctic terns (Gollop, Davis, and others, 1974).

Coastal development sites in Block C and at the Pokok and Camden Bay sites, as well as development facilities inland where gulls, terns, and jaegers often nest, could cause locally moderate effects on some nesting seabird populations. Spilled or leached contaminants from reserve pits or other sources could enter the food chain, reducing invertebrate foods or resulting in accumulation of toxic substances.

Some positive effects on seabirds can be expected. In spite of mitigation, a certain amount of debris can be expected. Black guillemots are known to nest in old oil drums and other debris and may respond favorably in some instances if more nesting sites are inadvertently made available. Local glaucous gull numbers could increase considerably around sanitary landfills because of the artificial food source. Over time, other gull species could also be expected to use such areas. Possible long-term increases to gull populations could be moderate to major, as a result of increased food. A population increase in gulls could have a negative effect on other seabird species because gulls eat the eggs and young of other birds. Glaucous gull predation on Canada goose and Pacific brant eggs in the Lisburne oil field was recently documented by Murphy and others (1986), who noted that predation upon goose eggs may be exacerbated by "an unnaturally high gull population in the Prudhoe Bay area." A nearby open dump may be the cause of the high gull population.

Because of widespread and intensive use of the 1002 area by shorebirds, there is a potential for a variety of adverse effects from petroleum development activities. As with seabirds, these effects include disturbance of nesting birds, ingestion of contaminants, or reduction of food resources because of contaminant spills. Shorebird nesting and staging concentrations occur primarily along the coast in riparian habitats (pl. 3C). Wet tundra and river deltas are important to migratory and staging birds. Habitats with a good mix of wet and dry terrain are ideal nesting sites for most shorebird species.

Recent work near Prudhoe Bay has shown that reduced numbers of shorebirds occur near roads in the oil field (Troy and others, 1983; Troy, 1984). Direct habitat loss by gravel placement and impoundments as well as effects from dust and noise could occur. Other potential effects, including occasional mortalities from traffic, collisions with towers and communications equipment, and contaminant spills, could occur to a lesser degree. The thaw-lake plains area in the lower Okpilak, Jago, and Niguanak River systems are high use areas that would be affected by development of potentially economic prospects in Block C. Any development on KIC coastal habitats would increase potential negative effects on coastal birds.

Mitigation

Carefully placing facilities, restricting transportation, and controlling pollutants would also minimize adverse effects to seabirds and shorebirds.

Conclusion

Overall effects to seabird and shorebird populations on the 1002 area would be minor if facilities and activities were minimized in the riparian and coastal habitats where nesting and staging are most concentrated. Moderate effects could occur where local development is intensive in areas with high seabird and shorebird use.

RAPTORS

The gently rolling terrain of the 1002 area provides only limited habitat for cliff-nesting raptor species, where rivers have cut steep banks or exposed rock cliffs. The 1002 area is important foraging habitat for the few cliff-nesting birds of prey that nest there and for those that nest farther south in the foothills and mountains. Short-eared and snowy owls nest in the open tundra and feed throughout the 1002 area, and in years when prey is abundant, owls are common.

Raptors, like most birds, are acutely sensitive to disturbance during their nesting period. If disturbed repeatedly, raptors typically abandon nests. During construction of the Terror Lake hydroelectric project on Kodiak Island in 1983, rough-legged hawks were absent from areas where they had successfully nested in 1980 and 1982 (Zwiefelhofer, 1985). With completion of the dam and elimination of a construction camp in that area, three of four hawk nests were again active in 1984. In contrast, however, gyrfalcons nested successfully within 1 mile of an airstrip built to support an exploratory well in the NPRA. The nest was occupied during construction activities and was located on the flight path used by approaching aircraft (P.E. Reynolds, unpublished data).

Potential conflicts in the 1002 area in known high-density raptor nesting habitat used by rough-legged hawks, gyrfalcons, and peregrine falcons (see section on Threatened and Endangered Species) could occur from road, collecting-line, and drill-pad systems located in Blocks A and D (pl. 3D). Carefully siting access and development facilities would reduce conflicts. Short-eared and snowy owls which nest on the open tundra could experience some reduction of nesting habitat.

Once nesting habitat needs are met, raptor populations and distribution vary with prey availability. There would be limited conflict between most raptor nesting habitat and potential development. Adverse effects would be directly related to the adverse effects on their prey base, such as small rodents, ptarmigan, and waterfowl. These effects are generally expected to be minor.

In 1984, the most common cliff-nesting raptor using the 1002 area was the golden eagle (Amaral, 1985; Mauer, 1985b). Golden eagle distribution appears to be positively correlated with caribou calving and postcalving use areas (Mauer, 1985b). The major effects anticipated on the PCH from development could cause an effect on golden eagles because of decreased prey abundance or modified distribution. This effect would be moderate rather than major because the affected birds are primarily immature (nonreproducing), and some other food sources do exist to help meet their needs.

Direct mortality of raptors resulting from collisions with towers, planes, or electrical wires would be minor.

Mitigation

Measures designed to reduce adverse effects to caribou during calving and post-calving could lessen effects of reduced prey for golden eagles.

Siting and designing powerlines and towers to minimize potential strikes, as discussed for waterbirds, will reduce direct mortality to a minor effect.

Restricting activities in known high density nesting areas near Sadlerochit Springs and Bitty Benchmark would further minimize adverse effects of oil development.

Other restrictions should include:

1. The authority to require aircraft to maintain 1,500-foot altitude (above nest level) within 1 mile horizontal distance of nest sites from April 15 through August 31 (or June 1 if a nest is found inactive).

2. Permitting activities within 1 mile of active rough-legged hawk, golden eagle, gyrfalcon, and peregrine falcon nests on a site by site basis.

3. Prohibiting permanent facilities and long-term habitat alterations from materiel sites, roads, and airstrips within 1 mile of rough-legged hawk, golden eagle, gyrfalcon, and peregrine falcon nest sites, unless specifically authorized by the FWS.

Conclusion

The golden eagle population using the 1002 area could be expected to decline moderately or change distribution as a result of major adverse effects on the PCH, an important prey species. Other raptors using the coastal plain could experience a minor decline in nesting success as a result of disturbance.

PTARMIGAN

Some ptarmigan habitat would be covered by structures and gravel fill. Habitat losses would be most noticeable where facilities were placed in high-use riparian willow areas. Some increase in mortality could be expected from hunting and traffic. Disturbance of nesting or brooding ptarmigan could occur if people or vehicles came too close to nesting birds, scaring off hens or scattering the young flocks. Predators take advantage of such disturbance to prey upon eggs and young. Jaegers have been observed to hover over people hiking across the tundra waiting for them to flush possible prey (R.L. West, unpublished data).

Mitigation

To minimize habitat losses and disturbance in areas particularly important to ptarmigan, permanent facilities should not be located within a 3/4-mile buffer zone around identified riparian areas.

Conclusion

The effect on rock and willow ptarmigan would probably be negligible.

PASSERINES

Several passerine, or perching, bird species are found throughout the 1002 area. Riparian willow habitat is used by many passerines for nesting and other activities (pl. 3C). Coastal areas are also important, especially for staging prior to migration. A buffer zone 3/4 mile out from the high-water mark of streams would protect most of the riparian willow habitat important to many passerine species. River crossings, marine facilities, and development of economic prospects in Block C could cause minor reductions in habitat availability or suitability, and nesting success of passerines.

Unless carefully controlled, contaminants could be released in fuel spills or breaching of reserve pits so drill muds and fluids flow across the tundra. Contaminant spills could have severe local effects of direct mortality and contamination of foods.

Lapland longspurs are the most common passerine species found in the 1002 area. They nest outside riparian zones and are often abundant in a variety of tundra habitats. Most proposed surface development in the 1002 area could be expected to affect some longspur nesting, mainly by covering vegetated habitat with gravel. Only a minor effect is anticipated because of the abundance of the species and its ability to use many common habitat types found in the 1002 area.

Minor to moderate positive effects may occur for two other passerine species. Snow buntings frequently nest in buildings and could find increased nesting opportunities with the construction of oil facilities. Ravens, being scavengers, might find increased food availability around landfills and construction camps, as well as from carrion along roadways.

Mitigation

The 3/4-mile buffer zone for ptarmigan would also protect most of the riparian willow habitat important to many passerine species.

Conclusion

Restricting development in riparian areas and controlling contaminants, coupled with the potential for positive effects on snow buntings and ravens, would result in overall minor negative effects of habitat loss and mortality to passerines as a group.

## FISH

Arctic char are the most sought after sport and subsistence fish species on the 1002 area. Arctic grayling are second only to char in providing freshwater sport and subsistence use. Grayling are found in more river systems than char but are in large concentrations at only a few locations. Grayling are not as tolerant of salinity as char and spend most of their lives in fresh water. Other fresh-water fish (whitefish, burbot, salmon, smelt, and lake trout) are not addressed in great detail because they are generally not common nor taken regularly in the 1002 area by sport or subsistence fishing.

Both direct (habitat loss or alteration) and indirect (increased regional fishing pressure) effects on fish would occur from oil development. Water withdrawal in critical areas and/or during critical time periods, and gravel removal from fish-bearing stream systems would not be permitted. Aspects of oil-development that could negatively affect fish are direct mortality or reduced invertebrate food resources resulting from oil or other contaminant spills, failure of sewage and waste-water disposal systems, blasting, and problems from channelization, culverts, and barriers to migration. The longevity and types of effects to invertebrates from oil and other contaminant spills were discussed previously. Overharvest could occur from sportfishing by the large numbers of people brought in to work in the 1002 area.

Most of the arctic char populations are anadromous and individual populations or year classes can be adversely affected over a wide range of fresh-water and brackish-water habitats in which they migrate. Major migration corridors are the Canning and Aichilik Rivers, which form the western and eastern boundaries, respectively, of the 1002 area, and the Hulahula River, roughly midway between them. The Canning River probably has the largest char run of any river in the area. The Hulahula River is likely the greatest contributor to the subsistence catch of char. Development near any of these three rivers could adversely affect arctic char. The pipeline and access road would probably cross the Hulahula River to accommodate development in the eastern part of the 1002 area. More than one crossing would increase the potential for adverse effects of decreased habitat suitability.

Grayling make extensive migrations to and from spawning, rearing, feeding, and overwintering sites. Because individual river stocks occur, the 1002 area population is vulnerable to impacts over a wide area. Major arctic grayling populations are found in the Canning, Tamayariak, Sadlerochit, Hulahula, Okpilak, and Aichilik Rivers (pl. 1B). Ensuring that effects on char are minimized would require that the number of river crossings was limited and all crossings were properly designed. Development of potential prospects and associated transportation corridors in Blocks A and B could create local minor adverse effects on fresh-water fish populations in the Canning and Tamayariak Rivers. Arctic char, grayling, and other fresh-water fishes use these rivers for spawning, rearing, feeding, and overwintering. Local populations of grayling use the Tamayariak River for feeding, spawning, and rearing their young. Development in Block A would require both water and gravel. If these materials were taken from the Tamayariak River, moderate adverse effects on grayling would result.

The Canning River is the only system in the area to have known populations of other fresh-water species, excluding ninespine sticklebacks which are common in many coastal streams and lakes. Sticklebacks, though having no importance as a sport or subsistence fish, are an important food source for other fish and birds. Culverts and other crossings should be constructed to avoid stranding sticklebacks in areas that do not provide overwintering habitat.

There are 62 species of fish that use coastal waters off the 1002 area (Craig, 1984). Docks and causeways at the Camden Bay and Pokok port sites could create physical barriers, cause changes in water chemistry, and cause direct mortality at water-intake structures. Population declines of coastal fish could be compounded if offshore and adjacent onshore development occurred, or coastal development near Prudhoe Bay expanded inasmuch as many of the anadromous species exhibit major east-west nearshore movements. Oil spills in coastal areas could result in major population reductions depending on the time, amount, and type of material spilled.

Mitigation

Properly locating and designing road and pipeline crossings and constructing those facilities when fish are not concentrated in the area will minimize impacts to fish. Further mitigation should include carefully locating and constructing docks, causeways and other water-based structures. Water quality and quantity in fish-bearing rivers and streams must be assured. Gravel removal and other stream alterations in important fish habitats should be restricted. Appropriate containment procedures and spill contingency plans for oil and other contaminants will also reduce potential effects of oil development on fish by minimizing direct mortality or reductions in invertebrate or aquatic plant food resources. Mitigation measures designed to adequately protect arctic char and arctic grayling will protect other fresh-water species. Proper culverting of road systems will reduce the potential of trapping fish in areas that do not provide overwintering habitat. Season and creel limits may be adjusted to protect sportfish from overharvest in certain areas if populations become stressed.

Conclusion

The recommended mitigation measures reduce the effects of oil development on arctic char to minor. Arctic grayling may be moderately affected locally in upper reaches of the Tamayariak River, but would otherwise experience only minor impacts. Effects on other fresh-water fish populations would also be local and minor. Development of KIC/ASRC lands or offshore areas could result in moderate effects on coastal fish through lost or reduced habitat values, inhibited movements, and direct mortality. Development of the 1002 area would result in minor effects on coastal fish populations in the vicinity of port sites. Elsewhere, the effects on coastal fish will be negligible. If an oil spill occurs along the coast or in fresh-water fish habitats, the effect to fish could become major.

THREATENED AND ENDANGERED SPECIES

BOWHEAD AND GRAY WHALES

See previous discussion under Seals and Whales.

ARCTIC PEREGRINE FALCON

Arctic peregrines are absent from the 1002 area from mid-September through April. Oil and gas activities during the summer when peregrines are present could have some minor adverse effects.

Habitat suitable for cliff-nesting birds of prey is not abundant on the 1002 area. No direct loss or alteration of historic peregrine eyries would be permitted under the terms of the Endangered Species Act (16 U.S.C. 1531). Formal consultation under terms of the Endangered Species Act may be required once a development proposal is prepared. Loss of suitable nesting habitat as a result of facilities placement would be minor since facilities would not be permitted within 2 miles of an eyrie or potential nesting habitat.

Human presence, air traffic, and construction activities near peregrine eyries may disturb nesting birds. Type, distance, frequency, and intensity of disturbance affect how peregrines react. Frightened adults flushed from an eyrie can injure or kill young. Peregrines may temporarily desert an eyrie after a disturbance, resulting in overcooling, overheating, or excess moisture loss from eggs; chilling, heat prostration, or malnutrition of the young; or predation on both eggs and young (Alaska Peregrine Falcon Recovery Team; Roseneau and others, 1980). Disturbance may also result in premature fledging causing injury or death of nestlings (Roseneau and others, 1980). The first sites to be deserted in areas studied in Alaska were those eyries closest to human activity (Haugh and Halperin, 1976).

Peregrines could be adversely affected during migration through the 1002 area from late August to mid-September. Food could be reduced for peregrines if prey (shorebirds and waterfowl) are displaced or reduced in number as a result of oil development. Some peregrine mortalities might result from collisions with towers, planes, or electrical wires.

Petrochemical or other toxic materials could be accumulated if peregrines ingest prey contaminated as a result of spills or leaks from reserve pits.

Mitigation

Mitigation would include controlling aircraft, noise, surface activities, or other disturbances within 1-2 miles of active nest sites, April 15-August 31. Construction of permanent facilities or other long-term habitat alterations (materiel sites, roads, and airstrips) within 1 mile of historic nest sites would require special authorization by the FWS.

Approved handling procedures for chemicals and toxicants will permit little or no adverse effects from contaminants. As discussed for other bird species, transmission lines would be designed to minimize the potential for collisions.

Conclusion

Mitigation will reduce effects to peregrine falcon to minor as concluded in the July 28, 1982, biological opinion appended to the Environmental Impact Statement and regulations for the exploration program in the 1002 area (FEIS, 1983). Protective restrictions (a 2-mile area closure) for the historic nest sites at Sadlerochit Springs and Bitty Benchmark on the Jago River (pl. 3D), and any occupied eyries located through annual surveys, should result in only minor adverse effects from disturbance and displacement. Prey reductions are generally expected to be no more than minor. Consequently, no reduction in the peregrine population would be expected. Exploration between June 1 (if a nest remains inactive) or August 31 (if a nest becomes active) and April 15 each year could be allowed with negligible effects on peregrines.

## Effects on Socioeconomic Environment

POPULATION

Oil development in the 1002 area would increase the local population due to transient workers and support service personnel. Additionally, North Slope Borough job opportunities would probably be created through tax benefits to the Capital Improvement Program as has occurred from Prudhoe Bay development. Many jobs would be generated as a direct result of oil exploration, production, and transportation. Each exploratory and confirmation drilling operation could require 50-75 people during construction of the airfield and drill pad, and 50-60 people during drilling. Drilling during production phases would use slightly smaller construction and drilling crews because much of the needed infrastructure (roads, airfields, etc.) would already be in place. Employment levels would be highest during the initial construction. As noted on figure III-1 (see also figure V-I), mapped prospects in the 1002 area may be grouped into three general "regions." During peak construction, an estimated 1,500 people would be employed per region. Operation and maintenance for each of these regions would require 200-500 people. An additional 450-900 people would be employed for 2-3 years to construct the primary road network and pipeline in each region. Rehabilitation of the entire coastal plain after the oil fields are no longer economically productive could require as many as 1,500 people for several years.

