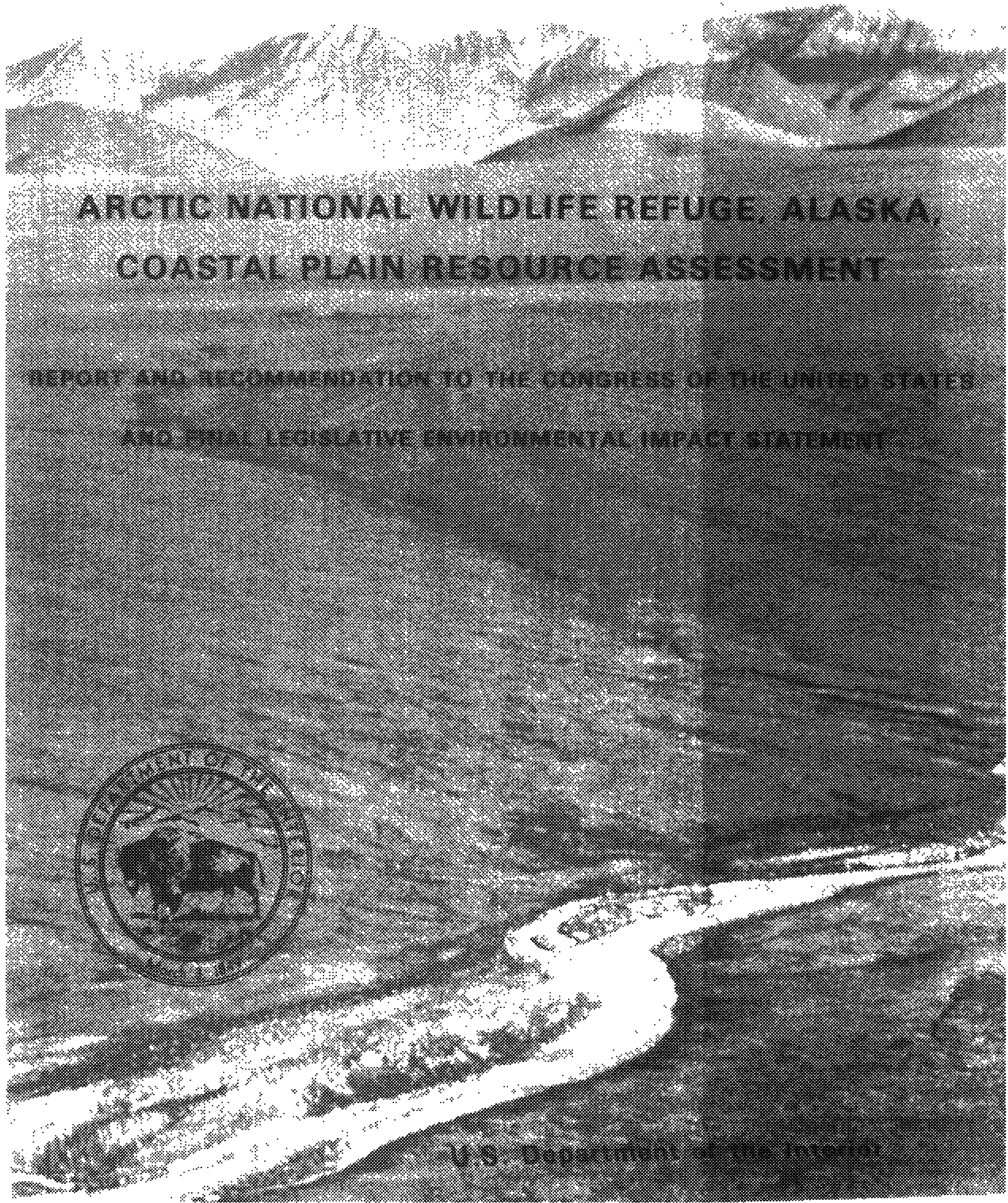
ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

REPORT AND RECOMMENDATION TO THE CONGRESS OF THE UNITED STATES

AND FINAL LEGISLATIVE ENVIRONMENTAL IMPACT STATEMENT



U.S. Department of the Interior

UNITED STATES

DEPARTMENT OF THE INTERIOR

ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

REPORT AND RECOMMENDATION TO THE CONGRESS OF THE UNITED STATES AND FINAL LEGISLATIVE ENVIRONMENTAL IMPACT STATEMENT

APRIL 1987

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 U.S. Geological Survey
and the Bureau of Land Management

ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

Report and recommendation to the Congress of the United States and final legislative environmental impact statement, 1987

Volume 1--Report
Volume 2--Appendix (Public comments and responses)

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Recommended citation for this report:

Clough, N. K.; Patton, P. C.; and Christiansen, A. C., editors, 1987, Arctic National Wildlife Refuge, Alaska, coastal plain resource assessment--Report and recommendation to the Congress of the United States and final legislative environmental impact statement: Washington, D. C., U.S. Fish and Wildlife Service, U.S. Geological Survey, and Bureau of Land Management, v. 1 (Report)--xviii + 208 p., 5 pls., 32 figs., 26 tables; v. 2 (Appendix--Public comments and responses)--ii + 998 p.

COVER PHOTOGRAPH

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

THE SECRETARY OF THE INTERIOR

WASHINGTON

April 21, 1987

Dear Reader:

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 set aside more than 100 million acres of land in Alaska as national parks, preserves, wildlife refuges, and wilderness areas. At that time, the Congress specifically left open the question of future management of the 1.5-million-acre coastal plain of the 19-million-acre Arctic National Wildlife Refuge because of the area's potentially enormous oil and gas resources and its important wildlife values.

ANILCA directed the Department of the Interior to conduct biological and geological studies of the Arctic Refuge coastal plain, and to provide the Congress with the results of those studies and a recommendation on future management of the area. The following report culminates more than 5 years of biological baseline studies, surface geological studies, and two seasons of seismic exploration surveys. The Arctic Refuge coastal plain is rated by geologists as the most promising onshore oil and gas exploration area in the United States. It is estimated to contain more than 9 billion barrels of recoverable oil, an amount approximately equal to Prudhoe Bay, which currently provides one-fifth of U.S. domestic oil production.

In 1986, U.S. domestic oil production dropped 9 to 10 percent; production is predicted to drop an additional 4 to 5 percent in 1987, if prices do not drop this year. At the same time, U.S. oil consumption, which has exceeded domestic production since the 1960's, is expected to increase. Our oil imports are projected to exceed 50 percent of consumption in the 1990's. America's growing reliance on imported oil for the rest of the century could have potentially serious ramifications for our national security.

The following report analyzes the potential environmental consequences of five management alternatives for the coastal plain, ranging from opening for lease of the entire area for oil and gas development, to wilderness designation. A legislative environmental impact statement has been integrated into the report.

Public hearings were held in January 1987 on a draft report and recommendation. These hearings were attended by representatives of the Governments of Canada and Alaska, Alaska Natives, other interested parties, and the general public. Seven thousand of the 11,000 comments received favored opening the Arctic Refuge coastal plain for oil and gas leasing and development.

Based on the analyses conducted, public comment on the draft report, the national need for domestic sources of oil and gas, and the Nation's ability to develop such resources in an environmentally sensitive manner as demonstrated by two decades of success at Prudhoe Bay and elsewhere, I have selected as my preferred alternative, making available for consideration the entire Arctic Refuge coastal plain for oil and gas leasing. Although the entire area should be considered for leasing, only a percentage would actually be leased, an even smaller percentage would be explored, and--if oil is discovered--a still smaller percentage would be developed.

The step-by-step environmental planning, review, and evaluation procedures included in a leasing program provide the best opportunity for the Department to decide what areas to lease, based on the most accurate and advanced information available at each step of the leasing process. Although the exact process depends upon the leasing program established by the Congress, compliance with the National Environmental Policy Act is required for each lease sale, exploration plan, and development and production plan.

The following report provides information critical for the Congress to consider in determining the future management of the Arctic Refuge coastal plain. The Congress must enact legislation to authorize an oil and gas leasing program for the area. We will work with the Congress to ensure that any leasing program developed will avoid unnecessary adverse effects on the environment.

Legislative proposals are currently in the Congress to establish the formula for sharing with the State of Alaska any revenues from an oil and gas leasing program in the Arctic Refuge coastal plain. There also is a proposal that would direct a portion of the Federal share of such revenues to conservation activities. We look forward to working with the Congress on such matters as well as in determining future management of the Arctic Refuge coastal plain. My preliminary recommendation (Chapter VIII) will become final upon formal transmittal to the Congress of the following report.

Sincerely,

Donald Paul Hodel

DONALD PAUL HODEL

SUMMARY

ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT
Report and Recommendation to the Congress/Final Legislative Environmental Impact Statement
APRIL 1987

Prepared by the U.S. Fish and Wildlife Service, in cooperation with the U.S. Geological Survey and the Bureau of Land Management, Department of the Interior, Washington, D.C. 20240.

TYPE OF ACTION

Recommendation for legislative action concerning future management of the 1.5-million-acre coastal plain of the 19-million-acre Arctic National Wildlife Refuge (referred to herein as the "1002 area"), located in northeastern Alaska.

DESCRIPTION OF THE PROPOSED ACTION

The Secretary of the Interior recommends to the Congress of the United States that it enact legislation directing the Secretary to conduct an orderly oil and gas leasing program for the 1002 area at such pace and in such circumstances as he determines will avoid unnecessary adverse effect on the environment.

The 1002 area is the Nation's best single opportunity to increase significantly domestic oil production. It is rated by geologists as the most outstanding petroleum exploration target in the onshore United States. Data from nearby wells in the Prudhoe Bay area and in the Canadian Beaufort Sea and Mackenzie Delta, combined with promising seismic data gathered on the 1002 area, indicate extensions of producing trends and other geologic conditions exceptionally favorable for discovery of one or more supergiant fields (larger than 500 million barrels).

There is a 19-percent chance that economically recoverable oil occurs on the 1002 area. The average of all estimates of conditional economically recoverable oil resources (the "mean") is 3.2 billion barrels. Based on this estimate, 1002 area production by the year 2005 could provide 4 percent of total U.S. demand; provide 8 percent of U.S. production (about 660,000 barrels/day); and reduce imports by nearly 9 percent. This production could provide net national economic benefits of $79.4 billion, including Federal revenues of $38.0 billion.

ENVIRONMENTAL EFFECTS

Potential impacts were assessed for exploration, development drilling, and production. Impacts predicted for exploration and development drilling were minor or negligible on all wildlife resources on the 1002 area. Production of oil is expected to directly affect only 12,650 acres or 0.8 percent of the 1002 area. Consequences on species such as brown bears, snow geese, wolves, moose, and the Central Arctic caribou herd are expected to be negligible, minor, or moderate.

Potential major effects on wildlife from production are limited to the Porcupine caribou herd and reintroduced muskoxen. "Major biological effects" were defined as: "widespread, long-term change in habitat availability or quality which would likely modify natural abundance or distribution of species. Modification will persist at least as long as modifying influences exist."

The Porcupine caribou herd has shown some preference for calving on the 1002 area including the upper Jago River area (84,000 acres or 5.4 percent of the 1002 area). A potential consequence would be displacement of portions of the herd seeking to calve in the upper Jago River area–the case only if the area were the site of a major producing oil field. It is unlikely, though possible, that such displacement would result in any appreciable decline in herd size.

The potential effects of oil and gas activities on the area's muskoxen are unknown, although biologists predict that major effects could be: (1) substantial displacement from currently used habitat and (2) a slowing of the herd's growth rate, as distinguished from a diminution in herd size.

Potential effects on Native subsistence fall into two categories: the village of Kaktovik and villages outside the 1002 area. In the case of Kaktovik, a major restriction of subsistence activities could occur. This would likely result from the physical changes proximate to Kaktovik which could interfere with traditional activities. Subsistence effects on villages outside the 1002 area, including those in Canada, are expected to be minimal.

ALTERNATIVES TO THE PROPOSED ACTION

Alternatives for the Congress that were discussed in the report and legislative environmental impact statement include: (1) Authorize leasing limited to a part of the 1002 area based on environmental considerations (Alternative B); (2) authorize further exploration only, including exploratory drilling (Alternative C); (3) continue current refuge status with no further oil and gas activity allowed (Alternative D); and (4) designate the area as wilderness (Alternative E). For purposes of environmental impact statement analysis, Alternative D is considered the "no action" alternative.

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ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT
Final report and legislative environmental impact statement, 1987

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ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

CONTENTS

ILLUSTRATIONS

[Plates in pocket]

TABLES

ACRONYMS AND ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AGL	above ground level
AMRAP	Alaska Mineral Resource Assessment Program
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
AS	Alaska Statute
ASRC	Arctic Slope Regional Corporation
BBO	billion barrels of oil
BLM	Bureau of Land Management
CAH	Central Arctic caribou herd
CCP	Comprehensive conservation plan
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
COST	Continental Offshore Stratigraphic Test
CPF	central production facility
DCF	discounted cash flow
DEIS	draft environmental impact statement
DEW Line	Distant Early Warning Line
DO	dissolved oxygen
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EIS	environmental impact statement
EOR	enhanced oil recovery
FASP	Fast Appraisal System for Petroleum
FEIS	final environmental impact statement
FR	Federal Register
FWS	U.S. Fish and Wildlife Service
GS	U.S. Geological Survey
ha	hectare
KIC	Kaktovik Inupiat Corporation
kg	kilogram
LEIS	legislative environmental impact statement
LNG	liquefied natural gas
MBO	million barrels of oil
MBO/D	million barrels of oil per day
MBO/Y	million barrels of oil per year
MCF	thousand cubic feet (of gas)
MEFS	minimum economic field size
MOU	memorandum of understanding
mph	miles per hour
MP_{HC}	marginal probability for hydrocarbons
NAAQS	national ambient air quality standards
NARL	Naval Arctic Research Laboratory (Barrow)
NEPA	National Environmental Policy Act of 1969
NEPP	National Energy Policy Plan
NNEB	net national economic benefit
NNSDC	Newport News Shipbuilding and Drydock Company
NOAA	National Oceanic and Atmospheric Administration
NPRA	National Petroleum Reserve in Alaska
NSB	North Slope Borough
O_3	ozone
OCS	Outer Continental Shelf
OPEC	Organization of Petroleum Exporting Countries Members: Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, Venezuela
PCH	Porcupine caribou herd
P.L.	public law
PM	particulate matter
ppm	parts per million
ppt	parts per thousand
PRESTO	Probabilistic Resource Estimates--Offshore
PSD	prevention of significant deterioration of air quality program
Stat.	Statute
TAGS	Trans-Alaska Gas System
TAPS	Trans-Alaska Pipeline System
TCFG	trillion cubic feet of gas
TIAS	Treaties and other International Acts Series
TS	Treaty Series
TSP	total suspended particulates
U.S.C.	United States Code
U.S.T.	United States Treaty
VSM	vertical support member
YPC	Yukon Pacific Corporation

ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA, COASTAL PLAIN RESOURCE ASSESSMENT

CHAPTER I

INTRODUCTION

BACKGROUND

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 including mineral leasing laws. This order culminated extensive efforts begun more than a decade earlier to preserve this unique part of Alaska.

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 today encompasses the existing 8.9-million-acre wildlife range and approximately 10 million additional acres of adjoining lands west toward the Trans-Alaska Pipeline System (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, muskoxen, 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 landscapes and habitats, because of the proximity of the Arctic coast to the mountains. Mt. Chamberlin, 9,020 feet; Mt. Isto, 8,975 feet; Mt. Hubley, 8,915 feet; and Mt. Michelson, 8,855 feet--the four tallest peaks in the Brooks Range--are in the Arctic Refuge. The Arctic Refuge contains the only extensive active glaciers in the Brooks Range. Found on the refuge is a full complement of arctic flora and fauna, including the calving grounds 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 goose, and other migratory bird species, and reintroduced muskoxen.

During the 1970's the Alaskan arctic coastal plain was the site of several studies on 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 TAPS to the west of the Range.

During the 7 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 [Arctic National Wildlife Range]. 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.

PURPOSE AND NEED FOR THIS REPORT

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

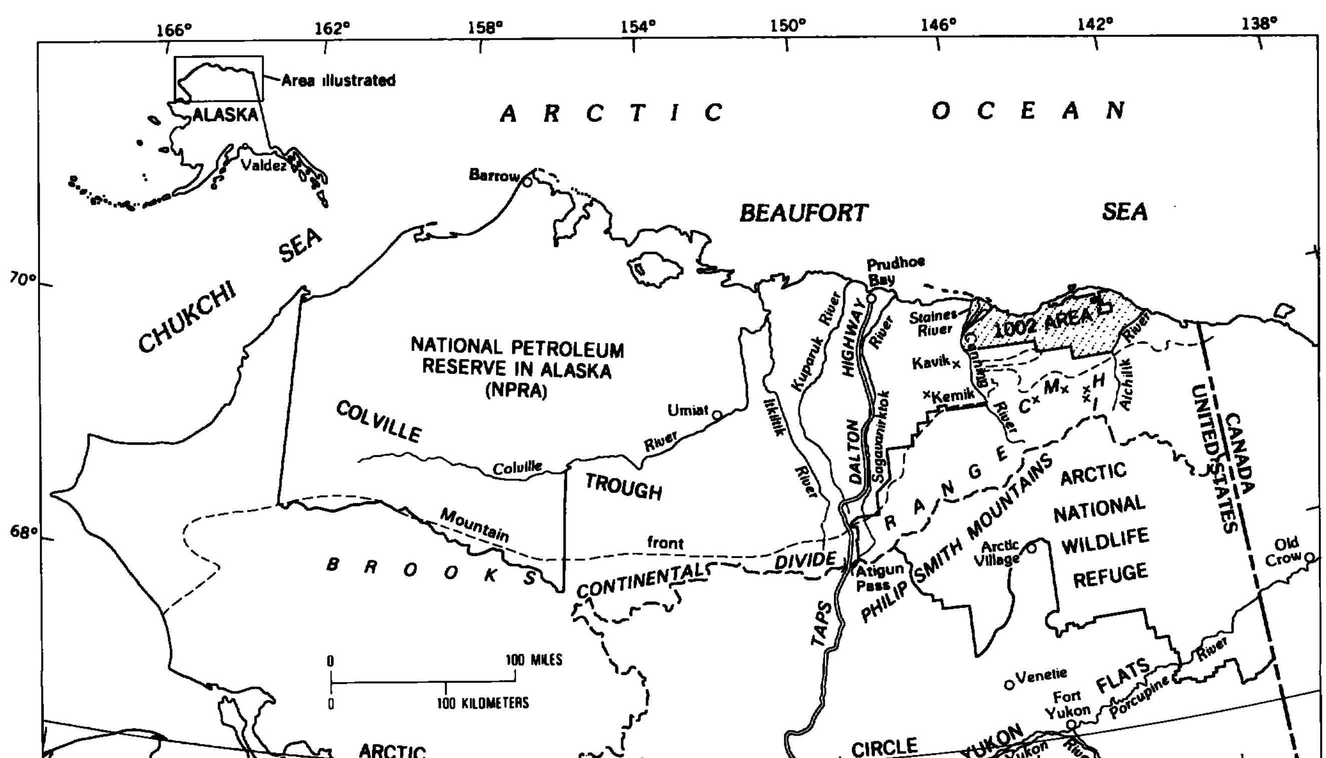

Figure I-1.—Index map of northern Alaska showing location of 1002 area in relation to the Arctic National Wildlife Refuge (Arctic Refuge), the National Petroleum Reserve in Alaska (NPRA), and Prudhoe Bay. Four highest peaks in the Brooks Range: C, Mt. Chamberlin; I, Mt. Isto; H, Mt. Hubley; M, Mt. Michelson.

3. To prepare a "Report to Congress" which describes the fish and wildlife resources of the 1002 area; identifies and estimates the volume and areal extent 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.

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 the listing of these publications.) The final baseline report was published in December 1986.

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 Fish and Wildlife Service 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 would avoid significant adverse effects on fish, wildlife, and other resources. Exploration included surface geological and geophysical work but not exploratory drilling.

The FWS published an environmental impact statement 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 (FWS and others, 1982, 1983).

~ 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 (hydrocarbon-reservoir potential). The FWS carefully monitored all activities, and no adverse effects on fish or wildlife were observed from helicopter-supported surface exploration during summer months. ~[1]

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 during the winters of 1983-1984 and 1984-1985. The seismic program provided 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 near bear dens) or where snow cover was insufficient to protect the tundra,

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[1]Symbol indicates modification of draft report. See page 6 for full explanation of symbols.

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, 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) of 1969.

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 recommendations 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 habitats, and other resources are avoided or minimized (Chapter VIII).

~ The first seven chapters of this report also constitute a legislative environmental impact statement (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 for the Congress to: (A) authorize full leasing of the entire 1002 area; (B) authorize leasing limited to a part of the 1002 area; (C) authorize further exploration, including exploratory drilling, only; (D) continue current refuge status with no further oil and gas activity allowed; and (E) designate the area as wilderness. For the purpose of EIS (environmental impact statement) analysis, alternative A is considered the "proposed action" and Alternative D is considered the "no action" or baseline alternative. ~

Estimates of conditional 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.

~ 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 further expansion of oil and gas activities in and around Prudhoe Bay. Chapter VI includes a general discussion of the potential for cumulative effects. Where information is available for a particular species, cumulative effects are added to the individual impact discussions. ~

~ Leasing and operations would be subject to all appropriate Federal and State regulations and further environmental evaluation at appropriate stages of the development. Depending on the decision of the Congress, this programmatic LEIS may suffice for initial leasing. However, exploration proposals normally require site-specific NEPA evaluations, and a development and production proposal would require a site-specific EIS. Any future EIS on development of the 1002 area would, to the extent appropriate, be tiered on this programmatic 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; Endangered Species 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. ~

~ Section 303 of ANILCA, which establishes additions to existing refuges, requires that the Arctic 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 between the United States and Great Britain (for Canada) for the Protection of Migratory Birds (39 Stat. 1702; TS 628), as amended.

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

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

5. Agreement on the Conservation of Polar Bears (TIAS 8409).

6. 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.

7. Convention on International Trade in Endangered Species of Wild Fauna and Flora (TIAS 8249).

~ PUBLIC INVOLVEMENT ~

During the early stages of preparing a preliminary draft report and detailed LEIS for departmental review, legal action was taken against the Department and the Fish and Wildlife Service by Trustees for Alaska and other environmental groups in Trustees for Alaska, et al, Civ. No. A85-551 (D. AK. Feb. 25, 1986). The plaintiffs contended that the Department's plans (that is, to circulate the report/LEIS for public comment concurrently with its submittal to Congress and to forward any comments received and the Department's responses subsequently) failed to fully comply with NEPA, and that the Department must provide an opportunity for public participation in preparation of the report/LEIS in advance of its submittal to Congress. The court ruled in favor of the plaintiffs. By court order dated February 25, 1986, the Department was directed to prepare both a draft and a final report/LEIS, and permit public review and comment on the draft report/LEIS. The court further directed that public meetings on the draft report/LEIS be held in Alaska and elsewhere and that the Department's responses to public comments be published locally before or at the time the final report/LEIS is submitted to the Congress. It was the position of the Department and the Service that a draft report/LEIS need not be circulated in advance and that a single detailed report/LEIS, as provided for in 40 CFR 1506.8(b)(2), fully complies with the requirements of NEPA.

Even though the government felt that the district court's ruling was incorrect, the Department of the Interior began the administrative process laid down by the district court because a final report/LEIS had already been delayed beyond the September 1986 deadline established by ANILCA. Subsequently, the Department unsuccessfully argued an appeal of the decision.

On November 24, 1986, the draft report/LEIS was made available for public review and comment. Originally scheduled to close January 23, 1987, the comment period was extended to February 6, 1987, at the request of the Governor of Alaska and others. Public meetings were held January 5, 1987, in Anchorage, Alaska, January 6 in Kaktovik, Alaska, and January 9 in Washington, D.C. Copies of the report/LEIS were sent to all Federal, State and local agencies with jurisdiction by law or special expertise; to the Government of Canada and the Yukon and Northwest Territories; to conservation organizations; to affected Native regional and village corporations and other organizations; and to the oil and gas industry.

During the comment period, 11,361 letters were received. The vast majority of these letters were generally a statement as to either (1) make the 1002 area available for oil and gas leasing, or (2) make the 1002 area a designated wilderness. Of those letters, 7,491 favored leasing and 3,707 favored wilderness designation. Letters were received from individuals in every State in the Union and Canada. Organizations, with such diverse positions as the Wilderness Society and the Alaska Oil and Gas Association, were responsible for 821 of the comments.

Substantive comments on the content of the report itself were received from 117 respondents. To facilitate analyses, the comments were broken down into the following categories: Federal governments, State and local governments, industry, organizations, and private individuals. Each of the 1,651 substantive comments was reviewed. General responses are contained in the "Summary of Consultation and Public Comments" section of this report and and duplicated in the appendix to this report (v. 2). The report was modified as appropriate based on comments received. Throughout the report, the symbol ~ indicates (1) passages that have been significantly modified from the draft LEIS published in November 1986 and (2) new material.

~ DEPICTION OF CIVIL BOUNDARIES ~

"Civil boundaries are the limiting lines of jurisdictional authority for the various levels of government. These boundaries are shown on topographic quadrangle [and other] maps of the Geological Survey, but they are invariably derived from another source. The Survey does not make original boundary surveys, and the boundaries shown on the maps are not intended as conclusive evidence of land ownership or jurisdictional limits. Original boundary surveys executed by the appropriate organization provide the definitive evidence for settling boundary questions. Nevertheless, the boundaries shown on Survey quadrangle maps are often regarded by the general public and local authorities as representing authoritative locations. For this reason, boundaries are delineated on these maps as carefully as possible from available source documents; but the fact remains that the source documents, not the topographic maps, have primary legal significance with respect to boundaries." From Thompson (1981, p. 73).

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CHAPTER II

EXISTING ENVIRONMENT

INTRODUCTION

The existing environment (this chapter) and subsequent analysis of environmental consequences (Chapter VI) are described in terms of three components: physical, biological, and human.

