AN ENVIRONMENTAL EVALUATION OF POTENTIAL PETROLEUM DEVELOPMENT ON THE NATIONAL PETROLEUM RESERVE IN ALASKA

Prepared by the U.S. Geological Survey

Under Section 105(b) of the
Naval Petroleum Reserves
Production Act of 1976

December 15, 1979

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General Contents

Preface

This is an environmental analysis of potential development, production, transportation, and distribution of petroleum resources from the National Petroleum Reserve in Alaska (NPRA). The analysis was accomplished by a task force within the Department of the Interior under authority of Section 105(b) of Public Law (P.L.) 94-258, the Naval Petroleum Reserves Production Act of 1976. The analysis is both broad and qualitative; its purpose is to apprise decisionmakers and the public of major environmental issues and concerns and to indicate impacts which would require in-depth analysis in any future program or project. Because no specific programs have been developed to date for NPRA, no site-specific analyses of impacts are possible. Such analyses will be possible only when specific lease sites and programs are identified. This impact analysis therefore considers those anticipated impacts that could likely be associated with future potential development. Depending upon location of potential development, many of the impacts discussed could be successfully mitigated or avoided; others would not even occur.

In the analysis of impacts, certain concerns evolved for the development and production of petroleum resources within NPRA and for transportation and distribution of the petroleum resources to refineries and market areas. The principal environmental concerns stemming from development and production are:

- Impacts on the Inupiat culture and lifestyle, particularly through effects on subsistence pursuits.
- Impacts on wildlife, especially on caribou and waterbirds.
- Depletion of gravel and water resources, which are in limited supply.

The Inupiat culture and lifestyle are currently under stress. Survival of the Inupiat culture as a unique and distinct entity depends upon the viability of its socioeconomic subsistence complex and its direct relationship and dependence on the arctic environment. This conflict is embodied in the joint role of subsistence and cash in the Inupiat economy.

Petroleum development in NPRA would further exacerbate this stress and further increase existing social and cultural problems. Traditional subsistence patterns would be further altered by disruption and reduction of the resource base. A further influx of workers, machinery, and introduced changes would increase demands on regional governmental and service infrastructure through increased demand for housing, health care, and transportation and could result in decreased quality of the available services.

Wildlife would be impacted by alteration or reduction of habitat, disturbance of migration patterns, and wildife population declines. Of prime concern is the Western Arctic Herd of caribou, which ranges over an area of 140,000 square miles, and calves in the Utukok River uplands area from late May until early June. These caribou, along with the bowhead whale, are a principal subsistence resource of the Inupiat. Petroleum development with its attendant gathering lines could seriously impede or alter the caribou migratory and calving patterns and could result in reduction or division of the Western Arctic Herd. Petroleum development, particularly in northern NPRA, would affect areas important to waterfowl, including most of the approximately 500,000 ducks that use NPRA in the summer and the millions of migratory birds that use the coastal zone barrier island-lagoon systems. Numerous geese occupy a unique molting area around Teshekpuk Lake and are especially susceptible to disturbance by noise and activities during the molting season.

Petroleum development within NPRA will require huge amounts of gravel and water, both of which are locally in short supply in the Arctic. Depending on location of development, gravel may have to be hauled hundreds of miles over ice roads in winter. Removal of gravel from beaches could accelerate shoreline erosion, and removal from the flood plains of rivers would alter streamflow characteristics and increase siltation during removal. Of major concern, however, is the allocation of a vital Arctic resource in short supply to petroleum development. Although water is generally available from deeper lakes and from rivers, sources may be considerably removed from the point of use.

The principal environmental concerns for transportation of petroleum resources from NPRA are:

- Impacts upon the Inupiat culture and lifestyle through increased access to the area and increased pressures on government and service infrastructures.
- Impacts on wildlife, particularly on caribou migration patterns and habitat access, from pipelines and roads.
- Potential oil spills along new pipeline or marine routes.

The transportation of petroleum to terminals along the Trans-Alaska Pipeline System would require extensive pipeline corridors which, along with roads associated with development, could provide ready access to parts of NPRA and surrounding areas now accessible only by aircraft or snow machine. Such access to existing villages on the North Slope could alter the Native culture and lifestyle of the villages through increased non-Native population and increased competition for jobs and new pressures on socio-cultural, governmental, and service infrastructures. The overall impact will be to further stress the Inupiat population through weakening local control mechanisms now acting as a buffer between Western and Inupiat cultural and economic systems.

Pipelines to transport oil from the well fields to terminals could block or alter migration routes of the Western Arctic Herd of caribou and result in division or reduction of the herd. Blockage of some routes through the Brooks Range could deny the herd timely access to the traditional calving grounds in the Utukok uplands or alter winter distribution which would affect subsistence hunting south of the Brooks Range.

New pipeline corridors or new marine routes would open new areas to potential oil spills, some of which could be major. Oil spills in Arctic waters are of particular concern, since oil trapped under multi-year sea ice may not surface for years.

In the analysis of impacts, the development and experience at Prudhoe Bay and the construction and operation of the Trans-Alaska Pipeline System (TAPS) were used as general models. Together they represent the current level of technology and experience in the Alaskan Arctic environment. It was also assumed that all existing laws and regulations applicable to petroleum development and transportation, as well as stipulations for Prudhoe Bay and TAPS, would be applied, but that accidents and unintentional violations could occur. Because facilities vary widely with petroleum reservoir characteristics, no specific well-field model was used. For the transportation of petroleum from NPRA to terminals, three general corridors were assumed for illustrative purposes. These are: 1) from eastern NPRA to TAPS at Prudhoe Bay, 2) from eastern NPRA to TAPS south of Prudhoe Bay, and 3) from southwestern NPRA to the Bering coast at an alternate site in the vicinity of Cape Thompson. A marine terminal at Barrow for submersible tankers is also considered briefly because of previous studies.

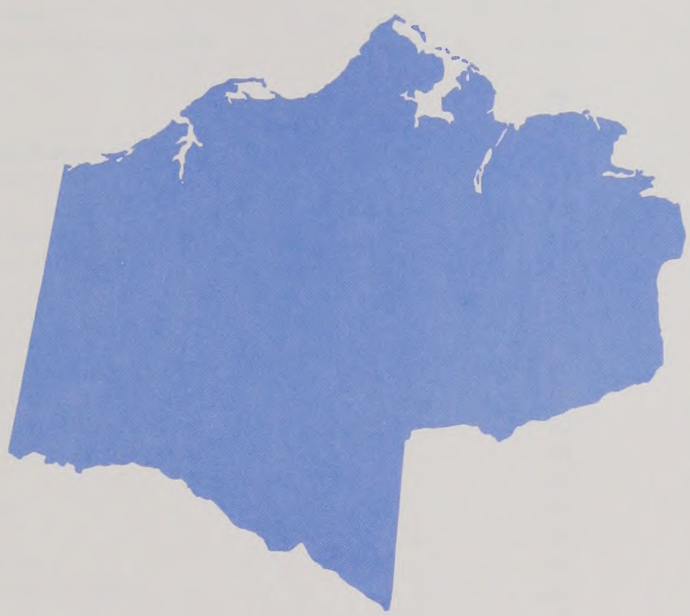
This study report consists of a preface, an environmental analysis, and three appendices — a description of the environment, a discussion of environmental and planning controls related to petroleum development, and a description of current and standard practices for petroleum development in the Arctic.

The preface capsulizes the purpose of the study, the assumptions of the environmental analysis, and the major environmental concerns identified in the analysis.

The environmental analysis consists of a detailed description of all impacts identified by the task force — major or minor, long term or short term.

The three appendices provide information upon which the analysis is based. Appendix A describes the affected environment. Appendix B discusses planning and environmental controls which would govern petroleum operations in NPRA. Appendix C describes current and standard practices for such operations.

Environmental Analysis



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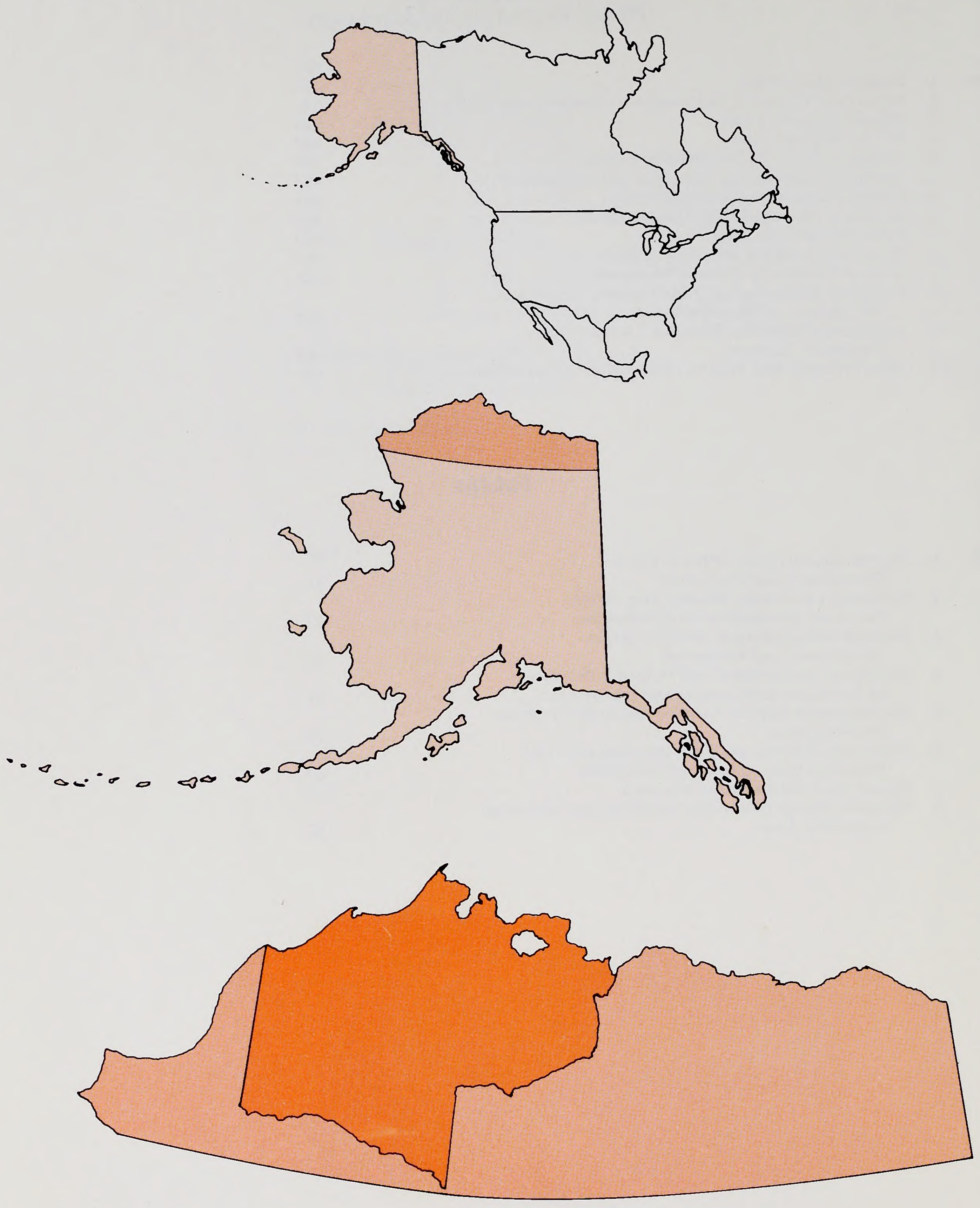


Figure 1. Location of National Petroleum Reserve in Alaska.

I. Introduction

The National Petroleum Reserve in Alaska (NPRA) is a 37,000-square-mile (96,000-square-kilometer) Reserve on the North Slope, lying between the Brooks Range and Arctic Ocean (figure 1). The Native people, the Inupiat, have for thousands of years based their subsistence culture in this region. Barrow serves as the seat of the North Slope Borough and the Arctic Slope Regional Corporation. Near Barrow is the Naval Arctic Research Laboratory, a base for scientific research on the arctic environment. Prudhoe Bay and the trans-Alaska pipeline lie 60 miles (96 kilometers) east of the Reserve.

A. Background

1. Executive Order 3797-A of 1923

On February 27, 1923, President Harding signed Executive Order 3797-A creating Naval Petroleum Reserve No. 4 (NPR-4), the last of four reserves to be placed under control of the United States Navy. Once the executive order had been codified as Federal Law 10 USC, Chapter 641, Section 7421 through 7438, the Secretary of the Navy was charged to "explore, protect, conserve, develop, use, and operate the Naval Petroleum Reserves," including NPR-4. As authorized under this executive order, the Department of the Navy has conducted and sponsored petroleum exploration within NPR-4.

2. Naval Petroleum Reserves Production Act of 1976

The Naval Petroleum Reserves Production Act of 1976, Public Law 94-258, transferred jurisdiction of NPR-4 from the Secretary of the Navy to the Secretary of the Interior on June 1, 1977. As of that date, all lands within NPR-4 were redesignated as the National Petroleum Reserve in Alaska (NPRA).

Under Section 103(b) of the act the Secretary of the Interior assumed responsibilities as of the date of enactment (April 5, 1976) for all activities related to the protection of environmental, fish and wildlife, and historic or scenic values. The act also authorized the Secretary to promulgate such rules and regulations as he might deem necessary and appropriate for the protection of such values within NPR-4 by the effective date of the transfer.

Under Section 104 of the act, except for the Barrow gas field or such other gas fields as may be necessary to supply natural gas to the Native people and to the governmental agencies at or near Barrow, production of oil and gas from NPR-4 is prohibited, and no development leading to such production from NPR-4 may be undertaken until authorized by Congress.

This section further provides that any exploration within the Utukok River and the Teshekpuk Lake areas, and such other areas as may be designated by the Secretary of the Interior as containing any significant subsistence, recreational, fish and wildlife, or historical or scenic value, shall be conducted in a manner which will assure the maximum protection of such surface values to the extent consistent with the requirements of the act for the exploration of the area.

Also under this section, the Secretary of the Navy was authorized to continue the ongoing petroleum exploration program within NPR-4 until June 1, 1977, at which time the Secretary of the Interior assumed responsibility for exploration. Any plans or substantial amendments to ongoing plans for the exploration of NPR-4 are required to be submitted to the Committees on Interior and Insular Affairs of the Senate and the House of Representatives.

Under Section 105(b) of the act the President is authorized to direct such Executive departments and/or agencies as he may deem appropriate to conduct a study, in consultation with representatives of the State of Alaska, to determine the best overall procedures to be used in the development, production, transportation, and distribution of petroleum resources in NPR-4. Such study shall include, but shall not be limited to, a consideration of the alternative procedures for accomplishing the development, production, transportation, and distribution of the petroleum resource from the Reserve and the economic and environmental consequences of such alternative procedures.

This study shall be completed and submitted to such committees, together with recommended procedures and any proposed legislation necessary to implement such procedures not later than January 1, 1980.

Section 105(c) of the act requires the Secretary of the Interior to establish a task force to conduct a study to determine the overall resource values of, and best uses for, the lands contained in the Reserve, taking into consideration 1) the Natives who live or depend upon such lands, 2) the scenic, historical, recreational, fish and wildlife, and wilderness values,

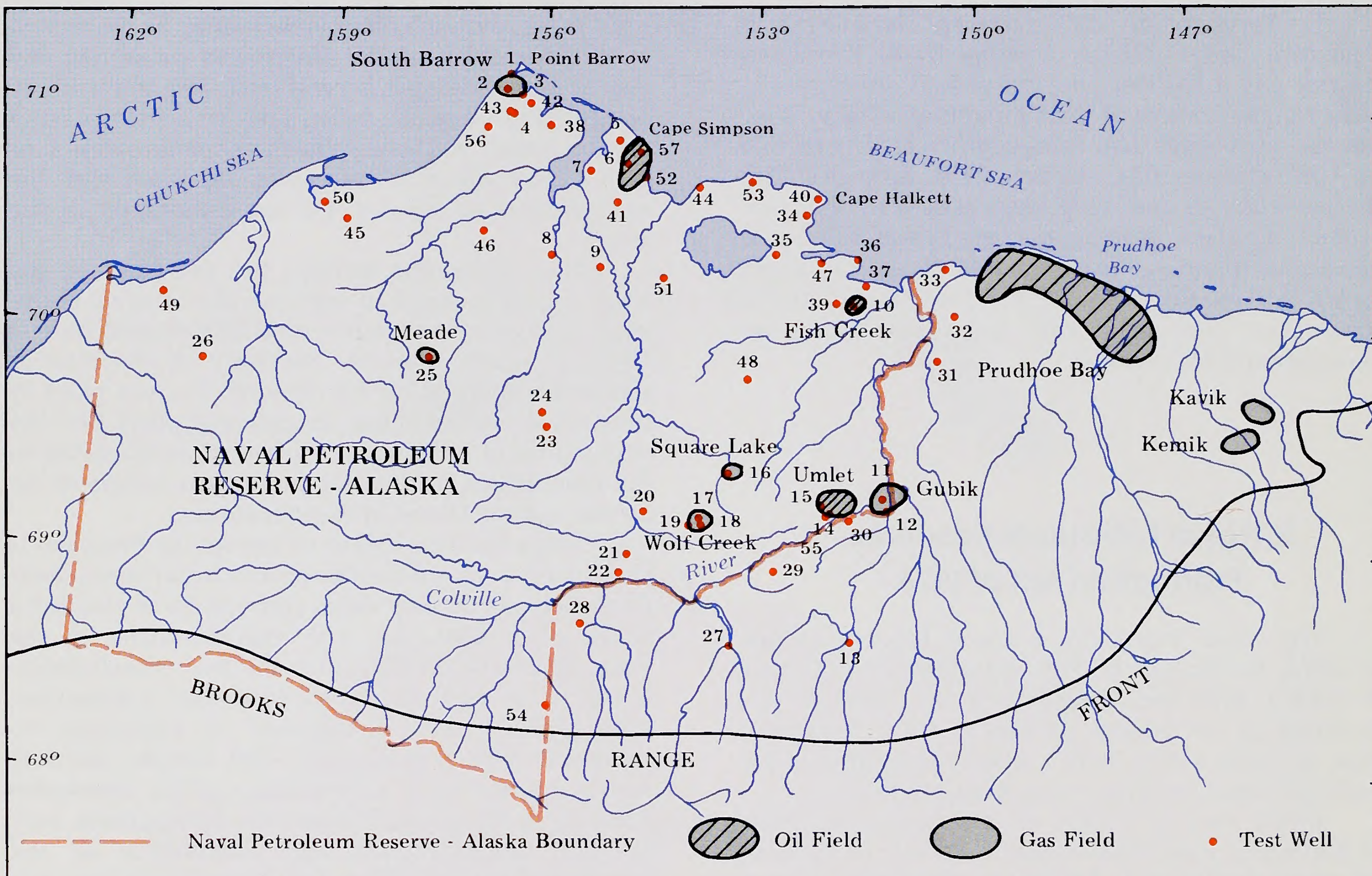
3) mineral potential, and 4) other values of such lands.

Under Section 107, if the Secretary of the Interior determines that there is an immediate and substantial increase in the need for municipal services and facilities in communities located on or near NPRA as a direct result of the exploration and study activities authorized by this title, and that an unfair and excessive financial burden will be incurred by such communities as a result of the increased need for such services and facilities, he is authorized to assist such communities in meeting the costs of providing increased municipal services and facilities. The Secretary of the Interior shall carry out the provisions of this section through existing Federal programs, and he shall consult with the heads of the departments or agencies of the Federal Government concerned with the type of services and facilities for which financial assistance is being made available.

3. Exploration and Petroleum Potential

Surface exploration within the area began in 1904, and various levels of geologic exploration have continued intermittently to the present. Following designation of the Naval Petroleum Reserve No. 4 in 1923, geologic mapping as a precursor to exploration was conducted from 1923 to 1926.

A major program, with the defined objective "to appraise the oil possibilities of Naval Petroleum Reserve No. 4 and surrounding areas" was begun in 1944. From 1944 to 1953 extensive geological and geophysical surveys were carried out, and 36 test wells were drilled in and adjacent to NPR-4. The locations of these wells are shown in figure 2. Test well drilling resulted in the discovery of a small oil field at Umiat; a gas field at Gubik; a small gas field at Barrow; three possible gas fields at Meade River, Square Lake, and Wolf Creek; and two minor oil



1.	South Barrow	1
2.	South Barrow Gas Field	
3.	Avak	1
4.	South Barrow	3
5.	North Simpson	1
6.	Minga (Velocity Test)	1
7.	Simpson	1
8.	Topagoruk	1
9.	East Topagoruk	1
10.	Fish Creek	1
11.	Gubik	1
	Colorado Oil and Gas	1
12.	Gubik	1
13.	Grandstand	1
14.	Umiat	2-11
15.	Umiat	1
16.	Square Lake	1
17.	Wolf Creek	2
18.	Wolf Creek	1
19.	Wolf Creek	1

20.	Titaluk	1
21.	Knifeblade	1
22.	Knifeblade	2-2A
23.	East Oumalik	1
24.	Oumalik	1
25.	Meade	1
26.	Kaolak	1
27.	Texaco E. Karupa	1
28.	Texaco W. Kurupa	1
29.	Arco Schrader	1
30.	McCulloch Colville	1,2
	McCulloch E. Umiat	2
	British Petroleum Umiat	
31.	Arco Itkillik	1
32.	Union Kookpuk	1
33.	Gulf Colville Delta	1
34.	Cape Halkett	1
35.	East Teshekpuk	1
36.	Iko	
37.	South Harrison Bay	1

38.	Atigaru Point	1
39.	West Fish Creek	1
40.	W.T. Foran	1
41.	South Simpson	1
42.	South Barrow	12,13,14,17,19
43.	South Barrow	16
44.	Drew Point	1
45.	Kugrua	1
46.	South Meade	1
47.	North Kalikpik	1
48.	Inigok	1
49.	Tunalik	1
50.	Peard	1
51.	Ikpikpuk (Drilling)	1
52.	East Simpson (Drilling)	1
53.	J.W. Dalton (Drilling)	1
54.	Lisburne (Drilling)	1
55.	Seabee (Drilling)	1
56.	Walakpa (Testing)	1
57.	East Simpson (Drilling)	1

Figure 2. Location of Petroleum Exploration Wells in and near NPRA.

deposits at Simpson and Fish Creek. The gas field at Barrow was developed for local use. This program was recessed in March 1953.

Since 1953 the Air Force has drilled a well at Barrow to replace a Navy gas well destroyed by fire and the Navy has drilled eight additional wells at South Barrow in order to assure a continuing supply of gas for Barrow. Petroleum exploration by the Navy includes two wells drilled in 1975; one in 1976; and six in fiscal year 1977. Seven exploration wells were drilled in 1977-78 and six wells were drilled in 1978-79 by the U.S. Geological Survey.