Although unlikely, if peak construction occurred throughout the 1002 area at one time, up to 6,000 jobs (drilling and construction of oil-field and main trunk pipeline) could be created. During the 30-year field life, 200-500 permanent jobs would be located within each prospective oil region or 600-1,500 permanent jobs in the 1002 area.

The year-round population at Kaktovik would probably not increase dramatically, although no increase in job opportunities is expected without oil development in the 1002 area. Most oil-field workers in the 1002 area would have permanent residences elsewhere, as do workers at the Prudhoe Bay complex and at military DEW-line facilities. A few small support industries might locate at Kaktovik, resulting in increased employment opportunities and some population increases.

Conclusion

A moderate increase in the permanent population at Kaktovik could occur. Elsewhere on the North Slope, and in Fairbanks, Anchorage, or south-central Alaska, the increase would be negligible to minor.

## EXISTING LAND USE

### SUBSISTENCE USE

Most effects on subsistence are directly related to changes in the availability of subsistence resources. Reductions in fish and wildlife populations, displacement of fish and wildlife from areas of traditional harvest, and reduced access to those resources will adversely affect subsistence uses. Kaktovik would be the village most directly affected. The more distant communities of Arctic Village, Venetie, Fort Yukon, and Old Crow, Canada, whose residents rely on caribou from the PCH found in the 1002 area, would experience indirect effects.

Effects of oil development on fish, wildlife, and their habitats were previously described. The severity of those effects is summarized at the end of this chapter. Resources of greatest concern relative to their importance in local subsistence use and likely severity of adverse effects from full leasing are the Porcupine and Central Arctic caribou herds. Waterfowl, fish, whales, and polar bears, are also of some concern.

Oil development would reduce access to subsistence use areas. The transportation infrastructure could affect the availability of harvested resources or the ability of local people to reach traditional harvest areas. The presence of up to 6,000 workers could result in competition for local resources, particularly if any workers become residents of Kaktovik and thus spend more free time in or near the 1002 area. Subsistence hunting would be restricted by safety requirements or for pipeline security. Loss of traditional harvest sites would occur in the vicinity of oil development facilities or where facilities disturb or displace fish and wildlife resources.

Caribou is the staple land mammal in the Kaktovik subsistence diet. They are hunted nearly year-round, with most Kaktovik households participating in the harvest (table II-3). Overall, 83 percent of Kaktovik's 1983-84 caribou harvest was within the 1002 area (Coffing and Pedersen, 1985). Consequently, caribou are of primary concern because of the major and moderate adverse effects on the PCH and CAH, respectively, which are anticipated under full leasing. Major changes in distribution or population reductions could result in a major restriction of subsistence use to the village of Kaktovik because of the reduced availability of this species at preferred harvest locations, as well as throughout the 1002 area. The greatest effects on other villages will be where the PCH, the most widely used migratory resource, is a significant component of the diet.

Moderate effects to the CAH would primarily affect Kaktovik, the village closest to the CAH segment which will be adversely affected by oil development.

Development of any potentially economic prospects found in the Canning River delta area within Block A would conflict with a winter and summer harvest area used intensively by Kaktovik residents. Because caribou are likely to avoid traditional calving grounds or their movements may be inhibited by development in Blocks C and D, loss of traditional harvest sites is a significant concern. Any inhibition to free movements during postcalving when caribou move back and forth to insect-relief areas along the coast could be particularly detrimental, because most subsistence harvest occurs along the coast during July and August. Marine facilities at Camden Bay and Pokok, as well as development of any potentially economic prospects which extend to the coast in Block C, have the greatest probability of direct conflict with subsistence users. Those coastal areas have been intensively used for caribou hunting since 1923, and harvest concentrations have been located there in recent years (pl. 2D). Based on the 1981-83 harvests of caribou during July only, the availability of, and easy access to the PCH during postcalving may be an important factor in determining annual harvest levels (Pedersen and Coffing, 1984). The July 1981 caribou harvest was three because postcalving caribou did not occur close to Kaktovik But in 1982 postcalving caribou were numerous along the coast east of the Sadlerochit River and even came onto Barter Island in large numbers; the July harvest then was 82. With post-calving caribou in moderate numbers along the coast east of the Hulahula in 1983, the July harvest was 29.

Another potential impact to subsistence is the avoidance of industrialized areas by village hunters. At present, part of the North Slope subsistence hunting range is within the rapidly industrializing central portion of the North Slope. Caribou hunting activity there by Kaktovik residents has declined in recent years. Pedersen and Coffing (1984) suggested that confusion over special harvest regulations associated with the industrialized area, lack of caribou in the area, disruption of access routes, or other reasons may have deterred Kaktovik caribou hunters. Such avoidance could occur on parts of the 1002 area that were developed. Given the nearness and greater use of the 1002 area by Kaktovik residents, such avoidance would severely limit the amount of area and resources available for subsistence uses.

Waterfowl are also used by residents of Kaktovik. Effects on major waterfowl species used for subsistence are expected to be minor. The only major effects predicted for waterfowl are for snow geese, a species present during fall staging. Due to difficulties in accessing snow geese use areas at that time and whaling activities, snow geese are not currently a major component of the subsistence diet.

Fishing was pursued by all Kaktovik households surveyed in 1984 (table II-3). Adverse effects on fish could affect this activity, although effects would be minor. Locally moderate effects on grayling in the Tamayariak River could result with development in Block A, which is not an important subsistence harvest area. The moderately negative effect on coastal fish likely if oil is also developed on KIC/ASRC lands or offshore areas would be the most noticeable effect on subsistence use of those species. If any oil spills occur, effects on fish could become major. Even in small quantities, spilled hydrocarbons can taint fish, making them inedible (Crutchfield, 1979).

The overall low level of adverse effects expected for fish suggests minor adverse effects on subsistence uses. However, there is potential for disturbance of traditional fishing sites and access may be modified. The main haul road/pipeline would have to be crossed to reach both the First and Second Fishing Holes on the Hulahula River (pl. 1B). The Hulahula River is the most important winter fishing river to Kaktovik residents (Jacobson and Wentworth, 1982). The First Fishing Hole is close to potentially prospective areas plus the airstrip associated with development in Blocks C and D. The access road and pipeline for those areas could cross the Hulahula River in the vicinity of the First Fishing Hole. The effects would be compounded by the additional adverse effect of increased competition for fish from oilfield workers.

The taking of bowhead whales has been characterized as one of Kaktovik's most important annual activities (Jacobson and Wentworth, 1982), particularly from a cultural standpoint. Subsistence harvest of whales should not be affected by coastal development, in light of minor adverse effects on whales (in the absence of oil spills). Noticeable effects in other villages which take beluga whales are not expected because only minor, local effects are anticipated to that species.

Although generally only one or two are taken, polar bears are used by most Kaktovik households because of community sharing of resources. While the effects of oil development on nondenning segments of the polar bear population are not well known, development activities may exclude female polar bears from denning in preferred onshore habitats in the eastern and coastal portions of the 1002 area. Polar bears are used for subsistence and in recent years more bears have been available than have been taken. Kaktovik elders recognize the sensitivity of the polar bear denning and no bears were taken during 1982-86 (U.S. Fish and Wildlife Service, unpublished data). Consequently there is some potential for a decrease in the availability of polar bears for subsistence take.

Specific subsistence hunting areas of concern vary with season. For example, although inland hunting by Kaktovik residents occurs much less during summer than during winter, subsistence activities on the coast greatly increase during the summer. Therefore summer operations along the coast could temporarily disrupt subsistence uses. Development of permanent port facilities and associated access corridors would be a permanent disruption.

Activities may also physically impact Traditional Land Use Inventory sites of the Arctic Refuge study area, many of which have present-use value as subsistence sites (Jacobson and Wentworth, 1982). These sites may or may not have tangible remains, and in many cases their boundaries cannot be easily delimited. Knowledge of an area and how to hunt it are skills gained and passed down through years of experience. These skills cannot be quickly acquired if subsistence users are forced to hunt new areas, and displacement of subsistence users from traditional use areas is expected to result in reduced harvest success.

A policy that prohibits the discharge of all firearms and hunting and trapping within 5 miles of development areas could result in major adverse effects by limiting resources and areas traditionally harvested in over half of the 1002 area. Measures to prohibit off-road vehicle use do not extend to local residents engaging in traditional uses. Subsistence users would not be allowed to use access corridors or aircraft facilities. Consequently subsistence use will be neither facilitated nor restricted by these measures.

Other important results of development, though difficult to quantify, are the potential psychological effects on local residents. Development near subsistence harvest areas may disturb people accustomed to sociocultural isolation and privacy while in the field. Increased air traffic and human activity are viewed as an aggravating intrusion by many local residents. The esthetic integrity of traditional hunting experiences would be diminished in rough proportion to the amount of disturbance encountered in customary use areas. Additionally, noise and visual presence of airplanes and helicopters flying over and landing in the area could reduce hunting success. Frequent disturbances also cause game to become more wary and more difficult for hunters to approach.

In some instances, the impact may be lessened by the availability of alternative resources or harvest areas. Because of the magnitude of the area and number of species which could be affected by full development, alternative subsistence resources and areas may not exist in every case.

Development activities could substantially increase employment and cash flow in Kaktovik. Therefore, alternatives to subsistence may become available and/or local residents' abilities to purchase equipment for subsistence harvest may increase. Such effects would be unevenly distributed within the community.

Mitigation

Measures previously recommended for 1002 area fish and wildlife and their habitats will also mitigate adverse effects to subsistence uses by minimizing the direct loss and displacement of subsistence species. In coastal areas, the protection of the natural environment, subsistence activities, subsistence resources, and access to those resources sought under the State-approved Coastal Management Program, as well as Federal stipulations that coastal zone activities be consistent with that program, would further minimize effects on subsistence.

Effects on subsistence can also be minimized by careful siting and proper design of facilities, not only to lessen effects to fish and wildlife but also to lessen potential conflicts with traditional harvest areas. Seasonal and area closures to prevent disturbances of wildlife populations during sensitive periods, and other mitigation measures described for fish and wildlife species using the 1002 area, will further minimize adverse effects to subsistence resources. However, for important subsistence resources--especially caribou, polar bear, and fish, and the vegetation, wetlands and terrain types which form the habitat bases upon which these species depend--major and moderate effects will remain because of the intensive nature of development.

Changes in policy regarding access and harvests near development sites would greatly mitigate adverse effects on subsistence uses. If subsistence users were permitted to use the development infrastructure, including roads and airports, to facilitate their access to subsistence resources, there would be a positive effect on their ability to harvest subsistence resources. Restrictions to subsistence uses from reductions in species availability or altered distributions could be offset if access to other areas and resources was allowed. Excluding development from traditional harvest areas and not restricting local residents' abilities to harvest resources from those areas would minimize adverse effects to continued subsistence uses.

Conclusion

The cumulative effect of reduced availability of subsistence resources through reductions in populations and habitats, displacement of animal populations, modified access to or closure of traditional harvest areas, and potential psychological effects of development on subsistence practices are considered in determining the overall impact of development that would occur as a result of full leasing.

Because effects of further exploration on fish and wildlife are expected to be no greater than minor, including those associated with drilling exploratory wells, a significant restriction of subsistence uses would be much less likely during that phase. The much greater intensity, duration, and amount of area involved in the construction and production phases would result in major or moderate adverse effects on fish and wildlife resources important to subsistence, as well as on continued access to those resources. Most important will be the likely decline or change in distribution of the PCH and CAH, and the harvest prohibitions near developed areas. These effects, in combination with adverse effects on other subsistence use species, disruption of traditional subsistence use sites, and likely psychological effects on a people accustomed to isolation, will result in a major adverse effect on subsistence uses within the 1002 area. Competition for resources and the potential for increasingly restrictive hunting regulations may add to the severity of impacts on subsistence uses.

Overall, a major effect (considered a significant restriction of subsistence uses under section 810 of ANILCA) could occur if Alternative A was implemented. If the Congress enacts legislation to authorize the Department of the Interior to lease the 1002 area, the Secretary of the Interior must, prior to actual lease sale, determine the effects on subsistence of such disposition in compliance with section 810 of ANILCA, unless the Congress were to exempt the Secretary from that requirement.

## LAND STATUS AND MILITARY AND INDUSTRIAL USE

Obviously, land use both on and off Arctic Refuge lands would change. No changes in existing military activities would be expected. Full leasing, however, would eventually introduce industrial development to an area now devoted to Native subsistence, Federal fish and wildlife management activities, and wilderness-oriented recreational uses. The scope of likely industrial development has been described in Chapters IV and V.

## NATIVE ALLOTMENTS

According to the full development scenario (fig. V-1), four Native Allotment parcels occur in areas of petroleum potential in Block C. Six Native parcels comprising 240 acres could be in the area that may be developed as a port facility at Camden Bay and two parcels totaling 120 acres are in the area of the Pokok port site.

Because of the relatively small size, scattered location, and general lack of overlap with potential prospects, allotments generally would not conflict with development.

Subsurface ownership under an allotment will be reserved to the government if it is determined that it may be valuable for coal, oil, or gas. The allotment owner would then be subject to the right of the government or its lessee to enter and use the lands for the development of the reserved minerals, subject to the duty to pay for damages to surface improvements and a bond to guarantee such payments.

## STATE AND LOCAL POLITICAL AND ECONOMIC SYSTEMS

Full leasing for the 1002 area would produce State and local economic benefits. Effects on national economics are discussed in Chapter VII. Income from the State's share of revenues derived from Federal oil leases on the coastal plain and from corporate taxes levied on the oil industry could produce major economic benefits to the State of Alaska. The State would also receive additional revenues through corporate taxes from any oil development on Native-owned areas adjacent to the 1002 area. Some minor secondary economic effects could result from employment and population increases in Anchorage, Fairbanks, and south-central Alaska. These effects would be similar to those described in the Beaufort offshore sale evaluations (U.S. Minerals Management Service, 1984), which estimated a 3-percent increase.

As is common at Prudhoe Bay, almost all the permanent jobs would be filled by commuters present at worksites approximately half the time each year (job sharing on a 24-hour basis) with residences outside Alaska. The number of jobs filled by permanent residents of the North Slope region, most of whom are Inupiat, would be expected to be small, based upon experience at Endicott and Prudhoe Bay oil developments. According to U.S. MMS (1984), a recent survey of workers at Prudhoe Bay showed that of 6,306 workers, only 178 (fewer than 3 percent) claimed either no permanent residency or a North Slope residency.

There will be an overall beneficial economic effect on the North Slope Borough through substantial increases in taxes and other revenue generated from development and production on the 1002 area. The Borough also would increase its tax base to the extent Native-owned lands were placed in commercial development status. ASRC would obtain substantial revenue through lease, exploration, and production of oil from its lands. KIC might benefit substantially by providing related support services.

Local economic benefits to Kaktovik would result from establishment of some support industries there, purchase of goods and services by oil-field workers who visit Kaktovik, and income from those local residents who obtain employment in the oil fields.

### Conclusion

Major positive State and local economic effects would be expected if the entire 1002 area is leased and from subsequent revenue from leases, taxes, increased local population and employment base, and other aspects of oil development.

## PUBLIC SERVICES AND FACILITIES

Transportation facilities associated with full leasing could result in greater connections between Kaktovik and Prudhoe Bay, as well as TAPS and the rest of Alaska. The existing Dalton Highway, adjacent to TAPS and connecting Prudhoe Bay with Fairbanks and other highways in Alaska, has sufficient capability to handle increased traffic during exploration, construction, operation, and rehabilitation with only negligible effect. Similarly, the capacity to handle increased movement of goods and supplies through Valdez, Whittier, Anchorage, and Fairbanks would only negligibly affect the existing transportation infrastructure.

The long-term capital improvement program of the North Slope Borough would be beneficially affected insofar as oil-field facilities in the 1002 area increased the Borough's tax base. This positive effect on the Borough's economy would increase its ability to provide improved public services and facilities.

### Conclusion

Restricting uses of the transportation infrastructure to those directly associated with oil development activities, as required to minimize effects on fish and wildlife species, will limit increased transportation opportunities which would otherwise result from full leasing. Additional Borough and local revenues will likely result in overall major increases in available public services and facilities.