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

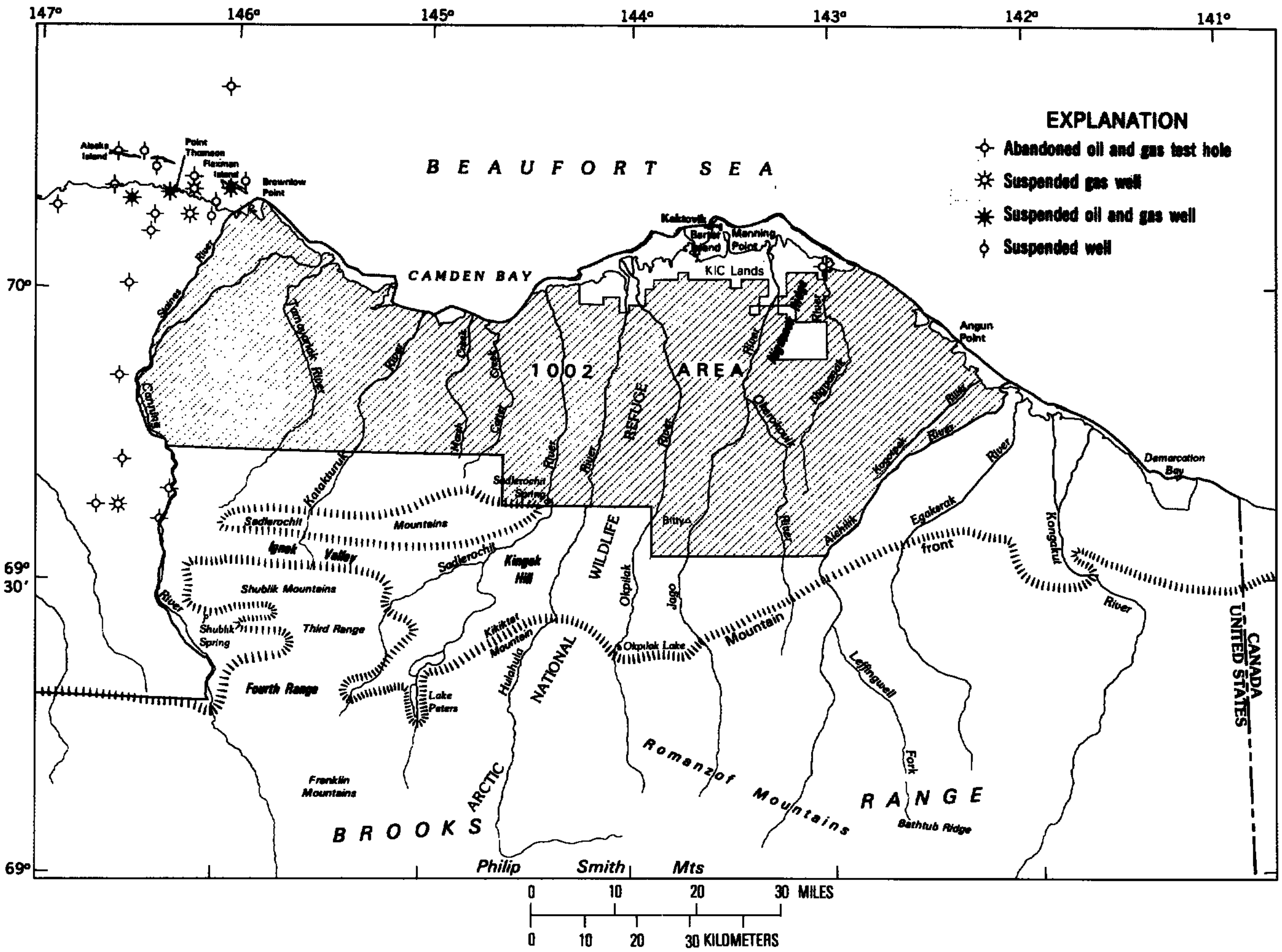


Figure II-1.—Map of northeastern Alaska showing the 1002 area and important nearby geographic features.

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 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 crop out near the middle reaches of the Katakturuk River; and oil-bearing sands and shales having an odor of oil crop out along the lower Jago River, about 10 miles south of Barter Island.

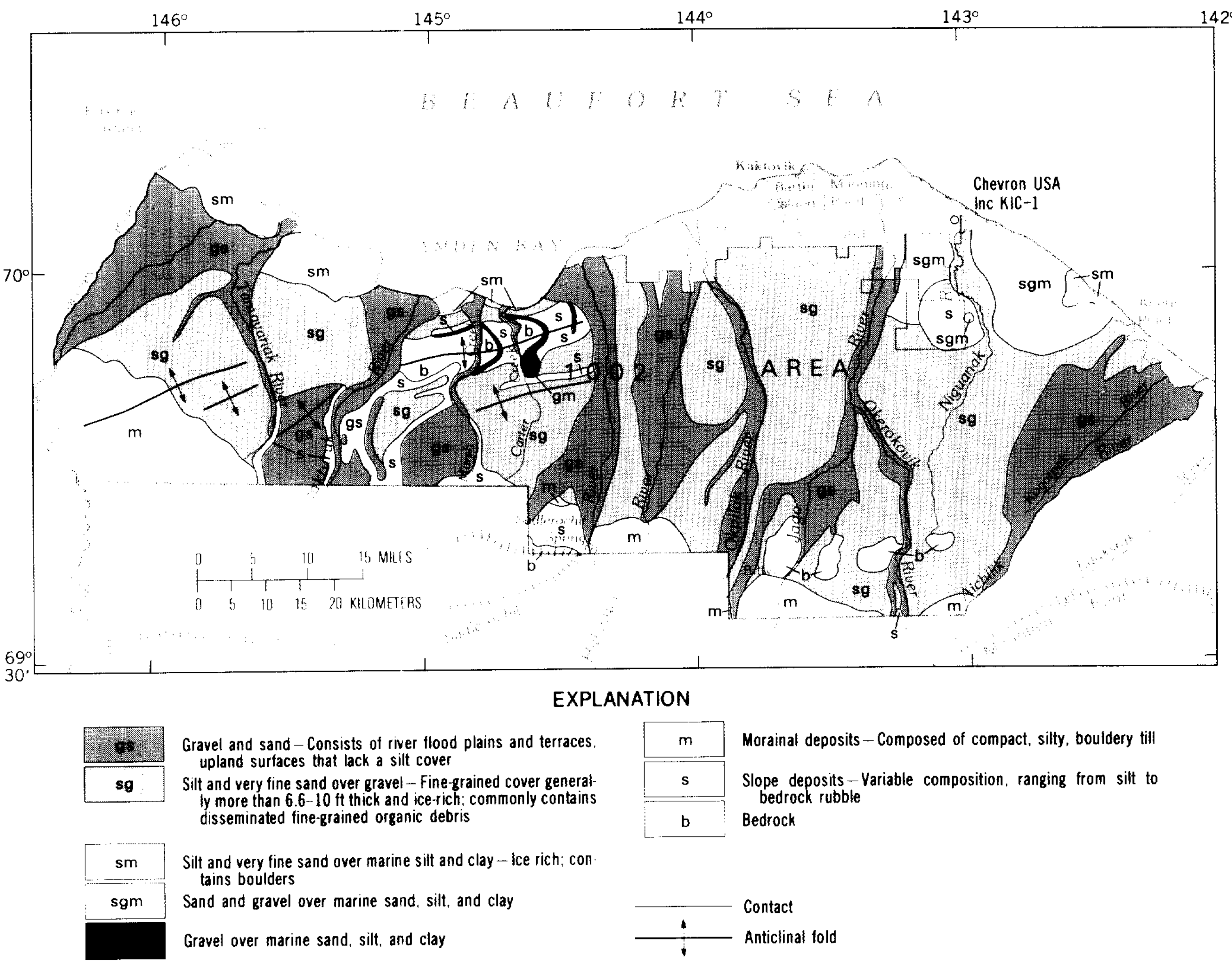


Figure II-2.--Generalized surficial deposits of the 1002 area. Map indicates surface materials only and not what could be borrowed for fill. Geology by Carter, Ferrians, and Galloway (1986).

Despite the arctic climate prevailing during the Pleistocene epoch, about 90 percent of the 1002 area is unglaciated. A large valley glacier extended northeastward approximately 12 miles into the area and probably about 7 miles along the Tamayariak River (southwest corner of 1002 area, map unit m on fig. II-2). 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 topographic 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.

Climate

The climate of the 1002 area is arctic marine, characterized by extremely low winter temperatures and short, cool summers. Winds are persistent throughout the year. Blizzards occur frequently 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 the maximum +85°F in July 1977. The maximum and minimum temperatures last only briefly, 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, vary widely. At Barter Island, the average January temperature was +4.5°F in 1981, -21.8°F in 1983. At Umiat, the average January temperature was -11.2°F in 1982, -42.1°F in 1984. In summer, variations are less pronounced but more important because the accumulation of 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 thaw indices 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 and 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). The combination of darkness and extreme cold in winter makes outdoor work difficult and often hazardous.~

Precipitation on the 1002 area is light but frequent, occurring 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 falls 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 fall at any time in 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 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 (1987), 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, 1987).

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 break up and pack much like fine sand; the snow often develops a density of about 0.4. As a result the actual winter precipitation may be about four times the 3.66 inches officially reported (Black, 1954). Wyoming-type snow gauges indicate that snowfall is somewhat less at Barter (an average of 5.4 inches of moisture over the last 6 years) than at Deadhorse (an average of 6.2 inches of moisture over the last 10 years) (George Clagett, Soil Conservation Service, unpublished data).

Easterly winds predominate most of the year. 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 coast 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, these storms can severely erode 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, clouds cover the sky 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° below the horizon, twilight permits many activities; at that latitude moonlight can be an important source of illumination. 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 air temperature in the lower atmosphere normally decreases with increasing altitude, in a temperature inversion, colder air is overlain by a warmer layer of air. During the summer, surface temperatures are warmer and fewer inversions occur.

Freezeup normally begins in early to mid-September. Drier areas freeze 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 long 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 freeze over all the areas within a day or two. Freezeup in the sea depends on late summer water temperatures, nearness of the ocean icepack, winds, and prevailing air temperatures. Generally, at least the nearshore sea is iced over by early to mid-October.

Thickness of the ice on the sea, lakes, and rivers is determined by numerous factors, including insulating value and thickness of the snow cover. Data from the Arctic coast indicate ice thicknesses 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 snowdrifts may be deep, 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 temperatures be average or even mild and the snowpack be very light, the ice may be as much as 7.5-8 feet thick.

The ground is frozen until June. Rivers fed by 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 of ice 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 both on top and into bottom ice surfaces, and large holes may be cut through by river waters draining in a swirling, fast-cutting manner. Nearshore, land-fast 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°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 National Petroleum Reserve in Alaska (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°F to +15.8°F. Similar temperatures have been found in a series of shotholes extending from the coast inland 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 permafrost temperatures range from about 31°F under the ocean at a depth of 70 feet, where annual change is negligible (Brewer, 1958a), to about 18.5°F beneath sandy unvegetated beaches, to about 15°F under dry tundra, to a minimum of about 13°F under very wet, low-centered polygonal tundra (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; this thickness is believed to result from an anomalous thermal conductivity because of the unusually 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 in the 1002 area 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 (figs. I-1, II-1) indicate that subsea permafrost occurs nearshore in 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 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 inflow of warmer water from major rivers.

Permafrost-related stream data for the 1002 area are sparse. But 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. The Shaviovik is shallow and 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 river (Brewer, 1958a) is about 5.4°F warmer than beneath the 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 an 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 forms in these cracks and is cemented by spring meltwater, leaving a vertical stringer of ice. This ice limits expansion of warming permafrost in summer and the adjacent mineral soils are displaced 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 to 200 feet and are easily recognized; 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, the beads located at the intersections of ice wedges, follow this pattern.

Most polygonal areas 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

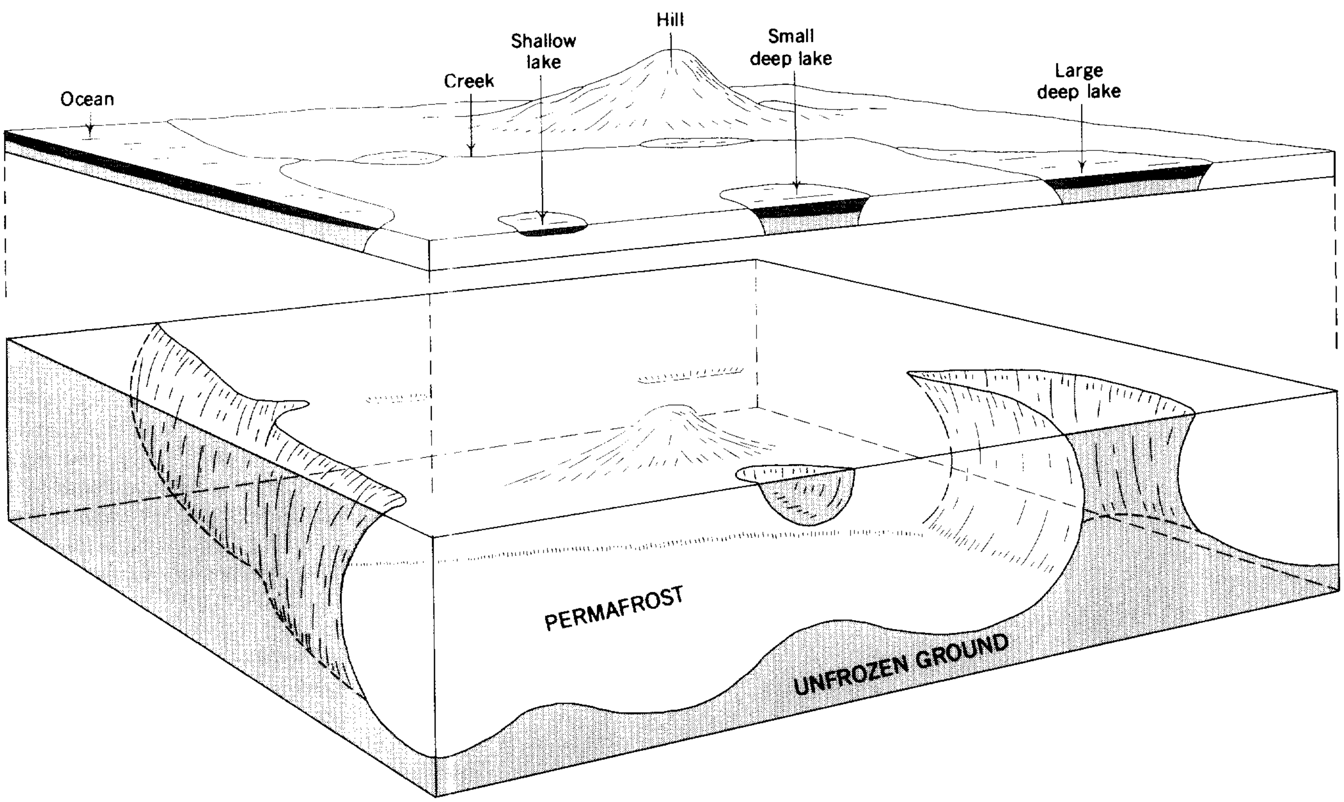


Figure II-3.--Schematic diagram showing the effect of surface features on the distribution of permafrost in the continuous permafrost zone. Modified from Lachenbruch, Brewer, Greene, and Marshall (1962).

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 that resulted 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 (fig. II-2, map unit gs). The Tamayariak, Katakturuk, Okpilak, Okerokovik, and Kogotpak Rivers, and especially the Canning, Sadlerochit, Hulahula, Jago, and Aichilik Rivers, 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. 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 containing cobbles, along the south boundary of the 1002 area. Downstream toward the Beaufort Sea the materials are 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 are poorly developed and frequently water saturated, and can generally be classed as tundra soils, wetland soils, or sand dunes. They tend to be sticky and claylike and are 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, although surface expression tends 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-thick 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

~ Despite the fact that 99 percent of the 1002 area is classified as wetlands, free water is limited and confined to the shallow zone above permafrost. The estimated 800- to 1,000-foot-thick impermeable permafrost precludes obtaining nonsaline water from within this zone. Although no wells have penetrated 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 are present 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 and may lodge in constricted areas, 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 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. 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 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. Various discharges reported for the spring range from 21.2 cubic feet per second (cfs) (Craig and McCart, 1974) to 35-53 cfs (Craig, 1977), and 88.3 cfs (Williams, 1970). Warm termperatures of between 43°F (Craig and McCart, 1974) and 50-58°F (Craig, 1977) have been measured. ~

Numerous small springs have been found 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 from freezing 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, is found in some smaller tundra streams and ponds.

~ Water quality of lakes and streams is lessened in winter because salts and dissolved organic material are excluded from the downward-growing ice. Dissolved oxygen levels can be depressed in the water that remains unfrozen owing to lack of aeration and the extended darkness that limits photosynthesis. 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. During summer, however, dissolved oxygen (DO) is at or near saturation in lakes and streams. ~

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).

~ Ice in lagoons begins 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 as much as 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 because permafrost often is susceptible to erosion, as are 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, the gradients of streams crossing 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 depending on storm intensity and nearness of pack ice from place-to-place and year-to-year along the entire Beaufort coast. Three to 6 feet of erosion per year may be the average. Erosion and deposition of eroded sands and gravel produces barrier-island or spit migration, especially where no vegetation is established. 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 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

Table II-1.--Ambient air concentrations measured at Prudhoe Bay, April 1979-March 1980, compared with national ambient air quality standards.

[Data from Crow and others (1981). Concentrations in micrograms/cubic meter. Monitoring data collected by Radian Corporation on behalf of ARCO. Alaska's ambient air quality standards are identical with the national standards, except that the State has an annual standard for total suspended particulates (TSP) at 60 ug/m^3]

Pollutant	NAAQS Time period	NAAQS Concentration	Site 1 High	Site 1 2d high	Site 2 High	Site 2 2d high
NO_2	Annual	100	4	--	3.5	--
CO	Annual	--	17.1	--	13.3	--
	8-hr	[1]10,000	86	70	95	75
	1-hr	[1]40,000	312	303	343	307
SO_2	Annual	80	0.5	--	0.4	--
	24-hr	[1]365	9	7		
	3-hr	[1]1,300	25	18	13	11
O_3	Annual	--	47.5	--	51.0	--
	1-hr	[1]235	113	105	113	113
TSP	Annual	75	11.4	--	6.7	--
	24-hr+	[1]260 [1,2]150+	[3]294	[3]119	[3]112	64

[1]May be exceeded once per year.

[2]+260 ug/m^3 is primary standard; 150 ug/m^3 is secondary standard.

[3]Surface winds: at site 1, 45 mph, with gusts to 60 mph; at site 2, 47 mph.

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, vehicle, 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 (generally less than 1 foot high) plants such as sedges, grasses, mosses, lichens, small herbs, and dwarf shrubs. 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 categorizing the Arctic Refuge soils, landforms, vegetation, and land cover 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-2). 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, 1986).

~ 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, Thlaspi arcticum, occurs in the 1002 area (Murray, 1980b; Felix, Lipkin, and others, 1985). An endemic of the Alaska-Yukon region, T. arcticum is known from several widely disjunct areas. Within the Arctic Refuge scattered populations have 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 (pl. 1A). It is also found in shrub tundra, dwarf heath, and 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. ~

winds are not greatly different, the general absence of north-south orientation suggests that the small thaw lakes found there are enlarged more by freezing and thawing than by mechanical (current) erosion.

Although precipitation 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 because of the generally coarse material involved. But 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 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 local damage. Since the mid-1960's epicenters of at least 6 shocks (5 of them offsnore) 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, 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, "Alaska" volume, map on p. 84).

Seismically active faults may occur; accordingly, 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, "Alaska" volume, 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 ~

Human activity currently affects air quality in Arctic Alaska only near villages and the Prudhoe Bay/Kuparuk development area. Air quality is 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.

In recent years Arctic haze has been reported, with the suggestion that some pollutants originate from the Ural Mountains (USSR) industrial complex (Rahn and Lowenthal, 1984). In April 1986, the National Oceanographic and Atmospheric Administration (NOAA) made one flight to investigate Arctic haze over Prudhoe Bay. At the time of the flight, there was a pervasive haze from several thousand feet to 20,000 feet in elevation, with clean air between that layer and the ground (Russell Schnell, NOAA, unpublished data). At higher altitudes, the sulfur dioxide, nitrous oxides, nitric acids, and ozone typically found in haze from the USSR were present. Lower levels of the haze were relatively clean, indicating that there was no contribution to Arctic haze from Prudhoe Bay activities.

Carbon-dioxide concentrations in the Arctic naturally show an annual cycle (Kelley and Weaver, 1966; NOAA, 1975). Concentrations are higher during the winter and under the snow (Kelley and Weaver, 1966); they are at their minimum in August, corresponding closely to the maximum vegetative bloom on the tundra.

Data on air quality in the 1002 area have not been acquired. However, because human activity is low, air quality in the 1002 area and the rest of the Arctic Refuge is expected to be generally very good, with ambient concentrations for air pollutants nearly at background levels. Current air pollutant concentrations are expected to result from a combination of natural sources and the residue of Arctic haze. Particulate matter (PM) can occur at high concentrations even in remote areas and in the absence of human activity due to windblown dust, soil or other surface cover.

Some data are available from Alaska's North Slope. Table II-1 summarizes monitoring data collected at Prudhoe Bay for a full year. The Environmental Protection Agency (EPA) reviewed these data and accepted them as meeting its siting, quality assurance, and other monitoring guidelines. During the data-collection period, North Slope production averaged about 1.5 million barrels per day. Arctic Refuge air quality is assumed to be at least as good as the ambient concentrations shown in table II-1.

Table II-2.--Landsat-identified vegetation cover classes and correlation with the U.S. Fish and Wildlife Service 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	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

WETLANDS

Approximately 99 percent (1.53 million acres) of the 1002 area is classified as wetland according to the FWS Classification of Wetlands and Deep-water Habitats of the U.S. (Cowardin and others, 1979) (table II-2). 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 one of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soils; (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: The 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 active flood plains where the depth to permafrost is great enough to allow for well-drained soils. Areas having a dense vegetative cover are characterized by permafrost occurring at 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 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 are as high as 1,250 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). Barren gravel crops out on the crests of several hills, particularly near the Katakturuk River. 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, during the thaw season. String bogs are often found in the channels, suggesting slow mass movement of the saturated soil. 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 deltaic 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 an active channel and one or more terraces. Most major rivers 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. These islands may be either unvegetated or vegetated. Unvegetated islands are subject to intensive water and ice scouring, and consist of gravel with little soil development. Vegetated islands are elevated slightly above the normal high water mark because of channel cutting and have a wide range of vegetation coverage, depending upon the extent and frequency of inundation. If present, soils consist of various thicknesses of silt loam, loam, and fine sandy loam over gravel and gravelly sands. ~

Land cover associated with river systems ranges from totally barren river gravels and mud to tundra 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). The relatively limited supply of riverine willow within the 1002 area is of significance to several wildlife species, as are riparian areas that are often snow-free earlier than other parts of the coastal plain. Smaller streams and quiet 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 occasionally exceed 6 feet in height.

Land-cover categories 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, most having 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. 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 locally, primarily near the flat braided-river deltas, and cover 3 percent of the 1002 area. Thaw-lakes are generally elliptical, shallow (2 to 6 ft), and geomorphologically short-lived. They form as a result of 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) at the 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, mostly low-centered polygons and string bogs, is nearly always present on thaw-lake plains.

The microtopography of thaw-lake plains (elevation variations of only a few feet) is the major influence on the distribution of plant communities, and small elevation differences create distinct patterns of plant communities and soil 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 1,970 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 unique assemblages of plants, such as the bryophytes associated with seeps in limestone, are present (Brown and Berg, 1980; Steere and Murray, 1976). The main land-cover classes include barren and scarcely vegetated scree and dry prostrate dwarf scrub.

~ Special Terrestrial and Aquatic Environments ~

Within the 1002 area, four distinct areas have been identified for their special natural characteristics.

SADLEROCHIT SPRING SPECIAL AREA

~ Sadlerochit Spring and the immediate area (640 acres), in the southern part of the 1002 area west of the Sadlerochit River (pl. 1A), have 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, as well as having exceptional scientific research and education values. Sadlerochit Spring is unique on the coastal plain 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 on the coastal plain near the foothills, it is one of the largest perennial springs on the North Slope of Alaska. Reported discharges range from 21.2 to 88.3 cfs (Craig and McCart, 1974; Craig, 1977; Williams, 1970); its waters are warm (50°-58°F) and 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; Craig and McCart, 1974; Williams, 1970). Sadlerochit Spring is a wintering area for fish (pl. 1B); such places 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 use the area throughout the year. ~

The Sadlerochit Spring Special Area, as designated by regulations for exploration in the 1002 area, encompasses an approximately 4,000-acre area within 1/2 mile of the spring outlet and extends 1/4 mile on each side of the river downstream 5 miles to the aufeis field [50 CFR 37.32(g)]. The spring and its surrounding area have been identified as a special area primarily for the unusual plant communities and associated diverse wildlife (pl. 1A). Because of the spring's special values, exploration activities have been prohibited. The Sadlerochit Spring area is used for traditional subsistence harvest, particularly in winter, when people from Kaktovik camp at the spring and hunt and fish (Jacobson and Wentworth, 1982).

~ KONGAKUT RIVER--BEAUFORT LAGOON ~

An area of approximately 133,700 acres at the mouth of the Kongakut River, and extending along the coast from Demarcation Bay to Angun Lagoon, was identified as a potential National Natural Landmark (Koranda and Evans, 1975). Most of this proposed National Natural Landmark lies east of the 1002 area within the Arctic Refuge Wilderness. However, about 25,000 acres extends into the extreme northeast corner of the 1002 area. The area was recommended for designation as a National Natural Landmark because it contains:

1. An offshore bar and lagoon ecosystem which supports a relatively diverse marine biota and terrestrial biota using the area for nesting and migration rests.

2. An Arctic river which flows from the mountain front and enters the lagoon ecosystem, perpetuating the marine conditions of fresh water throughout most of the summer, and the presence of spruce trees in the upper course of the river, accompanied by elements of the boreal flora (Koranda and Evans, 1975).

~ ANGUN PLAINS ~

On the eastern end of the 1002 area, one complete township (T. 6 N., R. 38 E.) was identified as a potential National Natural Landmark primarily because of its special geologic features. The area serves as " * * * a good example of the glacial gravel outwash plains found near the areas of maximum Pleistocene glaciation" (Detterman, 1974).

~ JAGO RIVER ~

It has been proposed (Viereck and Zasada, 1972) that parts of the Jago River drainage be included in a system of "Ecological Reserves" in Alaska. The area contains a complete array of tundra and flood-plain vegetation types and provides habitat for a cross-section of all Arctic Slope wildlife species. The drainage contains a glacier and outwash, an arctic river system, delta sand dunes, an arctic coastal lagoon system, small tundra lakes and streams, and offshore islands. The proposals suggested that specific areas for inclusion in the natural area system (that is, Research Natural Area) be selected by refuge personnel. No selections have been made.

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 supports 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) Coastal Management boundary includes State lands within the 3-nautical-mile offshore territorial limit, extending inland approximately 25 miles, and State lands up certain streams to include anadromous fish spawning and fish overwintering habitat. The NSB developed a Coastal Management Program approved by the State on April 17, 1985, 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). However, the Federal Office of Ocean and Coastal Resource Management in the Development of Commerce denied approval on August 8, 1986. The Program was not approved because the Federal officials felt it did not provide adequate consideration of the national interest in energy facility siting as required by Section 306(c)(8) of the Coastal Zone Management Act. It did not provide an adequate balance between energy development and subsistence use, but instead unduly restricted energy facility siting.