Immediately adjacent to the Reserve, oil companies have drilled six wells south and east of Umiat, two wells in the Kurupa and Killik Rivers areas southwest of Umiat, and three wells in the lower Colville River area. To the east of NPRA, the Prudhoe Bay field has been extensively developed.

Briefly, the Prudhoe Bay field consists of multiple stacked reservoirs, which reach their maximum development near the crest of the Barrow Arch. Along the north flank of the arch, the reservoir rocks are truncated and are directly overlain and sealed by very rich source rocks. Subsequently, these source rocks were buried to oil-generating depths, and the oil thus produced migrated updip into a trap on the crest of a structure formed on the Barrow Arch. It is this rare combination of highly favorable circumstances that resulted in the largest petroleum accumulation in North America. According to American Petroleum Institute and American Gas Association figures (1974), Prudhoe Bay proven reserves in the major reservoir are 9.6 billion barrels of oil and 26.5 trillion cubic feet of gas. The rarity of this combination of geological features suggests that hydrocarbon accumulation of similar magnitude may not exist anywhere else on the North Slope.

B. Study Approach for Environmental Analysis

As mentioned in I.A.2., Public Law 94-258 provides in Section 105(b) that:

> The President shall direct such Executive departments and/or agencies as he may deem appropriate to conduct a study, in consultation with representatives of the State of Alaska, to determine the best overall procedures to be used in the development, production, transportation, and distribution of petroleum resources in the reserve. Such study shall include, but shall not be limited to, a consideration of —
>
> 1) the alternative procedures for accomplishing the development, production, transportation, and distribution of the petroleum resources from the reserve, and
>
> 2) the economic and environmental consequences of such alternative procedures.

Responsibility for the Presidential Study was delegated to the Department of the Interior, which, in turn, assigned responsibility for the economic and policy analysis to the Office of Minerals Policy and Research Analysis under the Assistant Secretary for Energy and Minerals, and responsibility for the environmental analysis to the Geological Survey. This report, together with that of the economic and policy analysis, comprise the complete report of the Presidential Study mandated in Section 105(b) of the act.

This part of the report is an environmental analysis; it precedes any proposal or decision for the development of the National Petroleum Reserve in Alaska. As such a precursor, it puts forth various issues and concerns for consideration by the Secretary of the Interior, the President, and the Congress.

1. Environmental Analysis–Purpose and Scope

This environmental analysis assesses the impacts of potential oil and gas development within the National Petroleum Reserve in Alaska (NPRA). Its purpose is to provide a description of the environmental consequences of potential development, production, transportation, and distribution of petroleum resources on the physical, biotic, and human environments. The result of this analysis, together with those of the economic and policy analysis [Section 105(b)] and the land use study [Section 105(c)], provide the basis for subsequent recommendations to Congress.

The scope of this study is extremely broad, ranging from the onsite impacts of well drilling within NPRA through the overall impacts of transportation routes from NPRA to major refinery centers and regional oil and gas consuming areas in the conterminous United States. Development in any part of NPRA and major transportation corridors, both existing and proposed, are considered.

In addition to the broad geographic scope, this environmental analysis is, of necessity, qualitative in its consideration of potential development of the resources. Until such time as specific oil and/or gas fields are identified and specific infrastructures are designed to meet the individual field requirements, only a general model for development and production can be described. The model used in this analysis is based on the current activity at the Prudhoe Bay field and on the experience gained in the construction and operation of the Trans-Alaska Pipeline System, which together comprise the current petroleum production and development technology in the Alaskan Arctic environment.

2. Strategy for Analysis

To date no commercially exploitable reserves for the export of oil and gas have been located in NPRA. Although estimates of overall occurrences can be made, any assumption of a given field size at any specific location in NPRA would be pure conjecture. Similarly, a specific, detailed infrastructure cannot be described at this time. The number and spacing of wells, size and lengths of gathering lines, and the type and extent of support facilities are determined by the areal extent of the field, its pay thickness, and the porosity of the oil- or gas-bearing rock. Consequently, only a general model based on the Prudhoe Bay experience has been used as the basis for assessing environmental impacts.

Similarly, specific routes cannot yet be determined for transport of oil and gas from NPRA to transshipment terminals in Alaska and transport to the conterminous United States. Only general corridors to various prospective transshipment locations can be postulated. Various corridors through Alaska and the conterminous States, both existing and proposed, are described herein. None of the development or transportation models — bases for environmental assessment — represent proposals for NPRA.

In view of the nonspecificity of actions to be analyzed, two approaches to the environmental analysis have been developed. The first is a generic approach which evaluates 1) the environmental consequences of standard development and production procedures, incorporating current experience in arctic frontier areas, on the entire NPRA environment, and 2) the environmental consequences of current technology associated with oil and gas transportation and distribution. In this manner, areas of significant environmental concern are identified. Further, impacts on local, regional, and at-large levels can be identified. The second approach is related to identified land values in NPRA. In this approach, specific land values, as determined in the various field studies and analyses for the Section 105(c) study, are identified for designated petroleum activity areas delineated for the economic and policy study also conducted under Section 105(b). Combined, these approaches provide the most complete analysis possible at this time. If specific economically exploitable reserves are identified in the future, and if detailed plans for development are proposed, it is likely that environmental impact statements incorporating quantitative impact analysis will be required under the National Environmental Policy Act of 1969.

II. Environmental Impacts of Petroleum Development and Production in NPRA

For this study, environmental impacts are expressed as qualitative effects, changes, or consequences associated with prospective petroleum development. Preceding any proposed project, program, or special legislation, impact analysis is necessarily broad and cursory. The purpose of early impact identification is twofold: to apprise the public and decisionmakers of major environmental issues and concerns and to indicate expected impacts which would require in-depth analysis by any future program or project study.

Because no specific programs have been developed to date for NPRA, no site-specific analyses of impacts are possible. Such analyses will be possible only when specific lease sites and programs are identified. This impact analysis therefore considers those anticipated impacts that could likely be associated with future potential development. Depending upon location of potential development, many of the impacts discussed could be successfully mitigated or avoided; others would not even occur.

Alteration of the physical environment within the Reserve may be a direct consequence of activities, such as pad construction for roads, airfields, camps, and pipelines; disposal of waste; drilling of oil wells; installation of pipelines; operation and maintenance of roads, airfields, communication sites, and storage yards; construction of powerplants and pumping stations; use of temporary roads and trails; extraction of oil and gas and sand, gravel, and stone; manmade cuts; river and stream crossings; increasing human access and use; and occurrence of fires and oil spills. Alteration of the physical environment affects the plants and animals of the altered area in obvious or subtle ways. These effects, in turn, have an impact on the social and economic patterns in the lives of both residents of and visitors to the areas being developed.

Environmental impacts are divided into two categories: impacts associated with development and production, largely within NPRA, and impacts associated with transportation and distribution, largely outside NPRA. Lacking a project description, impact analysis derives from conventions of petroleum development which are described in Appendix C. Each analysis is further divided into three subparts; that is, impacts on the physical, biotic, and human environments. Detailed description of the environment is contained in Appendix A.

Impact identification is provided by tables indicating various actions and effects in terms of magnitude, duration, and location. The accompanying narrative explains these effects or impacts in qualitative terms, oftentimes modifying statements due to lack of basic information or project specifics. Above all else, major and significant impacts and special environmental considerations are identified for future reference.

Following is a key to the table categories and terms: 1) *action* is a discrete activity associated with construction, operation, or rehabilitation; 2) *impact* is a change or effect from the action (more than one impact may be listed for a given action, including primary and secondary impacts); 3) *magnitude* refers to the extent or significance of an impact, e.g., a) *major* impacts are significant and must be strictly controlled, b) *moderate* impacts are significant but generally self-limiting, and c) *minor* impacts are insignificant individually, but may be significant when cumulatively considered with other actions and impacts; 4) *term* refers to the duration of an impact, e.g., a) *short* term equals zero to 3 years, b) *intermediate* term equals 3 to 30 years, or the expected life of the project; c) *long* term equals more than 30 years, or beyond the expected life of the project; 5) *location* of the impact may be expressed as a) *onsite*, on a defined, directly impacted area, b) *local*, near or in the immediate environs, or c) *regional*, within the extensive environs, but nevertheless stemming from actions and impacts.

Use of and reliance on impact tables is limited to convenience and cursory evaluation. The table categories and terms are qualitative, general indications of expected impacts associated with petroleum development activities. Without project specifics, environmental assessment must be largely qualitative. If a project or program is defined in the future, the assessment procedure can be expanded so as to include quantitative evaluation of effects.

A. Physical Environment

Impacts on the physical environment usually are associated with surface disturbance and degradation of air, water, and noise quality. Physical conditions characteristic of the Arctic present applied problems, such as occurrence of ice-rich permafrost, wet or moist tundra, zones of natural erosion, and flooding.

Petroleum development, at the present state-of-the-industry, requires large quantities of water and gravel. Extraction and use of water and gravel, both of which are limited in amount and accessibility within the Reserve, can be expected to constitute a major physical impact. Future location of oil and gas fields and linking pipelines and roads will provide a basis for site-specific physical impacts, varying in magnitude and duration according to the affected terrain.

1. Land Characteristics

a. General Impacts

i. Permafrost Soils

Permafrost, or perennially frozen ground, in the Arctic coastal plain is largely rich in ice. Because of this, when permafrost is melted the ground loses volume. Ice-rich permafrost (and consequent severe thaw settlement) extends from the top of permafrost to a depth of about 20 feet (6 meters) in the Barrow area. In the silt-mantled upland that borders the northern front of the foothills, ice-rich permafrost may extend to depths of 100 feet (30 meters) and thaw settlement may be as great as 75 feet (23 meters) where the ice content of the ground averages 80 percent. The prudent engineer, therefore, either obtains adequate subsurface test data or assumes that permafrost is ice rich, that it will settle if melted, and designs accordingly.

Permafrost is in delicate balance between heat flowing from the earth and cold penetrating from the surface inward. Its balance is affected by changes in the ground-surface temperature. Changes in the ground-surface temperature are brought about by changes in solar radiation; heat gained or lost by convection or conduction; heat lost or gained by evaporation or condensation of surface moisture; heat conductivity, shading, and transpiration effects of vegetation; reflectivity (albedo) of the ground surface and its vegetative cover; and changes in snow-cover characteristics. Construction activities cause gross disruptions of this sensitive balance.

Insulation of the permafrost by layers of gravel placed beneath roadways or work and building pads can protect permafrost. Designing buildings to prevent heat loss is also a means of mitigating the effect of construction. Layers of board-stock insulation (styrofoam) have been used as a substitute for a part of the gravel to cut costs and to conserve gravel. Board for stock as an alternative to gravel as an insulation material has not been adequately time tested.

Permafrost can also grow upward or aggrade under thick pads of gravel on roads and airfields. Growth of permafrost into a linear pad, such as that beneath a road or the work pad adjacent to a pipeline, has at least one serious impact. On slopes as steep as 25 percent, where practice indicates that overlay pads are desirable, growth of permafrost into the gravel pad causes the water flowing through the active layer to be impounded. The active layer is a

Polystyrene insulation placed under work pads provides protection for the underlying permafrost and reduces gravel needs. (Atlantic Richfield Company)

Compression of the tundra mat by vehicles during the summer may cause gullying and slumping. Work crews made these tracks going back and forth. (Robert Lewellen)

surface layer of ground that is alternately frozen each winter and completely thawed each summer; its thickness varies from several inches to about 3 feet (a few centimeters to 1 meter). Impoundment or ponding degrades underlying permafrost. Attempts to relieve the problem by placing culverts through the pad channelize the water downstream from the culvert and start thermal erosion problems in an ice-rich slope. Careful design and proper insulation can alleviate or avoid these difficulties.

ii. Topography

In the study area terrain sensitivity is governed by such properties as vegetation, peat thickness, soil texture and ice content, and natural slope.

Vegetation has a direct influence on the amount of heat entering and leaving the ground. Removing, compacting, or otherwise disturbing the living vegetation, all other things being equal, leads to an increase in thickness of the active layer.

Removal of the peat layer, as in a borrow pit, exposes the soil to erosion by running water or melt by above-freezing air temperature. Thermokarst subsidence (settling or caving of the ground), gullying, or slumping may result at the exposed area. Compression of the vegetation and peat layers reduces their insulating properties, and, in areas of high-ice-content soils, thermokarst subsidence may ensue. The long-term reaction of terrain to disturbances that compress the peat layer (tundra mat) is not well known. Moderate compaction of the peat layer may lead to thermokarst subsidence that appears only after several years (Haugen and Brown, 1971). Scars left by the passage of vehicles which damaged the tundra cover 20 years ago are still apparent. On level terrain, surface disturbances are predominantly manifested as thermokarst subsidence and ponding. On sloping terrain, gullying and slumping develop from disturbances and may increase with time.

The time of year when the disturbance occurs is a critical factor in determining the depth of peat-layer change and the ensuing reaction of the terrain. Observations have shown that summer operations cause the most damage, typically in the form of rutting, thermokarst subsidence, slumping, and gullying, In summer, even one pass of a vehicle may compact or tear the vegetation enough to cause permafrost degradation and ground subsidence. Damage is likely to be least in winter.

In the treeless Arctic any structure becomes a landmark, and any slight elevation causes snow drifts to form in its lee. Creation of snowdrifts on the lee side and thinning of snow by scour on the upwind side of a structure, such as a road work pad, can have an effect on the mean annual ground-surface temperature, which, in turn, can affect the thermal regime of the vegetation, active layer, and permafrost.

iii. Water Resources

Water is a necessary component of any petroleum development scheme in NPRA. Some industrial uses of water include drilling, construction and maintenance of snow and ice roads and other roads, hydrostatic testing, and water flooding. The amount of water used for the current exploratory drilling program provides a measure for future requirements. A medium-depth hole requires about 5.25 acre-feet or 6,500 cubic meters of water, whereas a deep hole requires an estimated 26 acre-feet or 32,000 cubic meters. Ice road construction uses between 1 and 3.7 acre-feet (1,200 and 4,400 cubic meters) of water per mile (1.6 kilometers) of road. Domestic requirements depend on the number of people living on the site and the amount of water available for use. Domestic use can range from 75 to 200 gallons (283 to 756 liters) per day per person.

Natural water sources include lakes, streams, springs, ground water, snow and ice, estuaries, lagoons, bays, and the ocean. Other sources, such as reservoirs and storage tanks, are manmade.

Hydrologic systems in the Arctic are dominated by the presence of permafrost, which acts as a barrier to ground-water movement. There is essentially no ground-water discharge or recharge. Hydrologic systems, thus, involve surface processes of streamflow, lake storage, active-layer flow, and long periods during winter when snow and ice cover the surface.

Water availability from natural sources is a critical problem in the foothills region and inland areas of NPRA that are distant from deep lakes or rivers. Springs are extremely limited in NPRA and cannot be depended upon at any time as a source of water supply. Estuaries, bays, lagoons, and the ocean offer an abundant year-round supply of brackish to saline water that might be utilized when large volumes of water are required. A saltwater pipeline might be considered, in economically and environmentally feasible circumstances, to supply water to water-poor locations.

Greater volumes of water are available from a greater number of sources during summer than during winter. In winter, lakes are the primary sources of freshwater supply. However, because many of NPRA's lakes freeze to the bottom in winter, the number of lake sources which can be utilized for freshwater supply at this time of year is small. During winter, streamflow ceases, and any available water in rivers is stored in isolated pools.

Probable impacts of water use depend on timing, type of source, and distance of source from area of water use. The primary impact of water use from a lake is reduction of stored water. Depletion of winter water storage in lakes and river pools could increase the concentrations of dissolved constituents, including dissolved oxygen, in the remaining water. The severity of the impact of withdrawal depends on the

Bridges placed in the active channels of rivers can cause localized bank erosion and depth scour. (Charles Sloan, U.S. Geological Survey)

size and depth of the lake or pool relative to the amount of water withdrawn. Use of snow and ice for water supply could result in reduction of runoff and surface-water recharge, though these impacts would probably be minimal. If salt water is used, any accidental spill could have major detrimental impacts on land or in water bodies, such as killing vegetation, thereby promoting degradation of permafrost, or changing water quality. Remoteness of water sources may require road construction and pose a safety hazard to haulers during winter storms and periods of low visibility.

Impacts of water use are, for the most part, mitigable. If proper abatement measures are taken, the impacts of water use will be minor. Water needs should be supplied from sources where potential adverse impacts are least. In addition, use of several different water sources during winter months might lessen negative impacts on any one source. Winter water-supply problems could be alleviated through use of storage facilities (reservoirs and tanks) which would hold water collected during summer months. Conservation measures could be enacted to regulate water use during critical periods. Recycling water from mud pits and domestic water for industrial use might be considered. Snow fences and other snow-harvest methods could be used in conjunction with snow melters to take advantage of snow as a winter water source. Salt water could be used in place of fresh water for many industrial water uses. Maintenance and eventual revegetation of access roads to water withdrawal points, as well as stabilization and rehabilitation of side slopes, would prevent erosion and sedimentation. Finally, State water regulations must be enforced. This can be accomplished through monitoring efforts throughout the life of the project.

The flow of water on the surface and in the active layer is usually changed by any kind of construction disturbance which changes the thermal regime. On flat terrain, such as the coastal plain, surface drainage is poor at best, and linear fill structures act as dams to overland flow, causing ponding and winter icings along the structures. Melting of the underlying permafrost will normally result, causing settlement.

Gravel mining in rivers can change the river hydraulics so that erosion of bed and banks will occur. However, the greatest impacts on the hydrologic system are from structures placed in the active channels and flood plains of rivers. Bridges, pipe-support structures, road embankments, and river-training structures, such as spur dikes and revetments, interact with streamflow to cause erosion of banks and beds in some locations, deposition of sediment in other places.

Adverse impacts on streamflow can be mitigated in the following ways:

- Adequate cross drainage may be provided by culverts and bridges on roadways to prevent ponding and formation or enlargement of icings.

- Hot oil pipelines should be elevated, rather than buried, in ice-rich permafrost.

- Placement of structures in active channels and flood plains should be avoided where possible.

- Use of pile foundations and insulation of buildings to reduce heat loss will result in reduced thawing around these structures.

iv. Mineral Resources

Withdrawal of oil and gas is a depletion of mineral resources. In the same way, borrowing from the region's limited supplies of sand and gravel for construction purposes is, in most cases, also a depletion of a nonrenewable resource. Depending upon levels of development, millions of cubic yards of gravel could be required — by far the major impact upon the physical environment. The most likely sources of gravel are the deposits along modern beaches or the Colville River and its tributaries south of Umiat.

Some sand and gravel deposits are not renewable because they are in river terraces or raised beaches no longer being built by streams and waves. Other sources are modern flood plains in which the gravel is present only as a thin surface layer, a lag armor deposit; clastic sediment of gravel size is not now being transported by streams. Most coastal plain streams have such thin deposits of gravel that large areas would have to be mined to yield even modest amounts of gravel. Furthermore, in many areas of the coastal plain the stream gravel rests on bluish gray clay. If the clay is disturbed by mining the gravel, it would produce large volumes of suspended sediment having a slow settling velocity; the material would resist settlement in constructed settlement basins and would alter the clarity of the water for many miles downstream.

Borrowing of sand can have primary impacts similar to those of gravel removal. There is a great deal of sand in the dunes in the eastern part of the Reserve. However, removal of the overlying vegetation or peat layer will expose sand to erosion by wind or water.

Mitigation measures include a site-specific investigation before withdrawal and careful planning of routes from the quarry/borrow pit to the point of use. Sand and gravel should be removed from places where these resources are being replaced by streams or coastal currents before ancient deposits are mined.

The impact of oil and gas development on the region's coal resource would be to make the coal more accessible to potential markets throughout the world. It would also make coal resource studies easier and may provide avenues for transmittal of locally generated power developed from coal to Alaskan markets.

b. Activity-Specific Impacts

Following is a description of impacts to the physical environment based on activities associated with potential development and production of petroleum resources of NPRA. These activities are divided chronologically into construction, operation and maintenance, and rehabilitation. The impacts are summarized in table 1.

Table 1. Physical Impacts from NPRA Petroleum Development and Production

Source	Impacts	Magnitude[1]	Term[2]	Location[3]
Work and construction pads	Compaction, thaw, ponding	*/**	**/***	*
Borrow pits and quarries	Depletion of resource	***	***	*
	Change in topography	*	***	*
	Enlargement by thaw collapse; thaw lake development.	*/**	***	*
River crossings for roads and pipelines.	Erosion, sedimentation	*/**	***	*
Manmade cuts in rivers, lakes, sea banks.	Erosion, subsidence	**	***	*
Campsite and industrial waste disposal.	Collapse or seepage from sewage lagoon.	**	*/**	*
Pipeline construction:				
Buried	Thawing, rupture	**/***	**/***	*/**
Elevated	Thawing, rupture	**	*/**	**
Operation and maintenance	Degradation of permafrost	**	***	*
Rehabilitation and cleanup	Change in topography; degradation of permafrost.	***	**/***	**/***

[1] * = minor; ** = moderate; *** = major.
[2] * = short; ** = intermediate; *** = long.
[3] * = onsite; ** = local; *** = regional.

i. Construction

Previous experience in arctic areas has shown that many adverse effects of conventional construction practices can be avoided but that certain adverse effects cannot be mitigated even by superior design or practice. Thawing of frozen soil causes instability when the insulating vegetation and peat cover is removed or compressed by construction equipment. Solar radiation, together with runoff and flowing or ponded thaw-water, can cause substantial damage in a short time. These effects may lead to long-term slope instability, permanent modification of surface drainage, erosion and deposition, and lasting scars in the tundra mat.

Construction activity, particularly road construction, contributes to the formation of icings and can cause enlargement of existing natural icings. Icings, in turn, can impair or prevent vehicular traffic when they occur on roads and can temporarily divert surface-water flow. Diversion of surface-water flow near roads may mean increased erosion in unprotected areas.

Much of the facility and foundation construction will require temporary winter roads to move men, equipment, and materials to a work site. The type of winter road built is dependent on the terrain, snow conditions, and anticipated road use. In general, four types of roads can be built for anticipated needs: 1) trails where the snow is plowed aside to permit access; 2) snow roads on which snow is dragged and compacted to the required density; 3) ice-packed roads (on which water is sprayed to increase strength); and 4) ice roads formed on lakes or rivers. Frozen lakes, rivers, and areas with low-lying vegetation are preferable to upland areas for winter road construction.

Misuse of winter roads results from beginning winter road construction or use too early in the fall or extending use too late into the spring. Misuse also refers to continued use of a winter road that has not been properly constructed or that is in obvious need of repair. In permafrost regions the increased depth of thaw caused by surface disturbance along the roadway will result in severe thaw settlement, particularly in ice-rich soils. Thermokarst and surface-flow channelization may result even on relatively flat ground, and on sloping ground, gullying, slides, and siltation may occur. Secondary impacts could follow primary impacts of surface disturbance — for example, a deterioration of water quality may follow siltation.