## ARCHEOLOGY

More than 100 archeological sites have been identified on the 1002 area, outside the KIC lands. Thirty-four of these sites are recognizable structures such as cabins, caches, or graves, all but two of them on the coastline. The other sites, mainly tent rings, are situated along the primary rivers of the 1002 area, anywhere from 2-33 miles upstream from the coast.

Conflict between known archeological sites and projected oil field development might occur at Camden Bay and Pokok due to construction of marine and waterflood facilities at these locations (pl. 1A). Four known sites occur at Camden Bay and three have been located at Pokok.

Mitigation

Because known archeological sites in the 1002 area are small and precisely located, they can be easily avoided during construction and operation of nearby facilities. Before exploration or development work, contractors would be required to conduct archeological surveys in all areas that may be affected. Most, if not all, sites discovered in this process could be protected by avoidance. The preponderance of known sites and most likely the majority of undiscovered sites occur along the coast and major rivers, in areas that will be avoided for other reasons. Nonetheless, contractors will be required to exercise caution in their operations, and to cease activities when an archeological site is encountered, until appropriate protective measures are in place.

Conclusion

Impacts to archeological resources of the 1002 area should be negligible. A minor positive benefit may occur through the discovery, evaluation, and protection of any additional archeological sites during oil exploration and development.

RECREATION, WILDERNESS, AND ESTHETICS

Most recreationists currently travel to the 1002 area for a total wilderness experience and might perceive the existence of oil facilities in the area as lessening the quality of that experience. Fewer than 150 recreationists of all types (exclusive of local residents from Kaktovik) currently visit the 1002 area annually. Several hundred visitors fly over the area to sightsee or enroute to other destinations on the refuge.

Effects on recreation would result from activities affecting esthetics and access. The visual aspect of the 1002 area as a broad trackless wilderness would be destroyed by the addition of oil facilities. This may be considered a major adverse effect by those individuals desiring to fly over, photograph, or otherwise partake of a pristine Arctic wilderness. Similarly, those making float trips on rivers such as the Canning, Hulahula, and Aichilik may be esthetically disturbed by the visual impact of bridges, pipelines, or other facility crossings. For recreationists other than those seeking a purely wilderness experience, increased ease of entry to the area would be considered an improvement in recreational opportunities. The addition of roads, pipelines, airfields, and other infrastructure within the 1002 area will undoubtedly improve access. Of course, use of that access will generally be restricted so as to minimize negative effects of development on 1002 area fish and wildlife resources. Additionally, access may be limited for safety and security reasons. Notwithstanding that, experience on the Dalton Highway has shown that unauthorized public use is difficult to curtail.

Oil development and the associated infrastructure may displace some hunted and trapped species, adversely affecting recreational hunting and trapping opportunities. Because much of that displacement would be from the area in which firearms could not be discharged and access would be restricted, the net effect on hunters would be negligible.

Noise and visible presence of oil development facilities would not only eliminate the wilderness character in the areas of development, but there could also be some intrusion in the designated Wilderness Area from activities and developments adjacent to the 1002 area. Moreover, the existence of oil facilities and activities would eliminate the opportunity for further scientific study of an undisturbed ecosystem.

Mitigation

With careful planning and coordination for other reasons, each river should generally have only one facility crossing point throughout its length. Negative effects on recreationists in the adjacent wilderness could be mitigated somewhat if, wherever possible, no facilities were placed within 5 miles of designated wilderness. It is impossible to mitigate loss of the area's wilderness character where oil exploration and development occur.

Conclusion

The expected disruption of wildlife populations and natural processes would cause a major reduction in the value of the area as a pristine, natural scientific laboratory. The wilderness value of the coastal plain of the Arctic Refuge would be destroyed, except for the small area of the refuge between the Aichilik River and the Canadian border which is designated wilderness.

## Summary of Unavoidable Impacts, Alternative A

Compaction and destruction, as well as delayed growth of vegetation, in areas of further geophysical exploration (green and brown trails).

Loss of approximately 5,650 acres of existing coastal plain habitat (approximately 1,300 acres of Resource Category 1 and 4,350 acres of Resource Category 2) due to road and pad construction and gravel material sites.

Modification of about 7,000 additional acres of coastal plain habitat (1,800 acres of Resource Category 1 and 5,200 acres of Resource Category 2) due to secondary effects such as gravel spray, dust deposition, and altered snowmelt and erosion patterns.

Increased noise and disturbance level displacing wildlife throughout the 1002 area.

Loss of habitat values on approximately 78,000 acres of caribou core calving habitat (Resource Category 1) due to disturbance/displacement.

An unknown number (possibly hundreds) of small spills (diesel fuel, oil, antifreeze, etc.) resulting from vehicle and equipment operation and causing destruction of vegetation, contamination of waters, or mortality of small food organisms.

Displacement of caribou from approximately one-third of the core, concentrated calving areas within the 1002 area resulting in a large part of the projected population decline or distribution change for 20-40 percent of the PCH.

Reduced use or avoidance of approximately 72,000 acres of insect-relief habitat for caribou.

Direct loss of approximately 2,700 acres of muskoxen habitat.

Increased disturbance with possible avoidance by muskoxen of 71 percent of their high use, year-round with calving, habitats in the 1002 area resulting in a change in distribution, population decline, or no further expansion of the 1002 area muskoxen population.

Direct loss of approximately 140 acres of moose habitat.

Moderate decline in the wolf population due to the cumulative increase in mortality and decrease in production/survival due to reduced prey availability.

Displacement and increased harvest of wolverines.

Direct habitat loss of 3,500 acres of brown bear high- and moderate-use areas.

Loss of one brown bear per year from accidents or from being shot in defense of life or property.

Direct and indirect small mammal loss due to habitat destruction, road kills, etc.

Probable loss of the eastern part of the 1002 area as denning habitat for polar bears.

Direct loss of 2,000 acres cf snow goose preferred staging habitat.

Loss of habitat values from between 162,000 and 236,000 acres of snow goose preferred staging habitat within the 1002 area.

Direct mortality of birds due to strikes with towers, antennas, wires, and other structures.

Moderate decline or change in distribution of golden eagles as a result of decreased caribou prey.

Moderate loss of arctic grayling habitat in Block A due to stream alterations and direct mortalities.

Loss of subsistence hunting opportunities throughout approximately one-half of the 1002 area.

Unquantifiable loss of wilderness values throughout the entire 1002 area.

## ALTERNATIVE B--LIMITED LEASING

Under limited leasing the area designated as a core calving area for the PCH would not be leased. This would include all of Block D and parts of Block C (pl. 2A), an area of approximately 290,000 acres (19 percent of the 1002 area). Consequently the development scenario for limited leasing would only affect Resource Category 2 habitats. The analysis for this Alternative is based on the same methods and assumptions used for Alternative A and described in the introduction to this chapter. As depicted in figure V-1, the development scenario has no surface occupancy in the southeastern part of the 1002 area (that is, no access road extending south from the main east-west road nor other support infrastructure, drill pads, exploration, or production facilities).

Both the effects referenced and mitigation measures described by species under the full leasing alternative apply within the scope of development likely for leasing a portion of the 1002 area. In this discussion these references and discussions will be summarized or referenced rather than repeated in full. If there is a change in level or type of effect anticipated between full development and limited development, it will be emphasized at the end of the appropriate discussion.

### Effects on Physical Geography and Processes

Effects on the physical environment resulting from a limited leasing program would be similar to those resulting from full leasing, but to a lesser degree. Most important is the fact that by not developing economic prospects in Block D and parts of Block C, water and gravel requirements should be reduced by about one-third. Some of this reduction would occur outside Blocks C and D if water and gravel sources that would support development in those blocks were located in adjacent locations in the 1002 area.

### Effects on Biological Environment

#### VEGETATION, WETLANDS, AND TERRAIN TYPES

The additional exploration associated with limited leasing would require additional seismic surveys and exploration wells. As described for full leasing, these activities would result in visible trails, toxic materials spills, soil compaction, and delayed plant growth under ice roads, airstrips, and drill pads. With the restriction on surface occupancy of the southeastern portion of the 1002 area, one-fifth less area than under full leasing would be subject to these effects.

Approximately 3,800 acres, compared to 5,000 acres under Alternative A, would be covered with gravel for roads, drill pads, airstrips and other facilities. This decrease in gravel needs would result in 400-650 acres of gravel sites, a reduction of 100 acres from Alternative A, for a total direct habitat modification on nearly 4,400 acres of Resource Category 2 habitat.

Secondary habitat modifications resulting from gravel spray, dust, and changes in snow accumulation patterns would affect nearly 5,200 additional acres of Resource Category 2, 1,800 acres less than under full leasing. The possibility of habitat destruction or degradation from toxic materials and sea-water spills would be eliminated in important caribou calving, snow goose staging, and other fish and wildlife habitats.

The candidate plant Thlaspi arcticum is not known to occur in the area deleted from leasing under this alternative. Consequently, effects would be the same as for full leasing: potential loss of plants and habitat from gravel placement, dust deposition, or other development activities.

Mitigation

Consolidation of facilities, environmentally sensitive engineering, and control of toxic materials as described under full leasing could help reduce the area and magnitude of effects to vegetation and wetlands.

Conclusion

The expected total modification of existing vegetation and wetlands, both primary and secondary, because of gravel placement and associated secondary modifications for drill pads, roads and other oil development facilities, would be nearly 9,600 acres (over 0.6 percent) or 3,000 acres less than the area to be modified by full development. The effect would remain moderate because of the long-term or permanent effects on localized areas scattered through the 1002 area.

SADLEROCHIT SPRING SPECIAL AREA

The prohibition on activities in the Sadlerochit Spring area would prevent most negative effects. With no development in the southeastern portion of the 1002 area, oil development activities and people would be located much farther from the Sadlerochit Spring Special Area. Consequently, the likelihood of increased visitor use would be greatly reduced, preventing disturbance, any noticeable increase in fishing pressure, or competition with local Native subsistence uses in that area.

Mitigation

No additional mitigation would be necessary, given existing prohibitions on area activities.

Conclusion

Under current protective management stipulations, effects on the Sadlerochit Spring Special Area would be negligible.

COASTAL AND MARINE ENVIRONMENT

Limited leasing would affect coastal and marine environments at nearly the same level as full leasing. Although support requirements may decrease because of reduced inland development and use of coastal areas, two port sites are still recommended to support the limited development program, just as they were for full leasing. Spills of oil or other hazardous materials along the coast could severely affect coastal and marine habitats and fish and wildlife.

Mitigation

Again, environmentally sensitive construction of docks and causeways as well as proper management of fuel and other hazardous substances will minimize most adverse effects.

Conclusion

Because coastal activities would only be slightly less in magnitude but not area, a minor effect would result from limited leasing. Again, the cumulative effects of future developments or an oil spill could be major.

TERRESTRIAL MAMMALS

CARIBOU

With limited leasing, direct modification of caribou habitat would be reduced to 4,400 acres. Secondary habitat changes due to dust and gravel spray would be reduced to 5,200 acres. This would result in total habitat modification of nearly 9,600 acres versus direct and secondary impacts to 12,650 acres from full development. Most important, no habitat modification would occur in Resource Category I habitat. Reduced habitat modification and decreased human activities would be within the calving and post-calving range of the PCH only. Effects on the CAH which occupies the western portion of the 1002 area would be the same as for full development, with the exception of somewhat reduced support activities along the main access road and pipeline and perhaps at the Camden Bay marine support facility.

None of the PCH core calving area within the 1002 area, as determined from historical information, would be leased (pl. 2A). In addition to substantially reducing direct habitat loss, the absence of human disturbance in this important area would significantly reduce behavioral avoidance and decreased access by maternal cows and calves. The approximately 2-mile sphere of influence (Dau and Cameron, 1985) used to assess effects would mean lost or reduced habitat values on 10,000 acres of the PCH's core calving area (table VI-5). This compares with the projected displacement from approximately 78,000 acres under full development. Displacement from other concentrated calving areas not included in the core calving area would also be reduced, to 28 percent from 38 percent.

Not leasing the core calving area would eliminate barriers to free movement of caribou in all of Block D and much of Block C. This is most important relative to allowing caribou free access to the calving areas of greatest sustained use (Elison and others, 1986) as described above. Access to coastal insect-relief areas would still be inhibited since there would be no change in the east-west transportation/pipeline corridor, although traffic levels may be somewhat reduced. The approximately 2-mile sphere of influence used in assessing effects would mean lost or reduced habitat values on more than 68,000 acres of insect-relief habitat. (This compares with projected displacement from approximately 72,000 acres under full development.) Over 80 percent of coastal insect-relief habitats would remain unavailable under limited leasing.

Effects of disturbance from aircraft activities, etc., would be similar to but less than those described for Alternative A. Direct caribou mortality would also be less with no development on the area of greatest sustained calving use. A lower harvest and fewer vehicle/animal accidents would also be expected because of fewer workers and vehicle trips.

Mitigation

All measures recommended for Alternative A (pipeline design, limiting use of the infrastructure to development activities, closing areas to hunting and trapping, environmentally sensitive siting of all facilities, time and area closures) would apply in avoiding, minimizing, and otherwise mitigating potential adverse effects to caribou in developing all but the core calving area.

Conclusion

Only negligible effects on the PCH and minor effects on the CAH would be expected from further exploration on the 1002 area with exploration well and seismic activities confined to the winter season.

The CAH would experience the same amount of disturbance, barriers to free movement, increased harvest, and other adverse effects of oil development, because the level of activity would be the same in the area of the refuge that they use. Consequently, effects on CAH caribou by petroleum development would still be moderate, a 5-10 percent population decline or distribution change, under the limited development probable in Alternative B.

For the PCH, oil development would reduce their use of only 4 percent of the core calving area. However, 28 percent of the concentrated calving area and 28 percent of insect-relief habitats would be affected. A larger portion of insect-relief habitat could be affected if the main pipeline/road corridor proves to be a barrier to caribou movements. The habitat value losses represented by displacement, other disturbances and increased harvests, would be less than those under full leasing, as a result of protecting the core calving habitat. Based on protection provided and the overall reduction of oil-related activity, decline in the population or change in distribution of the PCH should be moderate, about 15 percent.

MUSKOXEN

Limited leasing would reduce the effects of oil development on the subpopulation of muskoxen in the Niguanak-Okerokovik-Angun River area (pl. 2C). Effects upon muskoxen elsewhere on the 1002 area would remain the same as those for full development. Direct habitat modification would be approximately 2,400 acres (0.3 percent of muskox habitats), 300 acres less than under Alternative A. Assuming muskoxen are displaced 2 miles away from all development facilities (Russell, 1977; Reynolds and LaPlant, 1985), then habitat value losses would occur on 254,000 acres of muskox habitat (table VI-6) (reduced from 256,000 acres for full development). This loss in habitat values represents approximately one-third of the muskoxen range on the 1002 area. Habitats used for high seasonal or year-round use, including calving habitat, would be disproportionately affected; muskoxen could be displaced from approximately 52 percent of those habitats--only a 1 percentage point decrease from the loss expected under full development. Mortality from hunting, vehicle collisions, and other accidents would be little changed because activities would still occur throughout most of the same muskoxen habitats.

Mitigation

Because essentially the same habitats would be affected by limited development, mitigation recommendations would be identical to those for full development.

Conclusion

Muskoxen and their habitats would be adversely affected to essentially the same degree by either full or limited development of the 1002 area. Therefore, effects of limited development would be moderate. While a major population decline is unlikely, the muskox herd is not likely to continue increasing in numbers or expanding its range at the current rate.

MOOSE

Effects of limited leasing upon the 1002 area moose population would be substantially reduced, because most moose habitat affected under full leasing is in Block D which would not be leased under this alternative. Direct habitat loss would be reduced to 10 acres from 140. The reduced work force and reduced proximity of that workforce to moose using the 1002 area would lessen the potential for direct mortality, the primary adverse effect.

Mitigation

None necessary beyond those measures recommended under full leasing.

Conclusion

The overall effect on the 1002 area moose population would be reduced from minor to negligible under limited leasing with elimination of nearly all habitat loss and vehicle activities in moose habitats.

DALL SHEEP

Few effects on Dall sheep are anticipated under limited leasing. Aircraft harassment and hunting pressure in areas adjacent to the 1002 area might be slightly reduced with fewer personnel in the area, particularly in those areas closest to Dall sheep habitats.

Mitigation

As for full leasing, more restrictive hunting regulations could be required.

Conclusion

Effects on Dall sheep would be negligible.

WOLVES

Direct habitat loss would be negligible. Protection of the PCH core calving area would better ensure the availability of an important prey species for the wolves using the 1002 area. The intrusion of development into some wolf habitat and direct mortality would be reduced from that expected from full development.

Mitigation

The same measures for adequate garbage control and enforcement of hunting regulations would be required as for full development.

Conclusion

The effect on the wolf population using the 1002 area would be minor.