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 Aichilik 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 at the end of this chapter 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.

~ During the recent seismic and surface geologic exploration programs on the 1002 area, the FWS consulted closely with the State of Alaska, Division of Governmental Coordination, to ensure that the exploration proposals were consistent with the State's Coastal Management Program. If development is allowed on the 1002 area, the FWS would continue this coordination. The State would review all projects and development plans for consistency with coastal zone management standards. ~

Fish and Wildlife Resources

The fish and wildlife 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 part of the 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) to contain 180,000 animals in 1986. The herd is increasing and is the sixth largest herd in North America (Whitten, 1987). The Western Arctic herd (population 220,000-240,000) is the only herd in Alaska larger than the PCH (Williams and Heard, 1986). Earlier estimates of the PCH populations were as low as 101,000 (LeResche, 1972). The most current photocensus of the herd was for 135,000 animals in 1983 (Whitten, 1984); more recent estimates are projections using productivity and mortality estimates. The lower levels of earlier estimates may reflect either a truly smaller population or less accurate or less complete survey techniques, or a combination of these factors. Caribou populations fluctuate unpredictably over the long term. The long-term maximum and minimum population of the PCH and the carrying capacity of the area are unknown.

The PCH ranges over 96,100 square miles of northeast Alaska and northwest Canada (figs. II-4 and II-5), and constitutes the largest population of large mammals shared by the two nations.

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 nearly 8.9 million acres (pl. 2A and fig. II-5). 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 (fig. II-5).

Spring migrations to the calving grounds start in April-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 PCH migrations vary annually depending on winter distributions, snow conditions, and the onset of spring weather. Most PCH caribou migrate from Canada, moving westward along the northern foothills of the Brooks Range to reach their calving grounds. In some years caribou also pass through the first snow-free mountain valleys east of the Aichilik River in Alaska. As spring progresses, caribou in the foothills spread northward along a broad front, mostly following the major river corridors and associated terraces where snowmelt has advanced.

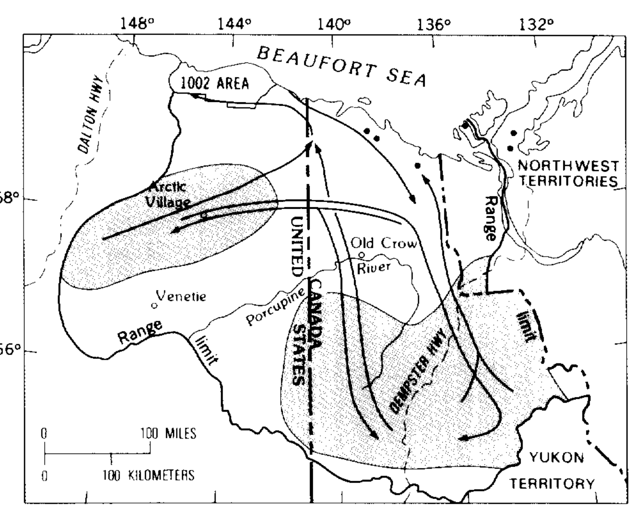


Figure II-4.--General range, migration routes (arrows), and winter range (shaded) of the Porcupine caribou herd. Solid circles indicate exploratory drill holes.

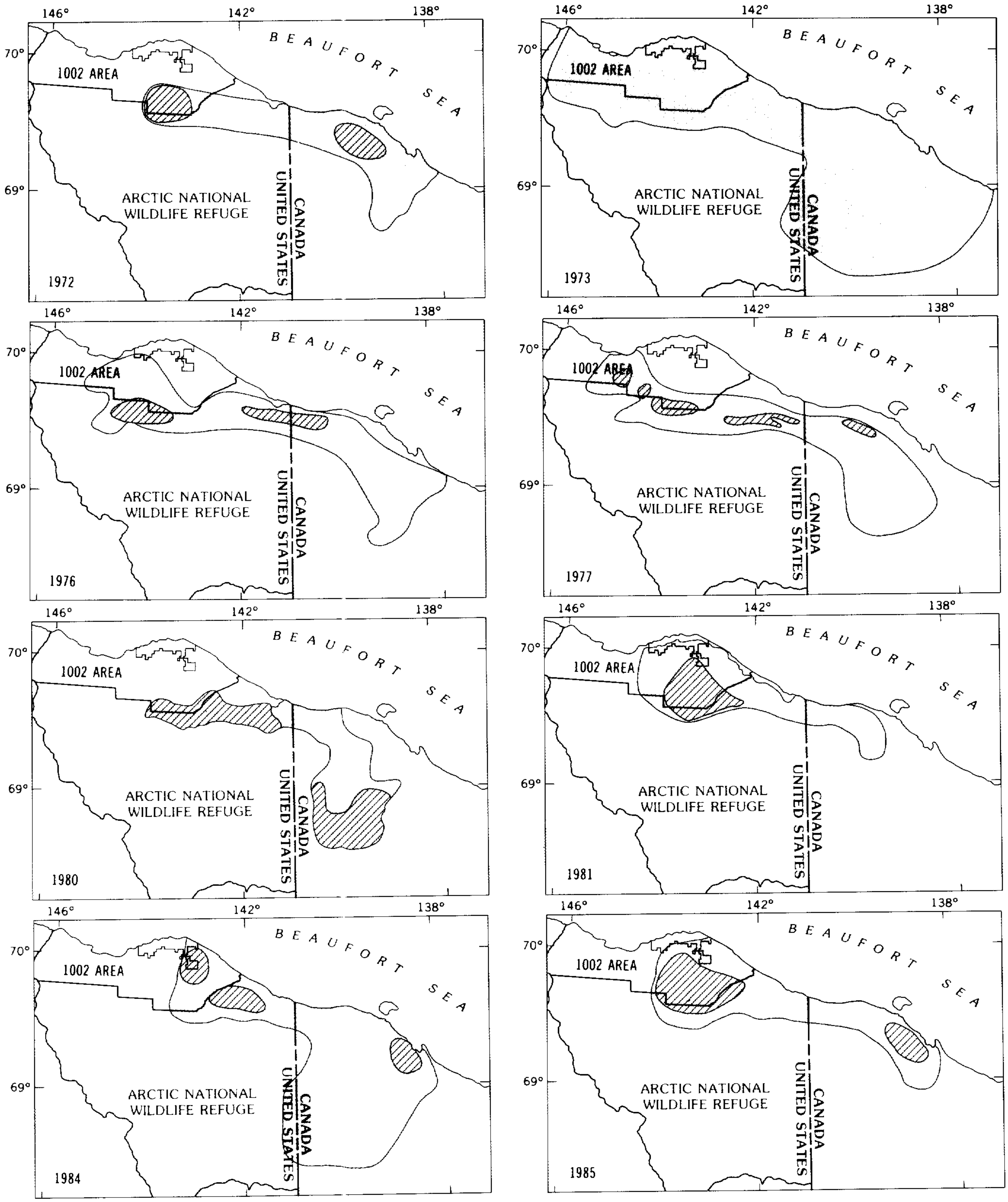
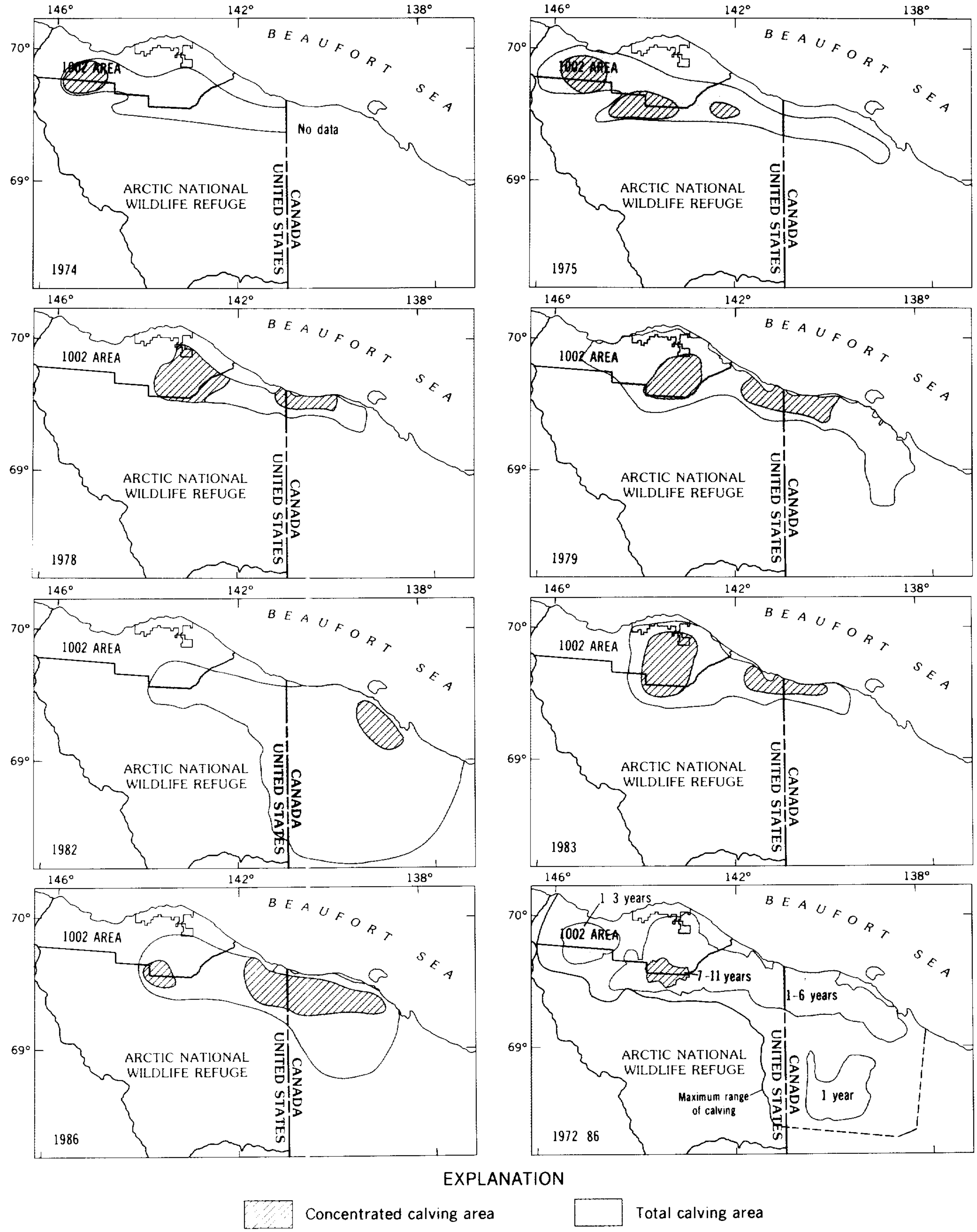


Figure II-5.--Total calving areas and concentrated areas of the Porcupine caribou herd by year for 1972-86 (15 maps) and composite map of all concentrated calving areas for 1972-86, including maximum extent of scattered calving (1 map).


146°
142°
138°
70°
69°
BEAUFORT SEA
1002 AREA
No data
ARCTIC NATIONAL WILDLIFE REFUGE
UNITED STATES
CANADA
1974
1975
1978
1979
1982
1983
1986
1972 86
1 3 years
7-11 years
1-6 years
1 year
Maximum range of calving
EXPLANATION
Concentrated calving area
Total calving area

PCH caribou have calved on the 1002 area every year for which detailed records have been kept (1972-86). (See fig. II-5.) Usually they begin to arrive on their calving grounds 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. Vegetation provides camouflage; this background presumably reduces predation on calves. Also, predator densities are apparently lower in these areas and, subsequently, calf survival is better (U.S. Fish and Wildlife Service, 1982; Mauer and others, 1983; Whitten and others, 1984, 1985).

Detailed observations of the PCH calving areas were made during 1972-86. The earlier information, 1972-77, was gathered as part of the Arctic Gas studies for a proposed gas pipeline from Prudhoe Bay across the Arctic Refuge to Canada. The Canadian Wildlife Service and Yukon Wildlife Branch conducted studies of the PCH during 1978-81 because of their concerns with potential oil and gas developments in the Yukon and Northwest Territories. The most detailed studies were part of the section 1002 baseline study, 1981-85, by the FWS in cooperation with the ADF&G and Canadian wildlife biologists. As a result of these studies, areas have been delineated where caribou were most abundant (concentration areas) at the peak of calving activity (pl. 2A and fig. II-5).

Densities for entire calving concentration areas in each year, 1983-85, were calculated using data collected from radio-collared females and with the following six assumptions.

1. The distribution of radio-collared adult female caribou are representative of that segment of the herd at the time of calving.

2. The population of the PCH was 135,000, 149,000, and 165,000 in 1983, 1984, and 1985, respectively (Whitten, 1987).

3. Adult females (those at least 3 years old) make up 35 percent of the total population (Whitten and Cameron, 1981).

4. The natality rate is 80 percent (Bergerud, 1980).

5. Yearlings make up approximately 12 percent of the total PCH population (Whitten and Cameron, 1981).

6. One-third of the yearlings are on the calving grounds at calving time; up to 60 percent of these are in peripheral areas and the remaining 40 percent in concentration areas (Whitten and others, 1984; FWS, unpublished data).

Calculated densities ranged from 46 to 128 caribou (including cows, calves, and yearlings)/square mile for each calving concentration area, 1983-85 (FWS, unpublished data). Prior to 1983, caribou densities in areas identified as concentration areas are largely unknown. However, limited measurements made in 1972 near the Jago River showed densities ranging from 8.2 to 375 caribou/square mile during June 10-17 (McCourt and others, 1974). As the difference between high density concentrated calving areas, and low density peripheral or scattered calving areas is readily apparent, use of the term "concentrated" by previous observers was assumed to reflect densities of similar magnitude.

On the basis of intensive counts using helicopters, as well as radio-telemetry surveys, calving concentration areas were found to contain predominantly adult females and their calves, and peripheral areas had proportionately more barren females, yearlings, and young males (Whitten and others, 1984; FWS, unpublished data). Consequently, the concentrated calving areas have been deemed to be the most important calving areas because (1) they support most of the parturient females and their calves, and (2) they are the areas having the highest caribou densities.

The open rolling hills and adjacent thaw-lake plains between the Hulahula and Aichilik Rivers have supported calving concentrations during 10 of the 15 years, 1972-86. Precise boundaries of concentrations vary annually. However, there has been a consistent and continued focus on this area by calving caribou for several generations (fig. II-5). The repeated use of certain portions of the concentrated calving area and the generally high reproductive success of cows calving in or near the area implies preference and value over other areas. Thus, these areas are considered valuable and important to the PCH. Of the 3 million acres identified as concentrated calving areas, 828,000 acres (28 percent) are within the 1002 area.

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. In years when calving is skewed to the east, usually due to late snowmelt on the coastal plain and/or deep snow on migration routes, there has been a distinct, consistent westward movement to the coastal plain after calving. The annual variability in concentrated calving areas is illustrated in figure II-5. Directional movement lessens once caribou have reached the calving grounds. 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 feeding areas in both spring and summer (Garner and Reynolds, 1986).

In all years of study, 1972-86, a majority of the PCH used the 1002 area for calving and/or postcalving activities. Recently the percentage of PCH cows using the 1002 area for calving was estimated to be 74 percent in 1983, 35 percent in 1984, 82 percent in 1985, and 24 percent in 1986. The 1983-86 estimates were extrapolated from locational data from radio-collared cows (Garner and Reynolds, 1984, 1985, 1987; FWS, unpublished data). In 1984, 38 percent of the PCH calved adjacent to the 1002 area, east of the Aichilik River, then within a week moved with their calves onto the 1002 area to join the 35 percent that calved on the area. Although only 24 percent of the PCH calved in the 1002 area in 1986, essentially the entire herd moved into the 1002 area after the calving period.

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, able to stand and nurse within 1 hour after 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 (Bergerud, 1974; Lent, 1964).

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 are common. Postcalving movements and aggregations show considerable annual variation.

Although rather small in proportion to the herd's entire range, the calving/postcalving area is an important, identifiable habitat repeatedly used by the PCH during these critical life stages. The reason for repeated caribou use of this area is unclear. Varying combinations of several factors in any given year--for example, advanced emergence of new vegetation, scarcity of predators, early snowmelt, topography, and/or proximity to insect-relief habitat (Cameron, 1983)--are probably responsible for the annual variations in use.

As temperatures rise in mid- to late June, swarms of mosquitoes emerge in the 1002 area. Harassment on warm, calm days by these insects drives the caribou into dense aggregations and results in their movement to areas of relief. The groups usually move into the wind, seeking relief on points, river deltas, mudflats, aufeis, large gravel bars, barrier islands, shallows of lagoons, and higher elevations in the mountains (pl. 2A). In some 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 during this period may be critical to herd productivity. In early July the herd usually moves east and south, vacating the 1002 area by mid-July. In some years, residual groups numbering as many as 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.

A draft international agreement for management of the PCH has been negotiated between the Governments of the United States and Canada. The State of Alaska and Canadian Territorial governments, as well as local users, participated in the negotiations. Other interested parties also attended the meetings. The purpose of the draft agreement is to facilitate U.S./Canadian cooperation and coordination of programs and activities aimed at long-term conservation of the PCH. The agreement will ensure that the PCH, its habitat, and interests of users of the PCH are given effective consideration in evaluating proposed activities within the range of the herd. All activities having a potential impact on the conservation of the PCH or its habitat will be subject to impact assessment and review and may require mitigation under the agreement. The agreement would establish an eight-member International Porcupine Caribou Board, made up of four members from each country, to make recommendations and provide advice on those aspects of conservation of the PCH that require international coordination. The Board would serve as a means of exchanging information on and facilitating cooperative planning for the PCH throughout its range. The draft agreement, initialed by the principal negotiators in Seattle, Washington, December 3, 1986, is being reviewed and discussed through public informational meetings in both countries before signing.

The PCH is harvested 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 1963-86 annual harvest of the PCH within Canada averaged approximately 1,800 animals for the years in which data were available (Yukon Territory Wildlife Branch, Canadian Wildlife Service, unpublished data).

The Central Arctic caribou herd (CAH) has been increasing, and in 1985 numbered about 15,000 animals (Ken Whitten, ADF&G, unpublished data). Since the CAH was recognized as a separate herd in the mid-1970's (Roseneau and Stern, 1974b), its range has been 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 (Trans-Alaska Pipeline System), Dalton Highway, and Prudhoe Bay-Kuparuk oil fields lie within the herd's range (fig. I-1). 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. They also move northward along the Canning River.

CAH calving activity has been concentrated in two areas: (1) west of Prudhoe Bay in the vicinity of Kuparuk and Ugnuravik Rivers (including recent oil development in the Milne Point and Kuparuk areas); and (2) east of Prudhoe Bay, mainly in the Bullen Point to Canning River delta area. Most years as many as 1,000 females calve in the Bullen Point to Canning River delta (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); however, concentrated calving has never been documented in the area.

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, the area used by as many as 7,000-8,000 caribou of the CAH for postcalving and for insect relief, given 1985 population levels (pl. 2B). During late summer, about 1,000 animals may remain scattered west of the Sadlerochit River and north of the Sadlerochit Mountains, primarily within the 1002 area. Riparian areas are used for travel as well as spring and summer feeding areas (Roby, 1978). In late summer and fall, CAH caribou are 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 Sadlerochit River and adjacent uplands to the south. The number of wintering animals ranges from a few hundred to a thousand.

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, 64 muskoxen were reintroduced to the Arctic Refuge in 1969 and 1970 (Roseneau and Stern, 1974a). The muskox population has grown exponentially since 1974 (fig. II-6) because of high productivity and low mortality. In 1985, the postcalving refuge population was estimated at 476, more than triple that in 1979.

Muskoxen are highly social and are usually found in mixed-sex herds. Herd size 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 Rivers for the past several years, with approximately 80, 160, and 230 animals, respectively, using those drainages. 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. Mixed-sex herds are also dispersing into new areas on the Katakturuk River and drainages east of the Aichilik River.

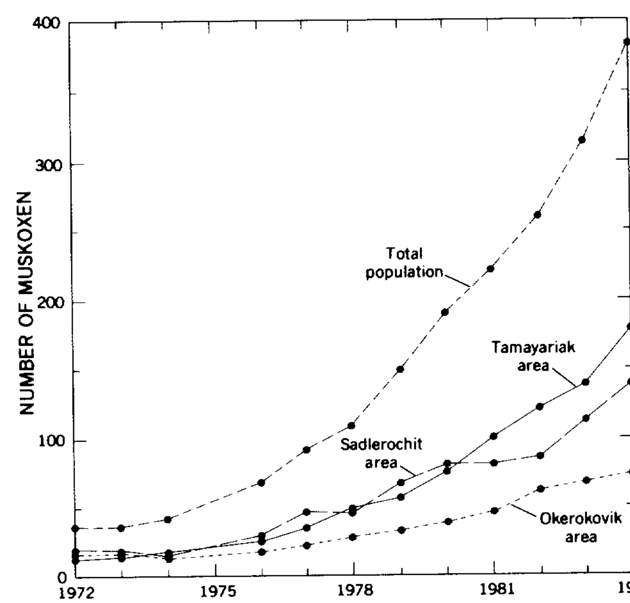


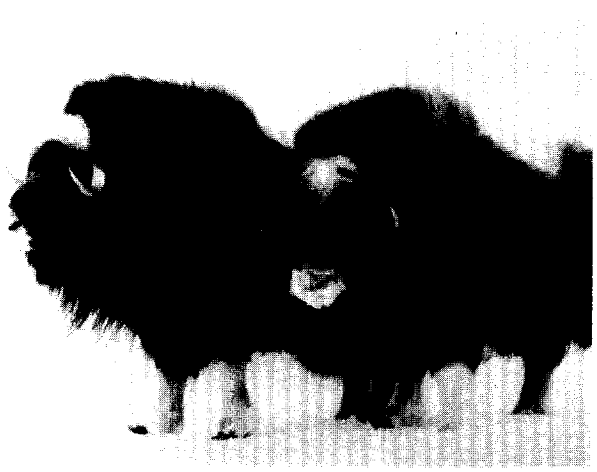
Figure II-6.—Estimated numbers of muskoxen in post-calving populations in the Arctic Refuge, 1972-84.

Table II-3.--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

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 having less snow cover in order 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-3 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.

Hunting of muskoxen 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 as many as 203 and 239 moose have been counted in the Canning and Kongakut River drainages, respectively (Garner and Reynolds, 1986). 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 at any one time probably does not exceed 25. In late August, moose begin to aggregate; the largest groups are found south of the 1002 area in October during the rut. 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, where available, is an important winter food.

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 is 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 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 usually south-facing windblown slopes and ridges. 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. The population density is lower on the 1002 area 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). Wolves mate 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 have been found 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 nine dead wolves, including six radio-collared animals, were found. Five of the animals were confirmed as rabid. Historical den sites on the Kongakut, Hulahula, and Aichilik Rivers were deserted in 1985, and the death from rabies of breeding wolves was suspected as the reason. However, four new dens were found, three occupied by wolves which were remnants of earlier packs. ~

Wolves on the North Slope 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 is 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, who harvest most in the Hulahula, Sadlerochit, and Okpilak River areas (Jacobson and Wentworth, 1982; Weiler and others, 1987). 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 tundra and winter habitats along the northern Alaska coast and onto the sea ice (Chesemore, 1967). Their range is limited 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 these 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 in the winter by Kaktovik residents 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, but a rough estimate of the 1002 area population can be made from the wolverine densities and assumptions used by Magoun (1985) for estimating the population in the Western Arctic. Using Magoun's assumptions, the estimated density for the 1002 area is 90 wolverines. This figure may not be 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. During June and July, wolverines 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; 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. It is not known whether the 1002 area wolverine population is resident or transient.

BROWN BEARS

Brown bears seasonally use the 1002 area. Brown bears north of the Brooks Range are at the northern limit of their range. 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). 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 are found throughout the entire 1002 area. They appear in late May and are generally most abundant during June and July when caribou are most plentiful. The bears breed during this same period. There are two known high-use areas. One, used by 50-70 adult bears and cubs, is in the southeastern part 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 areas (30-80 bears) are 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, crowberries, 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). Most dens are in the foothills and mountains south of the 1002 area; only seven of 199 (3.5 percent) known den sites within the northeast portion of the Arctic Refuge have been found on the 1002 area (Garner and others, 1983, 1984, 1985; Garner and Reynolds, 1986). Cubs are born in January and early February. Litters range from one to three; the average litter for bears using the 1002 area is 1.9 (Garner and others, 1984). 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 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).

Kaktovik residents 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 (Garner and Reynolds, 1986). 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, golden eagles, 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). Their impact on the vegetation is cyclic and corresponds to the 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 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.

~ All marine mammals in U.S. waters are protected under the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361). The goal of that Act is to restore and maintain marine mammal populations at their optimum sustainable population levels, as well as to protect subsistence opportunities for Alaska Natives. The Act establishes a moratorium on the taking (including harassment) and importation of marine mammals except by Alaska Natives for nonwasteful subsistence or handicraft purposes. Required negotiations to encourage international arrangements for research and conservation of all marine mammals have resulted in the 1976 international agreement on polar bears as discussed in that section. ~

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 1,300-2,500 (Amstrup and others, 1986). 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-five percent of dens located in 1983-86 were offshore. The onshore area from the Colville delta to the Canadian border is used by the Beaufort Sea population for denning. However, the most consistently used land denning areas were on and adjacent to the 1002 area where 1-2 dens were found by radio telemetry in 5 of the 6 years between winter 1981-82, when the FWS began a continuing study of North Slope polar bears, and winter 1986-87 (Amstrup, 1986; FWS, unpublished data). The ideal denning sites are riverbanks, draws, and the leeward side of bluffs and hills where snow accumulation is sufficient to support den construction. Sixteen dens were found in the 1002 area between 1951 and 1986 through FWS radio telemetry studies and Native reports (pl. 1E; Garner and Reynolds, 1986, table 15, p. 293; FWS, unpublished data). Another five dens have been located on ice near the 1002 area. ~

~ Three different parts of the 1002 area (pl. 1E) have been generally 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 activities have also been observed in other 1002 area locations, but data are inadequate to confirm recurrent use. Ten of the 12 land dens found through radio telemetry studies (1981-86) have been located on the Arctic Refuge; the other two were on Hershel Island, Canada. ~

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 (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 can extend out to 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. Nearshore open water 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. Additionally, 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. The treaty requires management of shared populations by consultation. 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 have concentrated seasonally in some years 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 6 years, with two bears being taken in 1984-85 and three in 1985-86 (table II-7) (Schliebe, 1985; Jacobson and Wentworth, 1982; FWS, unpublished data). Restricting the take of females and family groups to ensure population stability was a purpose of the November 1986 agreement between the North Slope Borough Fish and Game Management Committee and the Inuvialuit Game Council in Canada. ~

SEALS AND WHALES

Ringed seals, bearded seals and, occasionally, spotted seals are found in the Beaufort Sea and along the coast north of the coastal plain, including the lagoons of the 1002 area (Garner and Reynolds, 1986; 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 within the 1002 area is not well understood. 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 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 inhabits waters offshore from 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. These whales feed in Demarcation Bay east of the 1002 area; they also may use waters off the 1002 area (National Marine Fisheries Service, 1983). Belukha (beluga) whales also migrate through waters north of the 1002 area.