Proper use of winter roads is expected to produce minimal environmental impact. Although field tests indicate that surface vegetation is usually killed even under a properly constructed winter road, experience indicates that if the peat and moss layer is left intact (thereby protecting the mineral soil), the compacted vegetation and the snow overlay will possess sufficient insulating capacity to protect permafrost.

In the case of off-right-of-way trails, misuse is a possibility. An additional problem may be the indiscriminate creation of winter trails to and from a pipeline, camp, or well, especially in the tundra or where snow hauling is necessary. Controlled access to facilities and use of low-ground-pressure vehicles would mitigate these impacts.

Sand and gravel pads are used for year-round roads, camps, airfields, drill sites, storage areas, pump stations, power houses, and communications sites, or other work sites. Most structures or use areas require an insulating pad even for temporary use. A work pad, consisting of crushed rock, pit-run quarried rock, sand and gravel, or ther suitable material commonly combined with a buried layer of board stock insulation, provides a working surface that will prevent permafrost degradation. Design normally calls for a pad about 6 feet (about 2 meters) thick. Pad design is similar for most kinds of temporary structures; permanent structures are sometimes installed on piles or refrigerated foundations and do not rest directly on the pads.

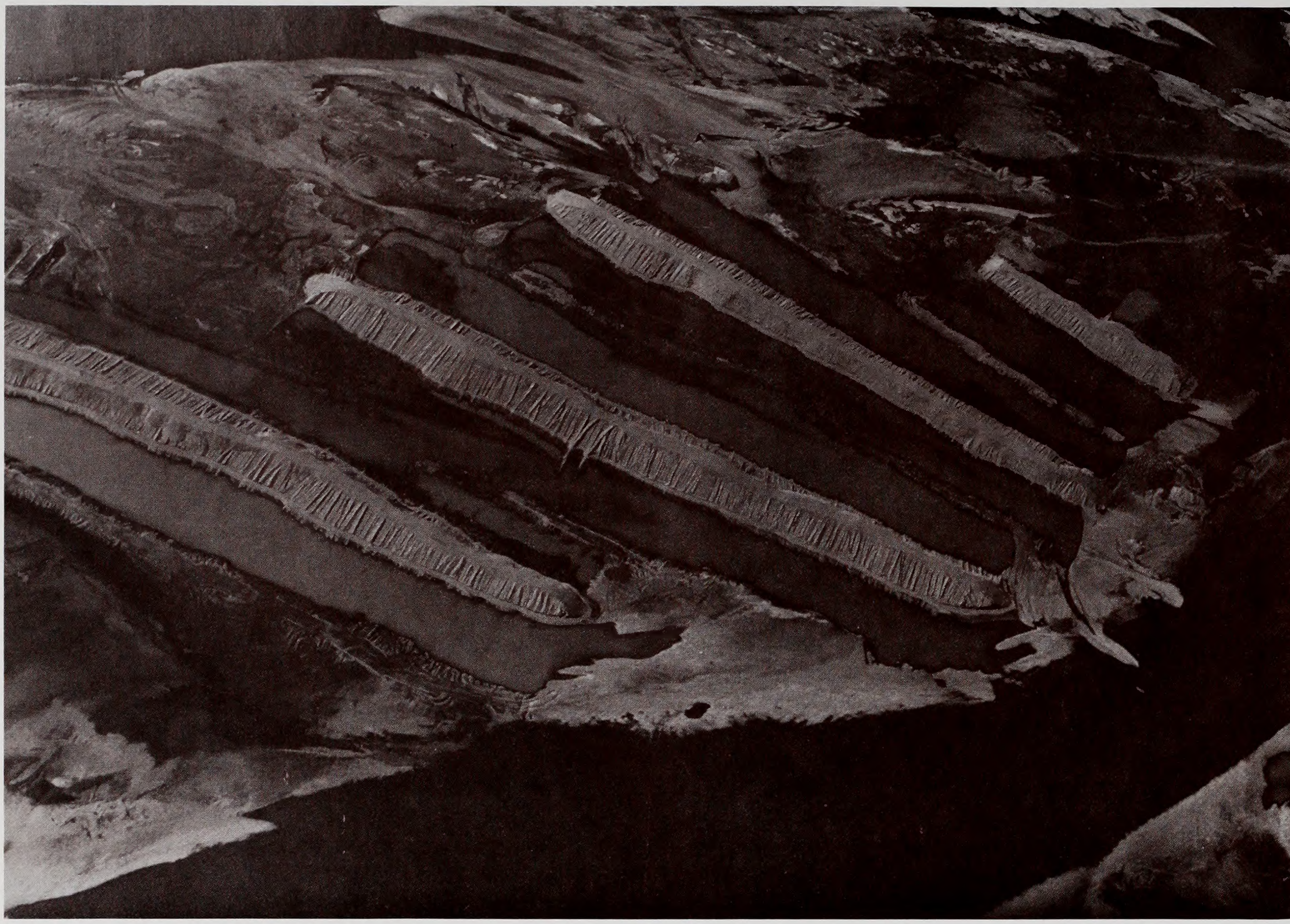
Pads can affect vegetation directly (onsite) by burial or indirectly by the dust clouds raised by passing vehicles (nearby). Pads commonly alter drainage to form ponds which further affect ice-rich permafrost uphill from the pad. Also, gullies commonly form on slopes where culverts in the pads channelize flow. This impact could be partially mitigated by shaping and orienting the pad to divert drainage and not pond it. This could be accomplished by building circular pads or by orienting one corner of a square pad upslope.

Quarries and borrow pits, like work pads, are common elements in normal arctic construction. These supply necessary building materials, such as sand, gravel, and stone.

Quarry materials suitable for use as riprap and dimension stone generally are not available in the coastal plain and foothills north of the Colville River. Exposed bedrock is generally soft sedimentary rock that fails durability and abrasion tests required of riprap to protect against river and ocean erosion — the major requirement.

Sand and gravel are available from the modern beach, raised beaches, river terraces, and some river channels and flood plains. Suitable coarse sediments are in short supply and are often located far from the point of need. Removing modern beach gravel involves the risk of causing undesirable shoreline changes at, or adjacent to, the borrow area. Raised beaches are also nonrenewable resources, as are river terraces. Borrowing from modern stream channels, in

The area below was traversed by a 37.5-mile ice road from Inigok to the Kikiakrorak River Delta. Proper construction resulted in minimal damage to the tundra, barely visible in the center of the photo (Husky Oil Company)



Gravel removal can alter stream channels and disturb fish habitat.

addition to disturbing fish habitat, risks altering the stream channel regime in areas in which the gravel is a thin deposit that is not renewed by spring floods. Most of the coastal plain streams' gravel deposits cannot produce the required volumes of material. Siltation is likely to accompany gravel removal but can be lessened through the use of a berm between the active river channel and gravel extraction operations. Burger and Swenson (1977) have stated that the TAPS stipulations covering the mining of material sites were inadequate and that violations and subsequent damage occurred primarily because of inconsistent interpretations of mining plans and inadequate enforcement of stipulations.

The impact of developing large volumes of gravel from the limited resources would be major, not to mention the impact of cost of long hauls on development plans and financing. These major impacts demand that most development work be done in winter and that permanent roads and other pads serve only the minimum essential facilities. The use of local sand deposits in combination with artificial insulation could help ease the need for scarce supplies of gravel and reduce indiscriminate mining.

Secondary impacts of material borrow also are to be expected. Quarry sites would leave scars along ridge crests and hilltops and would require erosion control to prevent soil flows, soil slumps, and landslides. Water is expected to fill upland pit sites and may rapidly generate thaw collapse of their banks. Depending on ice content of the soil, the area may form a thaw lake unless the pit is backfilled after use. Drainage from water-filled pits may cause gullying and some siltation.

Still another impact could result from the storage of ice-rich overburden removed in the developing of a borrow pit or quarry. If initially stored in frozen condition, thawing of this ice-rich material may cause siltation of lakes, streams, and the tundra.

River crossings for roads and pipelines require site-specific design and mitigation. A potential impact is failure of the crossing — whether a bridge or buried pipeline — adding pollutants or sediment to the stream. If a cold buried gas pipeline crossing is not properly designed, it could freeze ground water, resulting in frost-broken pipe, or disrupt groundwater flow, causing icings in the streambed. These changes in regimen can cause erosion or sedimentation at the site or downstream. Bridges, pipe-support structures, road embankments, and river-training structures, such as spur dikes and revetments, interact with streamflow to cause erosion of banks and beds in some locations, deposition of sediment in other places.

Impacts from crossings might be lessened by means of the following practices: burying the pipeline a safe distance below maximum river scour; designing above-river structures for placement well above flood level; and avoiding crossings where there are known icings.

Manmade cuts in river, lake, and sea banks, or through rock knobs and ridges cause varying impacts, depending on design and slope. Thaw of ice-rich soils in cuts may result in slumping or gullying. In terrain with a grade of 5 percent or more, gullies could reach depths of about 3 feet (1 meter) at the end of one summer, increasing to about 10 feet (3 meters) with time in areas of ice-rich soils. Cut grading would probably be required at approaches to river crossings. Thaw of ice-rich soil would produce thermokarst subsidence, slumping, and gullying and would lead to increased siltation of the river. In the Arctic, banks of all water courses — regardless of size — are potential sources of instability if disturbed. In dunes, cuts remove stabilizing vegetation and permit wind erosion.

Experience on the trans-Alaska pipeline led to minimized use of cuts, especially on side slopes in unconsolidated, perennially frozen deposits, or where overlay pad construction was used on slopes as great as 20 to 25 percent. Manmade cuts were found to add to winter maintenance problems by creating additional snow drifts, especially in cuts oriented north-south.

Campsites and waste disposal may present chronic problems unless facilities and practices are standardized. Camps at intervals along roads and pipelines and at well sites and port facilities require adequate water-supply and waste-disposal systems. Each camp requires a package plant with sewage lagoon and incinerator for burnable refuse, as well as places at which to dispose of unburnable solid wastes. The primary impact of a sewage lagoon is flooding of a vegetated area. The lagoon has the potential of heating the ground and starting thaw of permafrost, which could lead to collapse of the lagoon and escape of liquids. Under certain conditions, heat from a lagoon located near a large stream could thaw permeable alluvial deposits to allow escape of fluids to a stream, altering water quality in winter and perhaps affecting potability of the water during low-flow periods. A mitigation measure would entail placing the sewage lagoon away from any through-flowing waterways. Other mitigating procedures would involve: 1) reducing the temperature of effluent discharge to minimize thermal erosion; 2) recycling of water in a cascading system if certain processes do not require high water quality; and 3) use of a series of interconnected lagoons so that water for industrial use may be withdrawn from the last holding lagoon.

Five methods for disposal of unburnable solid waste are: 1) disposal in mounds on open tundra, adding a cover and seeding when storage is completed; 2) burial in existing borrow pits or quarries on an upland slope to stabilize any tendency in the existing pit to enlarge by thaw of permafrost; 3) burial in existing borrow pits near rivers and streams (possible flooding of the pits or ground-water seepage may carry major impacts); 4) burial in a new pit away from a stream; and 5) hauling solid waste out of NPRA for disposal elsewhere.

The incineration and burial of solid waste will cause localized air pollution from burning and terrain damage from burial. Buried waste can be a long-term source of annoyance due to the fact that burial in frozen ground with the prevailing low temperatures will prevent the breakdown and corrosion of materials which normally occur in warmer climates. Burial of solid waste can also create erosional and freeze-thaw problems in the area unless mounds are properly stabilized and revegetated.

Mitigative measures for construction waste disposal should consider: 1) using materials for construction and camp needs that will not produce a great deal of packaging or residue waste; 2) utilizing a garbage and "honey bucket" collection system to haul all construction wastes to permanent disposal areas either at base camp or areas with convenient transport out of NPRA; 3) instituting a recycling program for gray water and for construction materials that may be refabricated and reused; and 4) situating all solid waste burials where they will not adversely affect surface waters. State of Alaska law restricts solid waste disposal on permafrost, allowing it only with "special procedures" approved by the State. Further regulations require disposition of solid waste in such a way as to prevent waste materials, leachate, or eroded soil particles from entering State waters.

Construction of gathering lines carries varying impacts, depending on design and site selection. Pipelines to be considered are hot oil lines (either elevated or buried), or chilled or cold (ambient) gas lines. Normally, any pipeline would be accompanied by a parallel work road, either on a pad for summer construction, or on a much travelled winter trail for winter construction. In the coastal plain and foothills, the hot oil line would be elevated; the only below-ground sections would be those in alluvium along a major river, such as the Colville, or in specially designed sagbend animal crossings. In the mountains, it may be possible to bury segments of a hot oil line in bedrock or alluvial deposits, but where it passes over fill or other silty material, it would have to be elevated, according to current practices. Primary impacts of trenching for a hot oil line would be degradation of the permafrost. Burial of oil or gas lines in bedrock would occasionally require blasting, with possible effects such as rock falls and avalanches. A buried line could alter the hydrologic system enough to eliminate or create icings, and, by undercutting slopes, cause landslides and mudflows or increase erosion near the pipeline. Alignment to avoid known unstable areas could lessen or eliminate several of these impacts.

An elevated hot oil line is designed to prevent degradation of permafrost. The elevated line would have a visual impact but should not materially affect soils and permafrost. An added hazard of an elevated pipeline is vulnerability to vandalism and to slides, slushflows, and avalanches.

A cold or chilled buried gas line has a number of impacts in common with a buried oil line. In addition, it is subject to heaving of the ground and disruption of ground-water-flow systems that may cause icings. River icings can be viewed in terms of their effects on nearby structures or on the river regime. Structures such as compressor stations should be situated away from potential and observed icing areas. In permafrost areas, a chilled pipeline could reduce the depth of the active layer above the pipeline axis relative to areas away from the pipeline. The reduced active layer thickness could act as a dam within the active layer and redirect ground-water drainage on sloping terrain. Redirection of drainage could lead to slope instability at the point of discharge. In winter, ground icings could be formed along large sections of the pipeline as a result of ground water surfacing at the dam within the active layer. In ice-rich permafrost areas it may be advantageous to elevate a gas line.

Detailed discussion of impacts associated with pipelines — both oil and gas, buried and elevated — is available in environmental impact statements for the trans-Alaska pipeline (U.S. Department of the Interior, 1972) and the Alaska natural gas transportation system (U.S. Department of the Interior, 1976).

Oil and gas wells may carry impacts associated with transfer of heat from the hot oil coming up from great depth to the surrounding permafrost near the surface. Modern oil-field technology has devised methods to prevent this transfer of heat. Thus, the problem of collapsing oil rigs characteristic of the early drilling days has been solved. However, mud pits and other activities at a drill rig may transfer some heat to the top of permafrost and perhaps initiate thawing. Placement of mudpits away from through-flowing drainages may avoid impacts such as are possible with sewage lagoons (discussed above). Current NPRA practice is to excavate mudpits to depths such that total containment is provided below the permafrost table.

Accidents and failures may be associated with poor design or carelessness. Leaks, spills, or fires cause case-specific effects that cannot be predicted. Impacts from design error may well occur because existing arctic technology has not been thoroughly tested and is still being developed. Difficult working conditions for men and machines, particularly in winter, may increase hazards. Depending on size, an oil spill or fire can transfer enough heat to permafrost to cause thaw and collapse, if the albedo is altered, or if vegetation is killed and its insulating properties reduced. Oil-spill prevention and contingency plans and prompt action will minimize adverse impacts. Alyeska Pipeline Service Company prepared a contingency plan outlining procedures for handling construction-related oil spills. Despite that contingency plan, the effort expended by Alyeska and its contractors was not adequate. Numerous small spills and several serious spills occurred. Reporting of spills was inconsistent, and response to spills was, in many cases, quite poor. Minimizing the effects of oil spills includes education and training of employees, good

Elevated pipelines are designed to protect permafrost. (Atlantic Richfield Company)

Dust from construction activities can be a source of air pollution. (Alyeska Pipeline Service Company)

maintenance, and strict enforcement of oil-spill regulations and policies. Adequate surveillance and site-specific corrections during all project phases would lessen impacts.

ii. Operation and Maintenance

Operation and maintenance include routine inspections, providing upkeep and replacement parts, and mobilization of workers and equipment to meet emergencies. Correcting design failures is an important part of the operation and maintenance work.

Operating and maintaining a system of gathering lines would be based primarily on the use of aircraft to transport personnel from operating bases to work sites. Bad flying weather would require either postponing work or resorting to surface travel along the right-of-way.

From time to time, summer off-road traffic may have to be allowed with low-ground-pressure equipment to meet emergencies. In winter, some off-road traffic may be permitted, but if trail use continues when there is insufficient snow or ice cover, then the usual consequences of degrading ice-rich permafrost may be expected. Increasing the thickness of the active layer slightly by thawing the upper part of permafrost may still create saturated trails, but continued thaw of permafrost would create water-filled vehicle tracks. Close project surveillance and responsive adjustments can lessen adverse impacts of this phase of development.

iii. Rehabilitation and Cleanup

Most of the material that lies on the pads can be burned, buried, or hauled out. The gravel pads remaining after buildings and equipment are removed also require consideration. Removal of millions of cubic yards of gravel pads is a major and costly undertaking. Presumably the pads, by the end of the project, either have had permafrost aggrading upward into them with thermal equilibrium achieved, or, in a few places, have failed and settled. Removing the pads would leave a compressed layer of vegetation as a protective insulating cover on permafrost. This would lead in the long term to thaw of permafrost. Quite likely, some of the vegetation would be so mixed with the bottom of the pad that it would be picked up during pad removal. In addition, vehicles engaged in removing the pad might accidentally break the tundra mat as they worked. All these actions could lead to degradation of permafrost. To minimize impacts, then, pads should be left in place and reseeded; pads can also be graded and recontoured to blend with adjacent terrain. Nevertheless, they will be conspicuous for tens of years.

2. Environmental Quality

a. General Impacts

i. Air Quality

The most common air pollutants resulting from the construction and operation of oil/gas fields and transportation systems within NPRA will be dust, combustion emissions, and hydrocarbon vapors.

The primary impact of dust in the air is reduced clarity of the atmosphere, resulting in reduced visibility, at or near the dust-producing source.

Over time, and if in high concentrations, dust inhaled into the lungs can contribute to respiratory disease. This effect can be minimized by the use of filtering devices, such as masks.

Fallout of dust on the landscape produces secondary impacts, such as increasing the melt rate of snow by decreasing its albedo. Early snowmelt in downwind zones paralleling roads is an obvious effect of dust along the TAPS haul road.

Accumulated dust may smother vegetation; fallout of dust on standing or flowing water may slightly increase turbidity and decrease light penetration. These impacts are minor.

Dust can be controlled to a certain extent during construction and other periods of heavy road use by sprinkling roadways frequently with water. More lasting control of dust on roadways can be achieved by oiling roads, but runoff from oiled road surfaces can be a source of local water pollution.

Combustion emissions are composed of hydrocarbons, nitrous oxides, photochemical oxidants, sulfur dioxide, carbon dioxide, carbon monoxide, and water. Persistent winds near the ground tend to disperse emissions, but it is not uncommon to see a brownish haze over Prudhoe Bay in the winter.

The emission of water vapor and hydrocarbons can produce local ice fog under the temperature conditions that exist for most of the winter in the Arctic. The extent and duration of ice fog will depend on wind conditions and will worsen during infrequent periods of little or no wind. It is not expected that emission concentrations will ever reach levels that pose a significant hazard to human health, except under local, unusual atmospheric conditions.

Another effect of air pollution in the Arctic is reduced visibility. Reduced visibility in ice fog, complicated by natural fog conditions that can occur over much of the Arctic Slope in winter, can hamper aircraft operations and make ground vehicular movement difficult and hazardous.

Hydrocarbon vapors may escape from fuel, crude oil and/or gas storage, handling, and transport facilities. In sufficient concentrations, these vapors may be a hazard to human health and increase the possibility of fires.

In general, however, NPRA should not be impacted greatly by air pollution because the inversion layer is high and winds are persistent, allowing for wide dispersal and low concentrations of pollutants.

Mitigation of air pollution from combustion emissions can be achieved through use of effective anti-pollution devices on all sources, use of clean-burning fuels and maintenance of equipment to ensure the lowest possible emissions output. Operationally reducing the necessity for open flaring of gas or burning of oil from production tests would further mitigate air pollution effects of combustion.

ii. Water Quality

The disturbance of vegetation and soils that results from construction leads to increased erosion and thermal degradation of permafrost. Water bodies then receive a higher than normal sediment load and thus turbidity is increased.

Higher nutrient and organic loads normally accompany increased sediment loads. Increased organic loading imposes a higher oxygen demand on the receiving water, thus reducing the oxygen available to the biota.

The greatest disturbance and sediment concentrations occur when in-stream construction, such as pipeline ditching and backfilling, takes place. Such peak concentrations are short lived, and impacts are generally local. The long-term and wide-scale impacts from such activities are minor. Erosion of upland sites and aggravated thermal erosion of banks result in low concentrations of sediment. However, sedimentation resulting from these two situations is broader in scale and longer lasting.

Activities designed to create the least disturbance also cause the least erosion and result in little degradation of water quality from increased sediment loads. Disturbed soils can be stabilized through revegetation; disturbed streambanks can be stabilized with riprap or groins.

Heat can be conducted to the aquatic environment from a hot oil pipeline, as heated effluent from waste treatment plants, by cooling water from powerplants, or by radiation from gas flaring. Such activities tend to raise the temperature of the receiving water. The impact of raising water temperature is minimal in an environment like NPRA, where heat loss is rapid. However, warmer receiving waters could reduce ice thickness in winter and provide slightly more favorable conditions for aquatic organisms.

Secondary recovery of oil may necessitate water flooding of the producing reservoir for pressure maintenance. Except for Teshekpuk Lake, there are no large freshwater sources in NPRA. The ocean is probably the only reasonable water source for such activities in NPRA. Use of ocean water would require the operation of a heated pipeline to the field. Any leaks from such a line onto the land or into fresh-

Revegetation is part of the rehabilitation of disturbed areas. Here, hydroseeding is used to spread a mixture of water, grass seed, and mulch to prevent erosion along the trans-Alaska pipeline. (Atlantic Richfield Company)

water environments would have deleterious impacts. The significance of the impacts would depend on the amount and location of the spills. Impacts could be mitigated by minimizing the requirements for salt water and preparing an effective contingency plan for containment and cleanup of saltwater spills in the event they occur.

b. Activity-Specific Impacts

Following is description of environmental quality impacts associated with development and production of petroleum resources of NPRA. These impacts are summarized in table 2.

i. Construction

Construction activities, such as the excavation, transportation, and placement of fill material, cause dust to be entrained in the atmosphere. However, traffic on unsurfaced roadways and airstrips is probably the greatest producer of dust.