ARCTIC FOXES

Direct mortality, habitat loss, and artificial feeding would occur in all but the undeveloped areas in Blocks C and D.

Mitigation

No additional mitigation beyond that recommended for other species would be needed to reduce or eliminate effects on fox.

Conclusion

Effects on arctic fox would be minor, as under full development.

WOLVERINES

Limited development would result in localized, long-term displacement of a few wolverines in all but the southeastern part of the 1002 area. Reduction in both wolverine displacement and adverse effects to prey species and their predators would result in somewhat less severe effects on wolverines under the limited as compared to full leasing alternative. Increased human activities throughout the 1002 area could still lead to increased harvest.

Mitigation

Minimizing adverse effects to prey species and controlling access and harvest will help minimize the effect of limited leasing on wolverines.

Conclusion

Although the area affected is reduced from full leasing, the cumulative effects of displacement/avoidance, reduced food resources, and increased harvest would still result in localized, long-term changes in wolverine distribution, affecting a few individuals. Because of their sensitivity to disturbance and human predation, the effects on wolverines would be moderate.

BROWN BEARS

Development of potentially economic prospects within Blocks A, B, and most of C would affect areas used seasonally by brown bears at moderate to high density (pl. 1D). Direct habitat loss would be approximately 2,600 acres, 900 acres less than under full leasing, Alternative A. Oil-field activities would take place in 11 percent of brown bear high- and moderate-use areas (compared to 17 percent under full development). The limited leasing alternative would reduce adverse effects by protecting the core calving area of the PCH, an important prey species for brown bears on the 1002 area. Encounters between humans and bears may also be somewhat reduced, but some direct mortality of nuisance bears would be expected to occur throughout the remainder of the 1002 area.

Mitigation

Controls on handling garbage, on harvest, and aircraft overflights; fencing; monitoring; and one-half mile buffer zones of no activity around dens (described under Alternative A) would mitigate adverse effects.

Conclusion

The overall population reduction or change in distribution of brown bears as a result of direct mortality, harassment, loss of feeding habitat, and disturbance in denning areas would be reduced from moderate to minor, since their use of the calving area as an important feeding site would not be disrupted.

ARCTIC GROUND SQUIRRELS AND OTHER RODENTS

Localized habitat alterations and road kills would result from this alternative. Potential positive effects of protective cover in and under structures and debris could similarly result.

Mitigation

No additional mitigation is recommended.

Conclusion

Effects to these species would be minor due to local habitat losses and road kills.

MARINE MAMMALS

POLAR BEARS

Areas deleted for limited leasing have generally not been used by denning polar bears. The reduced overall activity (fewer vehicle, sealift, and air support trips) would not appreciably reduce potential disturbance of polar bears, because the more highly used areas around the coast and in Block C would still be open to potential development.

Mitigation

No additional mitigation measures are recommended over those for Alternative A. Development of a marine facility at Pokok and its subsequent use would result in the loss of repeatedly used denning habitat.

Conclusion

The overall effect of limited leasing would be moderate, mainly arising from the adverse effects associated with proposed marine facilities at Pokok.

SEALS AND WHALES

Activity, noise, altered habitats, and changes in availability of food sources from dredging and causeway construction and operation, ships and barges, and aircraft could adversely affect seals and whales. The effects may be somewhat less than for full leasing because the reduction of oil facilities would reduce the level of coastal logistical activities.

Mitigation

Recommended measures for full development would also apply to limited development. Not developing marine facilities in the Pokok area would further reduce the adverse effects of disturbance, noise, lost food resources, and altered habitats.

Conclusion

Effects on seal and whales would be minor. Withdrawing the proposed marine facilities at Pokok could reduce this effect to negligible by eliminating disturbances and habitat alterations from a sizeable part of the coastal area.

BIRDS

SWANS, GEESE, AND DUCKS

Direct and indirect habitat loss would be reduced somewhat as a result of limiting the development area. However, with the exception of snow geese, the area eliminated from leasing is not heavily used by waterfowl.

For snow geese, the direct loss of use areas would be 1,970 acres. A loss of 1,200 acres of preferred habitat is expected, nearly 800 acres less than expected from full development. The primary adverse effect, indirect habitat loss due to displacement, would also be substantially reduced.

Potential displacement would be reduced to between 95,000 and 135,000 acres, or up to 26 percent (as compared to 45 percent under full development) of preferred snow goose staging habitats within the 1002 area, resulting in moderate effects on population distribution and numbers (table VI-7).

Mitigation

Mitigation of impacts to swans, geese, and ducks would be the same as for Alternative A.

Conclusion

For waterfowl species other than snow goose, the cumulative effects of disturbance, habitat alteration, direct mortality, and contaminants would remain minor. However, disturbance could cause a moderate reduction in population or change in distribution for up to 26 percent of the snow geese using the 1002 area (5 percent of the Banks Island snow goose population).

SEABIRDS AND SHOREBIRDS

Under limited development, activities in coastal areas would be little reduced from those under full development. Consequently, effects on seabirds and shorebirds would be little changed. The potential for contaminant spills in developed areas would remain a concern. Although the areas which would be deleted from leasing are not sites of high seabird and shorebird density, several species, such as jaegers and plovers, nest and feed there. These birds would be unaffected by construction, traffic, noise, gravel placement, and other disturbances associated with development in other parts of the 1002 area.

Mitigation

Recommended measures would be the same as for Alternative A.

Conclusion

Overall population changes and habitat loss would be minor. Moderate effects may occur from development in areas of high use by seabirds and shorebirds. Bird mortalities and reduced food resources could occur in the event of spills of oil or other contaminants as described previously.

RAPTORS

Conflicts from development could still occur in raptor nesting habitat in Block A but would be eliminated from nesting habitats in the southeastern portion of the 1002 area. Most importantly, the reduction in golden eagle prey expected from adverse effects on the PCH core calving area caused by development would not occur with elimination of activities in Block D and part of Block C.

Mitigation

Mitigation measures designed for full development in Alternative A would apply, including activity restrictions near nest sites.

Conclusion

Because of a relatively protected prey base in the core calving area, changes in population and distribution of golden eagles would be minor rather than moderate as expected with full development. Effects on other raptors would be minor, and the potential for nesting habitat conflicts would be somewhat reduced.

PTARMIGAN

Not leasing the southern part of the 1002 area would reduce potential losses of some ptarmigan habitat.

Mitigation

Recommendations under full leasing would apply.

Conclusion

The effect of limited oil development on ptarmigan would be negligible.

PASSERINES

Adverse effects (habitat loss and disturbance, contaminants, and possibly decreased nesting opportunities or food availability for some species) would occur for passerine bird species except those using the core calving area habitats. Those effects are described in Alternative A.

Mitigation

Measures would be as recommended under full leasing.

Conclusion

Effects on passerines would be minor.

## FISH

Effects on fish under limited leasing would be similar to those under full leasing. Access corridors along the Hulahula River to development in the southeastern part of the 1002 area would no longer be required. Consequently, effects on arctic char and arctic grayling using the Hulahula River system would be eliminated, with the exception of some fishing pressure and one crossing by the main east-west pipeline/road corridor. Reduced gravel and water needs, fewer stream crossings, elimination of some potential for oil spills, and reduced human access/fishing pressure would reduce effects on arctic grayling in the Okpilak River drainage.

Mitigation

The same measures as those for Alternative A would also be appropriate for this alternative. Not developing the Pokok marine facility would reduce the potential for adverse effects on coastal fish.

Conclusion

Effects on fish throughout the 1002 area should be minor. If marine facilities were not constructed at Pokok, adverse effects on coastal fish would occur in a much smaller part of their habitats, resulting in negligible effects. An oil spill in a waterway or along the coast could cause a major effect on fish populations.

## THREATENED AND ENDANGERED SPECIES

BOWHEAD AND GRAY WHALES

See discussion under Seals and Whales.

ARCTIC PEREGRINE FALCON

Disturbance and reductions or displacement of prey would adversely affect peregrine falcons. The potential for conflicts between development and historic peregrine nest sites would be eliminated, because there would be no development, and probably no water withdrawal, in the vicinity of either known nest sites or much of the cliff-nesting habitat within the 1002 area.

Mitigation

Measures would be the same as those recommended for Alternative A.

Conclusion

Effects of development, disturbance, and reduced prey throughout the 1002 area except in Block D and part of Block C would have negligible impacts on peregrines.

## Effects on Socioeconomic Environment

### POPULATION

Development would require approximately one-third fewer workers and support service personnel under limited leasing than under full leasing. Employment opportunities during construction and restoration phases would total approximately 4,000 jobs. Permanent employment during production would range from 400 to 1,000 jobs during the 30-year lifetime of the 1002 area oil fields.

The year-round population at Kaktovik would increase somewhat, but less than for full leasing. Most workers would still be expected to maintain permanent residences elsewhere, similar to workers at Prudhoe Bay.

Conclusion

The expected population increase would be moderate in Kaktovik and negligible to minor in other Alaska communities.

### EXISTING LAND USE

SUBSISTENCE USE

Under Alternative B, villagers from Kaktovik could continue to pursue subsistence activities in the southeastern part of the 1002 area. This would include use of caribou and snow geese. Competition with oil-field workers, for harvest of fish and wildlife resources, would occur throughout the 1002 area. Intrusion of development activities into traditional harvest areas may occur in all but the southeastern part of the 1002 area.

Mitigation

As for full leasing, mitigation applicable to species used for subsistence would also lessen effects on subsistence uses. However, policies designed to reduce disturbance and other adverse effects to fish and wildlife species by restricting access and harvest in some areas would adversely affect subsistence uses.

Conclusion

The adverse effects of petroleum--reduced and displaced fish and wildlife populations used for subsistence, inhibited access to traditional harvest areas, and potential psychological effects--except in the core calving area of the PCH would have major adverse effects on subsistence activities. A significant restriction of subsistence use would be expected to result.

LAND STATUS AND MILITARY AND INDUSTRIAL USE

Land ownership would not change under this alternative, nor would any change in existing military activities be expected. Industrial development would occur in an area currently devoted to Native subsistence, fish and wildlife management, and recreational uses.

NATIVE ALLOTMENTS

None of the 1002 area parcels for which Native allotment applications have been made are in the area deleted from leasing; therefore, the areas affected would be the same as for Alternative A.

### STATE AND LOCAL POLITICAL AND ECONOMIC SYSTEMS

Economic benefits at the Federal, State, and local levels would still occur as described under Alternative A and in Chapter VII. These benefits could be one-third less than those for full leasing and development because the development of revenue-producing oil resources may possibly be that much less.

Conclusion

Although the overall benefits might be smaller than those expected to result from full leasing and development, limited leasing would still be a major positive benefit to State and local political and economic systems.

PUBLIC SERVICES AND FACILITIES

The tax base and employment opportunities would be approximately one-third less than for Alternative A.

Conclusion

The overall effect of increased public services and facilities would be a major benefit.

ARCHEOLOGY

Potential conflict between known archeological sites and projected oil-field activities might occur in four instances at Camden Bay and three at Pokok from construction of marine facilities there. Activities would occur at nearly the same level in coastal and river areas where undiscovered archeological sites are most likely to occur.

Mitigation

Surveys in areas to be developed and subsequent avoidance of known or discovered archeological sites will minimize the potential for site destruction.

Conclusion

Effects would be negligible.

RECREATION, WILDERNESS, AND ESTHETICS

The wilderness character of the 1002 area would be destroyed except in the southeastern part of the 1002 area and immediately adjacent wilderness areas.

Mitigation

Limiting numbers of river and stream crossings and not placing development facilities within 5 miles of designated wilderness areas would reduce adverse visual effects within the 1002 area and in adjacent designated wilderness areas.

Conclusion

A major loss of the wilderness character of the 1002 area would occur.

## Summary of Unavoidable Impacts, Alternative B

Compaction and destruction, as well as delayed growth of vegetation in areas of further geophysical exploration (green and brown trails).

Loss of nearly 4,400 acres of existing Resource Category 2 coastal plain habitat due to road and pad construction and gravel material sites.

Modification of about 5,200 additional acres of Resource Category 2 coastal plain habitat due to secondary effects such as gravel spray, dust deposition, and altered snowmelt and erosion patterns.

Increased noise and disturbance level displacing wildlife throughout all but the southeastern part of the 1002 area.

Loss of habitat values on approximately 10,000 acres of core caribou calving habitat (Resource Category 1) due to disturbance/displacement.

An unknown number (possibly hundreds) of small spills (diesel fuel, oil, antifreeze, etc.) resulting from vehicle and equipment operation and causing destruction of vegetation, contamination of waters, or mortality of small food organisms.

Displacement of caribou from approximately 4 percent of the core, concentrated calving areas within the 1002 area causing part of the projected population decline or distribution change for approximately 15 percent of the PCH.

Reduced use or avoidance of approximately 68,000 acres of insect-relief habitat for caribou.

Direct loss of approximately 2,400 acres of muskoxen habitat.

Increased disturbance to muskoxen with possible avoidance of 70 percent of the high-use, year-round with calving, habitats in the 1002 area resulting in a change in distribution, population decline, or no further expansion of the 1002 area muskoxen population.

Direct loss of approximately 10 acres of moose habitat.

Minor decline in the wolf population mainly due to increased mortality.

Displacement and increased harvest of wolverines.

Direct habitat loss of 2,600 acres of brown bear high- and moderate-use areas.

Loss of one brown bear per year from accidents or from being shot in defense of life or property.

Direct and indirect small mammal loss due to habitat destruction, road kills, etc.

Probable loss of the eastern portion of the 1002 area as denning habitat for polar bears.

Direct loss of 1,200 acres of snow goose preferred staging habitat.

Loss of habitat values from between 95,000 and 135,000 acres of snow goose preferred staging habitat within the 1002 area.

Direct mortality of birds due to strikes with towers, antennas, wires, and other structures.

Moderate loss of arctic grayling habitat in Block A owing to stream alterations and direct mortalities.

Loss of subsistence hunting opportunities in 40-50 percent of the 1002 area.

Unquantifiable loss of wilderness values in approximately 80 percent of the 1002 area.

## ALTERNATIVE C--FURTHER EXPLORATION

The first activities associated with further exploration on the 1002 area would be additional seismic work and surface geology studies. The effects of these exploration activities are fully described under Alternative A and will not be repeated here. Alternative C also provides an opportunity to collect further information regarding possible impacts of oil development, because exploration wells not previously permitted on the 1002 area would be allowed. This would assist in more accurately predicting environmental impacts and planning mitigation, should leasing be considered at some future date.

Effects and mitigation previously described for Alternatives A and B are referenced. Previously discussed literature on effects of exploration activities is also applicable.

### Effects on Physical Geography and Processes

The physical effects to be expected from additional surface geology and seismic exploration as well as the drilling of several stratigraphic test wells would be identical to those described in the seismic exploration and exploratory drilling discussions for Alternative A.

### Effects on Biological Environment

#### VEGETATION, WETLANDS, AND TERRAIN TYPES

Effects would be similar to those described for exploration under Alternative A. The generally temporary nature of exploration activities and possible location of test wells (Chapter V) would result in a minor effect on the vegetation, wetlands, and terrain types of the 1002 area.

#### SADLEROCHIT SPRING SPECIAL AREA

Current management regulations prohibit activities and would thus prevent adverse impacts in this area.

#### COASTAL AND MARINE ENVIRONMENT

Effects would be negligible because activities causing debris and disturbance in this area would be minimal and of a temporary nature. No greater than local, small contaminant spills are likely.

#### FISH AND WILDLIFE RESOURCES

Further exploration including the construction and drilling of single season or winter only multi-season exploratory wells would result in only minor or negligible effects on the fish and wildlife resources of the 1002 area as described for Alternative A. Fish and wildlife species which would be most affected by exploration activities are generally absent from the 1002 area during the winter period when these operations would take place. Further exploration involves short-term, local activities which would disturb or displace only those wildlife resources in the immediate vicinity. Although surface geology work would occur during the summer when fish and wildlife use of the 1002 area is greatest, it is very short-term, extremely localized, and results in almost no noticeable impacts.

The only species on which minor rather than negligible effects might occur are CAH caribou, which use the 1002 area during the winter, muskoxen, and polar bears. Short-term, localized displacements of caribou and muskoxen could occur in the vicinity of exploration activities. Polar bears could be disturbed from denning in such areas, as was suspected to be the case during the 1984-85 seismic program on the 1002 area.

Mitigation measures applicable to further exploration would be those from the regulations and special use permits governing the previous exploration programs in the 1002 area and the stipulations of the Chandler Lake agreement for the exploratory well on the KIC/ASRC lands. Additional measures applicable to exploration are detailed under Alternative A (time and area closures; aircraft altitude restrictions; controlling access, harvest, and contaminants; and actively monitoring all exploration activities as well as wildlife activities).