Bowhead whales are taken for subsistence by Kaktovik residents. 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 thirty-five species of birds have been recorded on the Arctic Refuge coastal plain (Garner and Reynolds, 1986, 1987). 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 are occasionally seen in winter on the 1002 area. Twenty-one species are found 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; Divoky, 1978). Greatest concentrations of summer resident waterbirds on the Arctic Refuge occur in two general habitats: shallow coastal waters and tundra wetlands (pl. 3, A and B). ~

~ Birds begin using coastal lagoons when the snow melts in late May and river overflows cover lagoon deltas, providing 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, when most birds leave the area. ~

~ Lagoon areas are important during all phases of the avian life cycle. More than 35,000 waterbirds of up to 33 species (primarily oldsquaw) may use the coastal lagoons during the open-water period (July-September) (Garner and Reynolds, 1986). 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, finding protection from predation during this flightless stage. The lagoons are also important feeding areas for oldsquaw, eiders, scoters, and other ducks, loons, phalaropes, terns, gulls, jaegers, and black guillemots (Divoky, 1978). ~

Migratory birds range internationally; 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 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. As many as 100 nests and 280 to 485 adult swans have been counted on the 1002 area during annual surveys (Garner and Reynolds, 1986). 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 lakes in the Demarcation Bay area (pl. 3A). Spring surveys in 1982-85 showed an average density 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: 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. Canada geese with broods seek lakes and lagoons for protection shortly after their goslings 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 (200,000 breeding birds), Anderson River delta (10,000 breeding birds), and Kendall Island (1,000 breeding birds) (Krebs, 1983) in Canada and, prior to fall migration, most move westward into the 1002 area only as far as the Hulahula River. Several hundred snow geese may use the Canning River delta and Katakturuk Plateau during fall staging. More than 595,000 birds were estimated for the entire staging area on the coastal plain in Alaska and the Yukon Territory, Canada in 1985 (FWS, unpublished data). The maximum estimated for the Arctic Refuge coastal plain (the 1002 area plus adjacent Wilderness coastal plain) was 325,760 in 1978 (Spindler, 1978), with an 11-year average of 136,000. The average number of geese using the 1002 area is 105,000, an approximate average of 22 percent of the Western Arctic 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 as far as 225 miles west of their southward migration corridor on the Mackenzie River 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 10,000 black brant 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) to the Mackenzie River, then south through the Mackenzie River valley and into the Canadian Provinces and the western U.S. (Koski, 1977a, b; Bellrose, 1980; Barry, 1967). 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 (Martin and Moitoret, 1981; Garner and Reynolds, 1987). 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 (Martin and Moitoret, 1981; Garner and Reynolds, 1986). 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. 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 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 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). From July 1985 to July 1986, Kaktovik residents harvested approximately 513 geese, mostly brant, and 251 ducks (S. Pedersen, ADF&G, unpublished data). 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. 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 Sabine's gull in the 1002 area are on the Canning River delta. Black guillemots nest only on the coastal beaches and shorelines. Gulls, terns, and jaegers feed and nest along the coastline and major coastal rivers. Jaegers feed on small birds, eggs, insects, lemmings, and carrion (U.S. Fish and Wildlife Service, 1982).

~ Shorebirds are present on the coastal plain from mid-May through the end of September in all habitats (pl. 3C). Tundra habitats within river delta areas and riparian habitats are particularly important to nesting and staging shorebirds. Eighteen 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 found on the coastal plain. (Additional details are in the subsequent section on the peregrine falcon.) 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 in mid-May, except for gyrfalcons which are resident and begin nesting as early as March. 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) are found on the PCH calving grounds and postcalving areas, where they prey on young calves and scavenge caribou carcasses (Mauer, 1985). ~

PTARMIGAN

Willow ptarmigan and rock ptarmigan are common breeders and fairly common winter residents 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 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 for subsistence 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 sparrow, 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 in the Arctic have developed extreme adaptations to a harsh environment. There is a limited period in which food is available to fish and generally a limited area in which they can survive during the long winter. ~

Coastal waters of the Beaufort Sea in Alaska 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 lagoons 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, round whitefish, ninespine stickleback, and burbot. Arctic flounder, fourhorn sculpin, broad whitefish, arctic cisco, and least cisco have been reported in the lower river near the mouth. Pink, chum, and sockeye salmon have been reported in the Canning River but are thought to be strays from other systems. Lake trout are found in several lakes within the Canning River drainage but outside the 1002 area. Other streams in the 1002 area (pl. 1B) that support major fish populations are listed below. ~

River system	Arctic grayling	Artic char	
		Resident	Anadromous
Tamayariak River	X	-	-
Itkilyariak Creek	X	X	-
Sadlerochit River	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 (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 results from 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 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 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 factor limiting Arctic anadromous and fresh-water fish populations (pl. 1B).

Springs supply most, if not all, of the free-flowing water 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 overwintering capabilities: they either freeze to the bottom by late winter or their water quality is poor due to 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 lakes further inland, 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 south of the 1002 area, arctic char, arctic grayling, and/or lake trout may be found. The lakes best known and most widely used for recreation and subsistence are Lake Peters and Lake Schrader in the headwaters of the Sadlerochit River. These 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 lagoons. 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 constitute more than 95 percent of the diet of ringed seals which, in turn, are the major prey of polar bears. Some winter subsistence fishing also occurs at fresh-water overwintering sites. The most notable of these are Fish hole 1 and Fish hole 2 on the Hulahula River (pl. 1B) where arctic char and arctic grayling are caught through holes in the river ice.

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

THREATENED AND ENDANGERED SPECIES

~ The Endangered Species Act of 1973 (16 U.S.C. 1531) provides for the conservation of endangered and threatened species. Taking, importing, transporting, or selling endangered and threatened species is prohibited under the Act, except for nonwasteful subsistence purposes by Alaskan Natives or non-Natives who are permanent residents of Alaskan villages. Federal agencies are prohibited from any action that would jeopardize the continued existence of listed 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 rare. In-migrations of bowheads occur after spring breakup, and out-migrations take place before fall freezeup.

ARCTIC PEREGRINE FALCON

Listed as a threatened species under the Endangered Species Act of 1973, the arctic peregrine falcon is the only terrestrial threatened or endangered species found in the 1002 area. In Alaska, most peregrine falcons nest on ledges of cliffs or bluffs along river courses, but cliff habitat is not abundant in the Arctic Refuge north of the Brooks Range. But 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 occupied 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 are 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 a relatively short time in Alaska. Arctic peregrines generally arrive at their North Slope eyries between April 21 and May 7, lay and incubate eggs 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 suggest that at least some North Slope arctic peregrines migrate along the coast of the Beaufort Sea. The lagoons, river mouths, and bays concentrate shorebirds and waterfowl, which are favored prey of the peregrine.

Nesting of peregrines in the Arctic Refuge north of the Continental Divide was documented 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 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.

HUMAN ENVIRONMENT

Population

The North Slope Census Region comprises the entire 88,281-square-mile northern coast of Alaska. The region is sparsely populated, having a density of one person per 220 square miles. With the exception of Anaktuvak Pass, the human population 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 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 (NSB, 1984b). Nearly 90 percent of the population is of Native Inupiat Eskimo descent. The population increase since 1970 has primarily resulted from the return of residents formerly living in Barrow 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 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).

~ Sociocultural System ~

In both the Inupiat and the Athabascan cultures of the Arctic, subsistence production is closely and intricately tied to a larger cultural framework of values. The harvest of renewable resources for local consumption is the cultural as well as economic foundation of human life for many of the people in this region. Embodied in the subsistence way of life is harvesting of the resources to meet nutritional needs, development of a self-image, transfer of cultural values to offspring during harvesting activities, and weaving of the social fabric through resources distribution to the extended family and beyond.

Western culture with its cash-based economy has already had a significant effect on the traditional Native culture, and the rate of change has accelerated in recent decades. There are benefits in the form of increased material well-being, education and health services. Nonetheless, alcoholism, drug abuse, and mental illness have increased dramatically during this period of intense cultural change.

The present subsistence way of life continues to support the material and emotional well-being of the villages. But severe strains are being placed on the adaptability of the culture by such recent major events as ANSCA, ANILCA, and economic developments. Subsistence activities have served as an anchor for Native cultures in these times of change and will continue to do so as long as adequate resources are available. The ability of the villagers to maintain their present way of life in combination with a mixed cash/subsistence economy will depend on several factors, among them the manner in which resources are developed; regional, local and individual efforts to manage sociocultural impacts; and the health of subsistence resources.

The Native culture in the area is not weaning itself from a subsistence way of life and purposefully converting to a cash economy; rather, it is using each for the support of the other to provide a balance.

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." Under the Marine Mammal Protection Act of 1972, and the Endangered Species Act of 1973, Alaska Natives are also permitted, under certain circumstances, to harvest marine mammals and endangered or threatened species when such harvest is for subsistence purposes. ~

~ Fish and wildlife populations in or adjacent to the 1002 area are utilized for subsistence by communities in northern Alaska and in the northern Yukon. Because it is located adjacent to the 1002 area, the community of Kaktovik is of primary concern relative to subsistence uses within the 1002 area. ~

KAKTOVIK

The ADF&G Division of Subsistence recently completed a detailed investigation, begun in 1980, of Kaktovik subsistence 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-7 displays Kaktovik's subsistence species use by season.

Approximately 68 percent of Kaktovik's present subsistence use area 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-8). 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 lightly used, account for 30 percent of the Kaktovik subsistence 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, 85 percent of Kaktovik households obtained all or most of their food supply from hunting, fishing, and gathering (J. W. Peterson, 1978, as summarized in Pedersen and others, 1985). More recent studies, also summarized by Pedersen and others

(1985), found that 80 percent of Kaktovik households daily consumed meats 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-4). 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 to supplement oil heat, and willows are used for heating and cooking while 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 hunting. Longer days, adequate snow cover, and milder weather make April and May the best months for snowmachine travel. Travel then extends across the tundra and to hunting camps along the Hulahula and Sadlerochit Rivers. During winter, foothills and mountain valleys are the most important places for subsistence hunting.

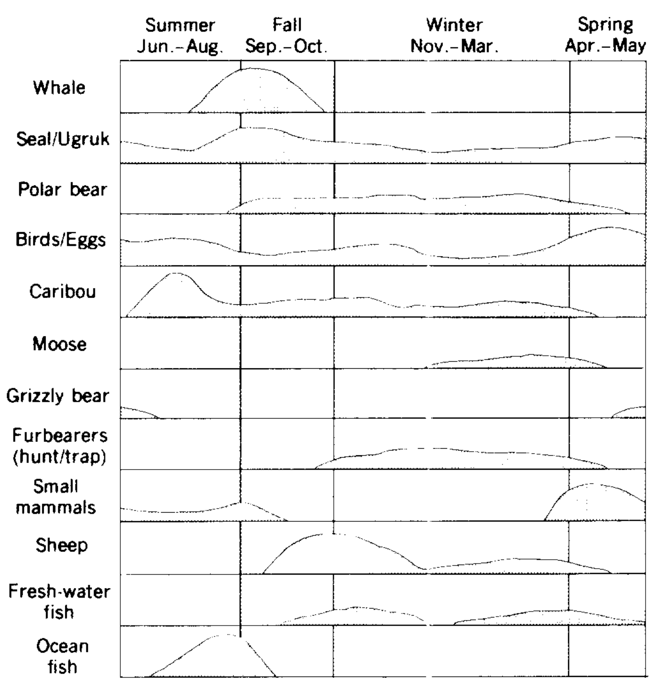


Figure II-7.--Yearly cycle of subsistence use by Kaktovik residents. Patterns indicate periods for pursuit of each species, based on abundance, hunter access, seasonal needs, and desirability. Modified from Jacobson and Wentworth (1982, p. 29).

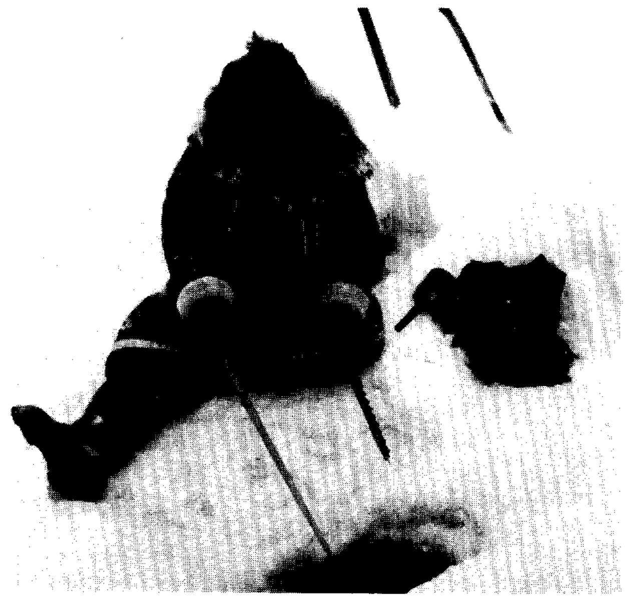


Table II-4.--Kaktovik participation in subsistence use, according to resource harvested.

[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	--

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 important in holiday feasts. Caribou hides are used for garments, boot soles, and blankets.

Caribou hunting 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 late October to late November, when there is enough snow for overland travel by snowmachine and daylight is not too brief, and 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 caribou harvested 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 the community's harvest came from each herd (Pedersen and Coffing, 1984; Coffing and Pedersen, 1985).

Most winter caribou hunting occurs along river valleys in the mountains. 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; 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 are hunted 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.

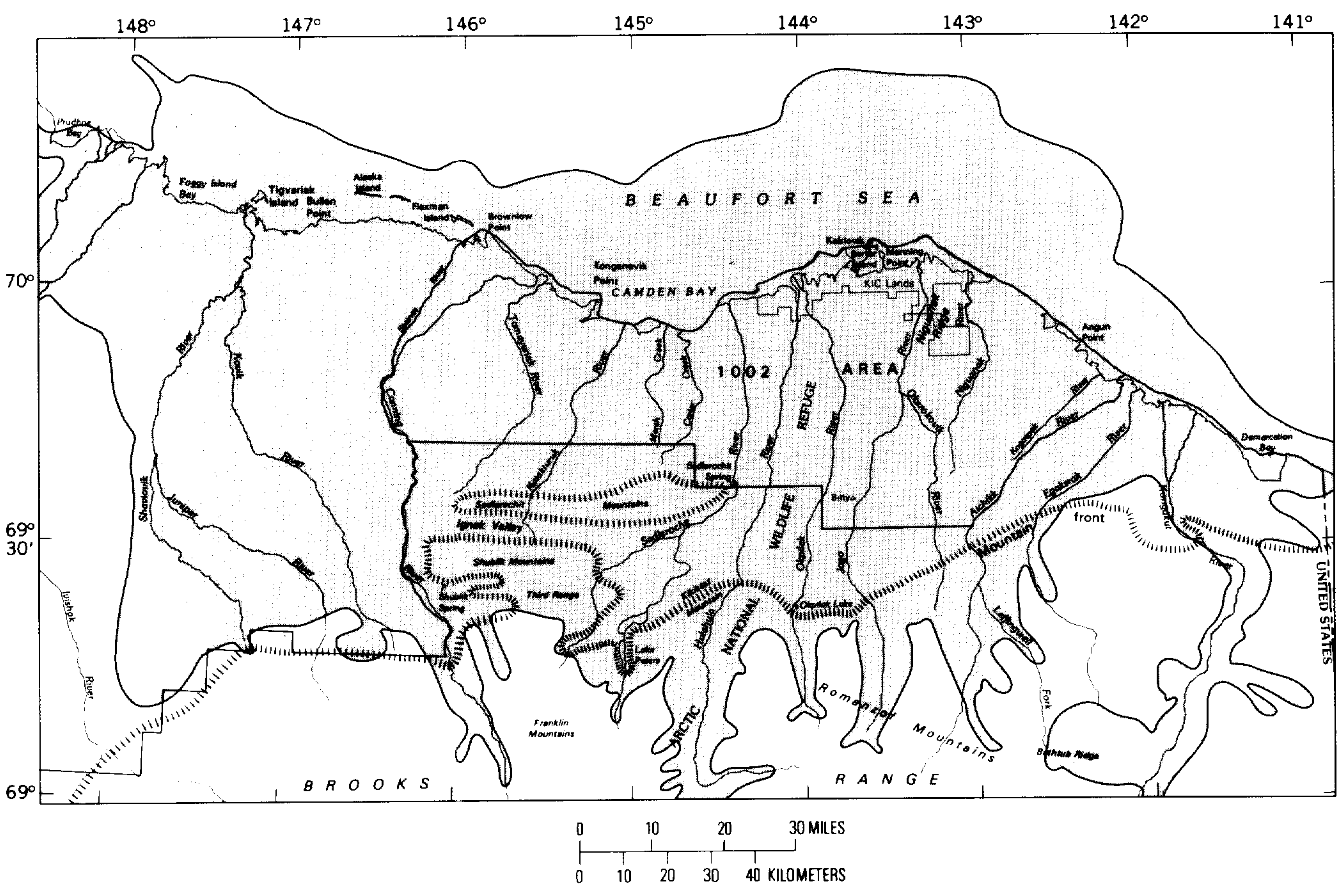


Figure II-8.--Extreme extent (patterned) of subsistence use by Kaktovik residents in the years 1923-83. Data from Pedersen, Coffing, and Thompson (1985).

Because they are rare within the 1002 area, Dall sheep are generally hunted outside the area, the hunting occurring from mid-October through March. The Hulahula River drainage within the mountains is hunted most extensively, beginning at the river's exit from the mountains near Fish hole 2 and continuing upstream 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 hunting has increased 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 number of sheep killed 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.

~ According to older residents, Kaktovik was a prehistoric whaling site with whale bones used for a walkway to the beach. In the period of recorded history, though, no whaling occured, perhaps because of unsuitable ice conditions and lack of equipment. Beginning again in 1964, whales (particularly bowheads and occasionally belugas) have been actively hunted. Whaling is viewed as one of the village's most important annual activities (Jacobson and Wentworth, 1982), expressing the cultural values of large group cooperation and sharing of resources, and being 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 198l. 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 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, but sometimes as far as 20 miles offshore from 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 and make an important contribution to the diet. Most seals are hunted from boats along the coast from July into September.

In recent years, most harvested polar bears 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 usually taken than any other species, usually incidental to other forms of hunting or when fishing nets are checked. However, during July 1985-July 1986, 531 geese were harvested; most were brant. During that same period, people from Kaktovik harvested 251 ducks (S. Pedersen, ADF&G, unpublished data). 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 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 fur buyers.

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 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.

~ OTHER COMMUNITIES ~

Several communities located relatively far from the Arctic Refuge utilize migratory species which may spend part of their life cycles in or near the 1002 area. Caribou are of particular significance, as well as snow geese, polar bears, and bowhead and beluga whales. Use of these migratory populations by other communities in Alaska and Canada is discussed below.

Caribou

Archaeological evidence indicates that people have been using caribou for at least 27,000 years, before the last glaciation in northern Alaska and Canada. Work done at sites occupied up to 1500 years ago near Old Crow, Yukon Territory, documented a subsistence economy centered on the interception of spring and fall migrations of caribou (Garner and Reynolds, 1986).

Today, harvest of caribou by communities in both Alaska and Canada depends largely on the variable distribution of the PCH from year to year. In some years, migration routes or wintering areas may not bring caribou near enough to a village to make hunting feasible. Still, the large amount of resources sharing and trading which occurs between villages reduces yearly variation between communities. The two villages other than Kaktovik that are most dependent on caribou using the 1002 area are Arctic Village, Alaska, and Old Crow, Yukon Territory; both are inland villages having little or no access to marine resources. Other communities whose residents hunt Porcupine caribou include Venetie, Fort Yukon, and Chalkyitsik in Alaska and Fort McPherson, Inuvik, Aklavik, Arctic Red River, and Tuktoyaktuk in the Northwest Territories.

Caribou is the most important food source for Arctic Village. Caribou from the PCH are usually 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 was reported to be 200-1,000 animals (LeBlond, 1979). Moose, fish, Dall sheep, waterfowl, and small mammals are also important, with an estimated 50 to 90 percent of all food consumed in the community derived from local wild resources (Caulfield, 1983).

Approximately half the food consumed by people in Old Crow comes from the land; of this, caribou is the most important. 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 en route to wintering areas. At this time they can be taken on land or by boat. Annual harvest of the PCH by Old Crow ranged from 250 to 1,000 between 1963 and 1986 (table II-5). People of Old Crow also harvest fish during the summer; moose, muskrats and waterfowl during spring; and rabbits and ptarmigan when available.

Other villages utilizing caribou from the PCH are located on the edge of the PCH range, and take caribou only in years when animals are available (U.S. Department of State, 1980). The estimated annual caribou harvest in Aklavik, Inuvik, Arctic Red River, and Fort McPherson, Canada, ranged from less than 100 to over 2,000 during 1963-86 (table II-5). Most of these animals are taken by the two communities of Aklavik and Fort McPherson (B. Pelchat, Yukon Wildlife Branch, and Don Russell, Canadian Wildlife Service, unpublished data). Alaskan villages of Venetie, Fort Yukon, and Chalkyitsik harvested 300-400 caribou in 1980-1981 (Pedersen and Caulfield, 1981). Sharing and trading of resources occurs between villages. If caribou are not available in Fort Yukon, for example, residents may trade salmon for caribou with residents of Arctic Village. Because of the well-established network of exchange, those who are unable to obtain subsistence resources for themselves are able to procure it from friends or relatives (Berger, 1977).

Use of Central Arctic Herd (CAH) caribou also occurs in communities other than Kaktovik. Residents of Nuiqsut, and some Barrow residents who travel to Nuiqsut for hunting, harvest caribou from both the CAH and Teshekpuk herd. The portion of the harvest from these respective herds is unknown (S. Pedersen, ADF&G, unpublished data). Residents from Anaktuvuk Pass harvest several hundred caribou annually from the Western Arctic herd, as well as some CAH animals. Through the harvest composition from each herd is not well known, it is believed that Anaktuvuk Pass residents rely primarily on Western Arctic herd animals, and harvest from the CAH is less than 100 animals (K. R. Whitten, ADF&G, unpublished data).

~ **Table II-5.**--Estimated Canadian harvest from the Porcupine caribou herd, 1963-86. ~

[Most of the estimates were obtained by conservation officers or biologists in the communities or by door-to-door interviews. Many figures are probably underestimates and reflect problems inherent in the data-collection methods. NA, not available]

Harvest year (12 mo)	Yukon Territory: Old Crow	Yukon Territory: Dempster South[1]	Yukon Territory: Total	Northwest Territories: Akla-vik	Northwest Territories: Fort Mc-Pherson	Northwest Territories: Total	Total Canada
1963-64	706	0	706	621	395	1,016	1,722
1964-65	769	0	769	774	492	1,266	2,035
1965-66	?	0	?	647	479	1,126	?
1966-67	592	0	592	477	479	956	1,548
1967-68	590	0	590	996	1,130	2,126	2,716
1968-69	557	0	557	541	742	1,283	1,840
1969-70	478	300+	778+	465	363	828	1,306
1970-71	450	300+	750	414	723	1,137	1,887
1971-72	485	250	735	616	250	866	1,601
1972-73	297	61	358	NA	NA	1,331	NA
1973-74	607	184	791	1,300	500	2,000	2,791
1974-75	382	24	406	NA	NA	1,331	NA
1975-76	785	29	814	NA	NA	NA	NA
1976-77	NA	239	NA	NA	NA	NA	NA
1977-78	537	29	556	114	350	564	1,120
1978-79	900	11	911	187	12	199	1,110
1979-80	800	44	844	147	168	315	1,159
1980-81	558	107	665	9	40	120	785
1981-82	1,000	42	1,115	300	1,500	1,800	2,915
1982-83	500	29	529	500	1,141	1,641	1,670
1983-84	1,000	100	1,100	NA	584	584	1,684
1984-85	250	37	287	----1,500----		1,700	1,987
1985-86	349	543	892	---1,570---		1,570	2,462

[1]From Dempster Highway game check station. According to Don Russell (Canadian Wildlife Service, Whitehorse, Yukon Territory, March 1987), only a small proportion of this harvest is considered to be subsistence harvest.

Snow Geese

Birds from the Western Arctic snow geese population occur as fall migrants on the 1002 area. The major subsistence use of this species is in the coastal areas of the Northwest Territories of Canada near the major nesting colonies and fall staging areas, and along the Mackenzie River, a major spring and fall migration corridor. Subsistence harvest in spring and fall is important to the coastal communities of Aklavik, Inuvik, Tuktoyaktuk, Sachs Harbor, and Paulatuk, and the Mackenzie River communities of Fort McPherson, Fort Good Hope, Arctic Red River, Norman Wells, and Fort Norman (T. W. Barry and W. Spencer, Canadian Wildlife Service, unpublished data). Scanty data are available from some of these communities (table II-6). Snow geese do not appear to be an important subsistence resource in the northern Yukon community of Old Crow because they are not easily accessible there (J. Hawkings, Canadian Wildlife Service, unpublished data).

~ **Table II-6.**—Spring and fall subsistence harvest of snow geese in the Northwest Territories, Canada.

[Data available intermittently for 1967-85. From Barry (1985)]~

Community	1967 Spring	1967 Fall	1968 Spring	1968 Fall	1978 Spring	1985 Spring & Fall
Tuktoyaktuk.........	2,162	1,158	---	---	4,348	3,500
Aklavik/Kendall Island[1].............	144	280	---	845	---	---
Sachs Harbor.....	1,055	45	---	---	---	---
Paulatuk...............	---	---	335	56	---	---
Fort McPherson .	---	---	4	10	---	---
Arctic Red River..................	---	---	0	0	---	---

[1] Kendall Island is a hunting camp primarily used by Aklavik residents.

Polar Bears

In addition to harvest in or near the 1002 area by residents of Kaktovik, the Beaufort Sea population of polar bears is harvested by Inupiat Eskimos of other North Slope communities in Alaska as well as by communities in the coastal areas of Canada's Northwest Territories. These communities include Nuiqsut, Barrow, Wainwright, and probably Point Lay in Alaska, and Tuktoyaktuk, Aklavik, and Inuvik in the Northwest Territories. Sachs Harbor and Paulatuk, Northwest Territories, may harvest a small percent of their kill from bears of the Beaufort Sea stock, according to current satellite telemetry data (S. L. Schliebe, FWS, unpublished data).