Construction activities will also require permanent or temporary airstrips. In winter, large lakes can be used when ice thickness is sufficient to bear the weight of aircraft. Removal or compaction of snow will accelerate the rate of ice formation. However, this increase in ice thickness would result in reduced water supplies, which would be of poorer quality.

Some lowering of water quality would result from construction activities, such as discharge of effluents from sewage treatment at work camps. The greatest disturbance and sediment concentrations occur when in-stream construction, such as pipeline ditching and backfilling, takes place. Such peak concentrations are short lived, and impacts are generally local. Erosion of upland sites and aggravated thermal erosion of banks result in low concentrations of sediment. However, sedimentation resulting from these two situations is broader in scale and longer lasting.

The impacts of air-transport-facility construction can be mitigated to some extent by: 1) following mitigative measures for construction pads at perma-

Table 2. Environmental Quality Impacts from NPRA Petroleum Development and Production

Action	Impacts	Magnitude[1]	Term[2]	Location[3]
	Water Quality			
Construction activities (stream crossings, dredging, roads and airfields, drill pads, causeways, camps, ditches, gravel extraction).	Surface disturbance, alteration of soil thermal regime, alteration of drainage pattern.	**	*/***	*/**
	Increased turbidity	**	*	**
	Thermokarst, icings, ponding, flood hazard.	*/**	**	*/**
Sewage effluent	Increase in organic nutrients; alteration of aquatic habitat.	**	**	**
Solid waste disposal	Leaching of organics and metals into active layer; degradation of surface water.	**	**	**/***
Thermal effluent	Heat transfer; possible reduction in ice thickness.	**	*	**
Saltwater transport — spills	Increased salt concentration in fresh water and active layer.	*	**	**/***
	Destruction of salt-intolerant flora; fish kills.	**	*	*
Oil spills (crude, fuel, lubricant).	Toxic effects on biota	***	**	*
	Interference with reaeration and photosynthesis.	**	**	*
Drilling mud — escape from pit.	Toxic effect on biota	**	*	*
Drilling	Depletion of water resource; impaired water quality.	*/**	*	*
Snow and ice roads	Depletion of water resources; altered drainage patterns.	*	*	*
Hydrostatic testing of pipelines, storage tanks.	Depletion of water resource	*	*	*
Water flooding (fresh water)	Depletion of water resource	***	**	**/***
Domestic water use	Depletion of water resource	**	**	**/***
Operation of pipelines	Thermokarst, frost heaves	**	**	*
	Ponding, change in vegetative patterns.	*	**/***	*
	Air Quality			
Construction activities (drilling, blasting, road pads, airfields, pipelines, camps).	Dust	**	*	*
	Combustion emissions	**	*	*
	Decreased albedo and increased snowmelt.	*	*	*
	Ice fog	**	*	**
Fixed plant operation (gas blowdown, powerplants, gas flaring).	Combustion emissions	**	**	*/**
	Decreased visibility	*	**	*
	Ice fog	**	**	*
	Impaired human health	*	**	*
Accidents (spills, blowouts, fires, explosions).	Hydrocarbon vapors (spills)	*	*	*
	Combustion emissions	**	**	*/**
Burning mudpits	Combustion emissions	**	*	*/**
Waste incineration	Combustion emissions	**	**	*/**

See footnotes at end of table.

Table 2. Environmental Quality Impacts from NPRA Petroleum Development and Production (continued)

Action	Impacts	Magnitude[1]	Term[2]	Location[3]
	Air Quality — Continued			
Fuel, crude oil, and gas (storage, handling, transfer).	Hydrocarbon vapors — potential fire or explosion and hazard to human health.	*	*	*
Pipeline operation	Change in microclimate — heat or cold transfer.	*	**	*
	Altered soil temperature regime	*	**	*
	Green trails	**/***	**/***	*
Traffic — air and ground	Dust and combustion emissions	*/**	**	*
	Noise Levels			
Fixed plant operation	Noise and vibration	*/**	*	**
Accidents (blowouts and explosions).	Noise and shock	*	*	*
Construction activities	Effects on humans — hearing loss, reflex changes, disturbed sense of balance, pain, fatigue, circulatory disorders, annoyance, decreased job performance.	*/**	*/**	*
	Effects on wildlife — similar to human effects, altered behavior and stress.	*/**	*/**	*
Traffic — air and ground	Noise and vibration	*/**	**	**

[1]* = minor; ** = moderate; *** = major.
[2]* = short; ** = intermediate; *** = long.
[3]* = onsite; ** = local; *** = regional.

nent airstrips; 2) allowing no permanent materials or fuel storage on frozen water bodies, including frozen lake winter airstrips; 3) confining winter airstrip construction to the frozen surface of lakes or other areas which would not degrade the ground surface; and 4) insulating the frozen surface of lakes used for winter airstrips by adding snow to prevent deeper freezing, and removing the increased insulation before breakup to allow for normal ice melt.

ii. Operation and Maintenance

Emissions from stationary sources, such as pump stations, compressor stations, powerplants, incinerators, and gathering centers in an oil or gas field, will have moderate, intermediate-term effects on air quality, particularly in winter, when a high-level inversion persists over most of the Arctic Slope. Persistent winds near the ground tend to disperse pollutants, but a brownish haze frequently exists over Prudhoe Bay in the winter. Open burning of oil from mud pits after production tests causes high-level local air pollution for a short period of time. The emission of water vapor from stationary sources, such as compressor stations, can produce local ice fog under the winter arctic temperature conditions. The extent and duration of ice fog will depend on wind conditions and will worsen during infrequent periods of little or no wind. Fires resulting from blowouts and oil spills can cause intense local air pollution of short duration. Secondary tundra fires can result in the destruction of vegetation and the insulating layer over the permafrost and local or widespread concentrations of smoke.

Secondary sewage treatment is required by law at all camps. However, discharge of treated sewage effluent into water introduces nutrients which can alter water quality. The degree of impact is dependent upon the type of receiving water body and the amount of effluent discharged relative to the volume of the water body. Accidents might result in discharge of raw sewage; if extensive or persistent, this would be difficult to mitigate and might have long-term effects.

Removal of solid waste from NPRA would pose no significant hazards to water quality of lakes, streams, or ground water in NPRA. However, water passing through a landfill carries out dissolved or suspended refuse contaminants; this results in degradation of water quality in the active layer. Lakes or streams into which this water drains become similarly degraded. Improper disposal of incinerator-process water and residues may lead to contamination of

A tundra fire, caused by a helicopter crash, destroyed the vegetative mat shown above. (J. C. LaBelle, AEIDC)

water bodies by introducing warm, acidic water containing high concentrations of dissolved and suspended solids. Aquatic biota may be adversely affected by these activities, but the degree of impact would depend on the nature of the contaminants and the characteristics of the receiving water body.

If the measures outlined in the State regulations are followed, adverse impacts to water quality will be minor or nonexistent. Diligent monitoring efforts will help reduce potential water-quality degradation.

Effective planning and design will eliminate many of the problems associated with sanitary landfill and incinerator operations in NPRA. Prudent site selection is also important. Maintenance of both incinerators and landfills will ensure their efficient operation and will lessen chances of breakdowns. Special methods of handling hazardous materials (oil, toxic chemicals, radioactive materials) should be outlined during the project's design phase and followed during the life of the project. Regulation of the types of material allowed in a landfill assures that hazardous materials will be disposed of properly.

The chemicals in drilling mud are capable of radically altering water quality if mud escapes from pits. The chance for accidental spills from mud pits can be lessened by lining mud pits with an impermeable membrane and constructing a stable berm around the pit sufficient to contain any drilling fluids plus any runoff or precipitation into the pit.

Accidental oil spills that could affect water quality can result from a loss of fuel or oil from storage tanks, fuel transport vehicles and other vehicles, or oil blowout, a loss of crude oil during drilling and testing, or from leaks in pipelines. The primary impact of an oil spill on water quality is to add oil constituents to water.

The degree of impact from a spill is dependent upon the size of the spill, the characteristics of the affected water body and of the spilled oil, the time of the year the spill occurs, and the effectiveness of containment and cleanup efforts. A spill in the active layer can impair active layer processes. It can reduce surface albedo, allowing more heat absorption and causing a deeper annual thaw. Oil spills occurring in winter pose fewer problems than those occurring in summer. Frozen ground and ice make containment and cleanup of the spill easier. Cleanup difficulties are experienced, however, when oil is spilled in ice-covered water.

Accidents are bound to occur with oil/gas development in NPRA. Measures can be taken, however, to decrease the chances for accidents to happen.

B. Biotic Environment

In comparison with temperate ecosystems, arctic ecosystems are less diverse and have shorter reproductive and growing seasons, lower overall productivity, and highly fluctuating population levels. Arctic ecosystems can be viewed as stable only over immense geographic areas, and they require long periods of time to recover following disturbance.

Many conflicts with fish and wildlife requirements will result from oil and gas development. For example, gravel removal may affect habitat along coastal beaches, Teshekpuk Lake, and along the Colville River. Water withdrawal during periods of low availability (particularly winter) may adversely affect fish and other aquatic life. In addition, preferred locations for camps and pipelines could coincide with prime wildlife use areas and migration routes.

Plant and animal species threatened by or in danger of extinction are protected by the Endangered Species Act of 1973. Actions leading to the loss or harassment of such species or their critical habitat are prohibited. Adverse impacts to endangered species may be irreversible and fatal. When specific petroleum development proposals are made in regard to NPRA, activities will be reviewed to reveal any conflicts with endangered species. These conflicts will then be reviewed on a case-by-case basis to determine what activity restrictions or prohibitions would be required to protect these species.

In many cases, impacts on the physical environment, described earlier in the text, are also impacts on fish and wildlife habitat, since virtually all of NPRA serves as significant habitat for resident and migratory fish and wildlife populations. In addition, human presence and activities stemming from oil and gas development may generate impacts on wildlife; these include artificial feeding or attraction to garbage, stress and avoidance patterns, and water, air, and noise pollution.

The mitigative measures described in this report may reduce but will not necessarily completely eliminate a project's impacts. The building of a road or a pipeline within NPRA could be well designed, built on schedule, and use all mitigative measures proposed and still produce impacts on wildlife, such as caribou, which require all of NPRA for habitat. The severity of impacts may be lessened through the use of mitigative measures, but residual impacts will occur. General mitigative measures may include, but should not be limited to: 1) the gathering of a com-

An impermeable layer of material between the soil and drilling mud pits reduces the chance of water and soil contamination. (Environmental Protection Agency)

prehensive biological data base and the formation of a team of biologists from both the State and Federal Governments as a part of the development process; 2) the utilization of proven arctic engineering techniques designed to minimize biotic impacts; 3) the consolidation and limitation of the size of developments to minimize fish and wildlife displacements or disruptions; 4) the insurance of provisions for fish and wildlife passage around, through, over, or under all structures or activity areas; 5) the establishment of procedures for the use of aircraft and surface vehicles and control of human activities to lessen wildlife disturbance and conflicts; 6) education of all project personnel to give them an awareness of the potential impacts of their actions; 7) provision for the continuation of baseline and impact studies on fish and wildlife resources during all phases of a proposed project, with the possibility of modifying a project if necessary; 8) the scheduling of development activities so that they do not coincide with significant fish and wildlife usage; and 9) provision for effective enforcement of stipulations.

All of the identified impacts and mitigative measures that follow are general and preliminary and must be reevaluated when any specific oil or gas development proposals are made.

Impacts of petroleum development on fish and wildlife are summarized in table 3.

1. General Impacts

a. Habitat

The wildlife habitat of NPRA is represented by the layer of organic matter that overlies the thawed permafrost surface in summer, its vegetative patterns, and related wetlands, lakes, and watercourses. It is this layer that supports the vegetation, providing the forage, nesting, resting, and concealment requirements of the resident and migratory wildlife.

Impacts to wildlife habitat are associated with: 1) any activity that removes, scars, or covers the surface vegetation which, in turn, leads to increased erosion, permafrost degradation, or drainage changes; 2) oil well blowouts, spills, leakage, or release of other toxic materials capable of killing or damaging vegetation; 3) any activity that will increase the frequency or intensity of tundra fires, such as a burning oil or gas well blowout; 4) degradation of the quality of land surface or water bodies by the disposal of solid or liquid wastes; 5) the creation of physical barriers, such as roads, pipelines, or other facilities, that separate large tracts of previously continuous wildlife habitat and may lead to differential use of habitats by wildlife; and 6) any activity, such as gravel or sand borrowing or water withdrawal, that will result in the lowering of habitat quality for

Table 3. Fish and Wildlife Impacts from Petroleum Development and Production

Source	Impacts	Magnitude[1]	Term[2]	Location[3]
Construction (material borrowing, foundations, facilities, pipelines, waste disposal, water supply, traffic, human presence, failure).	Loss/damage of aquatic, terrestrial, riparian, and coastal habitat.	**/***	*/***	*/**
	Mortality of fish populations	**	*	*/**
	Mortality of wildlife populations	**	*	*/**
	Blocks to fish passage	***	*/**	**/***
	Blocks to wildlife passage	***	*/**	**/***
	Fish entrapment	*	*/**	*
	Wildlife attraction or feeding	**	*/**	*
	Wildlife harassment	**/***	*/**	**
	Increased fish and wildlife harvest	**/***	*/**	***
Operations and maintenance (facilities, oil and gas wells, pipelines, waste disposal, water supply, traffic, human presence).	Loss/damage to habitats	**/***	**/***	*/**
	Mortality of fish populations	**	**	*/**
	Mortality of wildlife populations	**	**	*/**
	Blocks to fish passage	***	**/***	**/***
	Blocks to wildlife passage	***	**/***	**/***
	Wildlife attraction or feeding	**	**	*
	Wildlife harassment	**/***	**	**
	Increased fish and wildlife harvest	**	**	***
Rehabilitation (removal of facilities, revegetation).	Unknown—impacts depend on whether populations can recover following construction and operations impacts.	Unknown.	Unknown.	Unknown.

[1] * = minor; ** = moderate; *** = major.
[2] * = short; ** = intermediate; *** = long.
[3] * = onsite; ** = local; *** = regional.

The north-south migration of caribou, a vital subsistence resource, could be impeded by an east-west pipeline. (National Park Service)

aquatic invertebrates and, indirectly, for waterfowl and shorebirds.

In general, damage to wildlife habitat can be reduced by: 1) constructing compact facilities by utilizing directional drilling and multipurpose work areas to eliminate a proliferation of connecting roads and pipelines; 2) developing oil fields sequentially in relatively small parcels so that the first small parcel is developed, its oil produced, and area rehabilitated before another small parcel is developed; 3) scheduling construction and production activities for nonpeak wildlife habitat use periods; 4) utilizing prior planning based on specific research to eliminate or minimize vegetation scarring, oil spills, fires, pollution, or habitat fragmentation by pipelines and roads; and 5) limiting alterations to waterbird habitats.

Six unique ecological areas have been identified within NPRA. (See Appendix A for descriptions.) These are not necessarily the areas of greatest sensitivity to disruption of ecological functions, but they are identified so that general sensitivities associated with them can be noted. These areas are: 1) Teshekpuk Lake area — prime waterbird breeding and molting area and caribou summer and winter habitat; 2) delta of the Colville River — prime burrowing mammal habitat; high concentration of polar bear denning sites, prime bird habitat, overwintering area for fish, and seal habitat; 3) Utukok uplands — Western Arctic Caribou Herd calving grounds, spring migratory bird habitat, and good habitat for grizzly bears and wolverines; 4) Colville River bluff and high shrub zone — high density of raptor nests, including the peregrine falcon, and habitat for the largest concentration of moose north of the coniferous forest zone in North America; 5) Point Barrow area — a historically used ecological research area; and 6) Icy Cape — best example of a barrier island-lagoon system on the Chukchi Sea coast with prime waterfowl and shorebird habitat.

In addition to these six unique ecological areas, other types of habitat throughout NPRA are utilized at various times of the year by caribou and other animals. These areas are also sensitive to disturbance.

Six major ecologic systems have been identified in NPRA. These are described in detail in Appendix A. The marine and coastal zone of NPRA represents a narrow transition zone, or ecotone, between the mainland and the Chukchi and Beaufort Seas. Biologically, this ecotone supports a characteristic vegetation and is important to the life cycle of many waterbirds, the polar bear, and the arctic fox. This ecotone is particularly sensitive to disturbances caused by construction, gravel or sand extraction, sea and land transportation, and oil spills.

Wet sedge meadows found on the coastal plain of NPRA contain prime waterbird breeding areas and are sensitive to surface disruptions, especially from overland transportation. Upland tussock tundra is the most abundant vegetation type on NPRA, covering a significant portion of the coastal plain, especially the southern part, most of the foothills zone, and portions of the mountain zone up to altitudes of 3,000 feet (1,000 meters). This vegetation type is important habitat to herbivores, especially caribou, and is sensitive to surface disruptions, such as heavy vehicle traffic and oil spills. The riparian high shrub habitats in NPRA are of great importance to moose, raptors, and other wildlife. Any activities or alterations, such as transportation corridors, which parallel major river valleys can be expected to have impacts. Because of the generally dry, rocky nature of substrates in the alpine tundra zone, permafrost degradation and thermokarsting due to mechanical disturbance are not usually problems (Hok, 1971). However, repeated disturbance can cause damage to the shallow rooted vegetative mats. Lichens, an important component of alpine tundra, are especially sensitive to air pollution (Schofield, 1975); local sources of sulfur dioxide could have unfavorable impacts on fruticose lichens and, in turn, on the caribou which feed on them.

The aquatic habitats of NPRA include both freshwater and marine components necessary to the life cycles of fish, aquatic invertebrates, waterbirds, marine mammals, polar bear, and arctic fox. Defining impacts and designing mitigative measures for aquatic habitats of NPRA is made difficult by a lack of basic knowledge, especially of fish overwintering and spawning areas. The major dangers to aquatic habitat are from: 1) surface, shoreline, or bottom disturbance stemming from facility construction, excessive use of heavy equipment in waterways, excessive or incorrectly located material borrowing, and alteration of natural shoreline or bottom processes; 2) oil spills, seepage, or release of other toxic materials to waterways; 3) excessive water withdrawals, especially in winter; and 4) pollution of waterways through the discharge of sewage and other wastes.

In general, damage to aquatic habitat can be reduced by: 1) limiting all activities within or adjacent to waterways; 2) placing all storage areas for oil, fuel, or toxic materials away from waterways and locating wells away from watercourses; 3) limiting the amount of water use and using several withdrawal sites, especially in winter; 4) treating all sewage according to applicable standards prior to discharge to surface waters, and prohibiting discharge of solid waste to waterways or on top of ice; and 5) scheduling construction activities near waterways to avoid migratory fish runs.

b. Populations and Behavior

Wildlife populations of NPRA include both resident and migratory species that exhibit a variety of normal behavioral patterns and population fluctuations. Therefore, without a specific project description and complementary species studies, only generalizations of petroleum-related wildlife impacts can be made, using past studies and general wildlife observations. In general, the major impacts would result from disturbances to caribou during calving or migration; to birds, especially waterfowl and raptors, during nesting, molting, or migration staging periods; and to moose during winter when they are dependent on the shelter of river valleys. Any activity that increases the chance of direct animal-human conflicts, such as garbage disposal that leads to attraction of grizzly bears, wolves, arctic fox or other wildlife, could lead to the destruction of some of these animals in the interest of worker safety.

Construction activities, in general, will adversely affect fish and wildlife populations. The noise, dust, odors, movement of men and materials, and the general visual disruptions of construction will disturb wildlife to a certain extent because they have never been exposed to these activities or because these activities may be similar to other alarm-producing stimuli (Geist, 1975). Existing information indicates that disturbance or actual harassment has many direct and indirect detrimental effects on individuals and populations. Disturbance, by greatly elevating the body metabolism, raises the cost of living to the animal at the expense of its body growth, development, and reproduction. Disturbance can lead to death, illness, or reduced reproduction due to secondary effects of physical exertion and temporary confusion. Disturbance may result in avoidance or abandonment of certain areas leading to a reduction in the population's range, and ultimately to a reduction of the population due to loss of access to resources, increased predation, or increased cost of existence.

Developing specific measures for mitigating wildlife disturbance from construction activities is difficult without specific information on proposed activities and more observation of animal reactions or possible habituation to construction activities. Animal disturbance observations for past arctic construction activities are either nonexistent, undocumented, or of questionable value and concentrate on a narrow spectrum of disturbance-causing activities. Therefore, only general mitigative measures can be suggested: 1) confine or limit facilities to the smallest area possible to reduce overall impacts; 2) provide for fish and wildlife movement around construction facilities, and locate facilities away from traditional migration routes or calving or nesting areas; 3) conduct specific research on animal disturbance as part of the design stage of any oil and gas development plan for NPRA; and 4) design and enforce regulations that prevent workers from harassing wildlife.

Potential impacts to wildlife population levels and normal behavior patterns stem from: 1) activities that alter wildlife habitat, lowering its carrying capacity; 2) activities or surface disturbances, such as pipelines, roads, and seismic lines, that block or deflect wildlife from migration routes; 3) improved

Methods to prevent interference with animal populations were used during construction of the trans-Alaska pipeline. This lateral deviation avoids a peregrine falcon nesting site.

human access to wildlife populations via new roads or airstrips, higher income leading to greater mobility and increased human numbers, all facilitating increased harvest rates; 4) any activity which attracts wildlife and thus leads to human-wildlife conflict; and 5) aircraft and vehicle operation leading to wildlife disturbance.

These impacts can be reduced by: 1) limiting activities which disturb the surface and its vegetation, and rehabilitating and stabilizing disturbed areas; 2) providing for wildlife passage around, through, over, or under all obstructions based on a useable design; 3) limiting human access to fish and wildlife resources through contract stipulations and enforcement of existing or special game laws; 4) providing for proper liquid and solid waste disposal so wildlife is not attracted, and developing an antifeeding program; and 5) determining, through specific studies, optimum operating procedures for aircraft and vehicles to limit wildlife disturbance.

Aquatic populations may be viewed as comprising two groups: species incapable of making a behavioral change in order to survive, such as aquatic invertebrates and plants; and species capable of these changes, such as fish and marine mammals. Aquatic habitat impacts, as previously described, will affect both groups. However, aquatic invertebrates and plants will experience impacts in direct relationship to the intensity of physical or chemical damage to habitat. Fish or marine mammals that are capable of leaving an impacted area, where an exit exists, will still experience loss of habitat carrying capacity. Loss of aquatic invertebrates and plants can render an area uninhabitable by fish and marine mammals. If such a loss is widespread, long term, or due to toxic materials, it can form a barrier to fish migration.