### Effects on Socioeconomic Environment

The moderate effect on wilderness expected under further exploration makes it the only feature of the socioeconomic environment for which the effects of this alternative further exploration could be greater than minor. Seismic trails and well pads are visual remnants of exploration activity which may persist for several years, reducing the wilderness value of areas in which they occur. Rehabilitation of well pads would be slow, and the effects on the wilderness values of the area in and around pads would be moderate. Adequate snow cover to protect the surface, environmentally sensitive routing of trails, and other mitigation stipulations described for Alternative A and used in the previous 1002 area and KIC/ASRC lands exploration programs would minimize effects on wilderness, subsistence use, and archeology.

Reduction and displacement of fish and wildlife populations used for subsistence would be no more than minor, access to traditional harvest areas would generally not be inhibited, and potential psychological effects would be greatly reduced with the local, temporary activities involved in further exploration of the 1002 area. As described under Alternative A, previous evaluations of the effect on subsistence from 1983-85 surface geology and seismic exploration programs on the 1002 area have concluded that effects on subsistence use in the 1002 area would be minimal and there would be no significant restriction of subsistence uses (U.S. Fish and Wildlife Service, 1983a, b, and 1985a, b).

### Summary of Unavoidable Impacts, Alternative C

Compaction and destruction, as well as delayed growth, of vegetation in areas of further geophysical exploration (green and brown trails).

An unknown number (possibly tens) of small spills (diesel fuel, oil antifreeze, etc.) resulting from vehicle and equipment operation and causing destruction of vegetation, contamination of waters, or mortality of small food organisms.

Short-term, local increases in noise and disturbance levels causing short-term, local displacement of some wildlife in areas with exploration activities.

Short-term, local disturbance to subsistence users.

## ALTERNATIVE D--NO ACTION

Under Alternative D, the general physical and environmental conditions on the 1002 area would essentially continue as they are at present. Fish, wildlife, and their habitats would respond to natural forces. The FWS would amend the comprehensive conservation plan (CCP) and, depending on the stage of refuge planning, the individual management plans for the entire refuge to include the 1002 area, which would be treated as an integral part of the entire Arctic National Wildlife Refuge.

Refuge planning has not been completed, so it is impossible to predict exactly what will be contained in the CCP and resultant management plans. The 1002 area has not yet been included as a part of this planning process, pending a management decision by the Congress. To fulfill the purposes for which the Arctic Refuge was established as outlined in ANILCA [sec. 302(2)], the management goals (at least until further defined by the CCP) would be to: maintain the existing availability and quality of refuge habitats with natural forces governing fluctuations in fish and wildlife populations and habitat change; provide the opportunity for continued subsistence use of natural resources by local residents, in a manner consistent with sound natural resource management; and provide recreational and economic opportunities compatible with the purposes for which the refuge was established.

Planning that would include the 1002 area could result in an increase in commercial activities in the 1002 area as well as the rest of Arctic Refuge, if found compatible. Public debate of petroleum related issues as a result of the ANILCA section 1002 program will result in greater public awareness of the natural resource values of the Arctic Refuge. Thus, recreational use of the 1002 area would probably increase. The FWS permits activities on National Wildlife Refuges insofar as they are compatible with the purposes for which each refuge was established [the National Wildlife Refuge Administration Act Public Law 89-669, 16 U.S.C. 668 dd-ee and ANILCA section 304(b)]. Infrastructure associated with offshore developments could be permitted within the 1002 area provided it (1) did not lead to development and production from the 1002 area and (2) was found compatible with refuge purposes. Also, some minor compatible surface geology studies could be possible.

Major long-term benefits would accrue to fish and wildlife as well as their habitats from management of the 1002 area under this alternative. Adverse effects of Alternative D from activities such as sport hunting and fishing or other recreational uses, or from activities conducted for scientific studies, would be negligible on all species and resource concerns discussed in previous alternatives.

In accordance with the terms of ANILCA (and the Chandler Lake Agreement) petroleum exploration, development, and production could not occur anywhere on the Arctic Refuge nor on those lands owned by KIC and ASRC which lie within the refuge boundaries unless the Congress enacted legislation specifically designed to open ASRC's lands to these activities. Production of the estimated recoverable 3.2 billion barrels of oil would not occur.

Socioeconomic changes would be expected to continue in the manner and pace in which they now occur. There would be no (or few) new job opportunities, little increased cash flow, and little change in subsistence uses, so long as no infrastructure associated with offshore development were built on the 1002 area.

## ALTERNATIVE E--WILDERNESS DESIGNATION

If the Congress were to designate the 1002 area as Wilderness, an extensive continuum of undisturbed Arctic environment in the United States would be preserved, extending from the crest of the Brooks Range to the Arctic Ocean. Under the Wilderness Act (P.L. 88-577), the FWS would manage this area to maintain wilderness resources and values, preserve the wilderness character of the biological and physical features, and provide opportunities for research, subsistence, and recreation. Loss or alteration of fish and wildlife habitats would occur in response to natural forces (population cycles, weather, predators, disease, etc.). None of the oil exploration and development, production, or transportation activities described in Alternatives A, B, and C could occur. Government research concerning the Alaska Mineral Resource Assessment Program (ANILCA section 1010) could continue. In accordance with the terms of the Wilderness Act and ANILCA, future petroleum development would be prohibited anywhere on the Arctic Refuge, and would include the KIC/ASRC lands. Production of the estimated 3.2 billion barrels of recoverable oil would be forgone.

Previous surface geology activities in the 1002 area had no apparent adverse effects on area fish, wildlife, and wilderness values. Such activities would still be permitted as a prior existing use for scientific purposes in the 1002 area if it were designated as wilderness. By using similar protective stipulations effects on fish, wildlife, and wilderness values would be negligible. The opportunity for economic changes related to petroleum revenues, jobs, and other economic stimuli described in Alternatives A, B, and C would be lost.

Hunting, fishing, and trapping would be allowed. Motorized access via aircraft, power boats, and snowmobiles would be permitted for traditional uses only.

Unless the Congress made special provisions in its wilderness designation for the 1002 area, further petroleum activity on lands owned by KIC and ASRC would be precluded under the provisions of section 1003 of ANILCA and the Chandler Lake Land Exchange Agreement between the United States of America and ASRC.

## IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

### Mineral Resources

The recoverable oil resource estimate used for the assessment in this chapter and for the scenarios in Chapter IV is the conditional mean recoverable figure of 3.2 billion barrels of oil (BBO). The estimates range from a low of 0.6 BBO at the 95-percent chance to a high of 9.2 BBO at the 5-percent chance. If the Congress elects to permit oil and gas development and production on the 1002 area of the Arctic Refuge and if exploration efforts are successful, the amount of development would be directly dependent upon the actual amount of economically recoverable reserves discovered on the 1002 area. Those resources would be committed to development. The mean recoverable estimate provides a reasonable scenario for oil development. However, until reserves are confirmed, it must be recognized that actual development could be as little as that required to recover 0.6 BBO or as much as that needed to produce 9.2 BBO.

Infrastructure for a 0.6-BBO field would depend on the location of the discovery (or discoveries). For a discovery in the eastern part of the 1002 area, the pipeline requirements would be the same as in Alternatives A and B; one or two central production facilities may be required, and at least one port site. A discovery in the western area only would reduce the length of the pipeline. Depending on the leasing program selected, development might occur in the PCH core calving area.

The infrastructure for developing, producing, and transporting 9.2 BBO would not necessarily be three times that for 3.2 BBO. What would most likely change would be the amount of time required to produce the oil. Therefore, the impacts discussed for Alternatives A and B, depending on the scope of the leasing program, would be very similar. If species such as caribou and muskox did not readily habituate to development facilities and activities, and if suitable alternative habitats are not available, the impacts expected would be in terms of declines in population numbers and overall herd vigor, and major changes in behavioral patterns due to disturbance and displacement. Longer oil production times would also increase the potential for oil spills and other toxic/contaminant accidents, the results of which are detailed in Alternatives A and B.

### Biological Resources

Placement of gravel pads for roadways, pipelines, airfields, processing facilities, housing, and other infrastructure under full leasing will cover slightly more than 5,000 acres of natural vegetation. Although there can be some flexibility in siting so that higher value habitats can be avoided, the affected vegetation may be considered an irretrievable loss, at least for the duration of the life of the facilities. Up to an additional 500 to 750 acres of the coastal plain may also be permanently altered as a result of gravel mining.

Approximately 20 acres of shallow subtidal marine bottom could be permanently altered by construction of docks and causeways at each port site. A causeway could also have permanent effects on nearshore temperature and salinity regimes and circulation which in turn could alter species composition of planktonic and benthic organisms in the area affected or influenced by the causeway. Whether these populations would return to pre-project levels and composition following either deliberate removal of the causeway or natural erosion is problematical.

### Historical Resources

Irretrievable products of prehistoric culture such as archeological sites might be lost from looting and indiscriminate or accidental activity on known and unknown sites. Environmental training of personnel and stipulations for the protection of such resources would reduce the level of those losses.

Traditional subsistence life styles would be irreversibly and irretrievably lost or altered with the introduction of widespread industrial activity and greater opportunities for a cash-based economy.

The wilderness character of the coastal plain would be irretrievably lost (table VI-8).

**Table VI-8.**--Irreversible and irretrievable commitments of resources.

| Alternative | Loss of: Wilderness character | Traditional native life style/culture | Artifacts at development sites | Oil resources | Commercial development potential |
|---|---|---|---|---|---|
| A--full leasing | All | Most | All | Depletion | None |
| B--limited leasing | All | Most | All | Some | Minimal |
| C--further exploration | Some | Some | Some | None | Some |
| D--no action | Possible | None | None | None | Some |
| E--wilderness | None | None | None | None | Complete |

## COMPARISON OF SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Geological and geophysical investigations carried out in 1983-85, along with other available information, have revealed geologic structures with the potential for containing oil and gas resources. If the Congress allows oil and gas production from the 1002 area, exploration will proceed and, if oil and gas resources are found in economic quantities, production will result. Though the structures appear highly favorable, there is no assurance that they do in fact contain oil and gas. Nevertheless, based on favorable exploration results from the Prudhoe Bay oil field to the west and the Canadian Beaufort Sea and Mackenzie delta oil fields to the east, the prospects are encouraging. Even with negative results, it is expected that mid- to short-term changes caused by 10-15 years of exploration could occur before the area would be abandoned.

The short-term activities associated with further exploration of the 1002 area will lead to generally short-term displacement and disturbance of the area's fish and wildlife resources and subsistence users as described in this chapter. If further exploration indicates that the oil and gas structures are barren, there will be no need for production and transportation systems--the development efforts can be terminated, the lands reclaimed, and the area allowed to return as closely as possible to its present condition. In this case it is expected that there will be few or no residual or long-term effects on wildlife populations of the area. The area's wilderness attributes will be affected for a longer time, but are eventually expected to generally recover.

Long-term losses in fish and wildlife resources, subsistence uses, and wilderness values would be the inevitable consequence of a long-term commitment to oil and gas development in the area. If economic prospects are subsequently delineated, the area would be committed to petroleum operations for a period of 30-90 years with an estimated 3.2 billion barrels of oil being produced during that period. Initial economics would depend on oil, but it is expected that gas production from this area would also be economic within two to three decades. However, successful oil and gas exploration would lead to industrial development with an infrastructure as depicted in Chapters IV and V. Additionally, to be expected are pressure to use this area as a base to service exploration and development of the Outer Continental Shelf area to the north, possible interties with projected oil and gas development in Canada, and pressure on the Congress to open areas designated as wilderness in the Arctic Refuge to oil and gas exploration, depending on the location of actual discoveries. Moreover, an oil and gas development infrastructure in the 1002 area would be an impetus to development of State lands between the Canning River and TAPS to the west. If the infrastructure for 1002 area development also served potential offshore or other fields, it will add to the long-term commitment of this area to industrial use based on oil and gas development.

Commitment of the 1002 area to oil and gas development would provide the opportunity to extract the recoverable reserves in this area to help meet projected national energy needs. Oil and gas development would result in widespread, long-term changes in the wilderness environment, wildlife habitats, and Native community activities currently existing in the 1002 area, resulting instead in an area governed by industrial activities. These changes include displacement and reduction in the size of the Porcupine caribou herd as a result of widespread, intensive activities throughout one-third of its core calving area, as well as throughout a large part of its postcalving and insect-relief areas. The size of this herd reduction and its long-term significance to herd viability is highly speculative because relevant experience is lacking regarding the responses or adaptability of the PCH to such intensive activities. However, geography apparently limits the availability of suitable alternative calving or insect-relief habitats. The ability of the herd to successfully calve at even greater concentrations than at present in calving areas which remain unaffected by oil and gas activities is unknown. Mitigation measures such as environmentally sensitive siting of facilities, time and area closures, and harvest restrictions can minimize some adverse effects to the PCH as well as to other fish, wildlife, wilderness, and subsistence resources. But, even with effective mitigation, herd displacement or reduction could be as great as 20-40 percent.

Industrial development will also have a profound effect on the Native culture. Although it may provide jobs for a few members of the Kaktovik community, it will conflict with or hasten changes in life style from one of subsistence use dependent on the land to an industrial society with a cash-based economy. Increased educational and employment opportunities, and greater health services may be benefits but at the expense of traditional ways of life and community bonds.

With authorization of oil and gas development, KIC and ASRC will have the opportunity to develop their oil and gas resources adjacent to the 1002 area, further speeding the modernization of local life styles. The tradeoffs involved are a subjective assessment: lost opportunities to pursue traditional cultural activities and subsistence life styles for employment opportunities and economic gains which may be unevenly distributed throughout the community. Acceptability of these changes will only be partly a local decision, relative to the extent to which the development of an industrial-commercial base in Kaktovik is pursued.

Local people can either encourage or discourage ancillary development servicing the oil and gas industry. During hearings for the previous 1002 area exploration program, Kaktovik residents expressed concerns that their opportunities to pursue a subsistence life style not be diminished, including desires that fish and wildlife resources not be diminished or displaced, yet that they be allowed to benefit from jobs or other economic opportunities available. Residents of Arctic Village and other Native communities utilizing caribou from the highly migratory PCH were critical of any impacts to their subsistence use resources which could be caused by exploration. Views of Kaktovik or other villages regarding full development are unknown. The ASRC has publicly expressed its support for oil and gas development on both KIC/ASRC lands and the 1002 area. Congressional authorization of development would include authorization to develop oil and gas resources on the KIC/ASRC lands, which will add to effects on subsistence users and traditional lifestyles.

A decision to pursue oil and gas development on the 1002 area will result in the tradeoff of a gain of as much as 3.2 billion barrels of oil to meet that demand in the Nation's energy needs and offset oil imports with a loss of, at minimum, a significant part of the PCH calving grounds and other habitats, continued expansion of 1002 area muskoxen herds, notable staging habitats for internationally important, migratory snow geese, and numerous other fish and wildlife resources, significant restrictions to the continuation of subsistence activities by residents of Kaktovik, and existence of wilderness values on a vast expanse of fragile and limited Arctic coastal plain ecosystem. Moreover, pressures to discontinue or lessen pursuit of a traditional Native subsistence lifestyle, resulting in irreversible changes, will be minimized. Conversely, a decision to designate the 1002 area as wilderness will maintain those long-term fish, wildlife, subsistence, and wilderness values at a cost of a potential, but unconfirmed, 3.2 billion barrels of oil.

Additional tradeoffs involved in developing coastal plain oil and gas resources include loss of existing pristine air and water quality and gravel and water resources.