~ **Table II-7.**—Alaska Beaufort Sea harvest of polar bears, 1980-87. ~

[From Schliebe (1987). Harvest year is July 1-June 30. 1986-87 data through January 1987. Only part of the Port Lay harvest is believed to be derived from Beaufort Sea stock]

Year............	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87
Kaktovik.......	23	1	1	1	2	3	1
Nuiqsut........	1	0	0	0	0	2	1
Barrow.........	6	4	13	27	31	12	14
Wainwright ..	3	16	16	32	18	4	6
Point Lay.....	1	4	1	9	0	7	0

Harvest estimates for communities in Alaska utilizing the Beaufort Sea stock of bears are shown for the years 1980 through January 1987 (table II-7). Harvest in Canada is according to a quota system. Communities of Inuvik, Aklavik, and Tuktoyaktuk have a combined quota of 32 polar bears. The combined quota for communities of Paulatuk and Sachs Harbor, of which only a portion apply to the Beaufort Sea stock, is 39 (Taylor and others, 1987). Polar bears represent a substantial component of the cultural and economic base of the Inuit people of the Canadian Western Arctic. Hides have direct economic value, and in recent years the principal motivation for polar bear hunting has been the sale of hides (Stirling and others, 1975). Fur exports are an important source of cash in the economies of Mackenzie and "rim" villages. According to Brackel (1977), marine furs (white fox, polar bear, and ringed seal) provided 5 percent and 19 percent of the earned income in the Mackenzie and "rim" economies, respectively.

Whales

Inupiat residents of the community of Nuiqsut also harvest bowhead and beluga whales near the 1002 area. Although the community itself is not located on the coast, marine mammals are an important subsistence resource. Nuiqsut hunters in company with Kaktovik hunters sometimes hunt bowhead and beluga whales. Bowhead whaling usually occurs between late August and early October, the exact timing and length of the season depending on ice and weather conditions. The season may last between 2 weeks and 2 months. The bowhead is shared extensively with other North Slope communities and people as far away as Fairbanks and Anchorage. Whale baleen is bartered in traditional networks and is used in making traditional handicrafts (U.S. Minerals Management Service, 1986).

Beluga whales are harvested during the period of open water and are taken incidentally to the bowhead whale harvest in Nuiqsut (U.S. Minerals Management Service, 1986). Communities of the Mackenzie River delta (Inuvik, Aklavik, and Tuktoyaktuk) and Amundsen Gulf (Sachs Harbour, Holman, and Paulatuk), are also partially dependent on subsistence uses of beluga whales. Beluga whales are present in the Beaufort Sea north of the Arctic Refuge during spring and fall migrations where they generally follow the pack ice edge (Seaman and others, 1981). They are harvested in the Mackenzie part of the Beaufort Sea, where whales enter warmer waters of the bays near the Mackenzie River delta during early July and remain until the middle of August. Whaling for beluga near the Mackenzie delta is not regulated, and approximately 120 whales are taken per year (Brackel, 1977). Whale products are primarily used locally, although some products such as muktuk are occasionally sold. Beluga muktuk is often shared with relatives in Kaktovik and other Alaskan and Canadian villages. A variation in diet, and the sport and recreation of the hunt, with opportunities for socializing, are all important factors in whaling (Brackel, 1977).

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. Leases on 119 tracts totaling 592,142 acres of State lands west of the Canning River were offered January 27, 1987. Bids were received by the State on 26 tracts totaling 100,632 acres. ~

~ The Kaktovik Inupiat Corporation (KIC) has statutory entitlement to ownership of 92,160 surface acres within the Arctic Refuge north of the 1002 area. Subsurface ownership of these lands was conveyed to the Arctic Slope Regional Corporation (ASRC) by the United States under the terms of an August 9, 1983, agreement. The KIC/ASRC holdings are private lands; however, in accordance with section 22(g) of the ANCSA, these lands remain subject to the laws and regulations governing development of the Arctic Refuge. As such, oil and gas leasing and development cannot occur on the KIC/ASRC lands until authorized by an Act of the Congress (Section 1003 of ANILCA). ~

Submerged lands beneath the coastal lagoons in the area between the mainland and the offshore barrier islands from Brownlow Point to 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 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 from 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 are scattered throughout the 1002 area, and are largely traditional use sites, such as campsites.

NATIVE ALLOTMENTS

~ Within the 1002 area, the Federal Government has begun to process toward conveyances some 25 applications, involving 34 parcels for Native allotments. None of these parcels had been issued a certificate of allotment as of January 1987. In total, these applications cover approximately 2,315 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 government or its lessee would then have the right to enter and use the lands for the development of the reserved minerals, subject to the duty to pay the allotment owner 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, an allotment is not granted.

INDUSTRIAL USE

There has been no industrial land use of the 1002 area 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. The camp 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 about 1/2 mile from the present village and is largely self-contained, functioning as an entity separate from the village. As many as 70 DEW Line employees live at the site, most of whom are hired from outside the North Slope. In 1986 the site employed three Inupiat and two non-Inupiat residents of Kaktovik. Modernization of the Bar Main DEW Line site started in 1986 when a new pad and tower were constructed. Testing new equipment will run through 1988, after which minor facility modification may be necessary. The Bar Main DEW Line site will continue to be staffed for at least the next 20 years. ~

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. Advanced communications technology resulted in their deactivation in 1963. The lands (approximately 876 acres) formerly withdrawn for the two sites 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, and the village of Kaktovik. Two corporations, ASRC and 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 subsurface rights for the entire 5.6-million-acre area 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 that were transferred under the provisions of ANCSA and ANILCA.

~ Employment in the NSB increased from 977 jobs to 5,598 between 1970 and 1979. By September 1985, 9,234 workers were employed in the North Slope Borough; 86 percent of this employment was in the following major categories: mining, including oil development, 4,150 (45 percent); State and local government, 1,409 (15 percent); construction, 1,258 (14 percent); and services, 1,110 (12 percent). The remaining 14 percent were scattered in other smaller employment sectors (NSB Planning Department, 1986). The majority of jobs, principally at Prudhoe Bay and the military enclaves, are held by non-Native workers. However, participation by Inupiats in the labor market has been encouraged through NSB and ASRC programs. ~

The economy recently made a major transition from largely subsistence to mixed subsistence and cash. Through local-hire policies, the NSB has provided 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 DEW radar sites along the coast). Today, the production of oil at Prudhoe Bay is the basic economic influence.

The State-approved NSB Coastal Management Program was described under "Coastal and Marine Environment." Of the 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 will provide 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 and related facilities,

Cooperate and coordinate with private development,

Improve energy supply for local communities, and

Develop local energy resources.

PUBLIC SERVICES AND FACILITIES

~ Existing public services and facilities are described in the semiannual economic profile (NSB Planning Department, 1986). New oil and gas facilities assumed to result from existing offshore Federal leasing are described in scenarios for oil development in the Beaufort Sea (Roberts, 1987). ~

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 is 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, and 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 been abandoned.

Marine transportation is controlled by ice conditions and shallow nearshore waters. Major port facilities 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 snowmachines in winter.

The Trans-Alaska Pipeline System (TAPS) 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 assumption 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, 1987).

~ 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 was 45 students as of January 1987. ~

Kaktovik has a health clinic staffed by a health aide. Two NSB Department of Public Safety Officers are stationed 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 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 on the 1002 area--mostly scatters of lithic debris from the manufacture, maintenance, and use of stone tools--are not yet datable but may be considerably older.

Near the 1002 area sites have been dated to be as old as 6,000 years (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.

Archeological sites may occur almost anywhere in the 1002 area. However, some areas are much more likely to have sites, especially coastal areas and barrier islands. Most identified sites consist of the remains of sod houses, log cabins, burials, caches, lookout towers, and related features. Older sites may be 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 and would have been natural travel routes between the coast and the foothills. Sites known from the river courses are chiefly tent rings, although two interior sites have sod houses. Points of particular possibility 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 contain archeological sites throughout most of northern Alaska and Canada. There are relatively few such locations on the 1002 area, and sites that have been 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 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 is almost exclusively by aircraft and is costly. Nonetheless, recreational use of the 1002 area is slowly increasing as it becomes better known and as scheduled airline services to Barter Island improve.

The most common forms of recreation area are hunting, backpacking, and float trips on 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 pursue several of these activities. Kaktovik residents also engage in snowmobiling.

~ In 1986, 14 hunting guides operated on the refuge, though none guided on the 1002 area. Another 9 recreational guides conducted group float or backpack trips on the refuge. One or two guides operated recreational trips, at least in part, on the 1002 area during the past 5 years. 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 to sightsee or en route to other parts of 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 arctic ecosystems in North America. Approximately 8 million acres of the refuge is designated as wilderness by ANILCA section 702(3), and adjoins the 1002 area on the south and east, including the coastal plain from the eastern 1002 area boundary to the Canadian border.

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 meets these criteria (Garner and Reynolds, 1986). 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.

~ The 1002 area is the most biologically productive part of the Arctic Refuge for wildlife and is the center of wildlife activity. It serves as an important calving ground for the Porcupine caribou herd; it contains a high percentage of the refuge's observed muskoxen range; it is an important fall staging area for lesser snow geese; it provides nesting habitat for waterfowl and shorebirds; and it is frequently used by denning polar bears from the Beaufort Sea population. Migrating caribou and the postcalving caribou aggregation offer an extraordinary 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, accents the abruptness and rugged beauty of the area.

~ Although the esthetic value of the 1002 area had been temporarily reduced as a result of seismic exploration, the area remains noteworthy and its wilderness values have not been diminished. 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, 1987). ~

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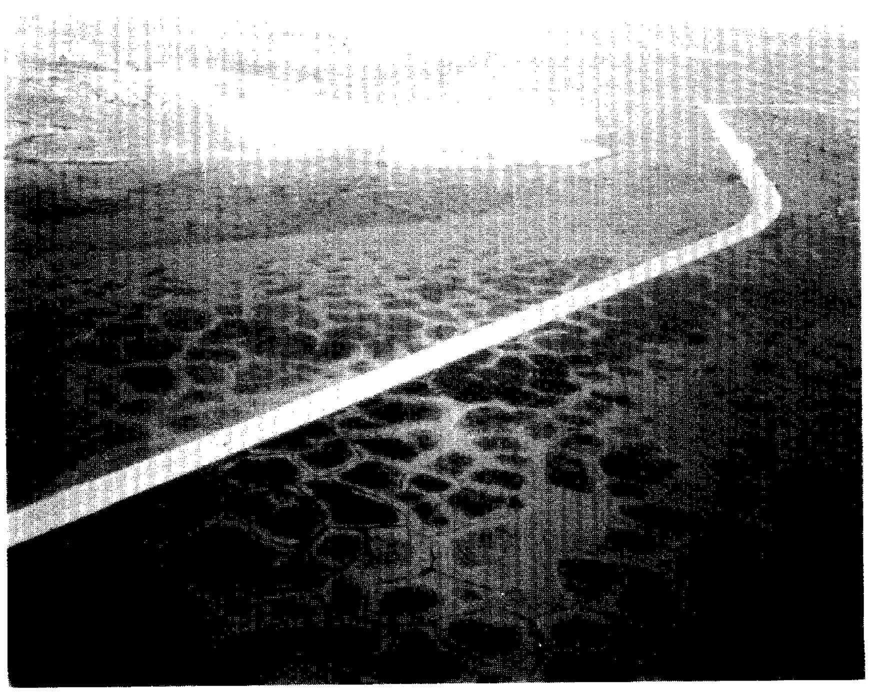
BRAIDED RIVER OF THE COASTAL PLAIN



LOW-CENTERED POLYGONS

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 1,336 line miles of seismic surveys (approximately a 3x6-mile grid) conducted by industry and the Department of the Interior. Although all seismic data were collected by industry, the analyses presented here are based on interpretations of that information 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 beneath the surface of the 1002 area, without reference to its recoverability; and fourth, the possibility of recovering these potential resources is assessed by including technological and economic considerations.

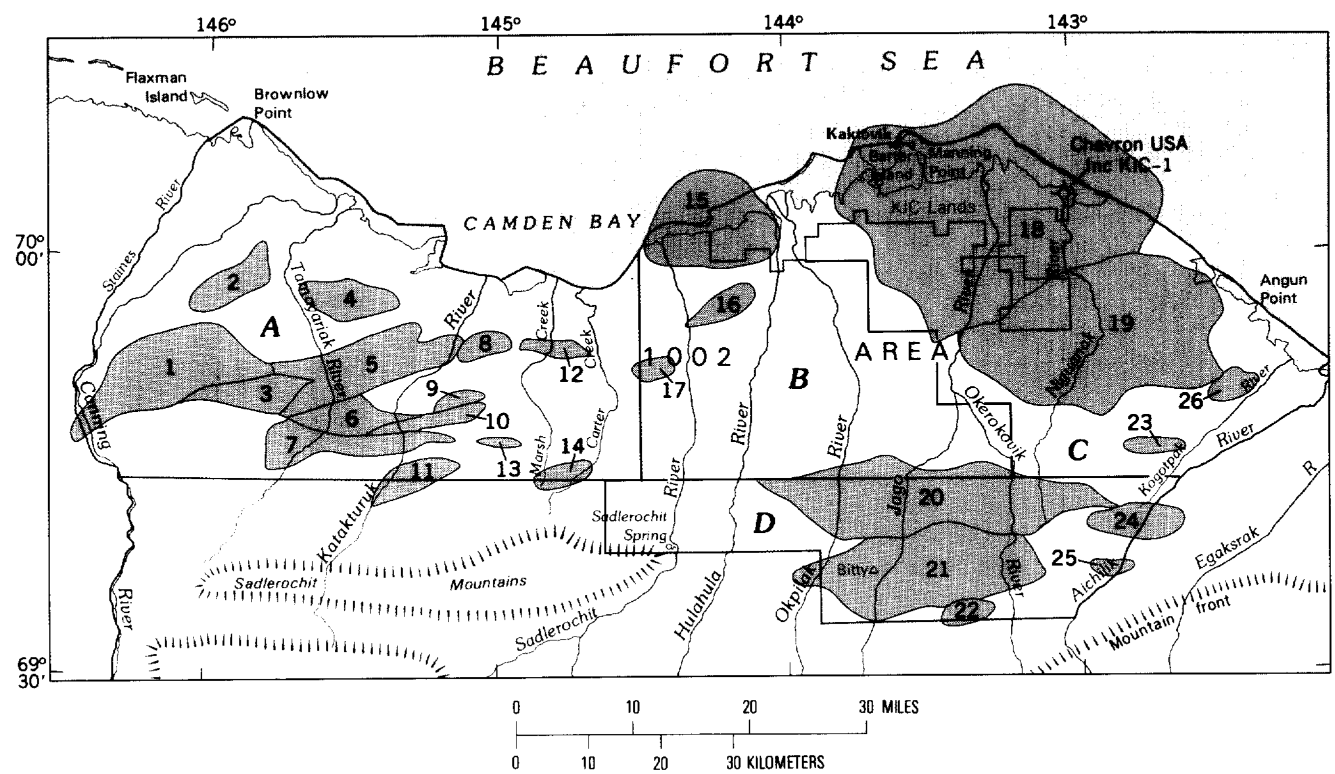


Figure III-1.--Seismically mapped prospects (1-26) and resource blocks (A-D) in the 1002 area. (Prepared by the Bureau of Land Management.)

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 in-place estimates made in this study, called the mean in-place estimate, is 13.8 BBO and 31.3 TCFG in-place.

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 petroleum engineering and economic considerations, resulting in estimates of economically recoverable resources. If there is economically recoverable oil present in the 1002 area (fields of more than 440 million barrels of oil, the chance of which is estimated to be about 19 percent), it is estimated that there is a 95-percent chance for more than 0.6 BBO and a 5-percent chance for more than 9.2 BBO recoverable in the area as a whole. The average of all the estimates of the conditional economically recoverable resources, the mean, is 3.2 BBO.

~ The statement that there is a 19-percent chance of finding recoverable oil in the 1002 area needs to be interpreted in the context of past experience in oil exploration and resource assessment. Generally speaking, the chance of oil's being present will be lower, the smaller the unexplored area being considered. The 19-percent chance for the 1.5-million-acre 1002 area thus indicates a very high potential when compared to the 27-percent chance for the 37-million-acre Navarin Basin or the 22-percent chance for the 70-million-acre St. George Basin (table III-1). Furthermore, the chance of finding a recoverable field will be lower, the greater the minimum economic field size. This occurs because, as past discovery statistics show, the number of fields of a given size is much lower for larger fields. There are fewer 1-billion-barrel fields than 100-million-barrel fields. Because of the high cost of operations in the Arctic, the minimum economic field size for the 1002 area is estimated to be 440 million barrels, an amount much higher than for areas in the lower 48 States. Despite this high threshold and the small acreage involved, the chance of finding a recoverable field in the 1002 area is 19 percent. This is an exceptionally high potential for oil and gas. ~

Gas was not included in the calculation of economically recoverable resources. Gas resources are unlikely to be economic in the 30-year time period being considered. Nevertheless, the gas resource estimated to be in-place is considerable, and would represent a major addition to the Nation's gas resources. At some time in the future, this gas resource could become economic and benefit the Nation.

Table III-1.--Estimates of undiscovered, conditional, economically recoverable oil resources in the 1002 area and in Outer Continental Shelf (OCS) planning areas (unleased lands). For OCS planning areas, some of the reported marginal probabilities may be based on the probability of occurrence of commercial gas accumulations. For the 1002 area, only oil was considered.

[In billions of barrels. Data for OCS resources from Cooke (1985). MP_{HC}, the probability that economically recoverable oil resources occur somewhere in the area.]

Planning area	95-percent case	Mean case	5-percent case	MP_{HC}
1002 area	0.61	3.23	9.24	0.19
Central Gulf of Mexico	.95	2.66	4.97	1.00
Western Gulf of Mexico	.55	1.83	3.49	1.00
Eastern Gulf of Mexico	.03	.36	1.48	.99
Southern California	.58	1.22	2.01	1.00
Northern California	.15	.42	.76	.60
Central California	.18	.56	1.01	.65
Washington-Oregon	.04	.18	.54	.20
South Atlantic Ocean	.34	.82	1.46	.25
Mid-Atlantic Ocean	.07	.23	.47	1.00
North Atlantic Ocean	.18	.35	.54	.30
Florida Straits	.01	.04	.12	.11
Navarin Basin	1.81	3.28	5.09	.27
Beaufort Sea	.21	1.18	3.07	.70
St. George Basin	.37	1.12	1.98	.22
Chukchi Sea	.96	2.68	4.88	.20
Gulf of Alaska	.12	.49	.86	.08
North Aleutian Basin	.08	.36	.76	.20
Norton Basin	.05	.28	1.02	.12
Kodiak	.04	.15	.26	.05
Hope Basin	.13	.17	.40	.02
Shumagin	.05	.05	.09	.03
Cook Inlet	.03	.18	.40	.04

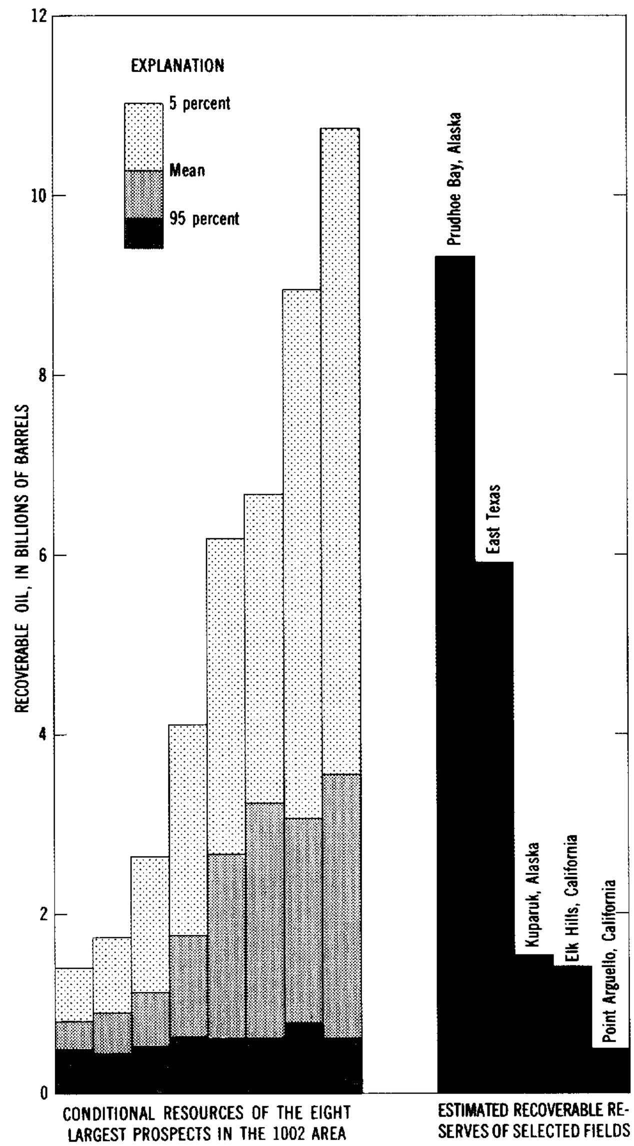
~ One way to assess the oil potential of an area is to compare estimates of the amount of oil in that area with the estimates for other areas. Table III-1 shows the conditional economically recoverable resource estimates for the 1002 area and for the Outer Continental Shelf planning areas. The table also shows the marginal probability (MP_{HC}) that economically recoverable resources exist in each area--in other words, the probability that the "condition" on which the conditional resources are based is true. If the conditional resource estimates are adjusted for their respective marginal probabilities, the 1002 area ranks sixth out of all the areas, with three of the higher five already in production. Consequently, these estimates show that the 1002 area is one of the most outstanding prospective oil and gas areas remaining in the United States. ~

An area's potential can also be assessed by examining the individual prospects identified within the area. Figure III-2 shows the conditional resource estimates for the eight largest 1002 prospects in comparison with the largest known fields in the United States. If recoverable resources are present, the two largest prospects each have a 5-percent chance of at least equaling the size of Prudhoe Bay; the next two largest prospects each have a 5-percent chance of rivaling the East Texas field; and the next four each have a 5-percent chance of exceeding fields such as Kuparuk, Elk Hills, and Point Arguello. The probability that any one of these prospects has economically recoverable resources is less than the overall area-wide probability of 19 percent. Although the chance of discovering a field of 10 billion barrels, or even 1 billion barrels, is small, the chance is far greater in the 1002 area than in other onshore areas of the United States. Such chances of an enormous discovery indicate a very attractive area for oil exploration. For perspective, in 1982, 1,402 new-field discoveries were reported for the United States, but only 652 million barrels of hydrocarbon liquids were discovered in the new fields.

SUMMARY OF METHODS

Methods used in estimating potential in-place and recoverable oil and gas resources in the 1002 area rely on two related techniques using similar components of the 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 taken to ensure consistent data treatment, honoring information from the geologic studies.

Generally, the assessment of in-place resources deals with prospects in the aggregate. 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. This includes both structural and stratigraphic traps. However, estimating 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 to reasonably be expected to contain commercial quantities of oil.



~ **Figure III-2.**--Conditional, economically recoverable oil resources of the eight largest prospects in the 1002 area compared with estimated ultimate recoverable reserves of five known producing fields. The recoverable resources are modified from McCaslin (1986, p. 318-319). The geologic probability of a significant oil occurrence in the eight prospects ranges from 3 to 10 percent. ~

~ The separate methods used meet specific requirements of the 1002 area study. First, assessment of the natural endowment of hydrocarbon resources is met by asssessing what is in-place, employing a broad-based view without economic constraints. Second, a site-specific evaluation of what may be a recoverable resource at a given prospect is made, taking into consideration economics, technology, and transportation under various assumptions. This recoverable estimate is then used to develop scenarios, impact assessment and national need determinations. ~

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 used in order to model the elements which determine recoverability and determine exploration, development, production, and transportation at that level.

~ Estimating either oil or gas in-place or the extent to which it is recoverable in an undrilled frontier area is difficult because of the uncertainties inherent in the process. The existence of potential hydrocarbon formations or prospects is not known with certainty prior to exploratory drilling. Information concerning the existence of potential producing fields is derived from inferences, extrapolations and subjective judgments. Geophysical data provide clues as to the existence and location of possible traps and their general dimensions, but geologic data on the quality of potential reservoir rocks are usually absent or limited. No data are available on the nature and distribution of included hydrocarbons or whether hydrocarbons are present at all. An exact prediction of resource quantities under such conditions of uncertainty is impossible because the uncertainties in the input data translate to uncertainties in the answers. ~

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 GS Bulletin 1778 (Bird and Magoon, 1987).