Principal impacts to aquatic populations may occur from: 1) the formation of blockages to fish passage (including pipeline or road crossings of waterways or accumulation of debris); 2) fish entrapment in borrow pits or reservoirs connected to waterways only during periods of high water; 3) channel, bottom, or current changes; 4) any activity that lowers the physical, chemical, or biological quality and, hence, the carrying capacity of the aquatic habitat (for example, oil spills, waste disposal, excessive winter water withdrawals, or siltation); 5) seismic operations through ice or adjacent to water bodies; and 6) increased harvest of fish and marine mammals due to increased access through new roads and airfields, higher incomes, and increased human presence.

These impacts may be mitigated to some extent by: 1) placing culverts, fish ladders, or other structures to allow fish passage at pipeline or road crossings of waterways, as well as during material borrowing or other activities in or adjacent to waterways; 2) following guidelines of Burger and Swenson (1977) for the prevention of fish entrapment during material borrowing; 3) immediately restoring all channels, bottoms or currents, to the previous natural condition; 4) conducting all seismic testing at a sufficient distance from water bodies to protect aquatic habitat, especially fish overwintering areas, or utilizing non-explosive techniques; 5) limiting human access to fishery stocks through contract stipulations and strict enforcement of existing or special fishery laws or regulations; and 6) avoiding excessive winter water withdrawals from fish overwintering habitats.

2. Activity - Specific Impacts

Following is a description of impacts on fish and wildlife associated with development and production of the petroleum resources of NPRA. These impacts are summarized in table 3.

a. Construction

In an arctic area, large-scale construction entails importation of all necessary equipment and workers. Petroleum development also requires large quantities of water and gravel from local and regional sources. During peak periods, construction, encamped workers, and the necessary support activities would introduce many disruptions to fish and wildlife populations and their habitat.

Large quantities of sand and gravel are required in the Arctic for insulation of all foundations to prevent permafrost thaw. However, only relatively small amounts of gravel are present in scattered locations within NPRA.

As possible borrow sites, the sand and gravel on the barrier island chains, the coastal beaches, and the shore of Teshekpuk Lake should be viewed as potentially nonrenewable resources important for their shoreline vegetation and wildlife usage, particularly by waterbirds. There may be some areas of littoral drift convergence and active deposition where borrowing may take place without serious disturbance to wildlife habitat, but most areas would be sensitive. Borrowing gravel from the barrier island chains or their protected beaches could disrupt the stability of the coastal bay-lagoon system, which is of prime importance to waterfowl. Borrowing from unprotected coastal or lake beaches could cause extensive erosional damage, as well as wildlife habitat disruption. If these areas are the only sources of gravel or sand and must be utilized, mitigative measures should include utilizing active littoral drift deposition areas first, and then using gravel only from other areas that can be easily restabilized to prevent serious erosion or wildlife habitat disturbance.

The Colville River drainage gravels and smaller gravel deposits on other streams will serve as the main

Disruptive activities and increased human access to lakes and streams may reduce fish populations. (Jo Keller, U.S. Fish and Wildlife Service)

Care must be taken to avoid excessive water withdrawal from overwintering sites or spawning beds. (Robert Lewellen)

borrow sources for any development within the interior of NPRA. The potential for damage to fish and wildlife habitat from uncontrolled borrow operations include: 1) blockages to fish passage; 2) fish entrapment in borrow areas connected to streams only at high water; 3) channel, current or other hydrological changes; 4) siltation; 5) damage to fish overwintering, spawning, and rearing habitat; and 6) damage to riparian wildlife habitat, especially nesting habitat for birds, including raptors, and moose habitat (Burger and Swenson, 1977; U.S. Fish and Wildlife Service, 1976).

However, most of these impacts may be mitigated by adopting and strictly adhering to guidelines for site selection, mining, and rehabilitation. Burger and Swenson (1977) have documented habitat damage from material borrowing on TAPS, stemming mainly from contract stipulation violations. Burger's and Swenson's recommendations for future material borrowing operations, in brief, are: 1) avoid material borrowing in or near endangered species critical habitat, active stream channels, and fish overwintering or spawning sites; 2) minimize erosion and siltation by using control structures, such as settling basins; 3) if possible, leave buffer strips at least 500 feet (150 meters) between mining sites and active streams; 4) locate access trails or other structures in the flood plain in such a way as to minimize damage and to provide for fish passage; 5) prohibit fueling facilities in flood plains; and 6) after mining, reshape borrow areas to fit existing topography and drainage and restore a natural condition by proper cleanup and revegetation as needed.

Work pads prevent permafrost degradation and provide stable work surfaces. A primary impact of construction of foundations would be the total loss of any vegetation or stream bottom covered and any increment it contributes to the fish and wildlife habitat. These impacts may result in a lower carrying capacity of an area due to the loss of habitat.

Other primary impacts of work pad construction have been described in the paragraphs relating to construction in "Physical Environment." However, there are additional effects of such impacts. The early greening of vegetation that is promoted by the dust from construction activities settling on snow may lead to an early snowmelt, which may attract caribou, leading to increased caribou/vehicle collisions.

The emission of sulfur dioxide from machinery can be detrimental to local lichens, a prime winter caribou food. The effects of sulfur dioxide on lichen are cumulative and would be concentrated near stationary sources of emissions. Some structures associated with the work pads and development, such as towers or powerlines, pose a hazard to birds during periods of reduced visibility. In addition to the design and methods used to mitigate impact on the physical environment, special care is needed to preserve routes for passage of fish and wildlife around structures or pads.

In addition, air pollution can be expected to have similar effects on animals as it will on people. Noise sources will produce stress or avoidance patterns near the development activities.

Both permanent and temporary solid and liquid waste disposal will be needed during the construction and operation phases. The long-term fish and wildlife resource impacts of waste disposal from oil or gas developments in the Arctic have not been adequately assessed. However, it is known that the usual practice of solid waste burial and discharge of treated liquid waste to natural water bodies or to the tundra surface will lower the overall quality of fish and wildlife habitats. Burial of solid waste will disturb the surface vegetation and may cause other impacts. Improper disposal of edible garbage will attract wildlife and lead to human-wildlife conflicts. Disposal of treated liquid wastes in natural water bodies or on the tundra surface may not only alter the natural nutrient cycle but can also introduce toxic substances to waterways. The establishment of permanent lagoon systems at base camps will necessitate a surface disturbance but should eliminate further contamination of natural surface waters. However, the migration of wastes through the active layer because of thawing of permafrost caused by discharge of relatively warm effluent to the lagoon should be investigated.

Specifically, impacts on biological systems can be reduced by: 1) treating liquid wastes and incinerating or transporting waste to suitable disposal sites; and 2) educating all workers as to the potential environmental impacts of their actions on habitat and providing effective penalties for infractions.

Water requirement during the construction period will be large. The magnitude of water withdrawal impacts will depend on: 1) season; 2) type of source; 3) location of source in relation to fish and wildlife use; and 4) the amount of water required.

In summer, if water withdrawals are spread out over several rivers or other large water bodies, impacts will probably be limited to small erosional problems at sites where the withdrawal occurs. Use of water from tundra ponds with no inlet or outlet could be particularly deleterious, as the habitat of aquatic organisms and waterbirds would be altered, and normal water levels would not be restored until the following spring. In winter, removal of water from stores beneath ice may create several ecological problems. If all water is withdrawn from an area supporting aquatic organisms, mortality of some or all species may occur. When some of the water is removed, organisms crowded into the remaining volume may cause a buildup of the waste metabolites or a decrease in dissolved oxygen concentration due to the respiratory activities. Partial removal may drain water from gravels which contain developing fish embryos. Most shallow ponds freeze solid in winter and water is unavailable.

The location of the water source may lead to other conflicts. Potential water sources in critical wildlife habitat should be used only after all other sources have been used and only to the extent that serious damage would not occur. Other potential water sources may not be located in critical wildlife habitat but could be located so far from the work sites that a substantial pipeline or road would have to be built to provide water in summer. In winter, ice roads could be built and water hauled in heated tank trucks. Both means of transporting water have physical and biological impacts already described.

The effects of obtaining water supplies during construction can be mitigated by: 1) avoiding any water body that is a significant aquatic habitat or that is so located that it requires a permanent road; 2) spreading summer and winter withdrawals among several sources to lessen overall impacts; 3) providing erosion control devices at all withdrawal points; and 4) controlling use of large, deep lakes as water sources.

Construction of gathering lines would directly affect vegetation and its habitat value within the construction rights-of-way and adjacent sites. If buried lines are used, damage to the active surface layer could be extensive. Use of elevated pipeline, as in the northern portion of the TAPS and proposed Arctic Gas line, can reduce potential permafrost damage. Stream crossings can affect fishery habitat by disturbing the benthos and producing temporary or permanent blockages to fish (U.S. Department of the Interior, 1972, 1976).

Disturbances to wildlife during construction would result from increased human activity, the operation of heavy equipment, and low-flying helicopters or planes (U.S. Department of the Interior, 1972, 1976). The linear nature of the pipeline route and the greatly increased human activity within a corridor also has the potential to inhibit or block migratory animal movements during both construction and operation. Restrictions of caribou movements by TAPS have been well documented (Cameron and Whitten, 1976, 1977, 1978). Restriction of caribou movement within NPRA could lead to overuse of other habitats and may lead to a reduction in the total regional caribou population.

Mitigation of pipeline impacts should begin in the design stage during route selection. The chosen route should avoid: 1) the critical habitat of endangered animals and plants; 2) traditional caribou migration routes, calving grounds, or other essential areas; 3) stream crossings at fish spawning or overwintering areas, or where the engineering design will not allow for fish passage; 4) bird nesting or molting grounds, especially those of white-fronted geese which are extremely sensitive to disturbance; and 5) paralleling any stream or river to minimize erosion, siltation, and damage to riparian habitats.

In addition to mitigative measures to protect the physical environment (described earlier), other measures include: 1) restricting public access to the pipeline rights-of-way and prohibiting camping,

NPRA development would require construction of permanent and temporary airstrips for transportation of workers and materials. (Grossmann-Granger Productions)

hunting, fishing, trapping or shooting; 2) immediately restoring disturbed areas as a part of, not after, the construction; 3) prohibiting animal feeding; and 4) working in winter, if possible, when fewer animals or birds are present.

Air transportation of workers and materials will require the construction of both permanent airstrips and temporary winter airstrips on frozen lakes. Inducing deeper freezing to accommodate large aircraft could eliminate water in fish overwintering locations, killing the fish concentrated there and killing eggs or fry in spawning gravel which normally would not freeze. There is also the possibility of damage to developing eggs from pressure and vibrations transmitted through the ice and water caused by heavy aircraft landings (U.S. Department of the Interior, 1978). Use of frozen lakes as airstrips invites the localized concentration of various pollutants on or adjacent to aquatic habitats (Bliss and Peterson, 1973).

Protection of water bodies can be assured to some extent by measures described in the appropriate section of "Physical Environment."

Extensive use of marine transportation is possible if development occurs near the coast. Assuming marine transportation methods would be similar to those used at Prudhoe Bay or at coastal villages and DEWLine sites, a summer barge transport mode would be used. This would require construction of wharves or causeways for direct freight handling or establishment of lightering beaches. Summer barge traffic would cause few impacts, barring accidents, such as oil spills, that would destroy marine life. Establishment of lightering points, even on gravel beaches, will subject the beaches to heavy-equipment movement leading to erosional problems and will disrupt the traditional waterbird and marine life use during the summer and may damage the winter habitat of polar bear and arctic fox.

Mitigation of the construction impacts of wharves and causeways and establishment of lightering beaches includes: 1) investigation of marine processes at prospective sites for wharves, causeways, or beach lightering points to allow for optimal selection; and 2) investigation of each possible site to insure that the chosen site has the least impact on waterfowl, polar bear, or arctic fox.

Permanent road construction similar to that at the Prudhoe Bay development would likely be part of the construction phase of any proposed NPRA petroleum development. Impacts on biological systems may include: 1) loss of vegetation due to covering by road foundation; 2) changes in vegetation patterns bordering the road due to marring, drainage pattern changes, and dust; 3) corresponding loss of wildlife habitat and carrying capacity due to vegetation loss; 4) change of stream bottom and riparian habitat at stream crossings; 5) possible formation of temporary or permanent blockages to fish and nutrient movement in streams or to migratory wildlife, such as caribou; and 6) loss of habitat to sensitive wildlife, such as all species of geese, due to the increased human activity, the operation of heavy equipment, and presence of low-flying aircraft. Since

The impacts of off-road transportation from geophysical surveys can be reduced by combining all seismic work to avoid repeated operations. (Grossmann-Granger Productions)

the construction of roads will progress relatively quickly, many impacts will not appear until the use of the road network commences. Alterations of caribou movements by the presence and use of roads in the Arctic and subarctic have been reported by the Alaska Highway Pipeline Panel (1978), Cameron and Whitten (1976, 1977, 1978) and Geist (1975). Cameron and Whitten (1978) have stated that caribou avoidance of the pipeline and haul road corridor of TAPS may be due more to the concentration of human activity within the corridor than to the physical presence of the road or pipeline. As with pipelines, mitigating the impacts of a road network construction must begin in the design stage. The chosen route should avoid 1) critical habitats; 2) migration routes; 3) fish spawning or overwintering areas; 4) bird nesting or molting grounds, especially for all species of geese, which are extremely sensitive to disturbance; and 5) routes paralleling rivers because of greater chance of erosion and habitat destruction. Mitigative measures during road construction should also be similar to those mentioned previously for pipeline construction.

A certain amount of off-road travel will be required during the construction phase. The consequences of off-road activities depend on the season, the degree of use, the nature and response of the vegetation and underlying permafrost to the surface modification, and the rate at which the damaged environment will recover. In addition to construction-related off-road travel, seismic and related geophysical operations will also be performed in winter. Surface damage, subsequent erosion, and loss of vegetation by overland travel on the tundra in summer has been well documented (Klein, 1969, 1973; Hok, 1971; Hernandez, 1973). In order to reduce the impact on the surface vegetation, only low-surface-pressure vehicles should be used. Other traffic and refueling operations should be restricted to prepared surfaces. Vehicles should not be used to harass animals.

Geophysical operations will require off-road travel. These operations should be restricted to winter because the mobile seismic crews often move via tracked or tractor-type vehicles that pull sleds. These "trains" are capable of causing surface damage unless a sufficient layer of snow is present to protect the surface and its vegetation. Even with mitigative measures strictly enforced, overland travel of this type may cause compaction and possible marring of the surface which can result in abnormal patterns of vegetative growth, ponding water, and minor erosion in summer months.

The impacts of off-road seismic work can be mitigated to some extent by: 1) combining all seismic work so the same surface area does not receive repeated surveys; 2) traveling only where and when sufficient snow cover has accumulated to protect the surface (normally between October 15 and November 1) and ceasing when snowmelt begins (early May); 3) properly disposing of all waste materials; 4) allowing no blading of the ground surface; and 5) avoiding steep slopes and snow-free areas.

Proper construction and use of winter roads, as described under "Physical Environment," will compact some vegetation and cause slight or temporary damage. In stable terrain, the use of the same route for more than 2 years, provided the peat layer continues to insulate against excessive summer thaw, is less damaging than a series of parallel roads across the terrain. For pipeline construction, thick snow-ice roads may be best (Bliss and Peterson, 1973) if sufficient snow or water can be obtained without causing other significant impacts on surrounding areas. Methods of mitigating winter road use have been described earlier.

Human presence during the construction phase and, to a lesser extent, during the operational phase, will be a source of impacts on both fish and wildlife resources. For purposes of discussion, human presence disturbances can be divided into authorized and unauthorized activities. Authorized activities include those that are performed within the environmental stipulations of various Federal or State permits. Authorized presence should not incur any additional impacts over and above those previously mentioned for construction activities.

Unauthorized human presence includes any nonconstruction-related activity by workers, including hunting, fishing, trapping, harassing or feeding wildlife, marring surface vegetation, or acts of vandalism. Unauthorized human presence in a relatively untouched environment, such as NPRA, can have major impacts and would be extremely difficult to control. This unauthorized human presence can adversely affect Native subsistence resources, as well as fish and wildlife resources. Mitigating unauthorized human presence will involve drawing up lengthy specifications as to what workers are authorized to do. However, these specifications are useless without some type of cooperative enforcement team and effective penalties. Some recommendations on mitigating unauthorized human activities are contained in Milke (1977) which addresses animal feeding. The following recommendations are applicable, with some modification, to most problems stemming from unauthorized human activity: 1) orientation classes should be given for all workers, including management and supervisory personnel, about the personal dangers and adverse biological consequences of animal feeding; 2) all edible garbage must be thoroughly incinerated; 3) all construction management personnel should receive additional training in procedures for eliminating accidental animal feeding by proper garbage disposal; 4) all construction camps and garbage dumps should be fenced and buildings skirted to lessen human and animal contacts; and 5) an effective regulation and enforcement program must be administered by personnel beyond the influence of contractors or unions.

Accidents and failures will occur, and impact assessment and mitigation for these incidents comprise a set of cases separate from normal plans and procedures. Through oversight, mistakes, equipment failure, field modification of previously finalized plans, or vandalism, failures in all aspects of the construction phase may take place. Failures may or may not result in serious impacts; in many cases, the difference may only be apparent years after construction is finished. Champion (1975) reviewed the causes for construction delays experienced during TAPS. For example, "holds" were placed on some construction activities until design of fish passage structures was completed. TAPS redesign was also required in many areas to allow for caribou and moose crossings. Champion also stated that in order to mitigate construction impacts, Federal and State biologists submitted a list of concerns reflecting locations, species, and critical time periods of fish and wildlife use to the builders of TAPS. The company then scheduled construction activities to avoid conflicts in almost all of the critical areas. However, Champion further stated that the biologists and the company both realized that timing "slippage" may be encountered and that the plans as formulated might not be operable.

Many of the mitigative measures for construction activities will call for a rigid schedule to be maintained in order to reduce the severity of impacts. In general, construction activities that take place in winter and are cleaned up by early May may cause the fewest long-term biological impacts. However, despite planning, events will occur that lengthen schedules and produce conflicts with fish and wildlife resources. An important mitigative measure for failures in scheduling might be to authorize field monitors to halt construction activities when significant impacts or accidents occur.

Some construction and unauthorized human activities have the potential of starting fires in the tundra of NPRA. Bare areas and the saturated nature of tundra should limit the spread of fire. However, significant localized impacts are still possible. The long-term effects of fire in the tundra, especially on the active layer and regeneration of mosses and lichens, are not well understood. Small fires of moderate severity do little damage to fish and wildlife populations and may provide improved habitat through increased nutrient cycling and new vegetative growth. Large, hot, severe fires can have detrimental effects, especially if such a fire leads to erosion of the burned site or prevents rapid regrowth of browse, cover, and nesting materials in a large area. Heaths, mosses, and lichens are very susceptible to fire and burn more completely than other groups of tundra vegetation; regeneration of mosses and lichens is very slow. Effects of fire on fish and wildlife species depend largely on the size, severity, and location of the fire with respect to their habitats.

Facilities like this well site and related transportation networks are sources of noise, air, and water pollution. (J. C. LaBelle, AEIDC)

b. Operation and Maintenance

Principal impacts on the biotic environment associated with the operation and maintenance phase include: 1) air and water pollution, 2) habitat loss or alteration, and 3) wildlife-human conflicts. (See table 3.) Many effects of the construction phase would be likely to continue, on a chronic basis, due to continued water use and waste disposal, traffic, and human activity. In addition, new impacts associated with well sites and production activities would be introduced. Some of the major, short-term impacts from construction, such as from excavation and the presence of large numbers of workers, would decrease.

Facilities, which include well sites and a related transportation and supply network, will be sources of human activity, noise, visual disturbance, and air and water pollution.

Cameron and Whitten (1977) noted partial or complete avoidance of the Prudhoe Bay complex by caribou throughout the course of a 1975 study. As late as 1972, caribou calving was reported within or immediately adjacent to the Prudhoe Bay complex, but in 1975 no newborn or very young calves were observed from the northernmost section of the haul road. The area was also previously used by caribou during annual postcalving movements along the coast and during oscillatory movements to and from the coast in response to changing insect density. Evidence of these movements is the visible caribou trail systems. Although movements within the Prudhoe complex still occur, they have been of considerably smaller magnitude in recent years.

Little is known about the impact of air pollution on animals except that birds have been known to strike powerlines, towers, and other flight obstructions during periods of low visibility. Health impacts on animals from respiration of pollutants are expected to be similar to those experienced by humans.

Possible partial mitigative measures for the impacts of operating facilities would be: 1) avoiding proliferation of facilities — the less land used, the better; 2) avoiding a linear set-up of facilities — use of the same surface area in a square configuration would be much easier for wildlife to avoid; 3) limiting the unauthorized and off-duty activities of the workers to eliminate animal-human conflicts; and 4) studying fish and wildlife usage of the area before construction, so that facility design will use a layout scheme that avoids, as much as possible, areas of significant fish and wildlife usage and eliminates the need for fish and wildlife crossing structures.

At camp facilities, frequent waterings to control dust will partially mitigate effects on fish and wildlife populations and their habitat quality. Air and noise pollution have been discussed under "Construction." Water pollution can be avoided by following the practices previously described.

Oil and gas wells, the presence and operation of drilling rigs, mud pits and ancillary facilities will represent a chronic disturbance to traditional fish and wildlife use patterns. Wildlife may avoid the area to varying degrees, depending on the species sensitivity and the ability to become habituated to disturbance. The most severe impacts on fish and wildlife resources would occur in the rare event of a blowout or rupture of a mud pit if toxic substances are present. Either event would cause some immediate direct mortality to fish and wildlife from contact or ingestion of oil or toxic muds, or from inhalation of poisonous gases. More importantly, the vegetation and waterways surrounding the drill site could be seriously altered or destroyed by oil or toxic mud contact. Drilling mud contains chemical additives that can be harmful to biota. Accidental releases of drilling mud into an aquatic environment, particularly a pond or lake, could kill benthic invertebrates and rooted aquatic plants. The extent and magnitude of impact would depend on the nature of the mud, the size of the spill, and the dilution afforded by the receiving body. Fires from burning blowouts may ignite the surrounding vegetation and induce erosion and permafrost degradation. The result of these events would be a decrease in the overall carrying capacity of the area.

Oil spills will affect individual aquatic organisms, as well as ecosystems. Zooplankton, benthic organisms and other invertebrates, fish, marine mammals, birds, and phytoplankton and other plant life can be severely affected by oil spills. Following is a list of possible impacts of oil spills in aquatic environments (Blumer, 1970; McKee and Wolf, 1973):

- Direct kill of organisms through coating and asphyxiation.
- Direct kill through contact poisoning of organisms.
- Direct kill through exposure to the water-soluable toxic components of oil at some distance in space and time from the accident.
- Destruction of the generally more sensitive juvenile forms of organisms.
- Destruction of food sources of higher species.
- Incorporation of sublethal amounts of oil and oil products into organisms, resulting in reduced resistance to infection and other stresses (the principal cause of death in birds surviving the immediate exposure to oil).
- Incorporation of carcinogenic and potentially mutagenic chemicals into marine organisms.
- Interference with natural processes of reaeration and photosynthesis.
- In freshwater environments, deoxygenation of water sufficient to cause fish mortality.
- Interference of migratory behavior of fish, marine mammals, and birds.