## SUMMARY OF RECOMMENDED MITIGATION FOR THE 1002 AREA

Following is a compendium of safety and environmental stipulations applicable to oil and gas exploration, development, production, and transportation on the 1002 area.

| | Stipulations | Results |
|---|---|---|
| 1. | Consolidate, site, construct, and maintain facilities and pipelines to minimize effects on sensitive habitats and species. Locate nonessential facilities outside caribou calving areas. | Will avoid or minimize disturbance in, or loss of, environmentally sensitive areas and allow free passage and natural movement of fish and wildlife. |
| 2. | Design all bridges and culverts to handle at least 50-year flood events. | Will prevent damage and disturbance of fish habitats. |
| 3. | Use ice or gravel-foam-timber pads, where feasible, for exploration wells. | Will reduce gravel requirements and acres of habitat modified. |
| 4. | Develop and implement an approved rehabilitation plan as part of leasing program. | May provide total or partial restoration of habitat values in affected area. |
| 5. | Prohibit off-road vehicle use within 5 miles of all pipelines, pads, roads, and other facilities, except by local residents engaged in traditional uses or if otherwise specifically permitted. | Will minimize disturbance to wildlife, reduce destruction of vegetation, and permit migration of large mammals. |
| 6. | Limit oil exploration, except surface geology studies, to November 1-May 1 (exact dates to be determined by Refuge Manager). Cease exploration activities and remove or store equipment at an approved site by May 15. Local exceptions may be made. | Will limit disturbance to periods when most area fish and wildlife species are absent. |
| 7. | Prohibit: gravel removal from active stream channels on major fish-bearing rivers; winter water removal from fish-bearing waters, or springs and tributaries feeding into fish-bearing waters; spring, summer, or fall water removal from fish-bearing waters at levels that will not easily pass fish or maintain quality rearing habitat. | Will minimize disturbance to fish and degradation of fish habitats. |
| 8. | Elevate pipelines to allow free passage of caribou in areas without ramps or buried sections. | Will allow migration and other movements of large mammals. |
| 9. | Place ramps over piplines at natural crossings or where development tends to funnel animals. | Will allow migration and other movements of caribou and other large mammals. |
| 10. | Bury pipelines where possible. | Will prevent or reduce visual disturbances and barriers to movements of caribou and other large mammals. |
| 11. | Separate roads and pipelines 400-800 feet, depending on terrian, in areas used for caribour crossing. | Will enhance crossing of linear structures by caribou and other mammals. |
| 12. | Restrict surface occupancy in the zone from the coastline inland 3 miles to marine facilities and infrastructure necessary to support activities outside the restricted zone. | Will permit caribou use of coastal insect-relief habitat and reduce disturbance of nesting waterfowl and other species. |

| Stipulations | Results |
|---|---|
| 13. Monitor populations, productivity, movements, and general health of key species. Research measures to further minimize adverse effects of development: Implement corrective actions. | Will allow early identification of problems and implementation of corrective measures for caribou, muskoxen, polar bears, snow geese, arctic char, and others. |
| 14. Close areas within 3/4 mile of high-water mark of specified water courses to permanent facilities and limit transportation crossings. Gravel removal may occur on a site-specific basis. | Will protect riparian habitat and reduce stream pollution and disturbance in an important and limited habitat. |
| 15. Acquire authority to require aircraft to maintain 1,500 feet altitude above nest level within 1 mile horizontal distance of historic peregrine or other raptor nest sites April 15-August 31 (June 1 if nest is unoccupied). | Will protect nesting peregrine falcons and other raptors from disturbance. |
| 16. Prohibit use of explosives or other noisy activities within 2 miles of raptor nest sites April 15-August 31 (June 1 if nest is unoccupied), unless specifically authorized by the FWS. | Will protect nesting peregrine falcons and other raptors from disturbance. |
| 17. Prohibit ground level activity, permanent facilities, and long-term habitat alterations (material sites, roads, and airstrips) within 1 mile of known peregrine or other raptor nest sites. April 15-August 31 (June 1 if nest is unoccupied) unless specifically authorized. | Will protect nesting peregrine falcons and other raptors from disturbance. |
| 18. Survey suitable habitat annually to locate nesting peregrines and other raptors. | Will avoid conflicts between development and nesting raptors. |
| 19. Track radio-collared female polar bears. Establish no-activity zone of at least 1/2 mile around any den. | Will prevent disturbance during denning. |
| 20. Avoid construction in coastal areas near river systems with topographic relief or bluffs. Minimize activities along the coast during late October-early November when polar bears come ashore to den. | Will reduce disturbance to polar bears, and prevent destruction of potential bear den and raptor nest sites. |
| 21. Close area within 5 miles of development and associated infrastructure to hunting, trapping and discharge of firearms. | Will increase public safety and reduce direct mortality of caribou, muskoxen, bears, and waterfowl; lower disturbance: and increase the likelihood of habituation by species encountering development. |
| 22. Prohibit surface occupancy in the Sadlerochit Spring Special Area (pl. 1A). | Will prevent degradation of a unique environment and prevent loss of water essential for fish overwintering. |
| 23. Define range of the candidate plant Thlaspi arcticum. Minimize surface occupancy in immediate vicinity of areas identified as supporting the plant. Position pads, collecting lines, and associated roads at least 1/2 mile from candidate plant locations. | Will prevent destruction of Thlaspi arcticum. |
| 24. Construct docks and causeways so that fish movements are not impeded and lagoon water chemistry is basically unchanged. | Will provide for fish and marine mammal movement and be less degrading to near-shore marine habitat. |

| Stipulations | Results |
|---|---|
| 25. Establish time and area closures or restrictions on surface activity in areas of wildlife concentration during muskox calving, April 15-June 5; caribou calving, May 15-June 20; caribou insect harassment, June 20-Aug. 15; snow goose staging, Aug. 20-Sept. 27; and overwintering and spawning. | Will protect species from disturbance during critical periods. |
| 26. Acquire authority to establish time and area closures and minimum aircraft altitude of 2000 feet above ground level (AGL) during muskox and caribou calving and caribou insect harassment, April 15-Aug. 15; and snow goose staging, Aug. 20-Sept 25. At other times the minimum altitude generally will be 1000 feet AGL over areas of animal concentrations. | Will protect species from disturbance during critical periods. |
| 27. Fence camps and pump stations; incinerate garbage daily; prohibit wildlife feeding. | Will reduce bear/human confrontations, and reduce attraction of and increases in scavenger populations. |
| 28. Limit use of development infrastructure, roads and airstrips, to persons on official business. | Will reduce disturbance levels and human/wildlife interaction. |
| 29. Inventory project areas for cultural resources, evaluate resources and implement mitigation to avoid or minimize impact. | Will preserve cultural resources (archeological and historic sites) to the maximum extent possible. |
| 30. Develop and implement plans for control, use, and disposal of fuel and hazardous wastes. | Will reduce potential for contaminant spills. |
| 31. Reinject drilling muds, cuttings, and other wastes where geologically feasible. Remove hazardous wastes to an approved disposal site. | Will minimize areas needed for reserve pits and reduce potential for contaminant spills. |
| 32. Provide: environmental orientation briefings for workers; program for monitoring development activities; continuation of fish and wildlife population monitoring; follow-up programs to evaluate effects; and adequate staffing for full and effective enforcement of mitigation. | Will increase environmental awareness of workers; give managers continuing baseline information to analyze effects of development and improve protective measures; help to ensure effectiveness of mitigation. |

## SUMMARY OF EFFECTS FOR ALTERNATIVES A, B, C, D, AND E ON THE PHYSICAL,

| | Alternative | | | | |
|---|---|---|---|---|---|
| | A | B | C | D[1] | E |
| | **Physical environment** | | | | |
| Water | Major--Dedicated industrial use of limited natural water supplies. | Major[2] | Minor | None | None |
| Gravel | Moderate--Translocation of natural gravel sites to manmade sites, changing contours, and creating scars where the gravel was both removed and placed, lasting beyond life of project. | Moderate[2] | Minor | None | None |
| Air | Minor--Limited to life of project and restoration. | Minor[2] | Minor | None | None |
| Permafrost | Moderate--Permafrost may melt under borrow sites and under vegetation disturbed by other development activities, causing sloughing, sloughing, and stream pollution lasting beyond life of project. | Moderate[2] | Neg. | None | None |
| Ambient noise | Major--Locations at work sites during life of project and restoration. | Major[2] | Minor | None | None |
| | **Socioeconomic environment** | | | | |
| Human population | Moderate | Moderate | Neg. | Neg. | Neg. |
| Subsistence | Major | Major | Minor | Neg. | Neg. |
| Native allotments | Major | Major | Minor | Neg. | Neg. |
| Land status and military | Neg. | Neg. | Neg. | Neg. | Neg. |
| Industrial | Major | Major | Minor | Neg. | Neg. |
| State/local political and economic. | Major | Major | Minor | Neg. | Neg. |
| Public services/ facilities. | Major | Major | Minor | Neg. | Neg. |
| Archeology | Neg. | Neg. | Neg. | Neg. | Neg. |
| Recreation, wilderness, and esthetics. | Major | Major | Moderate | Neg. | Neg. |

[1]Depending on final CCP.
[2]Effects will generally be the same as for full leasing but over less area.
[3]Moderate decline in age and horn size of male sheep south of the 1002 area may occur as a result of increased hunting.
[4]Could be major if access and harvest not controlled.
[5]Withdrawing harbor at Pokok Lagoon may reduce impact to minor for polar bear and negligible for seals and whales.

| | Alternative | | | | |
|---|---|---|---|---|---|
| | A | B | C | D[1] | E |
| | Biological environment | | | | |
| Caribou (PCH) | Major | Moderate[3] | Neg. | Neg. | Neg. |
| (CAH) | Moderate | Moderate | Minor | Neg. | Neg. |
| Muskox | Major | Major | Minor | Neg. | Neg. |
| Moose | Minor | Neg. | Neg. | Neg. | Neg. |
| Dall sheep | Neg.[3] | Neg.[3] | Neg. | Neg. | Neg. |
| Wolf | Moderate | Minor | Neg. | Neg. | Neg. |
| Arctic fox | Minor | Minor | Neg. | Neg. | Neg. |
| Wolverine | Moderate[4] | Moderate | Neg. | Neg. | Neg. |
| Brown bear | Moderate | Minor | Neg. | Neg. | Neg. |
| Polar bear | Moderate | Moderate[5] | Minor | Neg. | Neg. |
| Seals/whales | Minor | Minor[5] | Neg. | Neg. | Neg. |
| Ground squirrel/ other rodents | Minor | Minor | Neg. | Neg. | Neg. |
| Snow goose | Major[6] | Moderate | Neg. | Neg. | Neg. |
| Tundra swan | Minor | Minor | Neg. | Neg. | Neg. |
| Other geese/ducks | Minor | Minor | Neg. | Neg. | Neg. |
| Seabirds/shorebirds | Minor[7] | Minor[7] | Neg. | Neg. | Neg. |
| Peregrine falcon | Minor | Neg. | Neg. | Neg. | Neg. |
| Raptors | Moderate[8] | Minor | Neg. | Neg. | Neg. |
| Ptarmigan | Neg. | Neg. | Neg. | Neg. | Neg. |
| Passerines | Minor | Minor | Neg. | Neg. | Neg. |
| Arctic char | Minor | Minor | Neg. | Neg. | Neg. |
| Arctic grayling | Minor | Minor | Neg. | Neg. | Neg. |
| Other fresh-water fish | Minor | Minor | Neg. | Neg. | Neg. |
| Coastal fish | Minor[9] | Minor[9] | Neg. | Neg. | Neg. |
| Vegetation, wetlands, and terrain types | Moderate | Moderate | Minor | Neg. | Neg. |
| Sadlerochit Spring Special Area | Neg.[10] | Neg.[10] | Neg.[10] | Neg. | Neg. |
| Coastal/marine environment | Minor[11] | Minor[11] | Neg. | Neg. | Neg. |

[6]Effect on 1002 area population only. Moderate effect on total Banks Island, Canada, population.
[7]Some local effects could be moderate.
[8]Golden eagles only. Effect on other raptors minor.
[9]Could be moderate with development of KIC/ASRC or offshore areas. Other than minor effects expected in vicinity of port sites, effects on coastal fish will be negligible. Effects could be major with an oil spill in fish habitats.
[10]An exploratory well, water removal, or other activities in this area could increase effects to major.
[11]Oil spills and (or) cumulative developments could cause major impacts.

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# CHAPTER VII

# OIL AND GAS--NATIONAL NEED FOR DOMESTIC SOURCES AND THE 1002 AREA'S POTENTIAL CONTRIBUTION

## INTRODUCTION

Section 1002(h)(5) of ANILCA requires an evaluation of how hydrocarbon resources in the 1002 area of the Arctic Refuge relate to the national need for additional domestic sources of oil and gas. This chapter discusses this national need, and describes the potential contribution of oil from the 1002 area. Benefits which would accrue to the nation are described. They include gains in national income, reduced vulnerability to disruptions in the world market, and improvements in the balance of payments and national security. The analysis focuses only on oil because it is not anticipated that natural gas from the 1002 area will become economic to produce and transport to market within the timeframe considered.

The estimates used in this chapter depend on many variables. If the 1002 area were opened and leased in a timely manner, production would not be expected until about the year 2000. Therefore, the refuge's contribution to U.S. energy needs has been determined by comparing its production potential against projected energy needs, beginning about 15 years from now and extending perhaps 30 years out to the year 2030, possibly beyond. It is difficult to anticipate world oil prices beyond the year 2000 and the rate of real growth of the U.S. economy--two important determinants of the future demand for energy. Nevertheless, potential production from the 1002 area can be compared against various forecasts about future U.S. energy demand and supply. This chapter relies mainly on the Department of Energy's (DOE) long-term projections contained in its 1985 National Energy Policy Plan, but also considers several private forecasts.

## THE 1002 AREA'S POTENTIAL CONTRIBUTION TO U.S. NEEDS

The unique geologic features underlying the 1002 area create the potential for discoveries which would make a very substantial contribution to domestic oil reserves. Despite the area's remote location and hostile environment, it is the most attractive petroleum exploration target in the onshore U.S. Data from outcropping rocks within the area and from nearby wells, combined with seismic information gathered from 1983 to 1985, indicate geologic conditions which would be extremely favorable for major discoveries.

The billions of barrels of oil that may exist in the 1002 area could make an important contribution to the national need for domestic sources of oil. Alaska North Slope crude oil, especially that from Prudhoe Bay, now contributes almost 20 percent of domestic production. Production from Prudhoe Bay has peaked and a decline is expected no later than 1988. Arctic Refuge oil could help moderate this decline and substantially reduce the need for increased imports.

The oil resources and possible production capability of the larger potential oil fields in the 1002 area are substantial by U.S. standards. Estimates of oil in place range from 4.8 billion barrels (BBO) to more than 29.4 BBO. Recoverable resource estimates range from 0.6 BBO to 9.2 BBO. In some cases, the potential recoverable reserves of the 1002 area's fields may sizably exceed 1 BBO. Only 13 domestic fields with total reserves greater than 1 BBO have been discovered in this country. Their original reserves, remaining reserves, current production rate, and year of discovery are displayed in table VII-1.

If productive, the 1002 area's fields could be the largest domestic fields discovered since Prudhoe Bay and Kuparuk River in 1968 and 1969. Except for these, no U.S. field with reserves exceeding 1 BBO has been discovered since 1948. The size of the 1002 area's structures and their potential for oil accumulations are geologically the Nation's best onshore targets for the discovery of very large oil fields. If productive, the large fields would join the list of "giant" oil fields which have contributed over two-thirds of total domestic oil production. The previously discovered giants, except for the two Alaskan fields, are over 75 percent depleted (table VII-1), and even the Prudhoe Bay field is almost half depleted.

For purposes of assessing the 1002 area's possible contribution, the conditional mean recoverable resource estimate of 3.2 BBO has been used. The estimate for limited leasing is 2.4 BBO. These figures do not consider resources that may occur in undefined but potential stratigraphic traps (see Chapter III).

### Contribution to Domestic Oil Demand and Supply

It is important to assess the 1002 area's potential contribution to the national need for domestic oil production in light of supply and demand conditions. Oil consumption in the U.S. has exceeded domestic production for more than 20 years. Using the daily production estimates for the 1002 area, table VII-2 compares the area's contribution with the Department of Energy's (DOE) reference case projections for domestic oil supply and demand, taken from the 1985 DOE National Energy Policy Plan, to illustrate the magnitude of the contribution 1002 area oil production

**Table VII-1.**--U.S. oil fields having ultimate recovery exceeding 1 billion barrels of oil.

[BBO, billion barrels of oil; MBO/Y, million barrels of oil per year. From Oil and Gas Journal (1986) and Roadifer (1986)]

| Field | Year discov-ered | Original reserves (BBO) | Remaining reserves (BBO) | Current production (MBO/Y) |
|---|---|---|---|---|
| Prudhoe Bay, AK | 1968 | 9.47 | 5.10 | 568 |
| East Texas | 1930 | 6.00 | 1.11 | 48 |
| Wilmington, CA | 1932 | 2.55 | .36 | 41 |
| Midway-Sunset, CA | 1894 | 2.16 | .45 | 54 |
| Kern River, CA | 1899 | 1.99 | .92 | 51 |
| Yates, TX | 1926 | 1.95 | .90 | 45 |
| Wasson, TX | 1936 | 1.68 | .57 | 33 |
| Kuparuk River, AK | 1969 | 1.59 | 1.30 | 79 |
| Elk Hills, CA | 1911 | 1.47 | .70 | 47 |
| Panhandle, TX | 1921 | 1.46 | .07 | 11 |
| Kelly-Snyder, TX | 1948 | 1.35 | .15 | 19 |
| Huntington Beach, CA | 1920 | 1.12 | .07 | 8 |
| Slaughter, TX | 1936 | 1.03 | .06 | 24 |

could make in the face of increasing demand and steadily declining domestic production.