Sedimentary Rocks

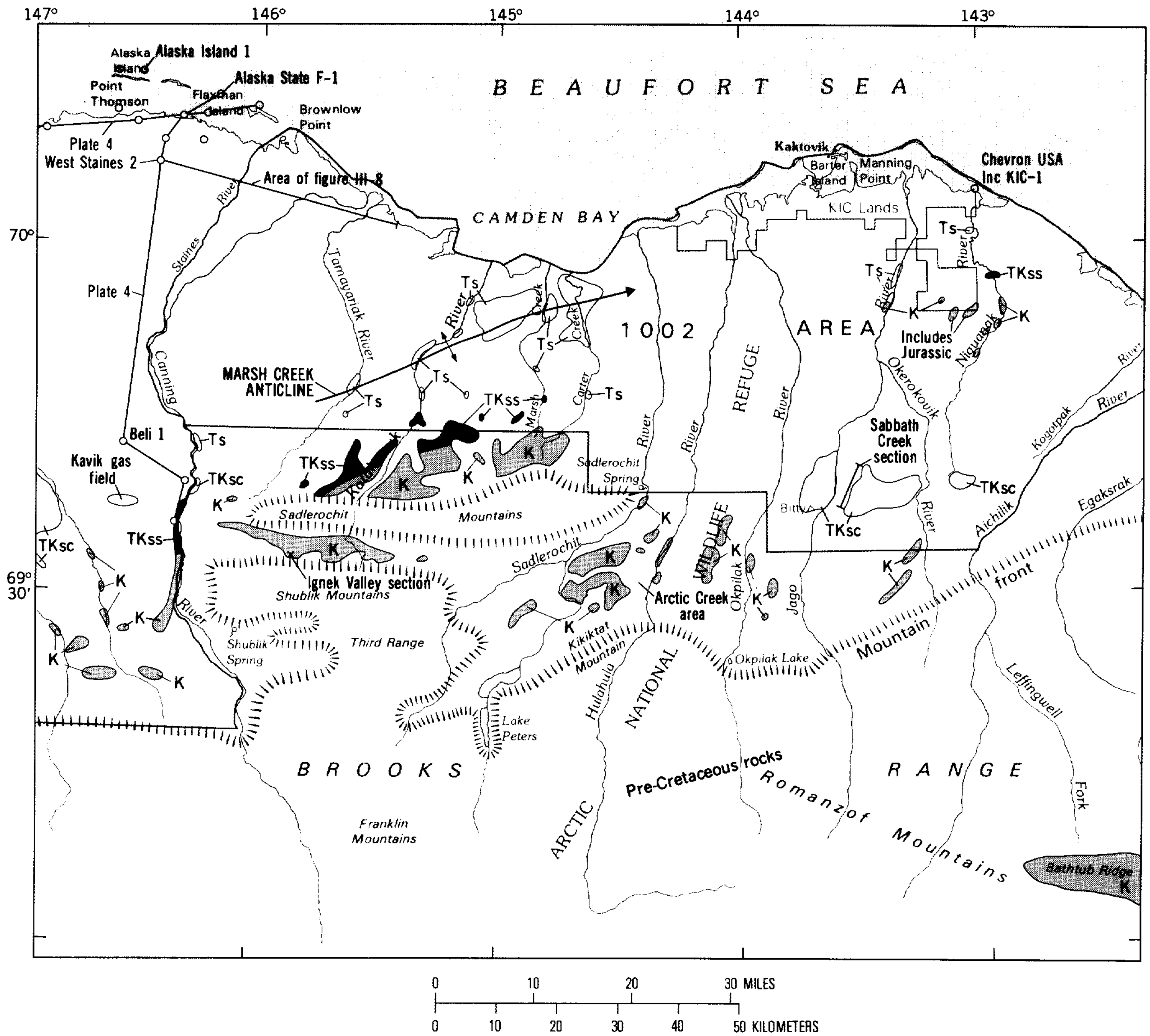
The area in and adjacent to the 1002 area is underlain by sedimentary rocks several tens of thousands of feet thick. These rocks range in age from Precambrian (greater than 570 million years old) to Quaternary (Bader and Bird, 1986). In northern Alaska, rocks prospective for petroleum (oil and gas) are 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, reservoir 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 Precambrian 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--might contain porous zones that could serve as reservoirs for oil or gas that may have been 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



EXPLANATION

Ts	Tertiary sedimentary rocks
	Paleocene and uppermost Cretaceous sedimentary rocks
TKsc	Shallow marine and nonmarine sedimentary rocks and conglomerate
TKss (black)	Deep-water marine sandstone and shale
K	Cretaceous sedimentary rocks
o	Drill hole

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. (Prepared by the U.S. Geological Survey.)

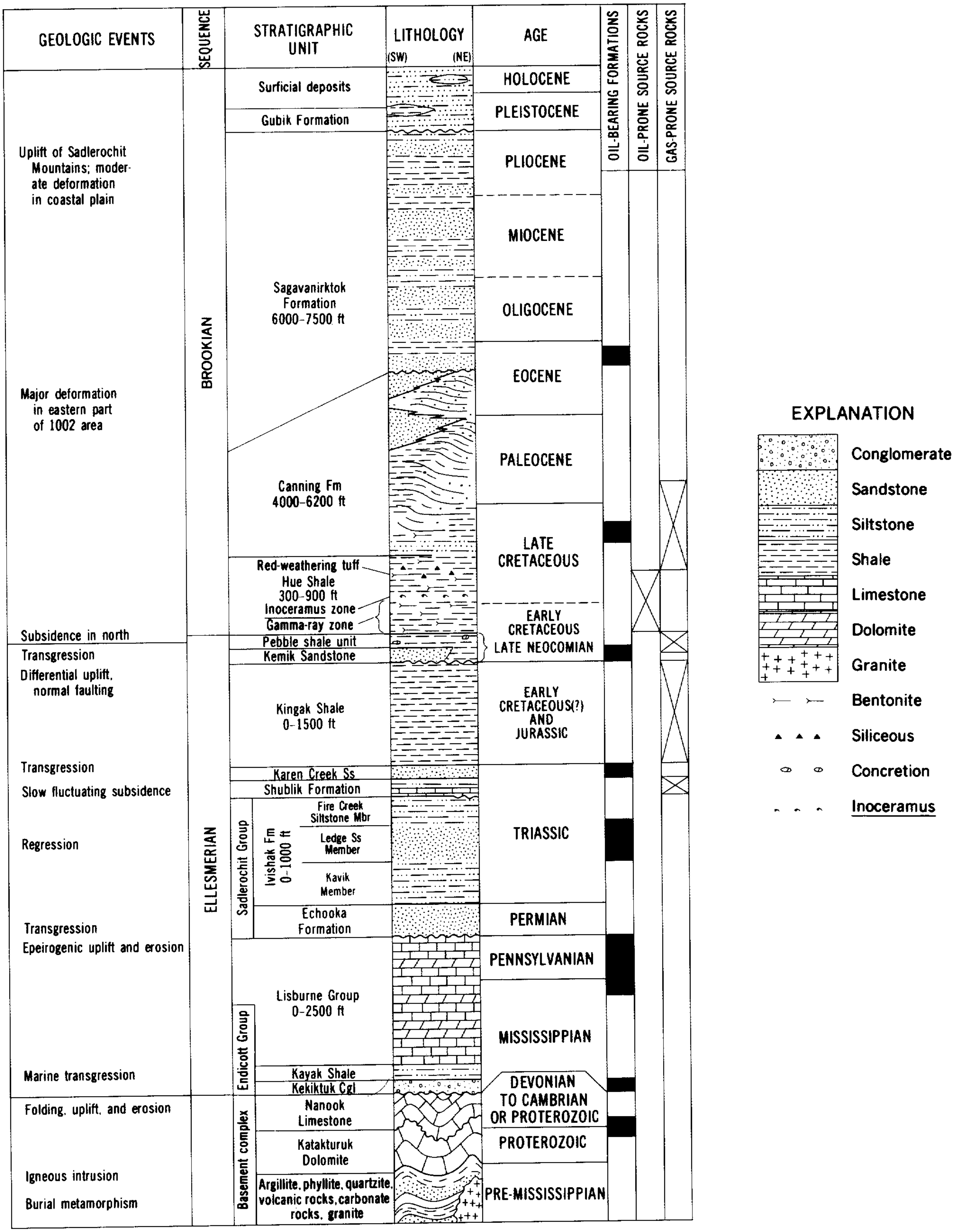


Figure III-4.--Generalized stratigraphic column for the 1002 area showing significant geologic events, oil-bearing formations west of the Arctic Refuge, and potential source rocks. The Hue Shale may range into the Paleocene in parts of this area. (Prepared by the U.S. Geological Survey.)

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.

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 the eastern and southeastern parts of the 1002 area.

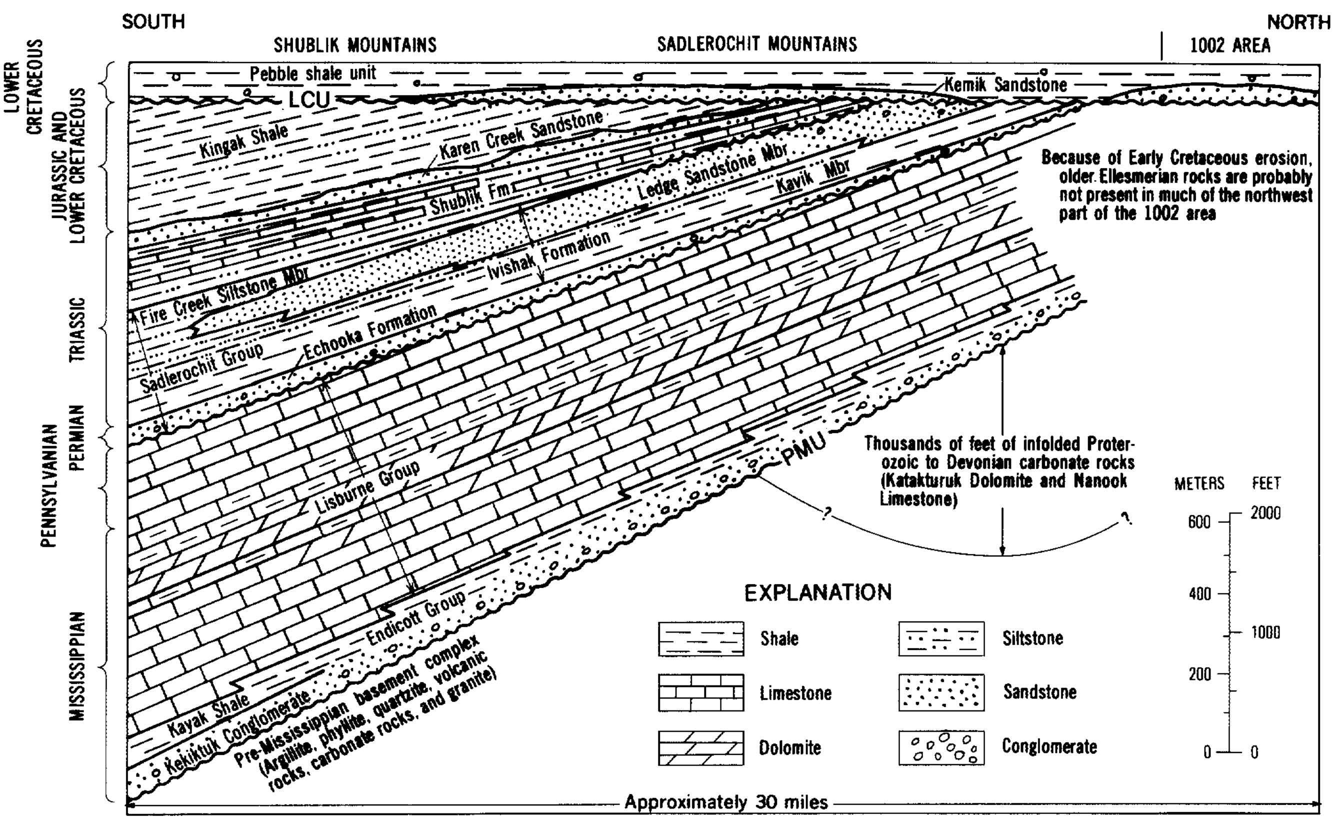


Figure III-5.--Diagrammatic section showing stratigraphic relations of the Ellesmerian sequence along the mountain front south of the 1002 area. (Prepared by the U.S. Geological Survey.)

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

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 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 (fig. III-7A).

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 a 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

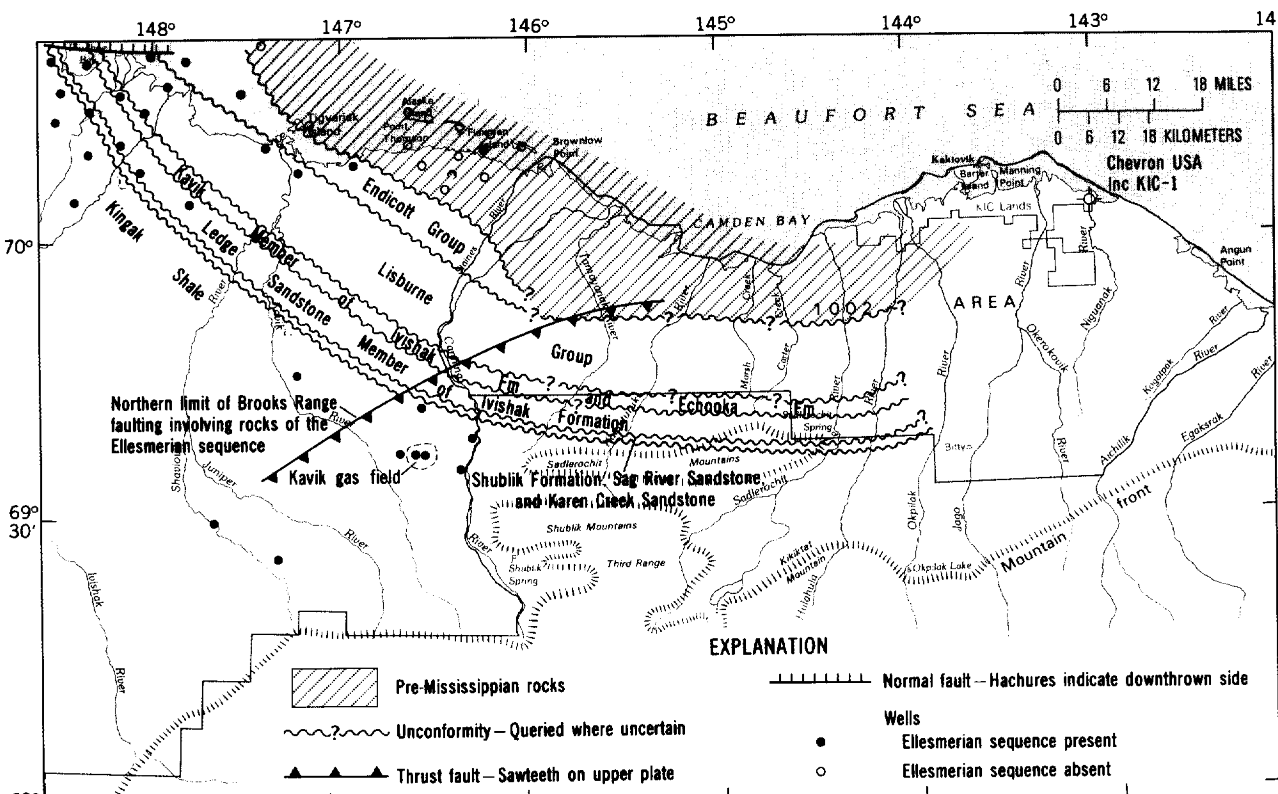


Figure III-6.—Map summarizing the northern limits of the Ellesmerian potential reservoir rocks preserved under the Lower Cretaceous unconformity. (Prepared by the U.S. Geological Survey; based on regional control.)

Member (formed from the upper offshore muds). The Ledge Member is 200 to more than 400 feet thick (fig III-7B) 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 source rock for Prudhoe Bay oil. A minor regression or increase in clastic input from the northern source resulted in deposition of widespread silt and fine sand on a broad shelf, which formed the 10- to 125-foot-thick Karen Creek Sandstone.

The basin subsided 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.

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, the Thomson sand, as much as 345 feet thick (fig. III-7C), 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

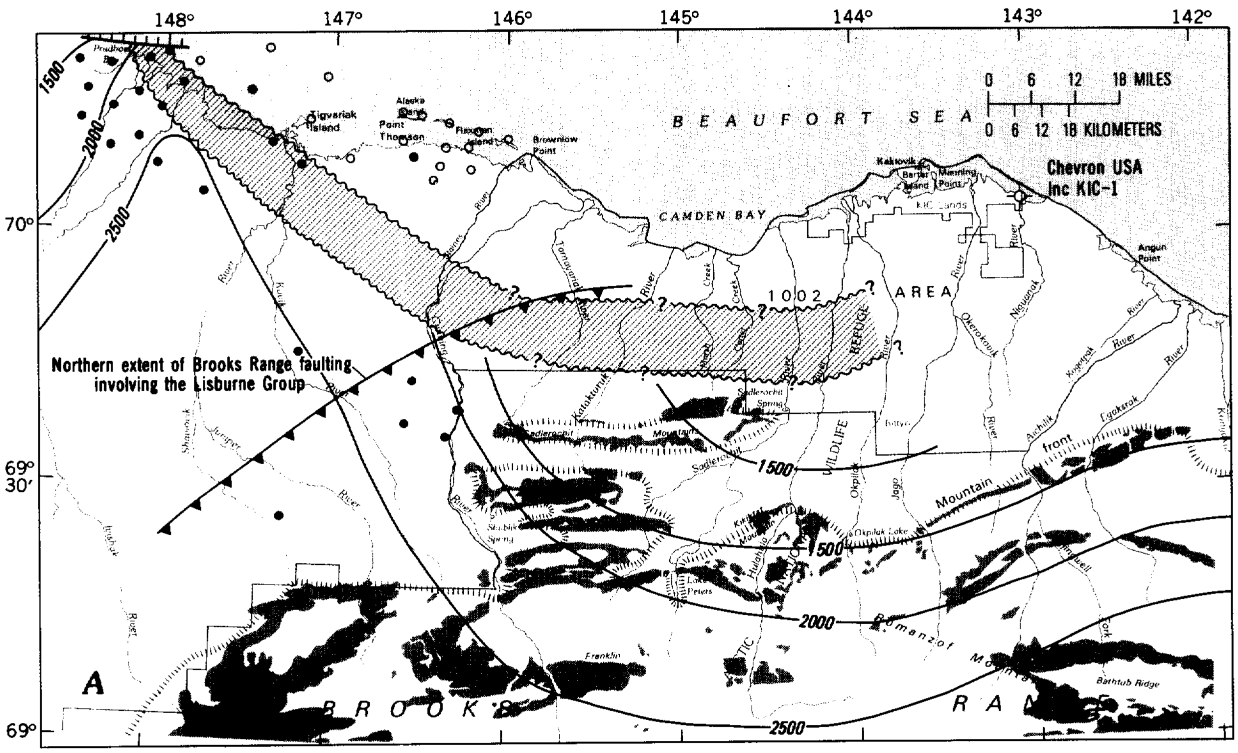
The Brookian sequence consists of thick northeasterly prograding basinal, basin-slope, and marine and nonmarine shelf deposits derived from the ancestral Brooks Range to the south and southwest. These deposits consist dominantly of shale, sandstone, conglomerate, and bentonite (consolidated volcanic 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, 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 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 source of sediment 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) that 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 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 (fig. III-3), 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 known as the Jago River Formation, probably was displaced northward by thrust faulting.


148°
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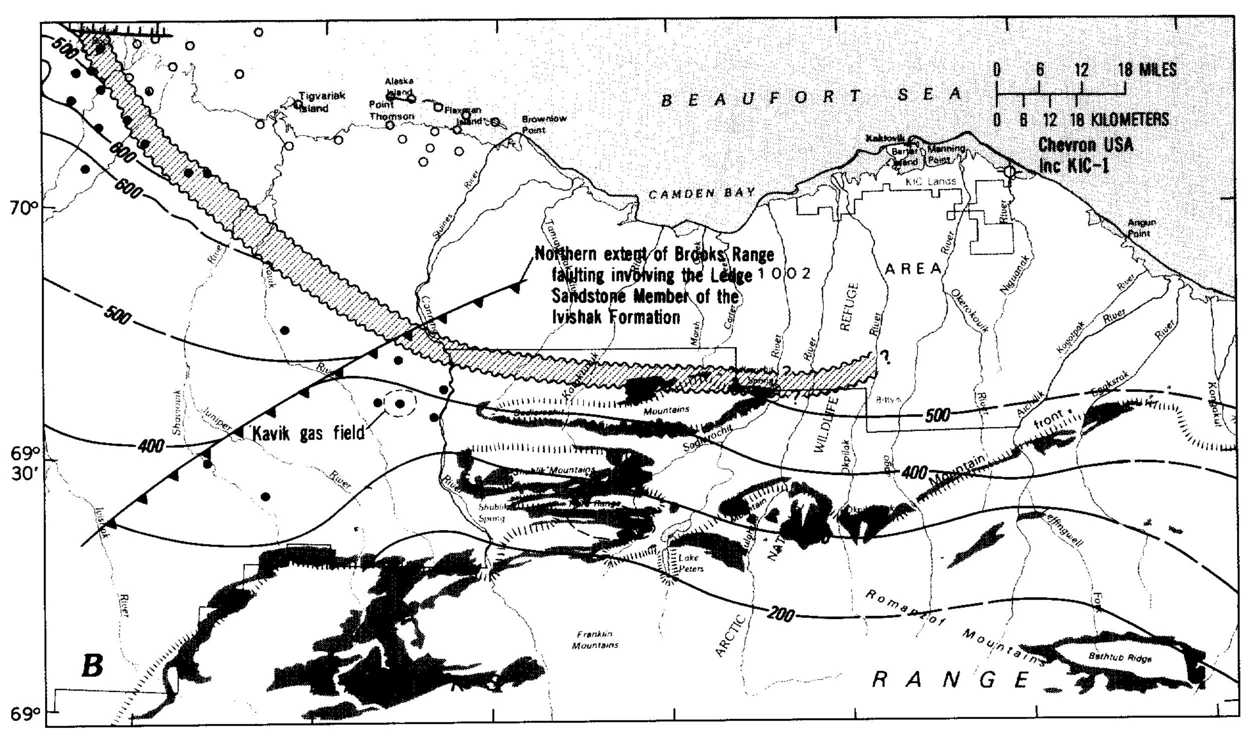
BEAUFORT SEA
Chevron USA Inc KIC-1
CAMDEN BAY
Kaktovik
Tigvariak Island
Point Thomson
Brownlow Point
Angun Point
1002 AREA
Northern extent of Brooks Range faulting involving the Lisburne Group
WILDLIFE
REFUGE
1500
2000
2500
500
Mountain
front
BROOKS
RANGE
A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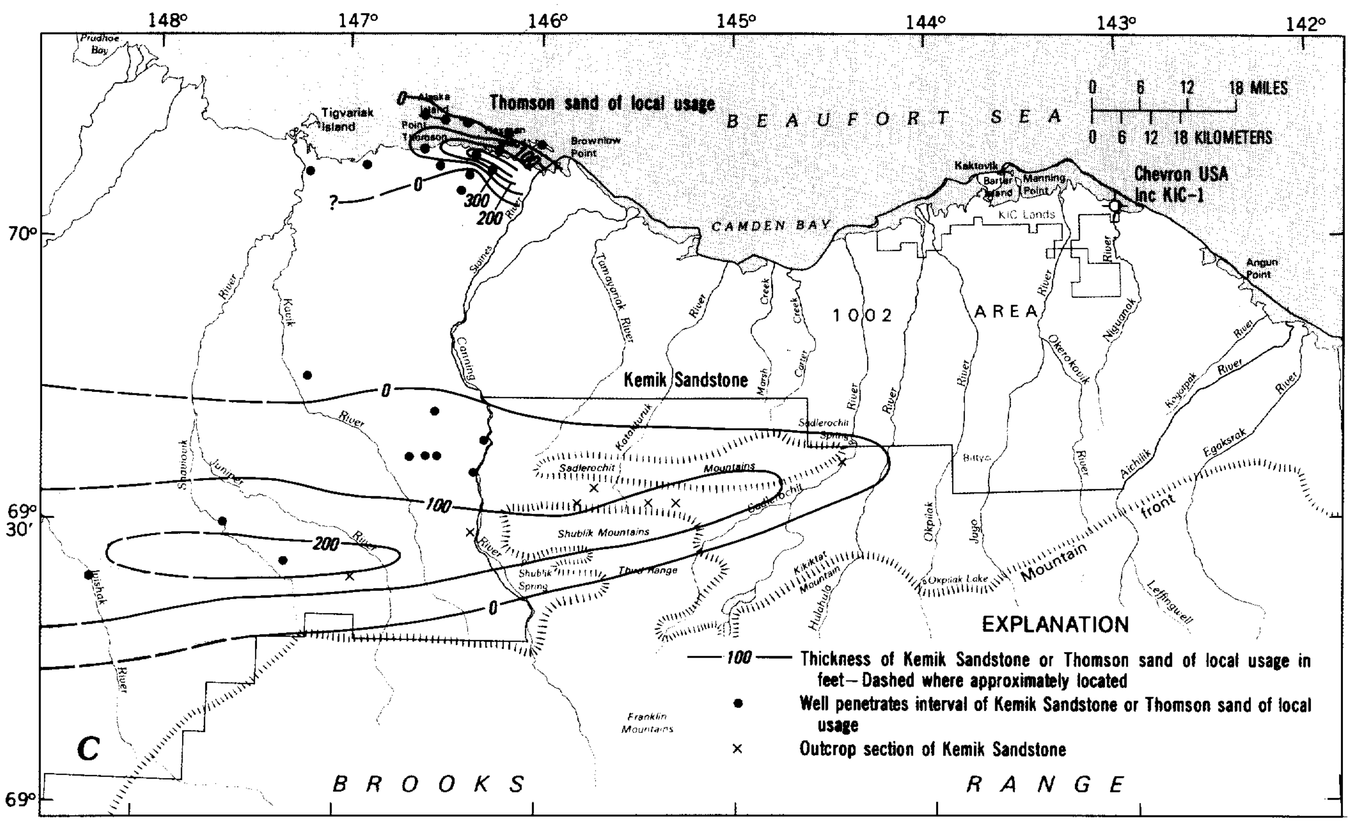
BEAUFORT SEA
Chevron USA Inc KIC-1
CAMDEN BAY
Tigvariak Island
Point Thomson
Brownlow Point
Angun Point
Northern extent of Brooks Range faulting involving the Ledge Sandstone Member of the Ivishak Formation
1002
AREA
REFUGE
WILDLIFE
Kavik gas field
500
600
400
200
ARCTIC
RANGE
B



EXPLANATION

A

- Zone of truncation of Lisburne Group by Lower Cretaceous unconformity
- Outcrop of Lisburne Group
- ?— Unconformity—Queried where uncertain
- Thrust fault—Sawteeth on upper plate
- Normal fault—Hachures indicate downthrown side
- —2000— Thickness of Lisburne Group in feet
- Wells
  - ● Lisburne Group present
  - ○ Lisburne Group absent

B

- Zone of truncation of Ledge Sandstone Member of Ivishak Formation by Lower Cretaceous unconformity
- Outcrop of Ledge Sandstone Member
- ?— Unconformity—Queried where uncertain
- Thrust fault—Sawteeth on upper plate
- Normal fault—Hachures indicate downthrown side
- —300— Thickness of Ledge Sandstone Member in feet—Dashed where approximately located
- Wells
  - ● Ledge Sandstone Member present
  - ○ Ledge Sandstone Member absent

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). (Prepared by the U.S. Geological Survey.)