Much of the research on oil spills in the Arctic has been directed towards predicting the impact of a pipeline rupture and therefore considered only crude oil rather than the refined oils that will be most commonly spilled during construction.

Deneke and others (1975) have stated that the degree and duration of damage to vegetation from oil spills is influenced primarily by the magnitude of the spill, season of occurrence, and existing soil moisture content. Rapid recovery of plant communities subjected to spills will occur only if root systems remain relatively unaffected, i.e., the fuel is prevented from soaking into the soil. Damage will be more extensive and long term when root systems are saturated with oil. Effects of damage will be manifested gradually over several seasons and will be influenced by winter stresses. Variation does exist in plant species susceptibility. For example, *Carex aquatilis*, a predominant sedge of the Arctic, is markedly resistant to crude oil damage; plant recovery can be enhanced through the application of fertilizer. Bergman and others (1977) found that all emergent vegetation and almost all macroinvertebrates were destroyed in a small pond as a result of an oil spill at a drilling site on the Arctic coast of Alaska. Heinz and Koob (1977) found an eightfold reduction in numbers of macroinvertebrates in an arctic pond 2 years after experimental oiling as compared with control ponds. Nauman and Kernodle (1975) stated the general effect of a fuel oil spill in Happy Valley Creek was the overall reduction of benthic invertebrates downstream from the spill. Bergman and others (1977) emphasized the strong dependence of waterfowl and shorebirds on these aquatic populations and the fact that contaminated ponds were rendered useless to waterbirds.

In a study of the effect of oil drilling on wildlife at a single site in the Mackenzie River Delta in 1971, Barry and Spencer (1972) found that of the more abundant bird species present within a 20-mile (32-kilometer) radius of the drill site in 1970, 43 percent were noticeably less numerous within 1 1/2 miles (2 1/2 kilometers) of the rig during summer 1971, 52 percent were not affected, and 5 percent (ravens and whimbrels) occurred more abundantly near the drilling rig. Geese and swans, when molting or in family group flocks with downy young, moved or stayed more than 1 1/2 miles (2 1/2 kilometers) from the drill rig. Other bird species apparently became accustomed to activity associated with the drilling rig and did not relocate. Helicopter operation at low altitudes caused the greatest disturbance, directly affecting waterfowl within a radius of at least 1 1/2 miles (2 1/2 kilometers) from the rig and indirectly affecting waterfowl mortality by allowing increased predation (by gulls and jaegers) of nests from which waterfowl were disturbed.

Mitigation of drilling impacts could include: 1) maximizing use of directional drilling; 2) sequencing development over a widespread field so that a small parcel would be drilled, produced from, abandoned and restored before another small parcel is utilized; 3) shielding drilling rigs within partitions, as at Prudhoe Bay, to lessen visual and noise impacts; 4) maximizing the effectiveness of blowout preventers and the containment of drilling wastes; and 5) regulating flight operations to and from drilling sites, especially helicopter flights, to specific flight paths and schedules according to season.

Gathering lines will continue to affect fish and wildlife populations and habitats throughout the project life. The magnitude of impacts on wildlife

Clean-up crews used vacuum trucks, sorbent materials, water, and hand tools to remove oil spilled during an accident on the trans-Alaska pipeline. (Alyeska Pipeline Service Company)

habitat from gathering lines will depend on: 1) the success of the revegetation; 2) the degree of restoration of natural drainage patterns, including elimination of any blocks to fish and nutrient movement in streams; 3) the success of permafrost insulation and dust control; and 4) the number of spills and amount of oil spilled during operation. In addition, should a pipeline rupture or malfunction occur, immediate repairs and cleanup operations will be needed to avoid serious effects. Such repairs or cleanup will possibly necessitate travel over a thawed surface with resultant impacts on vegetation and the habitat it represents.

Habitat impacts can be mitigated by: 1) immediately restoring vegetation after construction, with checks to see that reestablishment is successful; 2) restoring drainage patterns and water quality immediately after construction; 3) monitoring the success of permafrost insulation and dust control programs; 4) requiring an adequately prepared oil spill contingency team to be ready to react to spills on short notice; and 5) restricting vehicles to permanent roads or requiring use of low-surface-pressure vehicles, such as Rolligons, for inspection or repair.

The effects of pipeline operation and maintenance on caribou have been studied both in Alaska and northwestern Canada. Cameron and Whitten (1976, 1977, 1978) noted avoidance by caribou, especially cows with calves, of the TAPS corridor and a low rate of pipeline crossing even at specifically designed wildlife crossings due to the physical presence of the pipeline and road, as well as the high levels of traffic and human activity. Results indicate that the Central Arctic Caribou Herd, consisting of aproximately 4,000 to 5,000 caribou, is undergoing a separation into eastern and western components due to avoidance of the TAPS corridor. According to Calef (1974), the potential effects of a proposed gas pipeline project on the Porcupine Caribou Herd of northwestern Canada and northeastern Alaska will be compounded by and inseparable from those of the Dempster Highway; they will include: 1) direct mortality of caribou from hunting, from collisions with vehicles, and from injuries sustained in stampedes caused by disturbance; 2) disturbance by human presence, aircraft, equipment, and blasting; 3) physical barriers to migration, including berms, thawed rights-of-way, access roads, open trenches, and pipe strung on the ground; and 4) habitat destruction by fire, direct destruction, and terrain degradation. These effects can probably be expected along a pipeline/road system in NPRA.

The effect of permanent road operation and maintenance in the Arctic on caribou has received considerable study. The presence and use of an arctic highway represents a barrier to caribou movements. This disturbance factor is greatest on the tundra where the road is visible for long distances. Females with young are much more susceptible to this disturbance than are adult males. The barrier effect is least on caribou during major migrations involving large concentrations of animals and greatest on small bands or individuals during random or feeding movements. Disturbance delays the animals, reduces the amount of time spent feeding, and increases the metabolic rate, lowering survival potential. In addition, a road with high, steep berms or high piles of plowed snow at the road edge in winter may be a physical barrier. Although caribou can quickly adapt to noise without movement, trucks are both noisy and moving and road routes are frequently followed by low-flying aircraft in bad weather, compounding impacts. Dust raised by traffic increases the apparent size of a vehicle, increasing disturbance and carpeting adjacent vegetation with dust. Use of the road increases caribou exposure to vehicle mortality, and the road can increase access to caribou, possibly leading to increased sport or subsistence hunting (Alaska Highway Pipeline Panel, 1978; Cameron and Whitten, 1976, 1977, 1978).

Mitigative measures to reduce the impacts of road operation and maintenance include: 1) moving haul road traffic in convoys to reduce overall caribou disturbances; 2) plowing so that a snow barrier is not left alongside the road; 3) prohibiting salt use on these roads in winter so as to reduce wildlife attraction; 4) prohibiting flights along the road corridor at an altitude below 2,000 feet (610 meters); 5) closing the area on both sides of the road to hunting and camping; 6) preventing workers from feeding wildlife; and 7) studying impacts of road operation and maintenance so as to develop other mitigative measures.

According to Lent (1978), the large, highly mobile caribou populations of the arctic regions must not be considered able to withstand impacts of development because of the vast land mass they occupy. On the contrary, they are able to obtain high numbers only by long energy-consuming movements to and from specific areas that provide optimum conditions at specific times. These areas vary from year to year. The pathways of movement represent highly vulnerable "life-lines," essential for their well-being. The situation is analogous to and has the potential for proceeding in a similar fashion as the situation with the large, mobile mammals of the African savanna. In many areas development and restrictions to movements have resulted in fragmented small, sedentary populations, which, lacking free access to areas previously used to satisfy annual requirements, have become less productive, subject to stress mortality, and unstable.

The biological significance of noise impacts upon humans and/or animals from petroleum-related activities depends upon the intensity, frequence, and duration of the noise, the location of humans and/or animals in relation to the noise source, weather conditions, and the type of behavior caused or affected by the noise. For animals, the degree of impact varies with species and season.

Ambient noise levels in NPRA being low, any oil/gas production activity would result in greatly increased levels. However, most noise impacts would be localized and short term, in the case of construction activities, or moderate term, in fixed plant operations. With proper mitigation, noise impacts resulting from both construction and operations would be minor. Noise resulting from air traffic and overland transportation would produce impacts of a regional scope and could prove more severe than other activities, especially with regard to animals.

Known or suspected effects of noise on people include communication and sleep interference, hearing loss, changes in orienting and startle reflexes, disturbed sense of balance, pain, fatigue, circulatory difficulties, heart disorders, annoyance, and decreased job performance. The apparent effects of noise on animals are generally the same as those for humans. In addition to hearing loss and physiologic changes, changes in normal behavior patterns may occur.

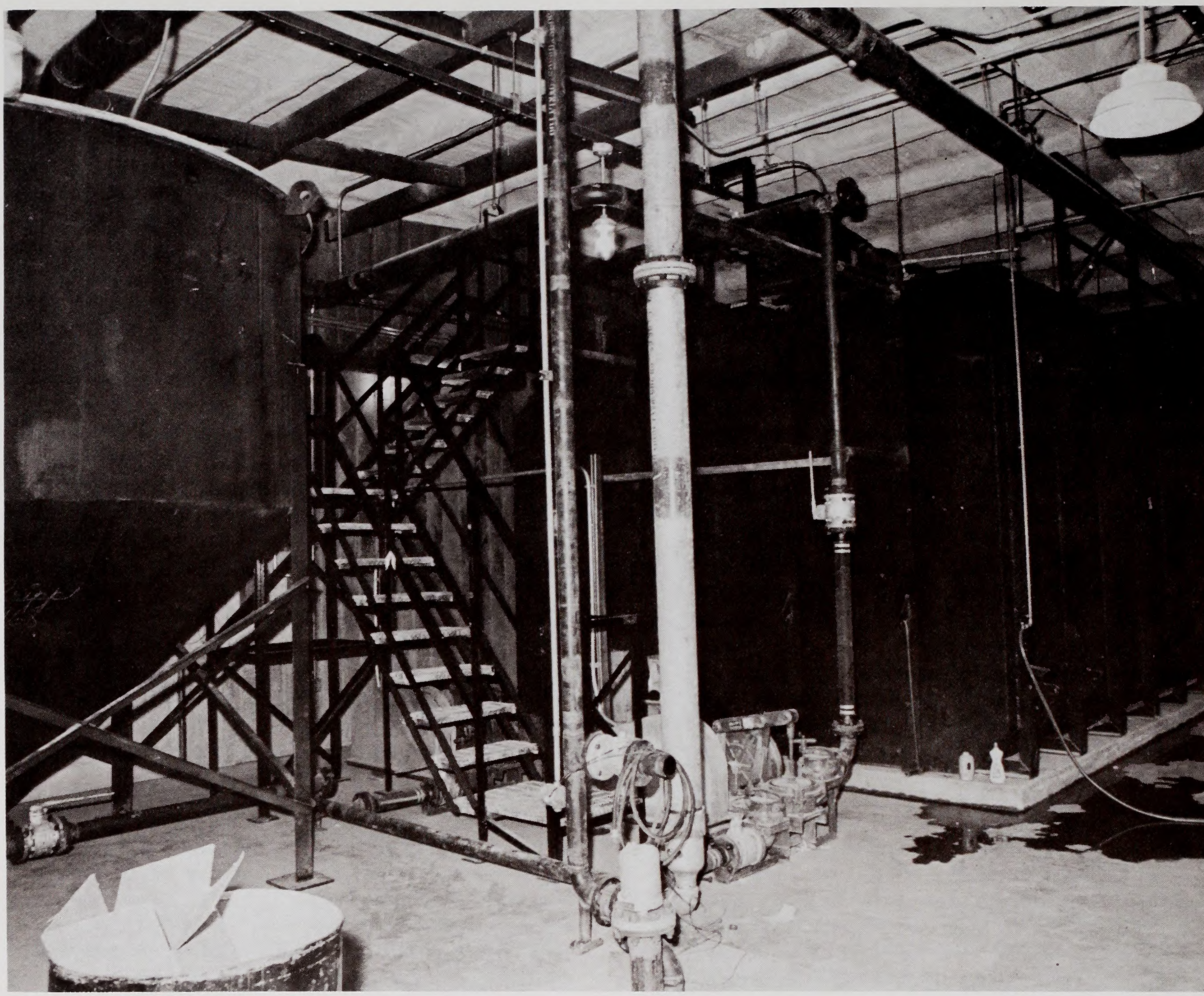
There are no definitive studies on pipeline-related noise impacts on wildlife. Some studies indicate that the most probable effect would be to reduce utilization of habitat areas affected by noise (U.S. Department of the Interior, 1976). However, several studies have been performed to determine the response of wildlife to simulated gas compressor noise. Although Geist (1975) questioned the validity of some of the data, the general results were that caribou, Dall sheep, red foxes, and snow geese all avoided the area around the noise simulator. Arctic ground squirrels showed no reaction and, although Lapland longspurs did not desert their nests, there was a tendency for the percentage of eggs hatched to decrease and for the predation rate to increase (U.S. Department of the Interior, 1976). Mitigation of noise impact would entail decreasing noise by insulation, mufflers, or use of quieter equipment. As suggested by Geist (1975), it may be more important to investigate the noise level at which disturbance first begins and the long-term reaction or habituation of wildlife to noise and other disturbances than to emphasize short-term reactions to simulated noise.

Vibration, like noise, can also have harmful effects on humans. The degree of impact is a function of exposure time, frequency range, and, in some cases, the area of the body to which the vibration is applied. Humans are especially sensitive to frequencies in the range of 4-10 Hertz. Within this range, vibration causes resonance effects on the internal organs and the upper torso and shoulder girdle structures. Other impacts are the same as those for noise.

The effects of vibration on animals are not known. However, it seems likely that vibration of the ground from the operation of heavy equipment could have disruptive effects on ground-nesting birds and burrowing small mammals.

Vibration can be minimized by installing and maintaining air or steel springs on vibration-producing equipment and using vibration-damping couplings.

Waste disposal during the production phase will require permanent facilities for industrial and domestic use. In addition to the impacts on physical environment described earlier, burial of solid waste will require some disruption of vegetation. The most efficient mode of waste removal might be to use freight barges on return trips to remove material for recycling or disposal elsewhere. Transporting solid



NPRA development would require construction of liquid waste disposal facilities. This secondary treatment plant at Prudhoe Bay purifies waste water through a biological process. (Grossmann-Granger Productions)

waste out of NPRA will directly affect fish and wildlife due to the increased air, overland, or barge traffic required. Mitigation of the impacts of a permanent solid waste disposal program has been described under "Construction" in the discussion of impacts on the physical environment.

A permanent liquid disposal facility will probably be similar to that in use at Prudhoe Bay. Sewage will probably receive secondary treatment, dried sludge will be incinerated, and the effluent will be discharged to lagoons. Potential impacts are discussed under "Construction" in the description of impacts on physical environment. If sewage is discharged into unprepared depressions or natural lakes, overall impacts would be great. Floating solids and sludge would be trapped by emergent vegetation, and fish and wildlife habitats would be altered.

If the nutrient load of discharged effluents is such that streamflow cannot adequately dilute it, eutrophication results. If dissolved oxygen levels are reduced sufficiently, fish mortality and/or changes in species composition of the aquatic ecosystem can occur. The degree of impacts is dependent upon the type of receiving water body and the amount of effluent discharged relative to the volume of the water body. Because streams play important roles in the life histories of many species of fish, they should be avoided as sites for discharge. Shallow depressions lacking flora and lakes devoid of fish would be better site choices. With proper site selection and effective monitoring to ensure compliance with State and Federal regulations, the impacts from treated effluent discharge will be local and minor. Effective planning and design will eliminate many potential water-quality problems in NPRA.

Water withdrawal will continue during the operational phase to serve both industrial and human use. Water supply to any permanent complex in NPRA would probably not be a problem in summer, but any petroleum development would make major demands on the already limited areas of free water in winter. The only known water source of suitable magnitude which could be used in winter with minimal adverse effects on aquatic life is Teshekpuk

Lake, provided natural water levels are not significantly altered (U.S. Department of the Interior, 1978). Use of other sources for winter water supply could impact aquatic life, as described in the preceding section.

Mitigation of the impacts of permanent water-supply withdrawal for an oil or gas development complex in NPRA would involve: 1) establishing of an artificial reservoir system, which would disrupt some present fish and wildlife habitat but will insure a winter water supply; and 2) maximizing water recycling to minimize withdrawal.

Geist (1975) summarized the disturbing effect of low-level aircraft overflights on large mammals as follows: 1) caribou are disturbed by low-flying aircraft approaching them to the point that they abandon ongoing activity and, at the worst, depart in panic; further, low-flying helicopters cause more visible disturbance than fixed-wing aircraft, and the higher the overflight, the less the visible response of caribou; and 2) studies on low-flying aircraft disturbance of other large mammals, including caribou, lack a sound, systematic investigation that pinpoints the ceiling and method of overflight which has the least effect; studies on the effect of multiple overflights and habituation are lacking.

Bird reactions to various aircraft in the Arctic have also been recently studied. Abandonment of habitat by birds due to aircraft overflight may depend on: 1) season; 2) species; and 3) level and type of disturbance (National Oceanic and Atmospheric Administration, 1977). Noise from aircraft has contributed to abandonment of nests and lowered fledgling success of Lapland longspurs. At the laying stage, common eiders flushed at the approach of low-flying aircraft. However, during incubation, common eiders remained on their nests, even when aircraft approached within 15 feet (5 meters). Similarly, brood-rearing female waterfowl did not relocate or abandon their broods after repeated aerial overflights, although nonbreeding birds abandoned such disturbed areas. Waterfowl vary considerably in their reaction to aircraft noise after the breeding season. Snow geese are perhaps the most sensitive of the arctic birds studied. Flocks of snow geese were flushed by fixed-wing aircraft overflights at altitudes up to 10,000 feet (3,000 meters). In contrast, helicopter overflights were found to have little effect on molting oldsquaws, and frequently disturbed areas were not abandoned by this species.

Mitigation of these impacts should include: 1) studies of low-flying aircraft disturbance of a variety of large mammals and birds to establish reasonable aircraft operation restrictions; and 2) until restrictions can be drawn up, avoidance of all areas used by sensitive wildlife species, such as snow geese, Dall

Construction activities may adversely affect wildlife. Helicopters, in particular, disturb nesting birds and large mammals.

Clean-up procedures, as shown above, include removal of all solid waste. (Atlantic Richfield Company)

sheep, or caribou, immediately prior to, during, and immediately after nesting, lambing, and calving periods.

Impacts from summer barge transport will be minimal if barges remain far enough offshore to avoid disturbing birds on the shoreline, if freight transfer is handled in a manner to minimize damage, and if no oil or fuel spills or other barge accidents occur.

Human presence and activity, while on a lesser scale than during construction, will continue during operation. The restrictions previously suggested under "Construction" may reduce disturbance from human activities during operations.

c. Rehabilitation and Cleanup

The rehabilitation and cleanup of any area disturbed by construction or operation activities should be a part of the overall plan for oil and gas development. The objective of any rehabilitation program should be to promote soil stability and encourage the reestablishment of natural plant communities. The main problem in any reseeding program is application of the seed before snowmelt occurs. The dry summer season and coarse-textured berm materials are not conducive to plant establishment. Other factors that limit native plant establishment and growth are warm surface soils and high soil water evaporation rates over any buried oil line, or cold surfaces and possibly shallow active layers over a buried, refrigerated gas line. Herbivore grazing coupled with moose and caribou trampling make it difficult to maintain a plant cover if the species grown are selectively grazed. Gravel berms, however, can be best left unseeded.

During the design stage of any proposed project, specific studies should be performed in areas of proposed development to test the applicability of revegetation studies done in the Alaskan and Canadian Arctic for past petroleum developments.

Mitigative measures for rehabilitation and cleanup include: 1) avoiding the disturbance of any organic layer over permafrost beyond actual construction areas to limit the area where rehabilitation will be needed; 2) applying dust control measures during all activities to avoid damage to vegetation outside work areas; 3) planning layout of material borrow sites so as to limit the area and degree of vegetation damage and soil erosion that might occur; 4) stockpiling vegetative organic mats stripped from work areas for reuse in restoration; 5) disposing of surplus excavated material in a manner that prevents further vegetation damage or soil erosion; 6) during any phase of development, restricting all mobile ground equipment to prepared foundations; and 7) studying the use of fertilizers in conjunction with any reseeding research. Additional cleanup procedures should include: 1) removal of all solid waste from work areas; and 2) restabilization and recontouring of slopes.

The impacts of abandoning oil and gas developments within NPRA are not predictable. However, it can be generally assumed that if development impacts have not been severe enough to prevent fish and wildlife resource recovery, complete abandonment of all facilities with some type of restoration may allow reasonable recovery of the present biotic resources.

C. Human Environment

Several subject areas contribute to knowledge of the human environment of NPRA; among them are archeology and history, cultural anthropology, socioeconomics, and outdoor recreation and conservation. Impacts on the human environment are associated with the land resource base or various segments of the population. Many impacts on the biotic environment also affect the human environment; for example, degradation or depletion of subsistence species (caribou) and application of special wildlife regulations (subsistence permits) are both "human" and "biotic" impacts. Social sectors within the Arctic region — mainly resident Inupiat and transient non-Inupiat — are variously affected by employment opportunity and industrial growth. Outdoor recreationists and conservationists represent groups within, as well as outside, the region and the State which are also affected by activities in the study area.

Members of the Inupiat and Western cultures operate from distinctly different sets of premises, and the level of mutual understanding may be limited. This difference in values is exemplified in the ways in which westerners and Inupiat regard land. The Western notion usually derives from some economic or recreational base. On the other hand, to the Inupiat, a landscape contains thousands of sites that are significant in a variety of ways. The meaning of each site is expanded and deepened through oral traditions and historical knowlege. Each person may have a lifetime of subsistence or social and cultural experiences at many sites, and the experiences and uses are passed from generation to generation. Old occupation sites and landmarks may also have supernatural associations that affect modern Inupiat use. Much of the value of a site may be invisible to a non-Inupiat. Nevertheless, alteration of sites constitutes a defacing of history and even may entail a threat of supernatural retribution. As a result of the multiplicity of types of sites and emotional associations, the Inupiat consider a whole array of values that may be unfamiliar to planners or developers.