The U.S. has stabilized its oil production capability and temporarily moderated the decline in domestic reserves since 1974. This is largely due to successful exploration and intensive exploitation of known fields, including the use of improved and enhanced oil recovery (EOR) technology, and to the 1.5 million barrels per day produced at Alaska's Prudhoe Bay.

U.S. crude oil production peaked at 9.64 million barrels per day (MBO/D) in 1970 and has been relatively constant over the last decade, being 8.90 MBO/D in 1985. However, in February 1986, the Department of Energy (DOE, 1986) predicted that domestic oil production would decrease by about 3 percent per year beginning in 1987, declining to about 8.05 MBO/D in 1990 and to 6.53 MBO/D by 1995. These estimates represent a substantial reduction from previous DOE forecasts. In June 1986, the Chevron Corporation predicted that production would decrease to 8.8 MBO/D in 1986 and steadily decline to 6.2 MBO/D by the year 2000 (Chevron, 1986). Other recent estimates suggest levels as low as 4.0 MBO/D by the year 2000. The lower forecasts are largely the result of reduced oil and gas prices, price uncertainty, consequent reduced drilling levels and discovery rates, higher annual production declines in known fields, and decreased emphasis on production stimulation projects (Spaulding, 1986; Doscher and Kostura, 1986; Kuuskraa, 1986).

**Table VII-2.**--The 1002 area's potential contribution to U.S. oil demand, production, and imports.

[In thousands of barrels per day. U.S. demand, production, and import data from U.S. Department of Energy, 1985d, tables 4-6 and 4-7]

| Year | 2000 | 2005 | 2010 |
|---|---|---|---|
| U.S. OIL DEMAND | 16,100 | 15,800 | 15,700 |
| 1002 area oil production: | | | |
| Full leasing | 147 | 659 | 404 |
| Percent of U.S. total demand | .91 | 4.17 | 2.57 |
| Limited leasing | 105 | 473 | 300 |
| Percent of U.S. total demand | .65 | 2.99 | 1.91 |
| U.S. OIL PRODUCTION | 8,600 | 8,200 | 7,400 |
| 1002 area oil production: | | | |
| Full leasing | 147 | 659 | 404 |
| Percent of U.S. total production | 1.71 | 8.04 | 5.46 |
| Limited leasing | 105 | 473 | 300 |
| Percent of U.S. total production | 1.22 | 5.77 | 4.05 |
| U.S. OIL IMPORTS | 7,500 | 7,600 | 8,300 |
| 1002 area oil production: | | | |
| Full leasing | 147 | 659 | 404 |
| Percent of U.S. total imports | 1.96 | 8.67 | 4.87 |
| Limited leasing | 105 | 473 | 300 |
| Percent of U.S. total imports | 1.40 | 6.22 | 3.61 |

Oil reserves decreased over 27 percent, about 11 billion barrels from 1970 to 1985 and declined annually during 14 of these 15 years despite extensive exploration and active field exploitation programs.

J. P. Riva (Riva, 1984; Riva and others, 1985; Gall, 1986), of the Science Policy Research Division of the Library of Congress, predicted that shrinking American oil reserves will plunge by 1990 to their lowest levels since shortly after World War II, based on current drilling rates. Riva predicts a decline from the 1985 reserve figure of 28.4 BBO to 25.1 BBO in 1990, and perhaps to as low as 23.2 BBO in 1995. The most significant declines in reserves will occur in the older, traditional oil-producing areas of the western United States, Texas, the Gulf Coast, and the Midcontinent. In the frontier regions of Alaska and offshore California, prospects are better for substantial reserve additions.

If current production and reserves in known fields are assumed (the reserves/production ratio), theoretically the Nation's oil reserves would be exhausted in about 9 years. But because oil-field production conventionally declines about 10 percent per year compounded, in practice it will take about 30 years to exhaust known reserves.

Production capability and reserves can be increased by (1) exploring for new fields; (2) extending or finding new reservoirs in known fields; (3) producing more of the total oil-in-place by enhanced recovery methods, infill drilling, well stimulation, etc.; and (4) developing improved production technology. Use of each technique depends on projected prices of oil and gas, economics, and relative costs of the technique.

From 1977 through 1985, a period of high oil prices and the greatest boom in domestic exploration history, an average of 930 million barrels of new reserves were discovered each year (MBO/Y). Revisions and adjustments added an average of 1483 MBO/Y. Consumption during the same period averaged almost 3000 MBO/Y. Reserves therefore decreased by an average of 565 MBO/Y. Approximately 7 percent of the increase resulted from discovery of new fields; 31 percent from the discovery of extensions and new zones in known fields; and 62 percent from EOR, other increased recovery methods, and statistical revisions. Oil is being consumed faster than it is being discovered, and the Nation is reducing its oil inventory.

The historical quantities of petroleum discovered per foot of exploratory drilling dramatically demonstrate the increasing difficulty in finding large oil and gas fields (table VII-3). No reversal of the trend has occurred since 1979.

Oil fields with recoverable reserves exceeding 100 (MBO) are frequently described as national class giants. Giant fields with reserves exceeding 500 MBO are supergiants or world class giants. Giants and supergiants are few in number, but contribute the bulk of the world's oil production. In fact, fewer than 300 supergiant oil fields (out of 30,000 oil fields worldwide) contain more than 80 percent of the world's known oil reserves. Over 40 supergiants have been discovered in the U.S., almost all prior to 1939. Only one was discovered from 1977 to 1985. More significantly, only five have been discovered since 1951: McArthur River (1965), Prudhoe Bay (1968), and Kuparuk River (1969), all in Alaska; Jay in Florida (1970); and East Anschutz Ranch in the Overthrust Belt in Wyoming (1981). Point Arguello in the Outer Continental Shelf (OCS) off California may be added to this list once the reserves are fully defined.

**Table VII-3.**--Historical recoverable U.S. oil and natural gas finding rates.

[Modified from U.S. Geological Survey]

| Period during which footage was drilled | Increment feet of exploratory drilling (billions) | Finding rate per foot exploration drilling Oil (barrels) | Gas (MCF) |
|---|---|---|---|
| 1859-1949 | 0.0-0.5 | 236 | 916 |
| 1949-1958 | 0.5-1.0 | 51 | 347 |
| 1958-1967 | 1.0-1.5 | 21 | 252 |
| 1967-1977 | 1.5-2.0 | 20 | 186 |
| 1977-1979 | 2.0-2.1 | 9 | 134 |

Discovery patterns for giant oil fields are only slightly more favorable. About two-thirds of the U.S. giants were found before 1940, 94 since, and the number of such discoveries decreases in each successive decade.

The onshore basins in the U.S. that hold the greatest potential for very large discoveries have already been explored, except for the 1002 area. While there are some very attractive offshore areas yet to be explored, the 1002 area is particularly promising because it contains extensions of other producing trends, and wells on adjacent properties show highly favorable evidence of petroleum deposits. These evidences, when combined with the structural traps mapped or inferred for the area, indicate that the 1002 area is currently the unexplored area in the U.S. with the greatest potential to contain giant and supergiant fields.

Not only might discovery of a supergiant field in the 1002 area make a significant contribution to domestic reserves and production, it could do so at a relatively low average cost per barrel because of economies of scale. The combination of high production and low average costs makes the total net economic value much higher for large fields. Moreover, because average costs are lower, larger fields can be produced economically and can contribute to the economy even when world oil prices are lower.

## Contribution to National Objectives

The potential contribution from the 1002 area's production goes well beyond that of simply providing a certain percentage of U.S. domestic oil needs that might otherwise have to be obtained from foreign sources of supply. Production of oil from the 1002 area can also help achieve this Nation's national economic and security objectives as well.

### FOSTERING ADEQUATE ENERGY SUPPLIES AT REASONABLE COSTS

DOE's 1985 National Energy Policy Plan has as its general goal fostering adequate energy supplies at reasonable costs. Adequate supply requires "a flexible energy system that avoids undue dependence on any single source of supply, foreign or domestic, and thereby contributes to national security (and) implies freedom of choice about the mix and measure of energy needs to meet our industrial, commercial, and personal requirements." The National Energy Policy Plan also recognizes leasing Federal lands as important in the Nation's effort to ensure long-term energy supplies.

### REDUCING DEPENDENCE ON IMPORTED OIL

Since 1970 this Nation has been heavily dependent on foreign petroleum supplies to meet domestic demand. The prospect is for continued U.S. dependence on foreign oil. Imports in 1985 were expected to average about 5 MBO/Y, to supply about one-third of domestic oil needs. DOE's latest forecasts show that U.S. dependence on foreign oil is expected to increase significantly by the end of the century and beyond. Table VII-2 compares the percent of the 1002 area oil contribution to U.S. oil imports.

The Nation's oil imports come from two general sources: members of the Organization of Petroleum Exporting Countries (OPEC), such as Saudi Arabia, Venezuela, Indonesia; and non-OPEC nations, such as Mexico, Canada, the United Kingdom.

Because of decreasing production in the U.S. and other non-OPEC nations it is likely that this Nation will become significantly more dependent on imports from the oil-rich Persian Gulf OPEC nations no later than the mid-1990's. If so, oil prices will also increase as supply competition decreases, and the Persian Gulf OPEC nations regain market leverage and control of the international oil market.

As imports have increased, the U.S. has become vulnerable to the actions of oil-exporting countries and has essentially become a price taker in the international oil market. The cost of imported oil to the U.S. economy is not only the price paid for the oil but also the losses caused by a disruption in supply, should one occur. Because domestic production substitutes for oil imports, the Nation benefits not only from the savings that result when the costs of producing additional domestic oil are less than the world price, but also benefits from the reduction in the economy's vulnerability to supply disruptions. The potential contribution of the 1002 area's oil resources should be gauged as a displacement of potentially costly and insecure imported oil by less costly, more secure production from domestic fields. The costs of a price change or a supply disruption will be less if the economy relies more on less expensive domestic supplies than on imported oil. U.S. oil reserve and production trends suggest a shift toward greater vulnerability, possibly exacerbated by the declines of 1985-86. Thus, the 1002 area's oil may be able to significantly reduce the economy's vulnerability to world oil market changes.

### ENHANCING NATIONAL SECURITY

Continued dependence on imports for a substantial part of U.S. oil consumption creates many national security concerns. The potential for a supply disruption limits the flexibility of U.S. foreign/national security policy, including the ability to respond to security threats. There is also potential for the U.S. to be drawn into dangerous political and military situations involving import nations. Dependence on oil imports entails dependence on extended supply lines (tanker routes), which are targets for attack; this adds to the defense burden. Key weapons systems in the Nation's current arsenal and under development are designed to use hydrocarbon fuel. The most secure sources of supply for such fuel are clearly domestic sources.

Secure oil supply lines can have a direct bearing on the achievement of national economic goals that depend on uninterrupted economic activity. Interruption of these supply lines, on the other hand, disrupts the production and consumption of goods and reduces economic activity. This occurred, for example, in the aftermath of the OPEC oil embargo in 1973 when a recession resulted.

### ACHIEVING A MORE FAVORABLE BALANCE OF INTERNATIONAL TRADE

The deficit in the U.S. international trade balance has increased significantly in the last decade. In 1984, it totaled a record $123 billion. In that same year, the gross cost of importing crude oil and refined petroleum products amounted to more than $59 billion, almost 50 percent of the deficit. If oil imports increase as projected, achieving a favorable trade balance will be even more difficult. The deficit trade balance in recent years has meant that more U.S. dollars are spent on foreign goods, leaving fewer dollars available to consumers and businesses for buying U.S. goods and services. Production from the 1002 area reduces not only the need for imported oil but also the amount of foreign exchange required to pay for imports, bringing a more favorable trade balance. Using the mean estimate of the 1002 area's anticipated production amounts, oil from the 1002 area could result in U.S. dollar savings spent on imports of $1.7 billion in the year 2000, $8.1 billion in 2005, and $5.8 billion in 2010.

PROVIDING ECONOMIC BENEFITS TO THE NATION

The importance of oil in the economy is widely recognized. In 1985, 42 percent of the energy used in the U.S. came from oil, of which approximately 9 MBO/Y was produced domestically and 6.8 MBO/Y was imported.

The cost of a resource that is so widely consumed in our economic system has a strong effect on economic productivity. The higher the cost of oil, the more other resources (labor, materials, energy) must be used or given up in acquiring it. As a result, these other resources are no longer available in the economy to help produce the income and the goods and services that support the American standard of living. Thus, the higher the cost of the oil used, the lower the productivity of the U.S. economy. The national need for oil is a need for the economic productivity and the gains in income that result when lower-cost oil is used to produce goods and services.

If oil can be produced from the 1002 area at a cost lower than the revenues generated from its sale, it will result in a net increase in national income and the Nation will realize a net economic benefit. The "net national economic benefit" (NNEB) is the expected net value of oil production, or the difference between revenues from sale of oil and the costs of exploration, development, production, and transportation. The NNEB includes economic benefits expected to accrue as bonuses, royalties, rental fees, taxes, and after-tax business profits. The NNEB expected from the mean potential oil production of 3.2 BBO from the 1002 area for full leasing is $79.4 billion in undiscounted 1984 dollars, and $14.6 billion discounted (10 percent real) dollars. Assuming production from a 9.2-billion-barrel field, a more optimistic economic assumption, and oil prices of $40 per barrel, the undiscounted NNEB would exceed $325 billion (1984 dollars). Potential oil production from limited leasing would contribute $54.0 billion undiscounted, and $9.4 billion discounted. (The discounted value was derived by using a discounted cash flow simulation model, in which annual revenues and annual costs for projected years of production are discounted to the present.)

PROVIDING FEDERAL, STATE, AND LOCAL REVENUES

Lease production from the 1002 area could be expected to generate revenues to the public as lease bonus payments and rentals, royalties, Federal corporate income taxes, severance tax payments to the State of Alaska, and State corporate income taxes. The revenues expected from providing this return to the public are shown in table VII-4 for the full leasing and limited leasing alternatives. Federal revenues include royalties, lease rental payments, and corporate income taxes. State and local revenues include property, severance, conservation, and corporate income taxes. Transfer payments from the Federal Government are not included, and the figures do not include Federal revenue sharing.

**Table VII-4.**—Estimated revenues, in billions of dollars, from full leasing and limited leasing.

[Bonuses, royalties, and lease rental payments are shown as Federal revenues. Portions of some of the seismically mapped structures lie outside the 1002 area. If these non-Federal subsurface areas are leased by others (for example, the State of Alaska or Native Corporations), portions of bonus, rent, and royalty income shown here as Federal revenue would accrue to those organizations]

| | Full leasing | Limited leasing |
|---|---|---|
| Federal revenues: | | |
| Undiscounted 1984 dollars.. | $ 38.9 | $ 25.9 |
| Discounted dollars (10% real)........................... | 8.0 | 5.1 |
| State and local revenues: | | |
| Undiscounted 1984 dollars.. | 16.1 | 11.0 |
| Discounted dollars (10% real)........................... | 3.6 | 2.4 |

CONTINUED USE OF THE TRANS-ALASKA PIPELINE SYSTEM

The Trans-Alaska Pipeline System (TAPS) is already in place and has been assumed as available to transport oil from the 1002 area. Oil from the 1002 area could play an important role in helping to offset the production declines slated for the Alaska North Slope, thereby reducing the per barrel transportation costs for oil from existing fields. Inclusion of the 1002 area's oil is, therefore, likely to prolong the useful life of TAPS and to permit additional production from North Slope fields which would otherwise be uneconomical.

## THE 1002 AREA'S OIL POTENTIAL COMPARED TO U.S. PROVED OIL RESERVES

Table VII-5 compares the 1002 area's estimated conditional economically recoverable oil resource to U.S. proved reserves. DOE's Energy Information Administration has estimated total U.S. proved oil reserves to be 28.446 BBO as of January 1, 1985. The 1002 area's oil potential equals 11.7 percent of this. The DOE National Energy Policy Plan (NEPP) has estimated that U.S. proved reserves will be only 11.602 BBO in the year 2000, thus making the 1002 area's oil resources 28.8 percent of the total. For limited leasing, the 1002 area's estimated recoverable resource would equal 8.4 percent of proved U.S. reserves in 1985, and 20.6 percent in the year 2000. These comparisons should be used with caution, however, because of differences in the items being compared. "Proved reserves" are those that have been demonstrated with reasonable certainty to be recoverable from known reserves. The 1002 area's economically "recoverable resources," on the other hand, are, by definition, speculative and less precise. The 1985 reserves figure is based on current oil prices at the time of the estimates. The recoverable resources figure for the year 2000 is based on DOE's NEPP reference case assumptions regarding world oil prices.

**Table VII-5.**—The 1002 area's conditional, economically recoverable oil resources compared with total U.S. proved oil reserves.