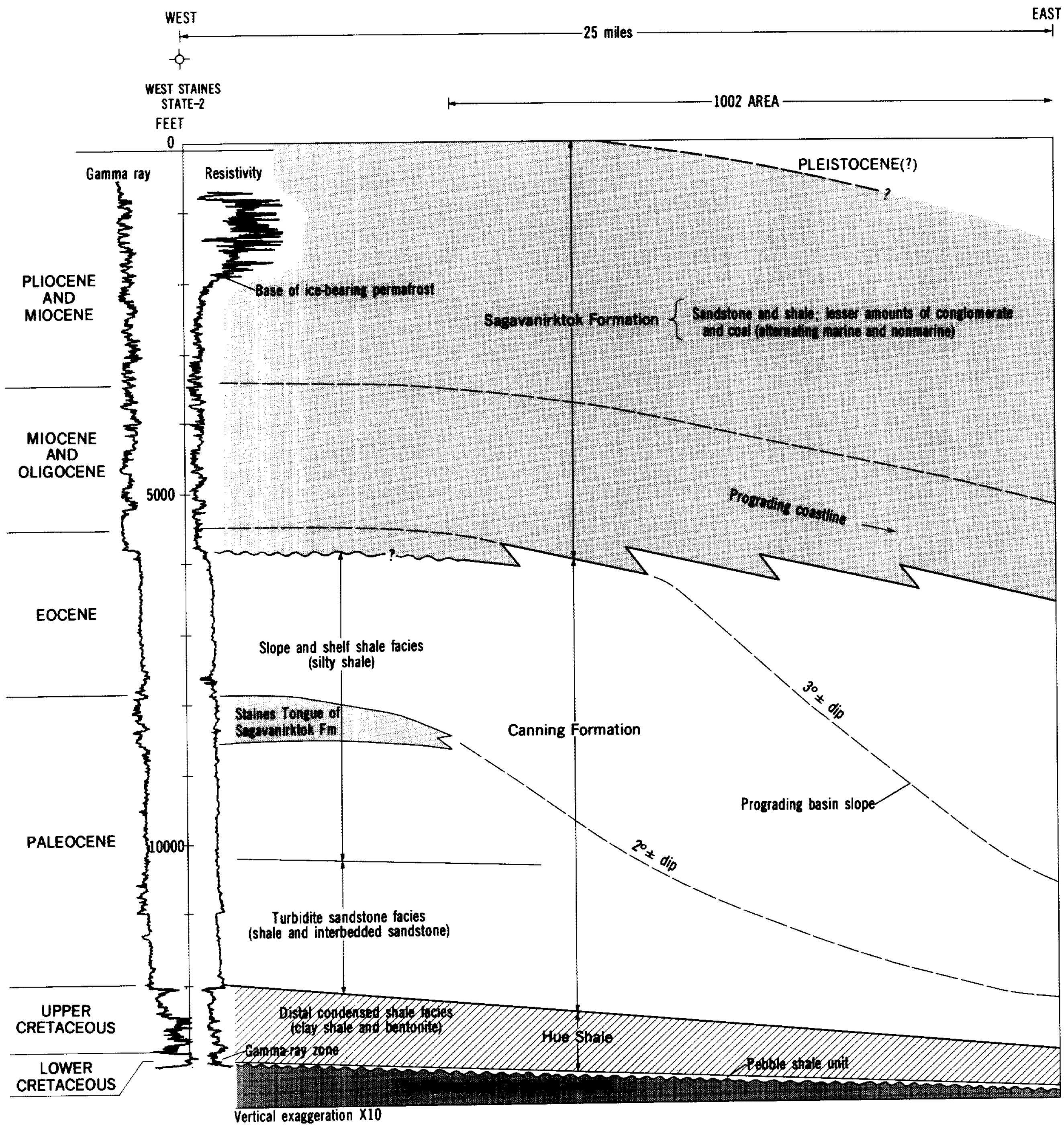


Figure III-8.--Diagrammatic section showing stratigraphic relations of the Brookian sequence between the Mobil West Staines State 2 well and the northwest corner of the 1002 area. Dashed lines represent time lines as inferred from seismic reflections. Depths on well logs are in feet. Ages based on micropaleontologic data. See figure III-3 for location of section. (Prepared by the U.S. Geological Survey.)

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, the youngest bedrock unit in the 1002 area, which 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 extensively folded and faulted. This structure 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. 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 foreland 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 north-verging thrust faults originate at depth, tend to cut through shale layers at low angles, and cut up-section more abruptly in overlying sandstone layers. 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, which was mapped over most of the area, shows several very large structural closures (fig. III-1). These closures are discussed with the various prospects or plays later.

Seismic reflections as well as outcrops indicate that Cretaceous and Paleocene rocks are generally much more deformed than either the underlying pre-Kingak or overlying post-Paleocene strata. The reason is that the Cretaceous and Paleocene rocks are mechanically weaker than the underlying pre-Kingak rocks and thus deform more plastically; they are detached from and in places separated by an unconformity from the gently folded overlying post-Paleocene section. Seismic reflections are discontinuous and very difficult, if not impossible, to map for any distance. 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. There seismic lines 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), 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 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 generation of oil and gas and the direction in which it migrated. In the 1002 area (where there is no well control), most of these data

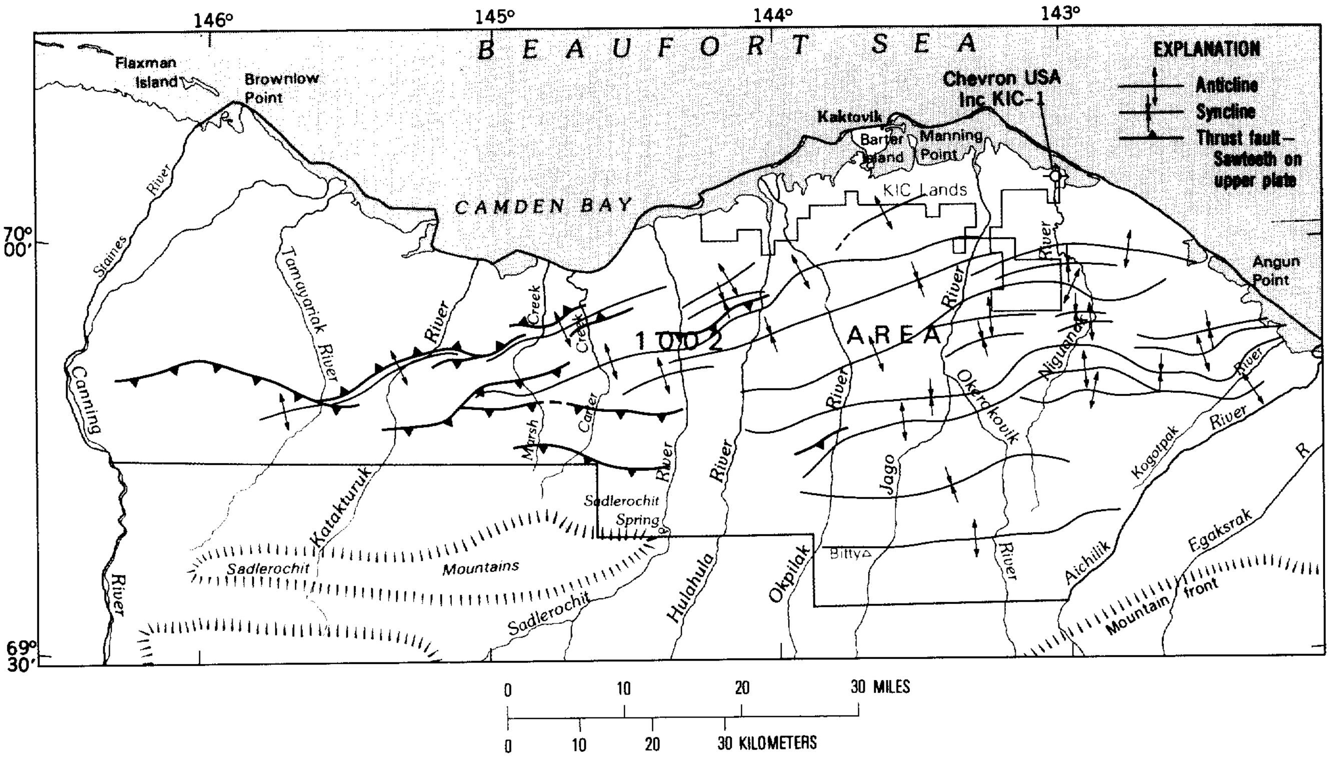


Figure III-9.—Generalized near-surface structural trends in Brookian rocks, based on seismic data. Because of structural complexity, not all features are shown, particularly in the east part of the 1002 area. (Prepared by the U.S. Geological Survey.)

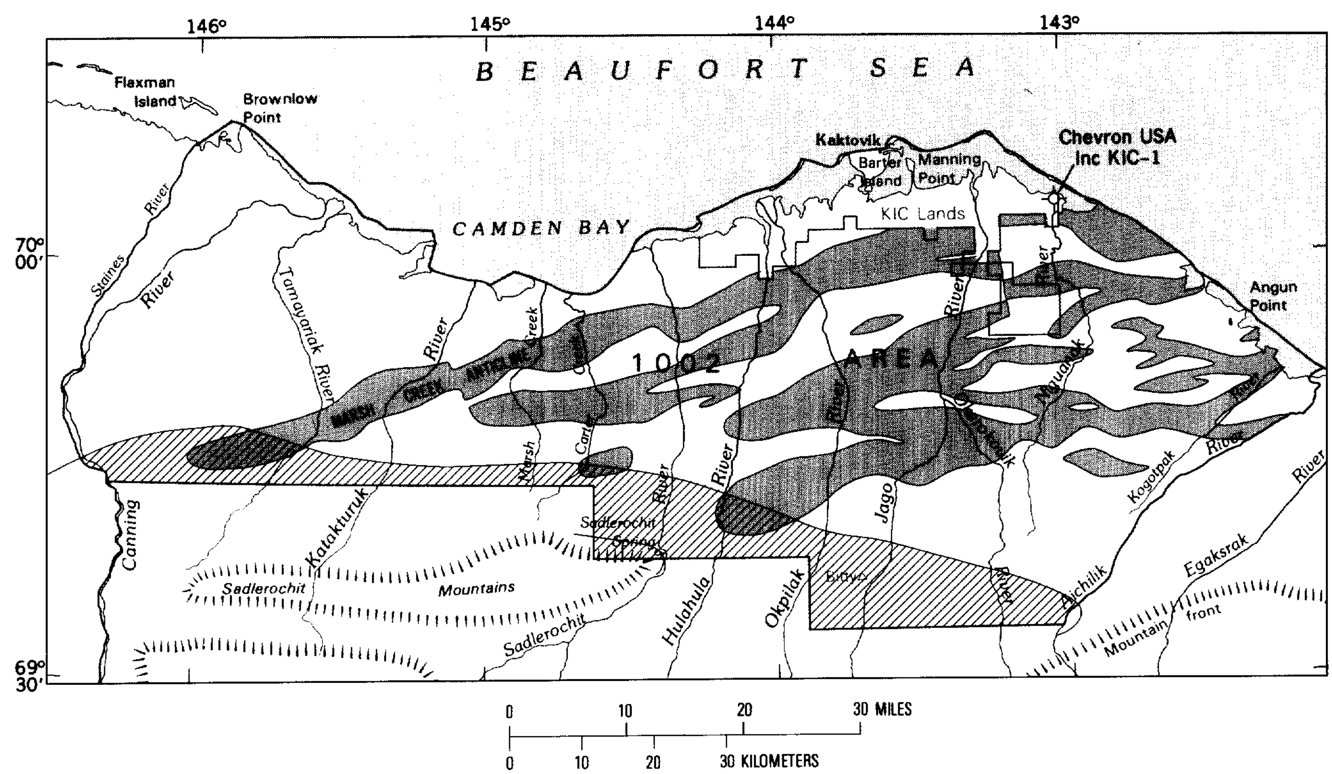


Figure III-10.—Trends of structural culminations in highly deformed Mesozoic and Tertiary rocks (shaded) and area of monoclinal north-dipping strata (line pattern) that may have petroleum potential in the 1002 area. (Prepared by the Bureau of Land Management.)

Table III-2.--Data on seismically mapped petroleum prospects in the 1002 area shown in figure III-1.

[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. Data from Bureau of Land Management, 1986.]

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	14,200	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.

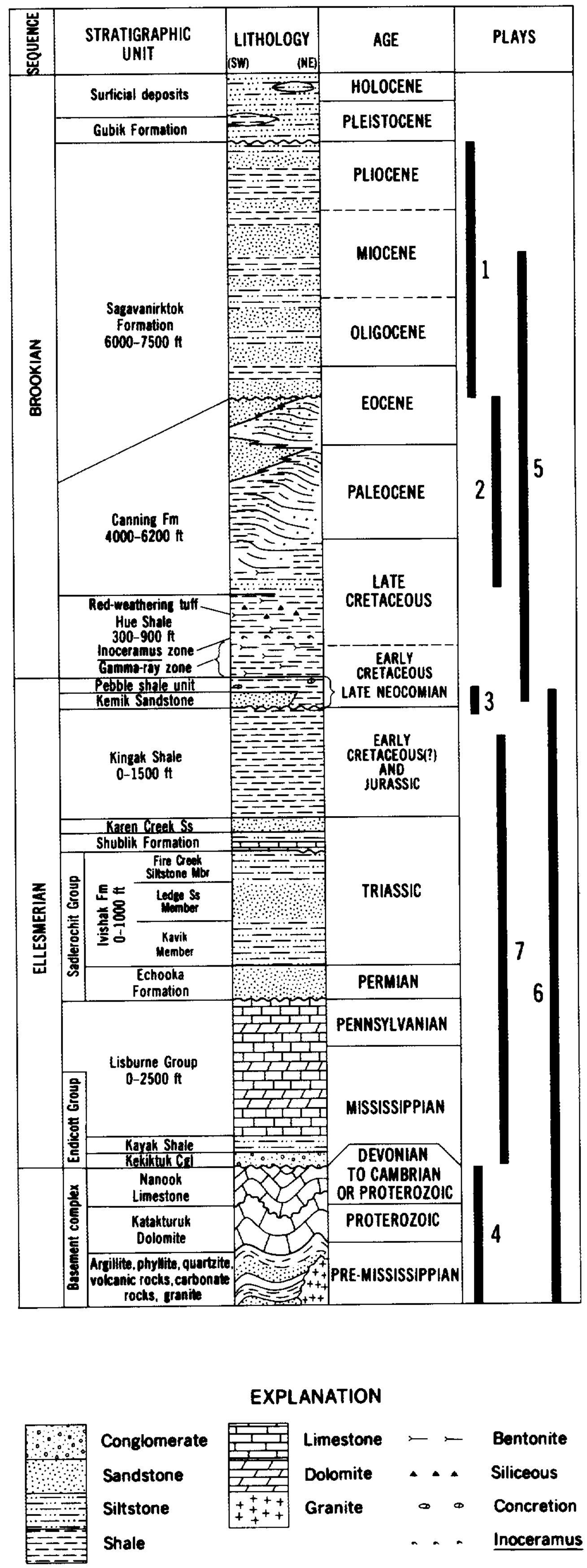
come from surface samples and seismic shot-hole samples or the data must be projected from wells or outcrops in adjacent areas. Because of the different and complex structural history of most of the 1002 area compared with that of adjacent areas to the west, some of the projections are tenuous.

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. However, analytical data on a limited number of samples of some units in or adjacent to the 1002 area indicate that all the above units except the Hue Shale are gas-prone source rocks 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 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 oil 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 depth, 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 National Petroleum Reserve in Alaska (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, 1986). But the present assessment uses a more efficient computer program (Fast Appraisal System for Petroleum--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 in-place oil and gas resources were estimated for each play. Estimates for each of the seven plays were aggregated using probability theory to produce estimates for the 1002 area.

Figure III-11.--Generalized stratigraphic column (facing page) for the 1002 area showing intervals of assessed plays. (Prepared by the U.S. Geological Survey and the Bureau of Land Management.)

DESCRIPTION OF PLAYS

Brief descriptions of the seven plays follow, including a cross section showing geologic relations and maps showing the play limits (fig. III-12). Some plays are similar or equivalent to oil and gas plays having 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.

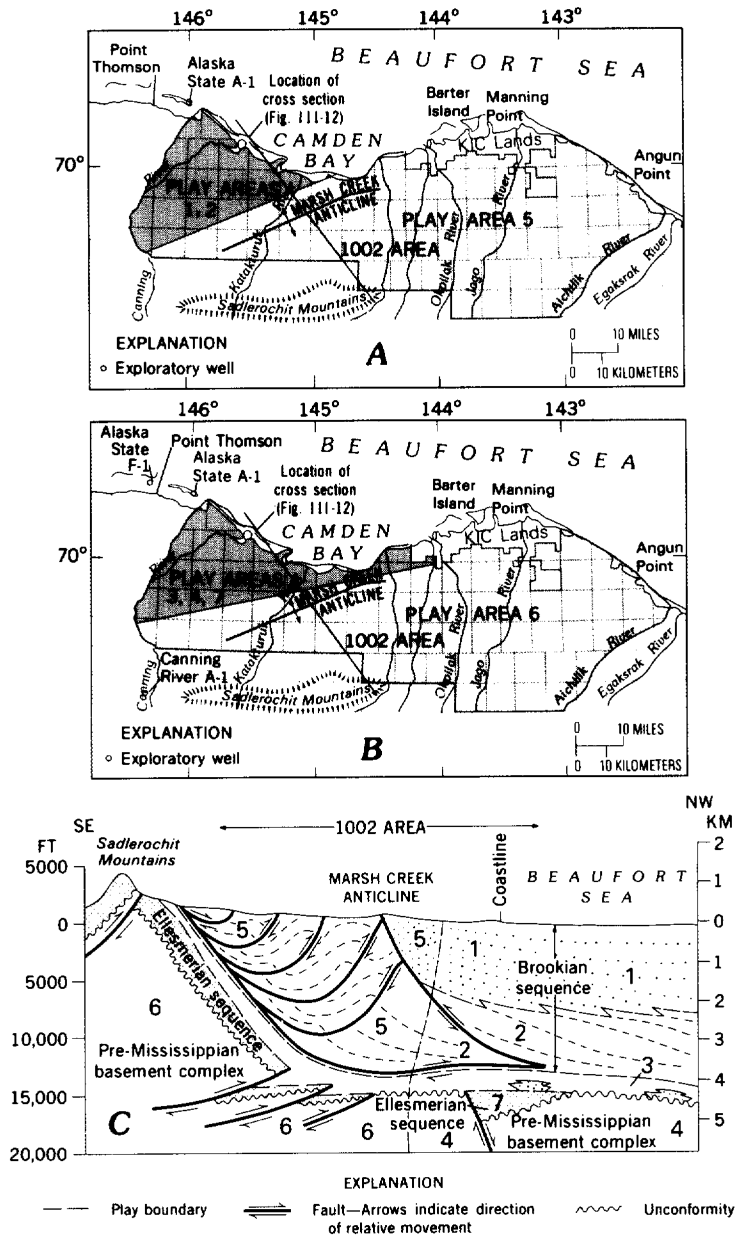


Figure III-12.--Maps and schematic section showing the seven assessed plays in the 1002 area: 1, Topset; 2, Turbidite; 3, Thomson-Kemik; 4, Undeformed Pre-Mississippian; 5, Imbricate Fold Belt; 6, Folded Ellesmerian/Pre-Mississippian; and 7, Undeformed Ellesmerian. (Prepared by the U.S. Geological Survey and the Bureau of Land Management.)

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-12A, C). The southeastern boundary is 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.

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 fields) and the small oil accumulations in northeastern NPRA (Simpson and Fish Creek fields) 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-12A, C). 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. 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-12 B, C). 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 fine-grained, well-sorted quartzose sandstone (Kemik) to 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.

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-12B, C). 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 to 25,000 feet.

Potential reservoir rocks may be dolomite, limestone, and sandstone. Dolomites may be vuggy as observed in outcropping Katakturuk Dolomite. 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 permeabilities of the matrices. Flow rates from basement rocks in the Alaska State F-1 well were about 3 million cubic feet of gas 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-12A, C). 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 (fig. III-3). The distribution of this thick section of rocks (Jago River Formation) 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 outcrops of these rocks.

Traps in this play are mainly structural and are 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-12, B, C). 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.

Reservoirs in this play consist of both carbonate rocks and sandstone. Potential carbonate reservoirs include the Katakturuk Dolomite, Nanook Limestone, other unnamed pre-Mississippian carbonate rocks, 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-2). 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 relation 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-12B, C). 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. Drilling depths to Ellesmerian rocks are 12,000 to 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 Kayak Shale, Ivishak Formation, Shublik Formation, Kingak Shale, and the overlying pebble shale unit and Hue Shale. These shales are expected to be submature to mature. Only the Hue Shale is expected to be an oil-prone source rock.

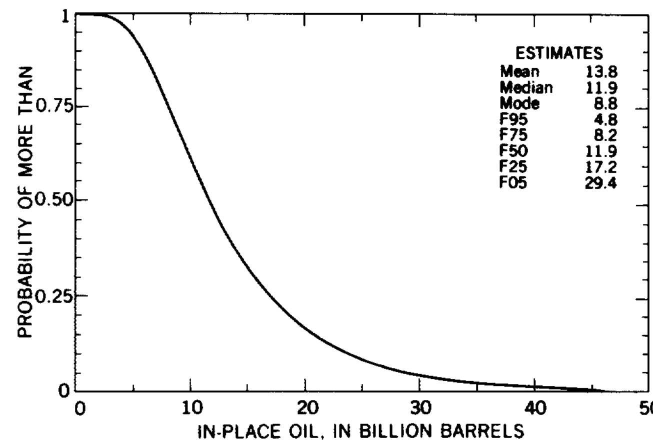
Postulated traps in this play are stratigraphic and depend for seals on the pebble shale unit or younger shales.

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-13. 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. There is a 100-percent probability of occurrence of some oil and gas somewhere in the 1002 area. 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.

ESTIMATED IN-PLACE RESOURCES

In-place oil and gas resources contained within the 1002 area are estimated to range from 4.8 billion to 29.4 BBO and from 11.5 to 64.5 TCFG, at the 0.95 and 0.05 probability levels, respectively (fig. III-13). Though indicating a relatively high degree of uncertainty regarding the true value, this wide range of values does indicate the potential for unusually large resources, or the possibility that there



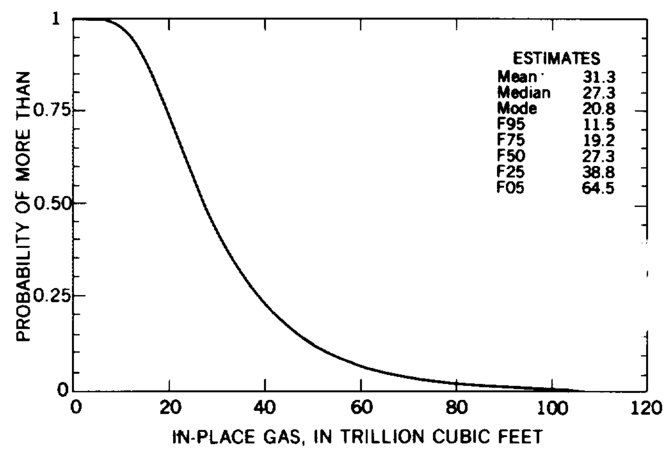


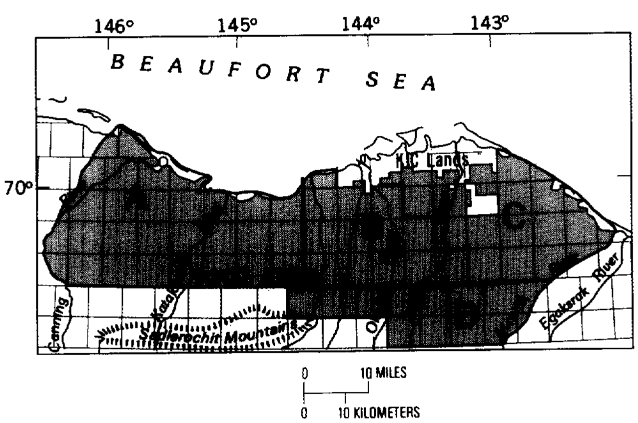
Figure III-13.---Probability curves showing the estimated in-place oil and total gas resources of the 1002 area. Oil in billions of barrels; gas in trillions of cubic feet. F, fractile. (Prepared by the U.S. Geological Survey.)

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, containing 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-14.

This assessment of oil and gas in-place represents those deposits which constitute the resource base without reference to recoverability. Included are accumulations 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-15 and III-16. 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.



	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

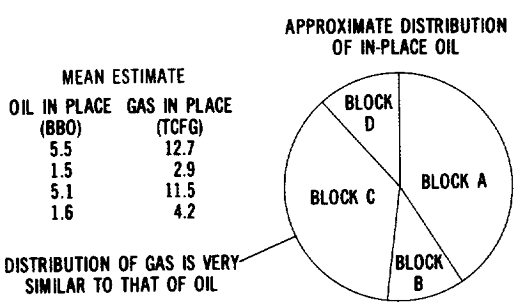


Figure III--14.--Resource blocks A-D of the 1002 area (shaded) and the approximate distribution of mean values of in-place oil and gas resources. (Prepared by the U.S. Geological Survey and the Bureau of Land Management.)

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 no 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

~ The estimate of economically recoverable oil resources for the 1002 area represents an assessment of only the structural prospects which were identified on the basis of the seismic interpretation (fig. III-1). As noted above, the 1002 area is expected to contain a very large additional volume of oil and gas in numerous smaller structurally controlled accumulations (for example, the Imbricate Fold Belt play) and large stratigraphic accumulations (Topset play). The economically recoverable resource estimate should be viewed as an "identifiable minimum" volume, which is constrained by economic and technical recoverability considerations. ~

Conditional estimates of potential 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 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.

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 geologic 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 either the prospect or area conditional resource estimates.

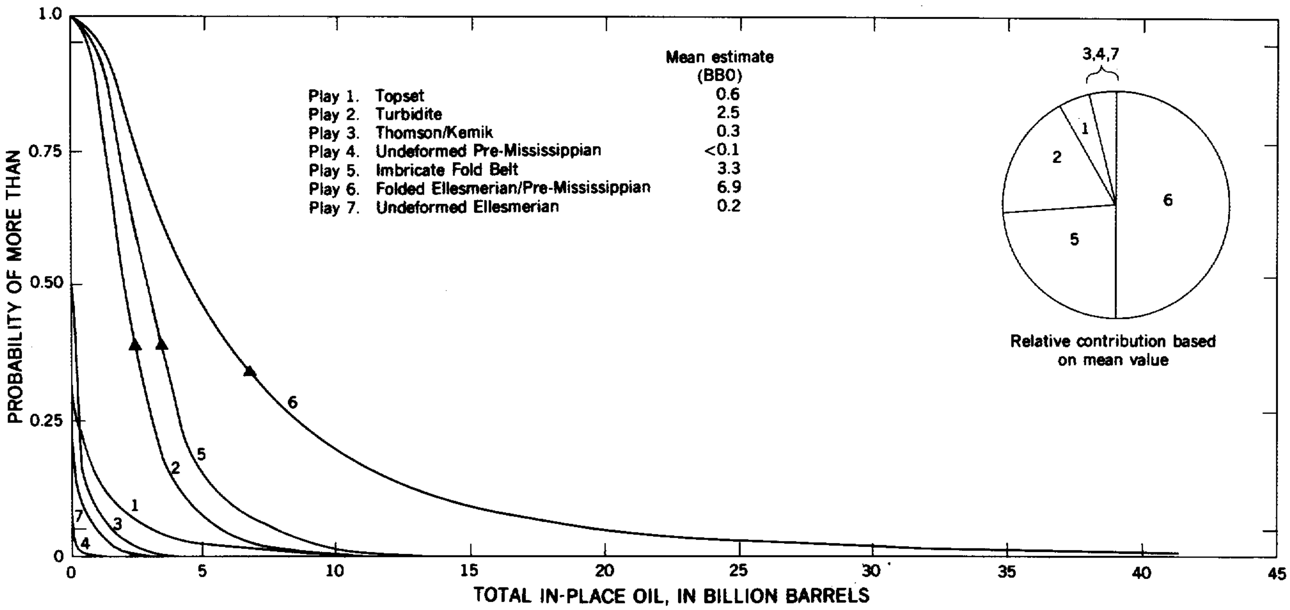


Figure III-15.--Estimated in-place oil for plays in the 1002 area, showing individual probability curves and relative contributions of the plays. Triangles show mean values on principal distribution curves. (Prepared by the U.S. Geological Survey.)