In past development studies, social impact analysis has not been adequately recognized. Sweeping socioeconomic change and growth from the trans-Alaska pipeline was largely recognized after the fact. Current analysis of Beaufort Sea Outer Continental Shelf oil and gas scenarios have identified impacts on the manmade and sociocultural environment stemming from petroleum development in the Arctic (Bureau of Land Management, 1978). Following is an analysis of human impacts which may be expected from NPRA petroleum development.

1. Archeology and History

a. General Impacts

Cultural resources encompass archeological, historical, ceremonial or religious sites, and resource gathering or hunting areas. Many such sites and areas do not have tangible remains nor can their boundaries be easily delimited. Fish camps and Native allotments are examples of such sites. Unexcavated archeological sites are the easiest to define because there are visible physical remains that can be quantified.

Many of the same sites that are important archeologically are likely to be of great historical and present-use value to the Inupiat. At the same time, many sites which are of extreme importance to the Inupiat may be of little or no value to archeology. Also, the values which are unique to each perspective may not always be in consort. For instance, a site that is still used for camping and hunting or travel routes may be of interest for complete protection by archeologists. This conflict is quite aside from any industrial conflict. It should be noted that identifications of sites from the perspective of the archeologist may end up conflicting with present Inupiat use of the land area. High ridges, lakes, riverbanks, and bars are susceptible to such confusions of values. Furthermore, not all sites of archeologic interest are related to the Inupiat culture.

Historical values, as with archeological and cultural values, must be viewed from the perspective of the regional inhabitants, as well as from the perspective of the State and national interest in historical subject matter. In this context, history is abundant and essentially untapped from both perspectives. From a local/regional context, the North Slope Borough Planning Department — through the Commissions on History and Culture, Planning and Zoning, and through the Mayor's Office and its Inupiat Language Commission — continues work on the Traditional Land Use Inventory (TLUI). This inventory, originally begun by the Regional Corporation and University of Alaska's Arctic Environmental

Lookout Ridge has been used as a travel route for several thousand years. Archeological sites in this terrain consist primarily of widely scattered artifacts. (C. D. Evans, AEIDC)

Information and Data Center (AEIDC) as a land selection tool, was later used to prove Inupiat land use and occupancy for the large expanses of the North Slope involved in the litigation *Edwardsen et al.* vs. *Morton*, later renamed *U.S.* vs. *ARCO et al.* Aside from its checkered career as a political document, the TLUI has largely been ignored as a document of import for archeological, historical, and cultural inquiry. Yet, it remains the single source document which ties sites, names, and types of uses from the present day to the sites and activities which have been and remain at the heart of the Inupiat existence in the Arctic. The tremendous wealth of information contained may prove to be the single best source of information about the Inupiat, documenting not only the sites but also their historical and cultural context in Inupiat life.

The TLUI dovetails well with the written documents of Western history and anthropology. Ships' logs, early exploration narratives, and anthropological studies all provide a slice of information about the tenuous relations of man to the harsh Arctic and the adaptive technologies and social strategies of the Inupiat in carving out a rich cultural and biological niche in this ecosystem.

Cultural resources can be categorized as static or dynamic. Static sites are primarily aboriginal archeological sites or European historical sites. Static sites are finite in number, and any physical impact on them is permanent. The number of dynamic sites fluctuates due to a variety of natural and cultural variables; eventually, an abandoned dynamic site becomes a static site. Impacts on the dynamic sites have to be judged on a case-by-case basis.

It cannot be assumed that sites without physical remains will not be affected by development. In many respects, they are more fragile because their importance rests in the mental or emotional expectations and perceptions of the people. It is impossible to quantify impacts on such sites, especially visual and audible intrusions.

Mitigating adverse impacts on archeological sites by excavating a site is presently more acceptable in northern Alaska than in other parts of the United States because the archeological data base is small. However, avoidance of sites is still preferable to a large-scale salvage archeology program. A salvage archeology program designed primarily for compliance with Federal statutes and for recovery of artifacts is not in concert with the aims of conservation archeology. The two basic tenets of conservation archeology are: 1) excavate only if a hypothesis is to be tested, and 2) attempt to test the hypothesis on sites in imminent danger of destruction rather than at sites that are convenient to excavate. The philosophy of conservation archeology can be compatible with salvage archeology if a well-thought-out program of salvage archeology is devised. Such a program must allow enough time between final selection of a petroleum-development site and actual development so as to permit appropriate excavations and analyses.

Cultural resource areas which are particularly vulnerable to impacts from development occur throughout NPRA. These areas include exposed coastline, water courses, and mountain passes. The coastline along the Beaufort Sea has been so severely eroded that few, if any, older sites remain. South and west of Barrow, the Chukchi Sea coast is eroding at a slower rate. Plentiful resources along the coastal zone draw and concentrate human populations today, as they have for thousands of years. With the greater density of both human activities and possible remains along the coast, particular caution should be taken when considering sites of industrial activities in that area.

Former coastal zones may contain sites which can be dated by geologic inference or methods. Similarly, sites buried under eolian sands can be dated through stratigraphic sequence, carbon-14 analysis, or by association with Pleistocene fauna. The former beach lines are limited in extent and are relatively stable, while eolian sands that cover much of the coastal plain are more susceptible to winds. These characteristics will influence excavation techniques.

Some natural features may have acted to channel activities. Travelers now tend to follow river courses or the west-trending ridges of the foothills. Passes tend to funnel both seasonal game and human travel. Such areas can be expected to incur a higher degree of damage to cultural resources simply because of the potentially greater local density of sites. Damage can also accrue to present human-use values, such as hunting, trapping, fishing, traveling, and camping. Activity which reduces the value of even one of these may have reverberating impact on all of the other values relating to present human use, by the Inupiat as well as by visitors to the area.

Understanding of the regional cultural development in the Arctic is limited. Therefore, each site offers the chance to increase that understanding. Damage to sites can be both incremental and cumulative in regard to the information base for a locality or the region.

b. Activity-Specific Impacts

The following is a description of the impacts on archeological and historical sites associated with development and production of the petroleum resources of NPRA. Those impacts are summarized in table 4.

Archeologists salvage artifacts and other remains from a site during construction of the trans-Alaska pipeline. Ideally, proper planning would allow sufficient time for this work to precede construction. (Alyeska Pipeline Service Company)

i. Construction

For many people the importance of an archeological site is represented by its artifacts. More important for interpretation, however, is the site context. Only when spatial relationships of artifacts and features have been recorded through controlled excavation can valid attempts at interpretation of human activities at the site be made. Hence, whenever soil disruption occurs at a site, it may be impossible to decipher context.

Activities such as excavating borrow pits, ditching, bulldozing, and blasting are the most obvious and immediate causes of site destruction. Degradation can also occur without causing apparent soil disruption. Contaminants spilled over or leached into a site could ruin chances for dating organic remains by carbon-14 analysis. Lowering of the permafrost level could subject the material remains to greatly increased rates of mechanical and chemical decay, in addition to increasing the incidence of frost heave and solifluction.

A construction or road pad may also affect local drainage patterns by blocking and channeling runoff, resulting in changes in local soil moisture content and in locations of areas subject to erosion. Erosion along such flow channels could affect a site situated close to or under a pad. Changes in moisture content of the local soils would also affect the depth of the active layer. The rate of decay of organic materials and change in cover vegetation could increase site susceptibility to wind and water erosion.

Work pad construction may have the effect of raising the permafrost level to at least the former ground surface. This type of freezing could have long-

Table 4. Impacts on Archeological and Historical Resources by Petroleum Development and Production

Source	Impacts	Magnitude[1]	Term[2]	Location[3]
Excavation (borrow pits, quarries, trenches, pits, blasting).	Obliteration of part or all of site(s)	***	***	*
	Buried site exposure	***	***	*/**
	Changes in artifact preservation	*/***	*/***	*
	Destruction of artifacts	***	***	*
Drilling	Changes in artifact preservation	*/***	*/***	*/**
	Destruction of artifacts	*/***	***	*
Construction:				
Snow and ice roads	Changes in artifact preservation	*/***	*/***	*
	Alterations in erosion pattern	*/***	*/***	*/**
Sand and gravel roads, work pads.	Site burial	*/***	***	*
	Changes in artifact preservation	*/***	*/***	*
Pipeline	Changes in artifact preservation	*/***	**/***	*/**
Human activity	Changes in artifact preservation	*/***	*/***	*
	Increased discovery and looting of sites	**/***	***	*
	Increased discovery and scientific consideration of sites.	**/***	***	*
Waste disposal	Chemical contamination of artifacts	*/***	***	*
	Changes in artifact preservation	*/***	*/***	*
	Strata disruption	**/***	***	*/**
Accidents (mechanical, chemical spills, fire).	Strata disruption	**/***	***	*/**
	Changes in artifact preservation	*/***	***	*
	Buried site exposure	***	***	*
Emergency clean-up procedures.	Strata disruption	**/***	***	*/**
	Changes in artifact preservation	**/***	*/***	*
	Contamination of artifacts	**/***	***	*
	Obliteration of part or all of site	***	***	*
	Buried site exposure	***	***	*/**
	Exposed site burial	**/***	***	*
Abandonment (stabilization, revegetation, contouring).	Strata disturbance	**/***	***	*
	Site burial	**/***	***	*
	Buried site exposure	***	***	*
	Artifact preservation changes	*/***	*/***	*
	Obliteration of part or all of site(s)	***	***	*

[1] * = minor; ** = moderate; *** = major.
[2] * = short; ** = intermediate; *** = long.
[3] * = onsite; ** = local; *** = regional.

term beneficial effects by preserving organic remains and maintaining stratigraphic integrity, but only as long as the frozen state continued. Once the compacted zone under a pad loses some of its insulating qualities, permafrost degradation results. Consequently, the site would suffer a higher rate of organic artifact decay and greatly increased rates of frost heave and solifluction. The latter two processes could result in total site destruction.

Sand and gravel borrowing now occurs both in river bottoms and in upland areas. Excavating in the river is least likely to cause damage to potential sites because the changes in channel configuration over time are likely to have destroyed sites in or adjacent to channels. Some sites may have been buried by alluvial deposition and would be difficult to detect. Borrowing near river channels could cause a change in the river course and thus endanger sites near the borrow pit that had not previously been threatened by stream erosion. In addition, sites revealed in the borrow pit banks could be destroyed by slumping of the banks.

Upland terraces and hilltops have consistently been prime sites of archeological material. These same topographic features are inland sources of sand and gravel. Destruction of sites can result from borrowing or from recontouring the borrow area to lessen the future extent of erosion.

Sites buried under eolian sands tend to be seriously affected if removal of the protective surface results in permafrost degradation.

Snow and ice roads entail borrowing, construction, and traffic activities which can affect archeological sites. Snow for road construction would generally be borrowed from drifts in the lee of a hummock, terrace, or hill. It is at the top or base of such features that many archeological sites have been found. Blading snow pockets is likely to cause direct accidental damage to vegetation and soils, resulting in increased erosion and site disturbance. Properly constructed snow or ice roads cause minimized permafrost degradation. At this time, thawing of the road has not been shown to seriously affect the vegetation cover, but the roads can temporarily block or change local drainage patterns. Sand and gravel roads and airfields would have the same effects as pad construction. Mitigation might include building as few roads as possible and avoiding probable site locations, as well as other actions described under "Physical Environment."

Off-road traffic could affect archeological sites by direct vehicle contact with surface features and by compaction. The best means of avoiding impact is to strictly regulate such traffic.

Construction of gathering lines would create impacts similar to pad and road construction. Excavation for placement of elevating piles or for burial of pipe would seriously affect any site uncovered.

An indirect impact of development operations is an influx of people to and near the construction sites. Many new archeological sites may be found and reported in the course of constructing roads or other facilities. Those and unreported sites will probably be scavenged. Improper or unsupervised collection has destroyed many sites in the past. More easily disturbed than archeological sites are those having less tangible values, such as those chronicled in the Traditional Land Use Inventory. An influx of people from outside the area, whether associated with development or taking advantage of increased access, may be unaware of such values at specific places. Damage to or disturbance of traditionally used sites may have secondary effects. Subsistence use may be diverted from formerly productive sites to less familiar areas, resulting in uncertain harvests. Impacts on TLUI sites (including sites not yet recorded) may also engender feelings of anxiety or hostility on the part of Inupiat residents.

Measures which could help protect or preserve archeological material might include (1) thorough survey of prospective pad sites, road routes and borrow sites, and (2) informing workers of the legal protection accorded to any site and encouraging persons to report cultural remains. Documentation of site location is important to archeologists and to the completion of traditional land use inventories being carried out by the North Slope Borough.

ii. Operation and Maintenance

Solid waste and drilling mud disposal has the potential of destroying archeological material in the active layer by contamination with leachates or by burial. Containment and insulation should keep waste frozen and prevent the dispersal of leachates.

Construction of service roads can have impacts like those described under "Construction." Accidents such as blowouts or spills at the well site would have varying impacts on archeological or traditionally used sites, depending on the location, season, volume, and extent or type of material spilled. Summer spills would have greater impact than winter ones, and the greater the volume, the greater the chances for detrimental impact on cultural resources. Emergency cleanup measures pose the danger of trampling and contaminating organic remains with chemical sprays.

iii. Rehabilitation and Cleanup

Further opportunity for damage to previously unidentified archeological resources exists during recontouring, surface stabilization, and revegetation. The potential environmental benefits of these activities are potential threats to this resource — that is, by mitigating one impact, another may be created. In this context, surveillance of activities may be the only mitigative measure possible.

2. Socioeconomics

Socioeconomic factors affecting the North Slope population, both the resident and transient sectors, are wide ranging and diverse. The cultural values of various residents and nonresidents are closely related to these factors. Inupiat subsistence patterns are based on social, economic, and cultural needs and traditions. In contrast, many people within and beyond the region and State believe that economic

Impacts on the human environment are a major concern in NPRA development. (Arctic Slope Regional Corporation)

growth and development are important to the Nation. Still other groups represent environmental conservation, scientific research, recreational sports, petroleum development, and other special interests. Therefore, a socioeconomic analysis of petroleum development impacts is complex.

a. Issues Overview

Following recent economic and political events, such as the Alaska Native Claims Settlement Act and Prudhoe/TAPS development, the North Slope Borough has identified several interrelated socioeconomic issues. NPRA and the Naval Petroleum Reserves Production Act constitute one of these issues. Domestic energy demands coupled with a major NPRA discovery may mean authorized production, either immediately or in the near future. The result of the authorization would be an interaction of energy resource development and local Native interests. Other related issues are the proposed gas pipeline from Prudhoe, the haul road, prospective OCS development, caribou, land tenure, and coastal zone management (Darbyshire, 1976).

Development of more than one project simultaneously would vastly complicate the picture. Impacts would interact synergistically: multiple impacts due to multiple development projects are probable and would modify and intensify the anticipated impacts of NPRA development. Additionally, events occurring outside the region may influence what happens in northern Alaska. For example, a war in the Middle East could put a premium on domestic oil deposits and accelerate plans to explore and develop these areas, including northern Alaska. Conversely, continued inflation could raise costs to the point where it would not be economically feasible to develop petroleum resources in the region until a later time. There is no way to predict these events and trends, but they could be as significant to the region as NPRA development.

Socioeconomic analysis entails more than a simplistic identification of positive and negative impacts because there are several viewpoints with different values to be considered. For example, some persons find positive value attached to the sequence of oil and gas discoveries, recruitment and training of Native men and women, paychecks, and ensuing economic well-being of a previously economically depressed group of people. Some Inupiat and perhaps most non-Native residents of the region subscribe to this viewpoint. From the point of view of a culturally conservative Inupiat, however, the above sequence could be interpreted as an unmitigated disaster. This sector foresees disrupted family and social ties, selection of young and strong people who could help with subsistence and sharing of food with dependent older and younger members of the community, a generation gap in cultural transmission, alienation of young people from the community, greater chances of community mortality by removing members of child-bearing age from the community, and so on. As seen through that cultural lens, nothing about the development sequence and its consequences is good because it interferes with the traditional Inupiat existence.

The adaptive Inupiat find themselves between two cultures. They want all the subsistence time they can get but accept the fact that they have to have cash to support subsistence activities. They do not endorse the kind of activity that destroys the subsistence base but need to work somewhere, so they ambivalently join work crews. This produces many kinds of conflicts because they do not control their own destiny nor like what is happening, with their assistance, to their homeland. They are torn between two roles: wage workers and true Inupiat.

Between these extremes are other possibilities and intercultural viewpoints, but there is no effective way to poll cultural values and perceived impact. Some older Inupiat may be becoming more tolerant of change, while many young people are becoming less so. The culture is in flux. Impact analysis is complicated not only by the unknowns of development but also by report limitations that cannot fully treat intercultural and cultural change.

Following is a discussion of the socioeconomic impacts associated with the potential development and production of the petroleum resources of NPRA. Because the socioeconomic impacts are not site-specific, but regional in context, they are discussed

Many Inupiat find themselves between two conflicting roles: wage earner and subsistence hunter. (Grossman-Granger Productions)

Table 5. Socioeconomic Impacts from Petroleum Development and Production

Factors	Primary Impacts	Secondary Impacts	Magnitude[1]	Term[2]
Population	Increase in number of people people in area.	Stress on infrastructure	***	*
		Stress subsistence resources	***	***
		Increase racial tension	**	*
		Increase cost of living	**	*
	Shift cultural composition of region to non-Native.		Unknown.	***
	Shift sex ratio of population to predominately male.	Worsen race relations	**	*
	Loss of regional isolation.	Make maintenance of traditional culture difficult.	***	***
Villages	Increase demands on infrastructure.	Stress existing infrastructure	***	***
		Improve infrastructure	***	***
	Increase demands on transportation facilities.		**	*
	Increase demands for housing.		***	*
Subsistence	Stimulate nontraditional use of wildlife.	Compete with subsistence use of wildlife.	**	*
	Change traditional land use patterns.	Make subsistence hunting more difficult.	***	***
		Make maintenance of traditional culture more difficult.	***	***
	Degraded habitat	Decrease subsistence resources	***	***
	Increase air traffic	Harass wildlife, especially subsistence species.	***	***
		Harass Native hunters	***	***
	Pipeline and roadway barriers.	Decrease numbers of subsistence animals.	***	***
		Increase access to traditional subsistence lands.	***	***
		Increase difficulty of locating subsistence animals.	***	***
Economics	Increase number of jobs in region.	Decrease unemployment	**	*
		Increase need for area resident job training.	**	*
		Increase cost of living	**	*
		Increase employment opportunities for women, young and old.	**	*
		Stimulate Native population stability.	**	***
		Stimulate competition between job time and subsistence time.	**	***
		Stimulate competition among workers for existing jobs.	**	*
	Increase opportunities for small businesses.	Decrease unemployment	***	*
		Increase opportunity for resident investment.	**	***
		Increase regional economic stability.	**	***
	Increase tax revenues	More money available to borough and villages.	***	*
		More jobs available to residents	**	*

See end of table for explanation of footnotes.

Table 5. Socioeconomic Impacts from Petroleum Development and Production (continued)

Factors	Primary Impacts	Secondary Impacts	Magnitude[1]	Term[2]
Economics Continued	Increase tourism	Increase job opportunities	**	***
		Tourist activities compete with subsistence.	***	***
North Slope Borough and Arctic Slope Regional Corporation.	Increase funds available	Increase investment opportunities.	**	*
		Increase job opportunities for residents.	**	*
	Increase in demand for employees.	Increase competition for workers.	*	*
		Increase operating costs	**	*
		Increase area inflation	**	*
	Increase number of responsibilities assumed.	Stimulate growth in local government.	Unknown.	***
	Increase investment opportunities.	Increase financial stability of ASRC.	**	*
		Increase local investment opportunities.	**	*
		Increase competition between new and previous investments.	*	*
Government and local politics.	Increase demands on local government.	Increase need for governmental employees.	*	*
		Increase costs of local government.	**	*
	Increase need for local control and participation.	————————	***	***
Lifestyle	Increase pressure for residents to accept change.	Increase difficulty of maintaining traditional culture.	***	***
		Decrease opportunities to pursue traditional activities.	***	***
		Stress traditional kinship patterns.	***	***
Social problems	Increase racial tension	Stress social structure	**	*
	Increase alcohol/drug abuse.	Increase area health problems	***	***
		Intensify area crime problems	***	***

[1] * = minor; ** = moderate; *** = major.
[2] * = short; ** = intermediate; *** = long.

Note: Socioeconomic impacts are the cumulative result of all aspects of petroleum development. Hence, this table considers those socioeconomic factors which are affected by the overall petroleum development rather than by the separate components of such development.

from the regional point of view. They are summarized in table 5.

b. Population

Oil development in NPRA will affect the growth and composition of the regional population. Effective separation of existing residential (traditional) communities and industrial sites will minimize potential conflicts and adverse effects.

Growth. Oil development in NPRA will result in increases in the number of people in the North Slope region. The severity of associated impacts will depend on where the development takes place, its size, and its proximity to traditional villages. Development in an area remote from these villages will minimize the impact of population growth on them, but even in remote areas, development will probably trigger slight growth in the smaller traditional villages and moderate growth in Barrow.

In general, population growth through immigration will create stress in the villages. People unaccustomed to the traditional village life of NPRA will probably desire more services and amenities than the present infrastructure provides, and such systems are already overtaxed in most villages. Housing would also be a critical problem. Regional population growth will impact subsistence, since many newcomers will want to hunt and fish and travel to remote areas and will compete, interfere, and cause friction with traditional gathering for these resources.

Cultural composition. Most new workers brought into NPRA will be non-Native, so ethnic composition in the region will shift in this direction; Prudhoe Bay development resulted in the non-Native component of the population becoming the majority group in northern Alaska. If the population of non-Natives increases in the traditional villages, where more than 90 percent of the residents are now Native, social and cultural accommodations would have to be made cooperatively to avoid misunderstanding and strife.

Sex composition. If the past history of large construction projects in the Alaskan Arctic is repeated, most of the new people brought into the area to work on oil development in NPRA will be male. During construction of the DEWLine and initial construction of the trans-Alaska pipeline and the Prudhoe Bay oil field, all workers were men. Recent changes in hiring practices, however, have increased employment of women.

The impact of another influx of a predominantly male population on the region would depend to a great extent on where it was concentrated. The Prudhoe Bay population was far from any traditional village, and the impact on villages was minimal. Such would probably also be the case in NPRA. If, on the other hand, development is close to a traditional village, the impact would be considerable. Social problems can be anticipated, including alcohol and drug abuse, racial intolerance, and competition between resident and nonresident men for resident women. Since the oil development companies feel pressure to hire more women, job opportunities for women from both within and outside the region would increase.