[In billions of barrels. Year 1985 data from Department of Energy (1985, p.5); year 2000 data, for lower 48 States only, from Department of Energy (1985e, table 3-15]

| | Year | |
|---|---|---|
| | 1985 | 2000 |
| U.S. proved reserves | 28.5 | 11.60 |
| 1002 area's recoverable resources: | | |
| Full leasing | 3.23 | 3.23 |
| Percent of U.S. total | 11.35 | 27.80 |
| Limited leasing | 2.36 | 2.36 |
| Percent of U.S. total | 8.30 | 20.34 |

## ANTICIPATED MARKETS FOR THE 1002 AREA'S OIL

Assuming that potential oil production from the 1002 area is similar in quality to current North Slope production, the marketing location for the 1002 area's oil could be expected to follow similar marketing patterns. Crude oil markets are already established for production from the Alaskan North Slope (ANS), and this system could probably be used for oil from the 1002 area. Oil produced from Prudhoe Bay and Kuparuk is transported via TAPS to Valdez and from Valdez by tankers to ports on the West, Gulf, and East coasts. The Trans-Panama Pipeline at the Panama Canal is used extensively to transport crude oil from the Pacific Ocean to the Atlantic. Crude oil is off-loaded on the Pacific side and loaded onto tankers on the Atlantic side for shipment to Gulf of Mexico, East Coast ports, Puerto Rico, and the Virgin Islands.

Significant discoveries have been made in California's OCS areas in the Santa Barbara Channel and Santa Maria Basin, and elsewhere. This potential production could effectively back-out a portion of the future ANS production that would otherwise be marketed on the West Coast. However, production from known ANS fields is projected to begin declining in 1987 and fall to approximately 29 percent of 1984 production by the year 2000 (Alaska Department of Revenue, Petroleum Revenue Division, 1985). At the same time, crude oil production from any discoveries in the 1002 area is not projected to be on-line until the late 1990's or after the year 2000. Therefore, the market opportunities for the 1002 area's oil could conceivably be available in roughly the same proportions as current ANS markets.

Because of the statutory ban on export of U.S. oil, the West Coast market is well established as the primary area for ANS crude oil; this is logical if viewed solely on the basis of transportation cost. Shipments to the West Coast increased to a peak of 0.9 MBO/D in 1980. Over the period 1980-84, an average 52 percent of ANS crude oil was marketed on the West Coast. Alaskan crude oil in excess of West Coast demand is transported to the Panama Canal for shipment to other markets.

## CONCLUSION

In summary, the 1002 area has a very significant potential to contribute to the national need for oil. Despite the degree of uncertainty, there is some chance that the area may contain a field the size of Prudhoe Bay. There is an even better chance of one or more smaller fields, still supergiants, totaling more than 3 billion barrels. Only actual exploration can provide the information needed to determine the extent and distribution of the resources, and, therefore, the potential benefit to the economy.

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# CHAPTER VIII

# SECRETARY'S RECOMMENDATION

The Arctic National Wildlife Refuge, comprising more than 19 million acres, is unique and one of the largest units of the National Wildlife Refuge System. The coastal plain portion of the refuge contains a variety of habitats that support fish and wildlife species such as muskoxen, snow geese, arctic char, and caribou of both Central Arctic and Porcupine herds. At the same time, the 1.5-million-acre 1002 area of the coastal plain has been predicted to contain as much as 29 billion barrels of oil and 64 trillion cubic feet of gas, making it the most outstanding oil and gas frontier area in North America.

Because of the enormous hydrocarbon potential of the 1002 area and its potential contribution to the vital need for domestic sources of oil and gas, the Department of the Interior recommends that the Congress enact legislation making the entire 1002 area of the Arctic Refuge available for oil and gas leasing, and authorize the Secretary of the Interior to impose necessary and appropriate measures to protect refuge resources and values and ensure coordinated and efficient oil and gas activities. Despite its remote location and hostile environment, the 1002 area is the most attractive onshore petroleum exploration target in the United States today. Development of its potential oil and gas resources could make a significant contribution to the economy and security of this Nation, and could be done in an environmentally responsible manner based on lessons learned at Prudhoe Bay, on the 1002 area, at the KIC/ASRC exploratory well, and elsewhere.

Leasing the 1002 area of the Arctic Refuge coastal plain would provide industry the opportunity to explore for and develop what is believed to be the last onshore area of significant oil and gas potential in the United States. The geology of the 1002 area indicates the potential for a very substantial contribution to domestic oil reserves. Data from nearby wells in the Prudhoe Bay area of Alaska and in the Canadian Beaufort Sea and Mackenzie delta, combined with the promising seismic data gathered on the 1002 area, indicate extensions of producing trends and other geologic conditions extremely favorable for discovery of one or more giant (reserves exceeding 100 million barrels) or supergiant (reserves exceeding 500 million barrels) oil fields in the 1002 area.

Alaska North Slope crude oil, particularly from Prudhoe Bay, now contributes almost 20 percent of domestic production. But contributions from Prudhoe Bay have peaked and a decline is expected no later than 1988. It has been estimated that shrinking American oil reserves will plunge by 1990 to their lowest levels since shortly after World War II, based on current drilling rates. The decline predicted from the 1985 reserve figure of 28.4 billion barrels of oil (BBO) is down to 25.1 BBO in 1990, and perhaps to as low as 23.2 BBO in 1995. Most significant declines in reserves will occur in the older, traditional oil-producing areas of the western United States, Texas, the Gulf Coast, and the Midcontinent. The onshore basins in the U.S. with the greatest potential for giant fields have already been explored, with the exception of the 1002 area. On the 1002 area and other frontier regions in Alaska and offshore, prospects are better for substantial reserve additions.

The U.S. oil demand predicted by the Department of Energy for the year 2005 is 16.5 million barrels per day. The Department of Energy further predicts that the U.S. will need to import 7.6 million barrels of foreign oil per day by the year 2005. Since the 1960's, the U.S. domestic oil production has not been adequate to fully supply the economy's need for competitively priced oil production, and this Nation's increasing demand for petroleum and petroleum-based products continues to surpass our ability to meet the demand domestically. As imports have increased, the Nation has become vulnerable to the actions of oil-exporting countries and cartels such as OPEC. Production of oil from the 1002 area could reduce this foreign dependence by almost 9 percent in the year 2005.

In addition to reducing the dependence on foreign oil, contributions from the 1002 area would enhance the national security of the country, produce a more favorable balance of trade by saving $8.1 billion in the year 2005 on the cost of imported oil, and provide overall enhanced economic benefits to the Nation. The contribution made by oil from the 1002 area could be expected to span over 30 years from the start of production. Based on the mean recoverable value of 3.2 billion barrels, production of oil from the 1002 area in the year 2005 could account for almost 4 percent of the daily U.S. oil demand and nearly 8 percent of the daily U.S. production. The net national economic benefits expected to accrue from oil production on the 1002 area could approximate $14.6 billion (present discounted value). The Federal leasing revenues from a program on the 1002 area are expected to total $8.0 billion (present discounted value). The State of Alaska would receive a share of that Federal revenue, and also it could receive an estimated $3.6 billion in tax payments related to leasing.

While our domestic oil supply picture has grown darker, the production of oil from North America's largest oil field at Prudhoe Bay has taught us much about how to protect environmental values. Even though the billions of barrels of oil reserves have been brought on line and the infrastructure developed to bring that oil oil to U.S. markets, the fish and wildlife resources of the Prudhoe Bay area remain extremely healthy. The Central Arctic caribou herd has increased substantially during the period that development has occurred within the heart of its range.

Estimated at about 3,000 animals in 1972, the herd now numbers more than 13,000. Similarly, important waterfowl species continue to successfully nest and rear their broods within the developed area. Although circumstances within the 1002 area may be somewhat different, the evidence derived from the Prudhoe Bay experience leads one to be quite optimistic about the ability to explore for and develop the hydrocarbon potential of the 1002 area without significant deleterious effects on the unit's wildlife resources.

Clearly, an area of such high natural resource value should be afforded special protection and steps must be taken to conserve the fish and wildlife and their habitats on the 1002 area. Therefore, the Department recommends that the Congress enact specific legislation that will provide the Department of the Interior with sufficient authority to control the development of oil and gas resources in the 1002 area by imposing appropriate mitigation measures. Those aspects of the opening legislation dealing with the elements of the leasing program itself should be patterned after the act authorizing leasing of the National Petroleum Reserve-Alaska, and should address other appropriate matters such as unitization, drainage, and suspension, as well as incorporate the Mineral Leasing Act of 1920 to the extent that it would not be inconsistent with this special legislation. Provisions should include the authority to issue regulations that ensure environmental integrity in all oil and gas operations in the area. This special legislation should grant the Secretary of the Interior maximum authority to structure a leasing program that permits the exploration, development, and production of these oil and gas resources in a manner that results in no unnecessary adverse effects on the refuge's fish and wildlife and their habitats and avoids unnecessary duplication of oil and gas activities. Further, such a program must ensure that any unavoidable habitat losses are fully compensated.

Because the area has not been fully explored by using exploratory drilling, it cannot be precisely determined where or how much development is likely to occur in the 1002 area. To assess anticipated impacts, the Fish and Wildlife Service (FWS) biologists based their analysis on development scenarios using the mean estimated recoverable resource figures for prospects in the 1002 area considered economical under the most likely scenario. If the entire 1002 area were leased and subsequently developed, the assessment predicts that there may be some long-term, widespread effects on the area's water resources, the Porcupine caribou herd (PCH), muskoxen, and the wilderness values of the area, for at least as long as oil and gas development activities influence the area. Overall, however, most adverse environmental effects would be minimized or eliminated through mitigation based on the vast amount of information and technology acquired during the development of the Prudhoe Bay area and from construction and operation of the 800-mile Trans-Alaska Pipeline. Development would proceed with the goal of no net loss of habitat quality, and unnecessary adverse effects would not be allowed to occur.

Therefore, if the Congress authorizes leasing of the 1002 area, the program would be designed by the Department to permit leasing first what the Department considers the more prospective areas. In this way, additional exploration, including off-structure test wells and delineation drilling, could get underway to determine the location and size of any oil and gas reserves on the coastal plain. Although preliminary data indicate excellent oil and gas potential in the southeastern corner of the 1002 area, leasing would be phased so the "core calving" area of the PCH would be last to be explored or developed. This phased leasing would allow time to study the effects of oil and gas development and transportation on other parts of the 1002 area, and to evaluate the types and degree of impacts on snow geese that stage in the core calving area and on the PCH. These studies would be used to develop any additional mitigation measures necessary to avoid or reduce impacts, and to determine compensation required in the event of significant unavoidable losses of habitat quality.

Authority for administering the leasing program should be vested in the Department, to be exercised through the FWS and Bureau of Land Management (BLM). As the agency with direct jurisdiction over these lands, the FWS must be delegated primary responsibility for overseeing all aspects of oil and gas exploration, development, and production within Arctic Refuge boundaries that could affect surface resources and values. BLM would use its expertise in mineral leasing and development to assist FWS in administering the leasing program. Competitive lease sales would be held in accordance with a timetable established by BLM, after consultation with FWS regarding environmental considerations. Development of the leases must be designed to avoid or minimize disturbance to wildlife and other surface resources; produce oil and gas in the most orderly, efficient, and economical manner; and maximize the contribution of the 1002 area's oil and gas production to the national need for additional domestic sources of energy.

In accordance with the August 9, 1983, agreement between Arctic Slope Regional Corporation (ASRC) and the Department, "no leasing or other development leading to production of oil and gas from ASRC lands shall be undertaken until Congress authorizes such activities on Refuge lands within the coastal plain or on ASRC lands, or both." Adoption of this recommendation by the Congress, even without specific reference to the ASRC lands, would open those lands to the production of oil and gas.

## CONSULTATION AND COORDINATION

The following agencies, organizations, or individuals have received for review and comment copies of this Draft Arctic National Wildlife Refuge, Alaska, Coastal Plain Resource Assessment.

### Members of the Congress

Senator Frank H. Murkowski
Senator Ted Stevens
Representative Donald E. Young

### Federal Agencies

Advisory Council on Historic Preservation
Alaska Land Use Council
Department of Agriculture
- Cooperative Extension Service
- Forest Service
- Soil Conservation Service

Department of Commerce
- National Marine Fisheries Service
- National Oceanic and Atmospheric Administration
- U.S. Weather Service

Department of Defense
- Alaska Air Command
- Department of Military Affairs
- Naval Arctic Research Laboratory
- U.S. Army, Corps of Engineers
- U.S. Army, Cold Regions Research and Engineering Laboratory

Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior
- Alaska Outer Continental Shelf Office
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Fish and Wildlife Service
- Geological Survey
- Minerals Management Service
- National Park Service
- Office of the Federal Inspector
- Office of the Solicitor

Department of Transportation
- Federal Aviation Administration
- U.S. Coast Guard
- U.S. Coast Guard Marine Safety

Environmental Protection Agency
Federal Information Center

### Alaska State Agencies

Office of the Governor (Clearinghouse)
- Alaska Oil and Gas Conservation Commission
- Alaska State Geological Survey
- Alaska State Historic Preservation Office
- Attorney General for the State of Alaska
- Department of Commerce and Economic Development
- Department of Community and Regional Affairs
- Department of Environmental Conservation
- Department of Fish and Game
- Department of Health and Social Services
- Department of Natural Resources
- Department of Policy Development and Planning
- Department of Transportation and Public Facilities

### Alaska Communities

Beaver Village Council
Birch Creek Village Council
Chalkyitsik Village Council
City of Anaktuvuk Pass
City of Arctic Village
City of Barrow
City of Fairbanks
Fairbanks North Star Borough
Kenai Chamber of Commerce
Municipality of Anchorage
Native Village of Eagle
Native Village of Fort Yukon
Native Village of Venetie
North Slope Borough
Rampart Village Council
Stevens Village Council
Venetie Village Council

### Alaska Native Groups

Alaska Federation of Natives
Aleut Corporation
Arctic Slope Regional Corporation
Bering Straits Native Corporation
Bristol Bay Native Corporation
Calista Corporation
Chugach Natives, Incorporated
Cook Inlet Region, Incorporated
Doyon Limited
Koniag, Incorporated
NANA Regional Corporation
Sealaska Corporation
The 13th Regional Corporation

## Environmental Groups

Alaska Center for the Environment
Alaska Conservation Society
Alaska Wilderness Council
Anchorage Audubon Society
Arctic Coastal Zone Manager
Centre for Northern Studies
Defenders of Wildlife
Ducks Unlimited
Environmental Defense Program
Friends of the Earth
Greenpeace
International Association of Fish and Wildlife
International North Pacific Fish Commission
Intersea Research Corporation
Isaac Walton League
Kachemak Bay Conservation Society
Kenai Conservation Society
National Academy of Sciences
National Audubon Society
National Rifle Association
National Wildlife Federation
National Wildlife Refuge Association
Nature Conservancy
North Pacific Fisheries
Pacific Seabird Group
Sierra Club
Southeast Regional Resource Center
Steering Council for Alaska Lands
The Real Alaska Coalition
The Wilderness Society
Trustees for Alaska
Wildlife Management Institute

## Industry

Alaska Oil and Gas Association
American Petroleum Institute
AMOCO Production Company
ARCO
Chevron USA, Inc.
Cities Service Company
CONOCO
Dames and Moore
Drilling Services, Inc.
Esca Tech Corporation
Exxon Company, USA
Geodata Corporation
Geodigit
Geo. Co. of Northway, Inc.
Geophysical Corporation of Alaska
Geophysical Service, Inc.
IMCO Services
International Association of Geophysical Contractors
Marathon Oil Company
Mobil Oil Corporation
Nissho-Iwai American Corporation
N.L. Baroid Petroleum
Northern Technical Services
Ocean Technology, Limited
Oil Patch of Alaska, Incorporated
Petty Ray Geophysical, Inc.
Phillips Petroleum
Placid Oil Company
Shell Oil Company
Sohio BP Alaska
Standard Oil of California
TAM Engineers
Tesoro Alaska Petroleum Corp.
Tetra Tech., Incorporated
Texaco, Incorporated
Union Oil Company
Variance Corporation
Western Geophysical Company
Woodward-Clyde Consultants
Alaska Oil and Gas Association
Anchorage Chamber of Commerce
Fairbanks Chamber of Commerce
Resource Development Council of Alaska
U.S. Chamber of Commerce

## News Media

Alaska Journal of Commerce
Alaska Magazine
Alaska Radio Network
Alaska Report
Alaska Review
All-Alaska Weekly
Anchorage Daily News
Anchorage Times
Associated Press
Cheechako News
Christian Science Monitor
Cook Inlet Chronicles
District Media Resource Center
Fairbanks Daily News Miner
Juneau SE Empire
New York Times
Nome Nugget
Northwest Arctic School District
Oil and Gas Journal
Outdoor Writers Association
Peninsula Clarion
Petroleum Engineer International
Tundra Times
USA Today
Wall Street Journal
Washington Post

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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