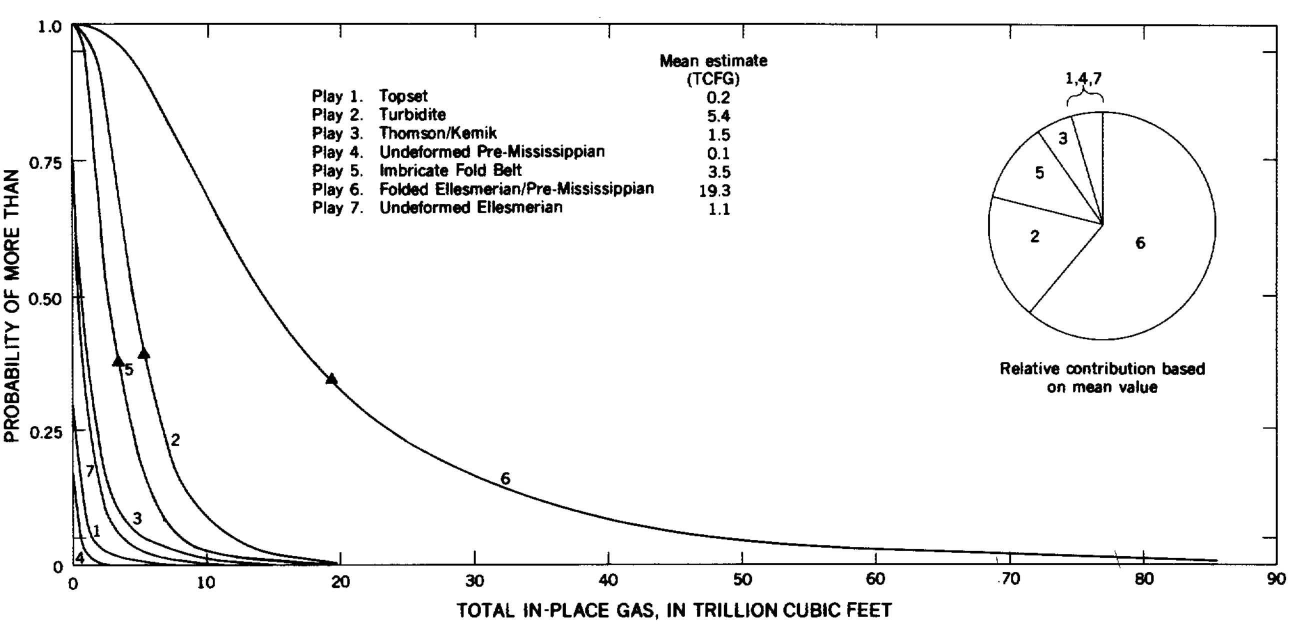


Figure III-16.--Estimated in-place total gas for plays in the 1002 area, showing individual probability curves and relative contributions of the plays. Triangles show mean values on principal distribution curves. (Prepared by the U.S. Geological Survey.)

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 data are entered, PRESTO starts its 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, by sampling from the input distributions, a prospect was found to be economically productive. The average of these productive trials for each individual 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 area-wide resources. 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 (fig. III-1; table III-2). 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, 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.

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.

Prospect risk factors were assessed on the basis of the probability of occurrence of significant quantities of oil, taking into consideration probabilities associated with the occurrence of minimum values and probability distributions for the reservoir parameters used for the various plays in the in-place resource assessment. New field wildcat success rates for the U.S. and for Alaska were considered. Prospect risk factors used range from 90 to about 98 percent, depending on such prospect specific factors as data coverage and quality, confidence in the interpretation, confidence in the existence of reservoir horizons, and type of trap. The average prospect risk value used for the 1002 area prospects was about 95 percent. For perspective, the reported national average for new field discovery wells has been about 16 percent for the years 1972-1985, but the average size of discoveries included in these statistics has probably been less than 1 million barrels, while the conditional mean size of the smallest prospect assessed in this analysis was about 20 million barrels (recoverable). For Alaska, from 1982 through 1985, two new field discoveries have been announced for 106 exploratory wells drilled, or about 2 percent (Jones, 1983; Jones and Hiles, 1984; Boyd and Hiles, 1985; Steenblock, 1986; Johnston, 1983, 1984, 1985, 1986). The Alaska statistics reflect the economic realities of a high-cost environment. ~

~ As generally defined for use in the PRESTO model,. area risk is based on the probability that at least one accumulation exists as modeled in the area. For this analysis, the area risk was based on the probability that at least one of the five largest prospects exists as modeled. Based on individual prospect risk factors, this probability was 30 percent (70 percent area risk). The rationale for using this approach is that there must be at least one field in the area large enough to bear the cost of a regional transportation infrastructure in order for commercial development to occur. This may be considered overly conservative, in that it does not take into account the possibility of offshore development. Commercial development in the eastern Beaufort Sea would lower regional transportation costs, resulting in a lower minimum economic field size. However, it is beyond the scope of this analysis to speculate on the probability of commercial development in the eastern Beaufort Sea. ~

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-3 and are discussed at greater length 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 economically 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 the lowest development costs.

Minimum economic field sizes were also 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 "most favorable case MEFS."

~ Sensitivity analyses were conducted to determine effects of variations in several economic parameters, including oil prices, on the economics of "typical" prospects in the western and eastern parts of the 1002 area. The lowest oil price modeled was $22 (year 2000 price, 1984 dollars). The MEFS for the eastern Arctic Refuge prospect using this price is more than 2 billion barrels (recoverable). For western Arctic Refuge, the MEFS would be about 1.4 billion barrels. Minimum field sizes for actual prospects in the 1002 area, using this price, were not estimated, but it is likely that the minimum for the area would be close to that for the "typical western Arctic Refuge" prospect (1.4 BBO). All else being equal, the effect of this would be to lower the marginal probability for commercial hydrocarbons from the 19 percent most likely case. ~

Table III-3.--Undiscovered, conditional, economically recoverable oil resources in the 1002 area.

[BBO, billion barrels of oil. Prepared by the Bureau of Land Management]

	Greater than	Economic scenario: Most likely case	Economic scenario: Most favorable case
A. Conditional, economically recoverable oil			
Probability	99%	0.49 BBO	0.18 BBO
	95%	.59	.23
	75%	1.12	.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
B. 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.

PRESTO ANALYSIS RESULTS

Economically recoverable estimates of oil resources were calculated using two economic scenarios. The results and economic variables that significantly affect the estimate of the minimum economic field size are shown in table III-3.

The most favorable 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 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, resulting in a wider range of conditional values containing lower values. This is offset by the increased marginal 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.

~ MARGINAL PROBABILITY ~

The marginal probability is an output of the PRESTO model that indicates the chance that an area having the characteristics specified by the inputs will contain at least one field with economically recoverable resources. The input parameters which most directly affect this output are the area geologic risk (a function of the individual prospect geologic risks) and the minimum economic field size estimated for each prospect (see "Economic inputs," this chapter).

As a consequence of the area geologic risk, the results show a 30-percent chance that an exploratory drilling program would find hydrocarbons. There is a 63-percent chance that, if hydrocarbons are found, the amount would exceed the minimum economic field size for at least one prospect, resulting in the marginal probability of 19 percent. Stated another way, assuming 1,000 areas similar to the 1002 area, 300 would have hydrocarbons and 190 of these would have at least one prospect containing resources exceeding the minimum economic field size.

The statement that there is a 19-percent chance of finding recoverable oil in the 1002 area needs to be interpreted in light of past experience in oil exploration and resource assessment. Generally speaking, the marginal probability of finding oil will be lower, the smaller the unexplored area being considered. The 19-percent probability for the 1.5-million-acre 1002 area thus indicates a very high potential when compared to the 27-percent probability for the 37-million-acre Navarin Basin or the 22-percent probability for the 70-million-acre St. George Basin (table III-1). Furthermore, the marginal probability of finding a recoverable field will be lower, the greater the minimum economic field size, because, as discovery statistics show, the number of fields of a given size is much lower for larger fields. There are fewer 1-billion-barrel fields than 100-million-barrel fields. Because of the high cost of operations in the Arctic, the minimum economic field size is 440 million barrels, which is much higher than for areas in the lower 48 States. Despite this high threshold, the chance of finding a recoverable field in the 1002 area is 19 percent. This shows an exceptionally high potential for oil and gas. For perspective, in 1982, 1,402 new-field discoveries were reported for the United States, but only 652 million barrels of hydrocarbon liquids were discovered in the new fields.

RESOURCES BY BLOCK

To provide a basis for assessing the consequences of 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-14. This allocation is based on the unconditional resource potential of the individual prospects contained in each block. See figure III-1 and table III-4. A similar resource allocation, by percentage, was made to "activity areas" in Section 105(b) Economic and Policy Analysis for the National Petroleum Reserve in Alaska (U.S. Department of the Interior, 1979).

Table III-4.--Distribution, by block, of estimated unconditional mean recoverable oil resources in the 1002 area. (Prepared by the Bureau of Land Management.)

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 mid- to late-1990's, and which could be explored for, developed, and marketed within the 30-year timeframe at expected costs and prices. This study recognized four factors: (1) the high costs of North Slope natural gas at market, (2) uncertainty that any gas transportation system will be developed for the North Slope, (3) additional costs of transporting gas from the 1002 area to the northern terminus of such a pipeline, and (4) the quantity of known reserves elsewhere on the North Slope that would presumably be developed before the 1002 area. Therefore, this analysis assumes that there will be no demand for acquiring acreage in the 1002 area in the early to mid-1990's for seeking and producing natural gas, and further, that any gas discovered through oil exploration will remain undeveloped or will merely be used locally for fuel. ~

It is assumed that any gas resources discovered through oil exploration activities will remain undeveloped or will be used locally, although potential gas resources in the 1002 area are not 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 (1986).

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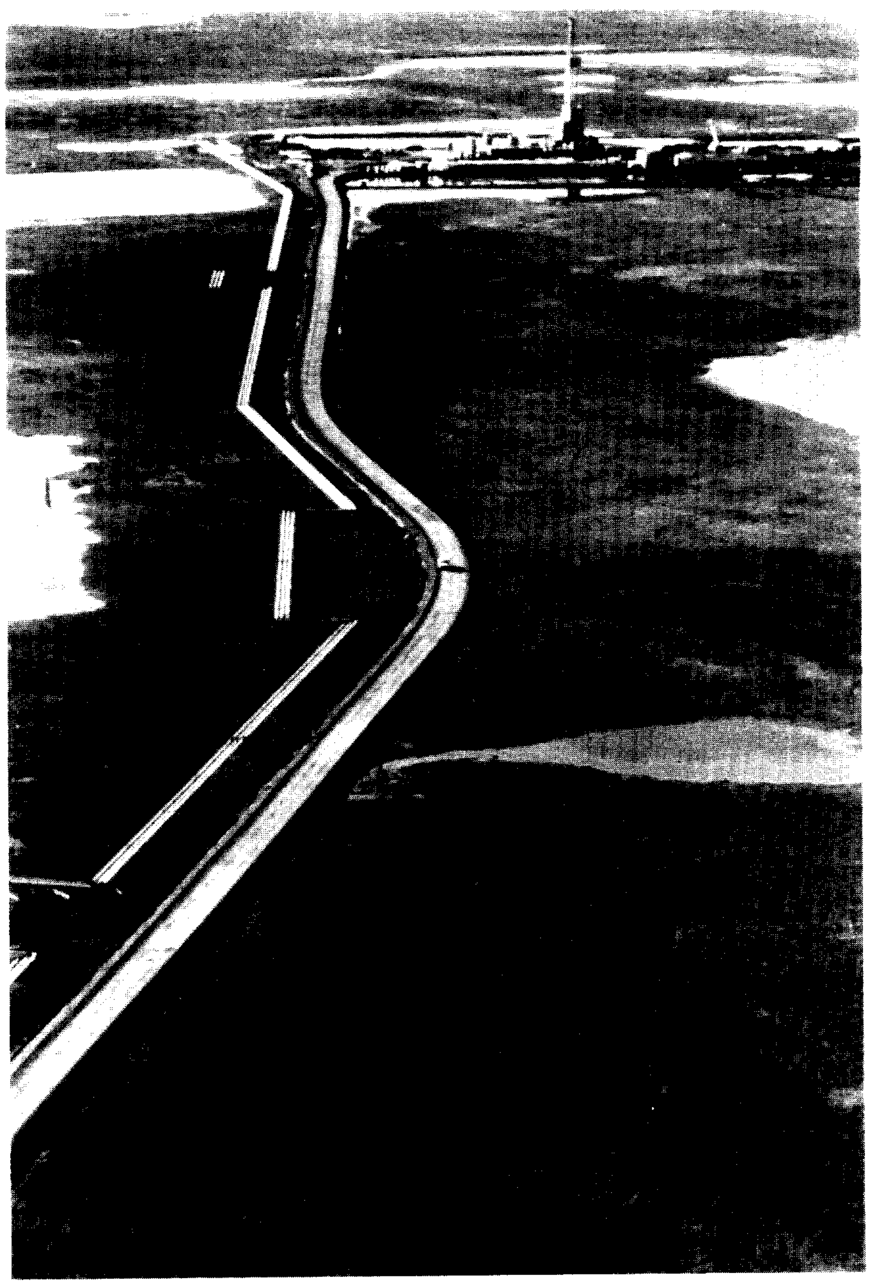

OIL-FIELD DEVELOPMENT

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. Advances in arctic engineering and oil-field development and/or site specific factors in the 1002 area may allow for the construction of smaller pads and roads requiring less gravel than those described in the following scenarios. 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 outside 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. Of course, if no oil is present, there will be no impacts from development and production. ~

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 transport North Slope oil from the 1002 area to market. The exploration, development, and construction scenarios presented herein are general concepts and must not be considered to be final engineering solutions for oil and gas production from 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 measurement 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 exploratory drilling operations, including construction, drilling, and testing, can be completed within approximately 170 days, a well can probably be completed in a single winter season (Mitchell, 1983b). On the North Slope, exploratory wells to a moderate depth can usually be drilled in a single season, whereas most deep wells (deeper than 10,000 feet) would require two seasons. Decisions to allow year-round drilling activity will be made on a case-by-case basis. ~

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 the 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.

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 rig and the ancillary equipment can be transported overland by low-ground pressure vehicles or flown in by C-130 aircraft.

~ The drilling pad can be constructed of ice, excavated material, gravel-foam-timber, or other possible combinations. The 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) covers 5-10 acres of ground surface. The construction and drilling camps contain sleeping and eating accommodations, communication equipment, power generator units, storage space, shops, and offices. An initial 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 the used drilling muds and "cuttings" from the well, and (2) to contain formation fluids originating from a "kick." ~

~ Reserve pits generally cover 0.5 to 2.0 acres (parallel to the drilling pad); they are 10 to 20 feet deep. A small flare pit is excavated at the corner most distant from the drilling rig, in case it is needed for gas flaring during testing. The material excavated from the reserve and flare pits is used to level the drill pad, providing a cover averaging 2 feet deep over the tundra surface. This material is used to backfill the reserve pit upon pad abandonment. ~

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. 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. Therefore, as much as 15 million gallons of water may be needed to drill one exploratory well.

~ The limited availability of fresh water on the Arctic Coastal Plain, particularly in winter, is not a problem unique to the 1002 area. The various sources used and methods developed to satisfy water requirements in other areas in the Arctic (the Prudhoe Bay development area near the mouths of the Sagavanirktok and Kuparuk Rivers to the west) will be applicable to activities in the Arctic Refuge. Just as water availability varies by location, solutions to providing/obtaining water will have to be considered on a site-by-site basis. The several sources and methods used to obtain winter water supplies in earlier exploratory development and production activities in Arctic Alaska are mentioned elsewhere in this report. These include existing naturally deep lakes and deep pools along rivers that do not freeze to bottom in winter; melting lake and river ice, including large aufeis deposits downstream from the several large springs south of the 1002 area (Childers and others, 1977), trapping and melting snow; creating water reservoirs by excavating deep pools in lakes or along stream channels in conjunction with gravel removal operations; and desalinating marine waters obtained beyond the barrier islands. ~

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, using 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 in a manner similar 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 typically 50-100 feet deep for the conductor casing. 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 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 exploratory 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 a portion of the drilling pad is constructed with enough gravel to provide a stable and suitable surface on which to store the drilling equipment and camp during the summer. A wood and timber drilling platform or base may be an alternative to using gravel. At the end of the first drilling season the well is freeze protected with a low-freeze-point fluid 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 low-freeze-point fluid in the upper part of the well is removed, and drilling is resumed. ~

Development

Following a discovery of oil from exploration drilling, a confirmation or delineation well is drilled. 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. The purpose for 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. If so, the airstrip, roads, and pad for support of the drilling rigs could 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 several oil fields, were others 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, again with an all-season gravel pad. Once each 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 having 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 (Trans-Alaska Pipeline System) 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). After production from the reservoir is no longer economic, the field would presumably be abandoned, although this has not yet occurred on the North Slope. 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, depth) and performance (spacing and production rate of wells) 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, 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 gravel pad (fig. IV-1). This typical North Slope practice reflects economics, engineering considerations, and environmental impact mitigation. A vertical hole is drilled to a predetermined "kickoff" point where a controlled deviation (drift) from vertical is begun. 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 formation. 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.

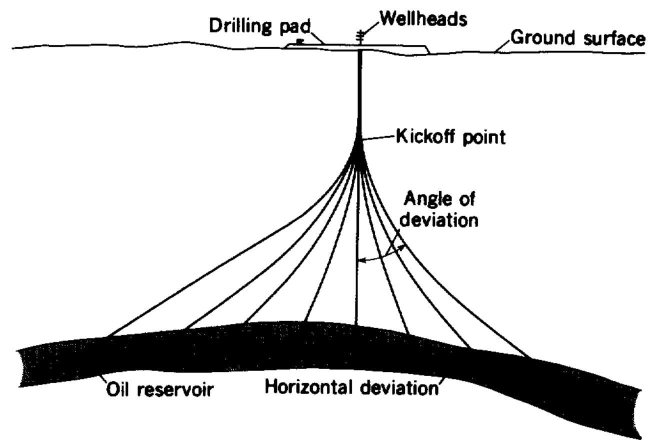

Figure IV-1.--Directional drilling from a single location.

~ Unless advances in technology dictate otherwise, most development wells for the 1002 area would likely be drilled with an angle of deviation between 0° and 60° from an assumed kickoff point as shallow as 500 feet. The actual kickoff point depends upon geologic conditions and reservoir depths. The maximum practical angle for directional drilling on the North Slope is now about 90°, with the horizontal deviation reaching a possible distance of more than 12,000 feet in some of the deeper reservoirs (that is, deeper than 10,000 feet) (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.

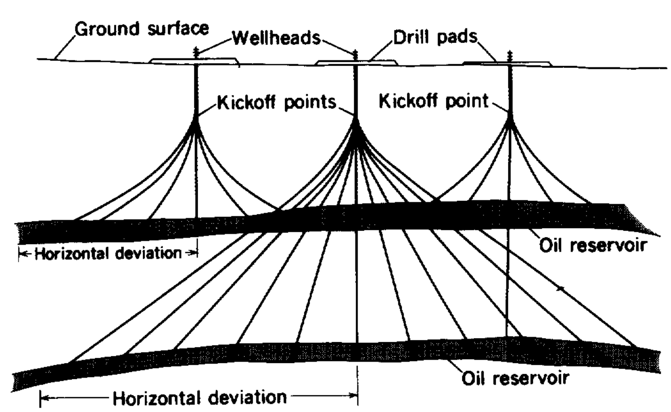

Figure IV-2.--Horizontal deviation versus well depth.

~ 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 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 1 per 5 acres (West Sak Pilot Project) to 1 per 320 acres (initial Prudhoe Bay development), 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 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, drilling pads, roads, airstrips, pipelines, water and gravel sources, base camps, construction camps, storage pads, powerlines, powerplants, support facilities, and possibly a coastal marine facility. All would be of permanent construction and have a useful life of 30-50 years. The airstrips, 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 needed. ~

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, the separated gas is compressed, returned to the production well, and injected into the space between the casing and tubing, where it 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). In enhanced oil recovery, any excess gas is injected back into the reservoir through gas injection wells to maintain reservoir pressure.

The separated 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 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 treated-sea-water 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, enhancement of existing lakes and river oxbows, 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. ~

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, "Alaska" volume, 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 may provide all the field's needs for arctic diesel and jet fuel, or fuel needs could be transported into the field. 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.

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 initial 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 from the well are placed in a reserve pit on the drill pad. Spent drilling muds are generally pumped into the annulus of previously drilled production wells. Hazardous solids and solids containing hydrocarbons must be removed to and safely contained in a government-approved site, such as an abandoned gravel pit. ~

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.

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.

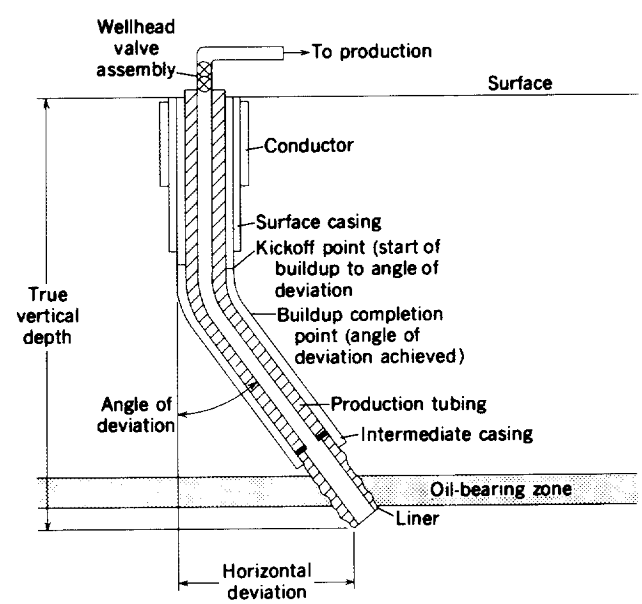

Figure IV-3.--Production-well design.

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 8-24 inches in diameter and be built parallel to the roads connecting the drilling pads and the CPF. They are commonly placed on elevated steel vertical support members (VSM). Pipelines, pump stations, and the VSM's are discussed in more detail later in this chapter.

MARINE FACILITY

A marine facility would be required for major equipment sealifts. 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 sea-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.

~ Camden Bay and Pokok were selected as two possible sites for marine facilities, given the development scenario derived under the Chapter III resource assessment (fig. V-1). There may be other potential marine facility sites. All potential sites would be analyzed in detail before final selection. Camden Bay and Pokok were selected because they are similar to Prudhoe Bay in having sufficient water depth 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 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. However, Camden Bay and Pokok were used to assess environmental impacts under the various scenarios. ~

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 TAPS is in place and operating. As production of the Prudhoe Bay oil field declines, TAPS should have adequate capacity to accommodate 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 1, 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 create 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; it 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.

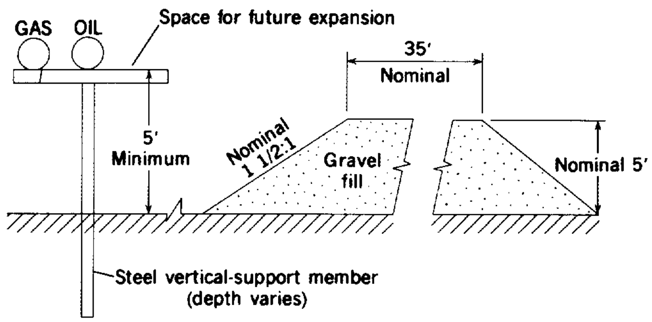

Figure IV-4.--Typical cross section of pipeline and road development. No scale.

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-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 a 7-acre (approximately) gravel pad. Other related facilities are described below (Mechanics Research, Inc., 1977).

SURGE AND STORAGE TANKS

Pipeline hydraulic design analyzes normal hydraulic gradients and the effects of pressure surges, which are controlled 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 communication control 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, 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. Common-carrier circuits, telephone, and mobile radio systems would be incorporated into the overall pipeline communication system.

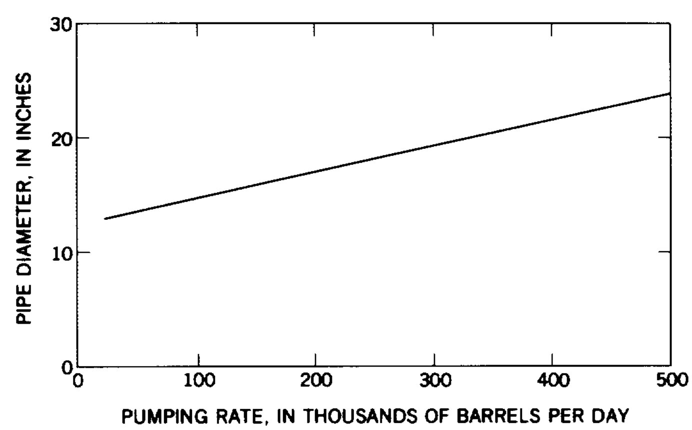

Figure IV-5.--Land-pipeline pipe diameter versus pumping rate. Modified from Han-Padron Associates (1985, fig. 7.2-1).

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 were 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 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 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 would 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 could be filled with water and provide areas 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 effects on the fisheries.

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 airfield development, that is, 5,000-6,000 feet long, 150 feet wide, and 5 feet thick.

CONSTRUCTION CAMPS FOR
ROADS AND PIPELINES

Camp buildings would be portable self-contained modules, 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 located at the sites chosen for the permanent pump station. 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 when no longer needed or be used for road maintenance camps.

OIL-SPILL CONTINGENCY,
INCLUDING LEAK DETECTION

The first lines of defense against oil 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, includes 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, either the all-season road or a gravel work road should be close 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, hours 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 streams 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 potential borrow pit sites 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, "Alaska" volume, 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, "Alaska" volume, 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 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 is probably 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. 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.

~ Maintenance and repair work on a marine pipeline in the Arctic would be difficult during the ice season (normally October through July). 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. ~

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 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 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 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 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 1986, the Yukon Pacific Corporation (YPC) amended its application 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 at 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 Alaska North Slope natural gas outside the United States would require approval of the President of the United States, pursuant to the Alaska Natural Gas Transportation Act of 1976. ~

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 the 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 facilities shared with oil development and transportation on the 1002 area. Ideally, the vertical support members 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 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 the 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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