Large, predominantly male populations isolated in remote enclaves experience many internal problems. Many have been successfully mitigated in the Prudhoe Bay area by keeping the workers onsite for relatively short periods and paying for their transportation back to point of hire on a regular basis.

c. **Regional Isolation**

Until the recent past, northern Alaska was isolated from much of the rest of the country, which helped preserve the unique culture of the Inupiat people. Periods of industrialization in the past have reduced isolation and made retention of cultural values difficult. Additional development would tend to repeat these effects.

d. **Native Population Stability**

Relatively large numbers of northern Alaskans have periodically left their traditional villages in the past for employment in such places as Fairbanks and Anchorage. Greater training and employment oppor-

NPRA development would require additional housing in the region. Modern houses, such as these in Barrow, are usually prefabricated outside the area.

tunities within the region would reduce the need for long periods of separation from family and home.

e. Villages

The traditional communities represent the continuum of use and occupancy of the region — a conserving force of Inupiat culture. Petroleum development, however controlled, will bring in more workers and machinery and will introduce changes. Induced growth and a demand for expanded infrastructure and services will affect the entire region. Primary, secondary, and cumulative effects on the resident population will far exceed any incremental changes associated with project specifics, such as numbers of workers or miles of pipeline and roads.

f. Infrastructure

Oil field development within NPRA would increase demands on regional infrastructure. Transportation facilities, communications, public safety, and hospitals are already severely taxed within the region. Improvements have been made in some of these areas in recent years, particularly in Barrow. It is doubtful, however, that the regional infrastructure will be able to absorb a significant influx of new residents and new activities in the near future. The severity of this impact, then, depends on when development takes place. Development in the next few years would have greater impact on the regional infrastructure, while impacts of later development may be less severe. Furthermore, some aspects of the infrastructure(s) would be impacted less than others. For example, improvements in education facilities have been a first priority in the borough, and at the present time these facilities are either well developed or are under construction in all villages of the region. Since early phases of development would probably not bring families into the region, at least initially, significant increases in educational facilities would not be required immediately.

Development would initially increase crowding in already crowded village housing conditions and would decrease the quality of the services available to most residents of the region. An overstressed infrastructure would have an impact on government. Residents will expect solutions to those problems from that government.

In the past 7 years, two villages have been resettled in the borough — Nuiqsut and Atkasook — on sites of historic importance to the Inupiat. The borough has no plans at present to encourage more new villages in the region, largely due to problems anticipated in providing adequate current infrastructure services.

g. Transportation

Increased development in NPRA would increase pressure on existing transportation facilities and create a need for developing new ones. Since air transportation is the most frequently used travel mode in the region, the most immediate need would be in this area. The severity of this impact would depend on where development takes place. If development happened to be close to one of the existing villages, existing transportation facilities might need only to be expanded to accommodate large aircraft and increased air traffic. In the Barrow area little expansion would be needed. However, it is more likely that development would take place far from the traditional villages, and new transportation facilities would have to be developed. This would place increased demands on gravel sources which, in turn, would affect other aspects of the regional economy, since gravel is in short supply and is needed for most construction projects. Gravel mining is often destructive to the environment and the food sources the environment supports.

Development would also create a need for additional road systems, and pressure to build roads from existing villages to the development site would mount. Road building would intensify pressure on gravel resources and would have other effects. Increased transportation facilities would take non-Natives into remote areas and would impact subsistence activities. Increase in the number of vehicles would change the local travel modes and routes and would intensify traffic problems in the traditional villages, problems already apparent in Barrow.

Bulky and nonperishable items are freighted into the area by tug and barge. An increase in development would accelerate these activities, creating an increased need for dock facilities as close to the development site as possible. Job opportunities for area residents would be increased, as would the amount of money available in the region. Increasing the marine facilities and traffic would increase the possibility of accidents in waters containing ice, which, in turn, might affect marine mammals on which area residents depend. Construction of dock facilities would interfere with marine subsistence resources by altering breeding, feeding, and resting activities and might ultimately affect the subsistence harvest of these resources.

h. Housing

The need for additional housing would also increase with development. The need would come from two sources. Increased activity would stimulate population growth, and new residents would require additional housing units. Even though most employees associated with development would probably live onsite in company dormitory-type housing, some would bring their families into the region. Many of these families would be housed in or around the traditional villages, thus creating the housing need. Some former Barrow residents, both Native and non-Native, would return if more jobs were available. A second housing need would come from employed area residents who would, as a result of increased cash available to them, want to move into new housing or to renovate and enlarge old housing. The immediate effect of these pressures would be to create overcrowding in the existing facilities and to intensify the already severe housing shortage.

Subsistence is an economic, social, and cultural endeavor. The bowhead whale hunt is a community event steeped in tradition. (C. D. Evans, AEIDC)

i. Subsistence

Exploration and development of mineral resources in NPRA will produce many impacts on the land, its resources, and, thus, on the traditional subsistence base. Many impacts on the terrain (i.e., on the physical environment) and on wildlife habitat (i.e., on the biotic environment) are also impacts on the subsistence resources.

Subsistence activities are economic, social, and cultural endeavors. If subsistence is to be maintained and protected, three basic propositions need to be recognized: 1) subsistence occurs within a social, cultural, and economic context; 2) legislation should be flexible to recognize that change is a process of adaptive strategies made by cultural groups to maintain themselves; and 3) public policy, legislation, and regulations can directly affect the viability of subsistence (Worl, 1977).

All land designations and human uses of NPRA will displace or affect traditional land use. Subsistence hunting, fishing, and gathering activities cannot be discussed solely in terms of harvest areas or current patterns. Animal source areas, migration routes, and seasonal and cyclic variables form a complex network in time/space that, in turn, determines what, where, and when resources will be harvested. Seasonal or cyclic failure of a primary resource may completely alter "normal" patterns, as may hunting restrictions or quotas like those currently in effect on caribou and bowhead whales. Such variables may force reliance on different geographic areas and species. For example, an entire drainage may be the source area for one fish camp. Construction activities that result in reduced fish populations may cause temporary or permanent abandonment of the drainage and camp, and, concurrently, increase pressure on another drainage's resources.

It is not possible, therefore, to strictly delineate zones of current or primary subsistence activity and leave the rest of the map open to other use assignments. If hunters and hunted require extensive ranges which change over time and from season to season, then development activities should be restricted to the smallest possible area, and the logistical connections between development sites should not be allowed to fragment extensive habitats. Moreover, seasonal scheduling of exploration, development, and operations should avert conflict with periods critical to animal resources (e.g., calving, migration, molting) and to subsisters. For instance, exploratory activities conducted in winter do not conflict with migratory bird breeding or hunting. However, effects of exploration are often subtle. Winter seismic operations may kill fish under several feet or meters of ice. Off-road operation of heavy equipment in winter may modify drainage patterns that will affect growth of plants which may, in turn, be important to calving caribou months later. The long-term effects of apparently minor or local actions may be very great.

When the extensive primary and alternate hunting areas of various villages are joined together, the need for open range is clear. It becomes apparent, for example, that there is no break between the range of concern to Anaktuvuk Pass villagers (extending west, northwest, and north toward caribou summering and calving ranges in NPRA) and the ranges of concern to Barrow, Wainwright, Point Lay, and Point Hope. All of these villages look to the same source areas for the caribou herd that moves through their overlapping hunting grounds. Growth in northern Alaska's industrial and economic bases, and in its total population, will inevitably result in pressure on wildlife populations and in reduction of productive environments through developments, such as roads, pipelines, and work sites.

Conservation designations, such as refuges or ranges, may be positive with regard to subsistence to the extent that they preserve habitat. But to the extent that they encourage tourist and sport hunting and fishing uses, they can create only negative effects on the subsistence resource base. Unless such designations result in the type of wilderness park advocated for the northern Yukon Territory by Berger (1977), the subsistence commons will be fragmented.

An open-range approach to NPRA requires a limitation of land uses and an unconventional approach to land ownership and designation. Lacking these basic premises, specific mitigations relating to a given road, gravel pad, or pipeline merely distract the analysis of basic issues.

At a public meeting on NPRA activities held in Anchorage on February 8-9, 1978, Native people stated their concerns about incursions into traditional land-use areas. Below is a sample of comments that indicate the kinds of impacts — physical, biotic, social, economic, and cultural — that Native people fear and dislike:

- Exploitation of resources.
- Commercial extraction and exhaustion of resources.
- Intruders with no long-term identity with the area.
- Need for local control of resources because permanent occupants of the country have a long-term view of conservation and use.
- Families must be able to work as teams for division of subsistence labors and cultural transmission of environmental knowledge.
- Government and commercial interests are dominated by greed, which, in turn, produces destructive domination of Native people.
- Even if laws and regulations were written correctly, some government operative must interpret and apply them, usually with bias against Native people.
- Native people do not want to trade subsistence life for anything whites have to offer — not money, nor jobs, nor store-bought things.
- Eskimo people have welcomed and helped white people, only to have them use data and testimony against Eskimo people.
- When a sportsman mounts an animal head on his wall, it is like mounting a Native head on the wall.
- Village people don't know what is happening; they feel victimized.
- Economy, culture, esthetics, and historical values are all one big entity, not four different things.
- Many different development entities are working to destroy Native homelands, resources, and ways of life.
- Fish and animals of land and sea feed the whole community, so communities must be a part of land-use planning and decisions.
- A Native from one community wouldn't presume to tell people of another village what to do; nor should State and Federal Governments try to tell village people what to do via fish and game regulations.
- Whites have a false notion of the "Last Frontier"; Native homelands are not frontiers, they are home.
- People of Point Hope use all of the whale, except liver and lungs, and skin of these parts of the whale is used for drums; Eskimo food was the only thing available in the old days, and now high prices make store foods impossible to use for a main diet; from Point Hope, whales are shared with people of Kotzebue, Kobuk, Kivalina, and Noatak.
- Subsistence is the historic answer to human survival in Alaska; if the Government can't regulate unemployment, how can it regulate subsistence? It can't take subsistence away if there are no jobs.
- Oil exploration and development causes too much traffic; it scares and drives away game.
- When conflicts arose in Lower Cook Inlet over development and oil leases, the people all voted against development.
- Rapid pace of development is always a threat to subsistence.
- Hunger, not regulations, determines Native subsistence.

- Cash and subsistence now have to go hand in hand, in a mixed economy.

- When Native people lived their own lifestyle, they were healthy; after forced schooling and other white impacts, health is down, suicide and crime are up: who are the civilized people?

- To solve subsistence problems, eco-cultural regions must be established, with fish and game regulations by local people in each region; must remove State Fish and Game Department bias and incompetence.

From these comments it is apparent that lifestyle, economics, government, and other impact topics blend together. Therefore, treatment of specific impacts on Inupiat culture must be conditioned by a broad understanding of these subjects in the context of the lives of the people in the region.

j. Economics

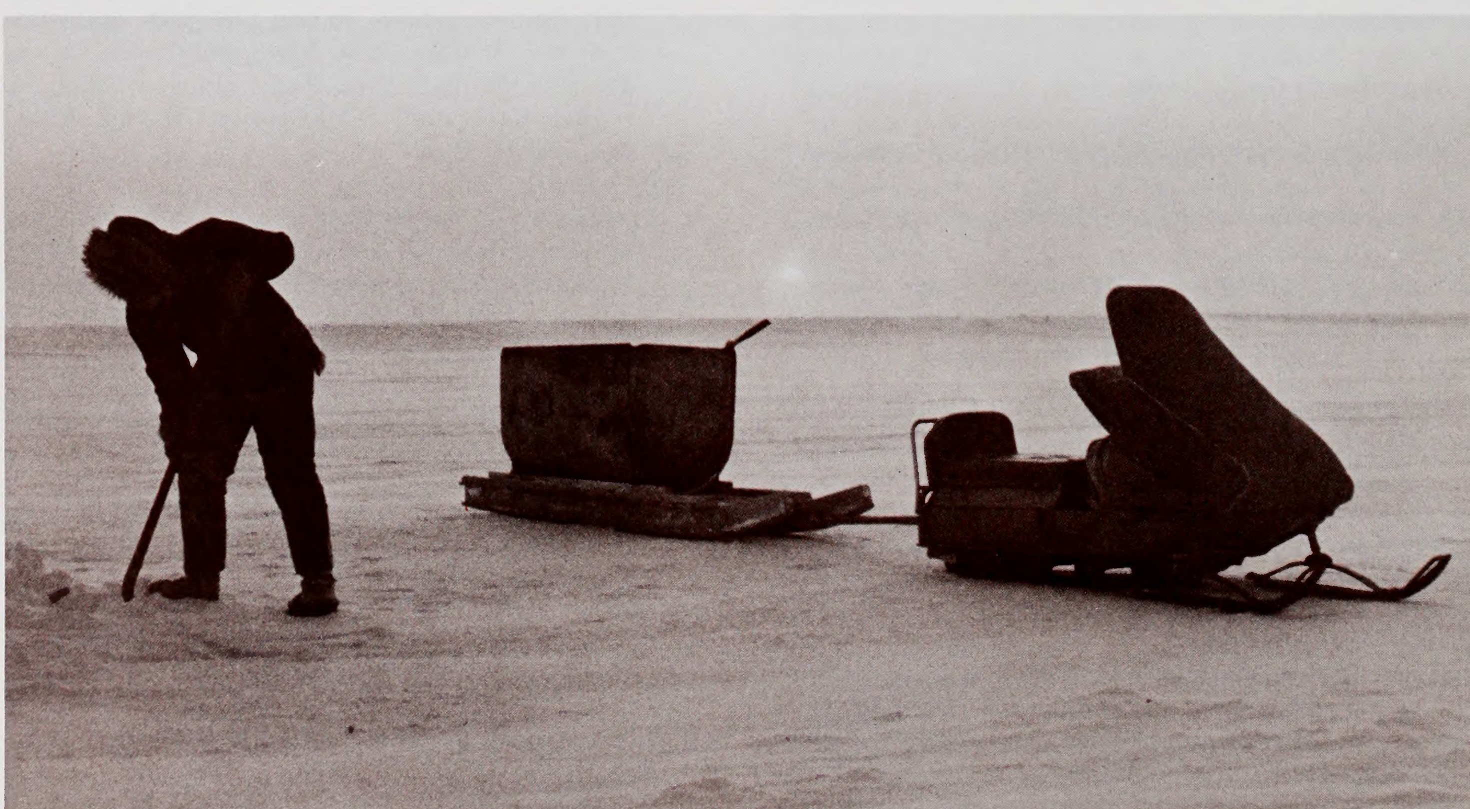
NPRA oil development and accompanying growth would increase job opportunities and expand the potential market for business enterprises and investments. The borough tax base would increase, which would further facilitate capital improvements. Industry employment, cottage industry, and other tourist services would expand job opportunities for residents. Recreational and sport hunting pressures could adversely affect Native subsistence livelihood.

Jobs. The number of job opportunities available to North Slope Borough residents would increase with development of oil fields in the NPRA area. Furthermore, it will be easy for residents of the traditional villages to take these job because of the proximity of development to the villages. Additional job opportunities would be created in the villages, especially those jobs created by the borough. The most immediate effect would be an increase in the amount of cash available to residents. Cash may be used for gasoline and hardware needed for subsistence activities. More cash will also allow people to purchase and improve housing and to improve their standard of living generally. At the same time, increased demand for purchased goods would stimulate inflation and increase the cost of living — perhaps already the highest in the Nation.

Many unskilled area residents would require special training to qualify for newly available jobs. Many would find training difficult to obtain since classes would not generally be available locally, would be time consuming, and would require leaving the region. Jobs also tend to compete with traditional subsistence activities. The intensity of this impact would vary seasonally, being most intense during the spring and summer, when the availability of subsistence resources is high, and least intense during the winter, traditionally a slack subsistence period. Excessive subsistence hunting, resulting from increased cash, could cause too much pressure on subsistence species.

Small business opportunities. Development of oil fields in NPRA would increase the number of small business opportunities throughout the region, particularly in Barrow. Elsewhere, the importance of this opportunity depends on the distance from a village to the development area. An increase in small business opportunities represents an increase in the

Snow machines have become an integral part of subsistence activities. (Grossmann-Granger Productions)



number of vocational options open to area residents. In the past, opportunities for small businesses have been limited because of the small potential market. A significant increase in small businesses in Barrow accompanied development in the Prudhoe Bay area. Development in NPRA may accelerate this trend in Barrow and might spread it to other villages. A rise in the number of small commercial enterprises in the area would increase pressure on the supporting infrastructure.

Arctic Slope Regional Corporation and Village Corporations. NPRA development would increase investment opportunities for Native corporations. The Arctic Slope Regional Corporation (ASRC) may be able to benefit directly from these developments because of its regionwide operations. Village corporations may benefit differentially, with those village corporations located closest to the activity probably benefiting most, but some increased investment opportunities may be available to all village corporations. Such investments, particularly if they are made locally, would lead to increased corporate stability and community diversity. Furthermore, increased investment opportunities would increase cash availability within villages and to the shareholders of the corporations. These factors would compete with subsistence activities and would provide the region with more cash. Another result might be that ASRC would find local investment opportunities stimulated by NPRA development competing with other investments already made or anticipated. This will be discussed more fully in a later section.

Taxes. Development of oil fields in NPRA would mean an increase in the amount of taxes available to the borough and to communities. The most important source of tax revenue would be property taxes. These would be levied directly on oil field-related property and indirectly on individuals through an increase in personal property made possible by increases in available cash. Most tax revenues, however, would come from oil-related properties, lessening the tax burden on individuals. Thus, increased taxes on oil properties may relate directly to subsistence by providing more cash for individuals and to villages by increasing the amount of money available to them for village projects. An increased tax base would also provide more funds to the borough government for capital improvements.

Tourism. Oil field development in NPRA would increase the attractiveness of the area for tourists and enhance the development of a tourist industry. Furthermore, increased revenues in the region would allow improvements in tourist facilities. Opportunities for increased small businesses related to tourism would be particularly enhanced. Community museums, arts and crafts cottage industry, and a variety of tours can be anticipated to develop. These factors would directly affect personal incomes and activities within the villages. However, drawing the area to the attention of tourists may directly affect many of the resources that have traditionally been used by the Inupiat for subsistence. Tourism would increase the sport hunting pressure on subsistence species and would take tourists into those remote areas that have traditionally been used only by Natives. Conflicting or ambivalent interactions may occur between tourists and residents.

k. North Slope Borough and Arctic Slope Regional Corporation

Both the borough and regional corporation were established in 1972 and have been required to respond to rapid economic and political change. Increased revenues and opportunities are advantageous, whereas staff capabilities and program subsidies are limited. Local sectors find it difficult to keep pace with and respond to much larger sectors, such as State and Federal Government and industry.

The primary effect of NPRA oil development on the borough and regional corporation would be an increase in operating funds. For the borough government this increase would stem from an expansion of the tax base. Availability of additional funds would stimulate growth of borough government. Increased funding would expand programs and job opportunities for both the borough and the corporation, which would variously affect both the region's and the communities' economies.

Employment. Oil development in NPRA will impact both the North Slope Borough and Arctic Slope Regional Corporation by affecting the people who are available to them as employees. Presently, many jobs available in these communities are associated with these two agencies. However, increased development in the region would create other jobs and thus stimulate competition among potential employers for employees. This, in turn, would tend to raise salaries, which would benefit individuals but would increase borough government operating expenses as well. The quality of employees available to the borough and ASRC may drop, and less qualified and less ambitious individuals may have to fill some positions. On the other hand, more job opportunities will exist for older and younger individuals — two groups which at present are experiencing relatively high unemployment throughout the region.

Investment. Oil field development in NPRA would impact ASRC and the village corporations by slightly increasing investment opportunities, particularly in the region. These investment opportunities may compete with other investments the corporations are involved in. For instance, NPRA investments might compete for ASRC dollars with similar investments anticipated on lands directly controlled by the Native corporations. On the other hand, some NPRA investments by the corporations might complement other investments. Many ASRC subsidiary companies are involved in tourism, construction, heavy equipment maintenance, and the like, and they may find new opportunities associated with increased NPRA development.

l. Government and Local Politics

Municipal and village governments would be heavily affected by growth in Barrow and other villages. Because of past Native population dominance,

A successful whaling captain passes out choice portions of the whale at Nulakatuk, the ceremony that marks the end of the whaling season. (C. D. Evans, AEIDC)

local government would have difficulty changing its policy from a Native bias and constituency to address greater diversity. Even if enclaves and work-site compounds are the rule as development progresses, the municipalities would have to respond to different needs of non-Natives who demand government services and who seek to integrate themselves into government and politics. Long-term development activities would change the residence tenure of non-Natives, which previously was mostly short term or seasonal. As "permanent" residents, they would insist on full participation in government and politics. Practically, this would put immense stress on municipal and local governments and could produce social tensions. Non-Native voters and political blocs would increase their power as their population and permanence are established.

As development and increased populations negatively impact the subsistence resource base, thus reducing traditional subsistence activities, and as "migration" to the full-time cash economy becomes more necessary to well-being, the traditional bases of esteem and leadership in Native villages may erode. The whaling captain or the outstanding hunter and provider of food for less fortunate villagers may lose status. If local governments switch from a Native to a non-Native power base, residents may become political stepchildren. Such a situation would exacerbate resentments and a sense of helplessness among Natives. These possibilities are already viewed with foreboding by Native people, and friendly accommodation is unlikely. If a political power struggle ensues on the North Slope in the wake of development and subsistence-resource diminution, social conflict will surely result.

This forcast — speculative, but based on existing factors that are well on the way to combination — illustrates the synergism of networks and systems in the physical, biological, and cultural fabric of northern Alaska. No amount of minor tinkering or public relations mitigation is going to improve the forecast and the emerging reality — only major policy decisions can change the sequence. Development and the impacts and populations that it brings should be controlled. Cooperative governmental and social institutions should begin as early as possible to reduce the social impacts of change and should substantively involve the local people in land-use decisions. Current legal and administrative frameworks do not have capabilities to adequately integrate the interests of Native people and the fragmented objectives and agents of the national interest.

The development of mutual respect is basic to governmental and social mitigations. Workers coming to NPRA should undergo at least a rudimentary training program to acquaint them with Eskimo history and prehistory and the Natives' present way of life with its traditional elements. In the past, imported work crews and professionals have not demonstrated understanding of Inupiat people and their long history of adaptive response to the Arctic; ethnic stereotyping could be reduced or avoided by such training — important in a situation of potential conflict. A major change from the early contact period — when whites depended on Inupiat people for their very lives — occurred when whites imported their own modules and capsules along with all their food, clothing, and support. The Native ceased being a lifesaving friend and became a minority person in a white compound. Training and a renewal of functional relations with the Inupiat could be critical in developing mutual respect.

Various governmental bodies, acting under such charters as the Marine Mammals Protection Act or Endangered Species Act, have set up elaborate and costly research, regulatory, and enforcement programs. Similar programs to promote cultural diversity may be necessary. No economic activity will occur in NPRA without Government support or license. Certain provisions of legislation, such as the National Environmental Policy Act, as well as special statutes, would be appropriate to assist the economic-social-cultural transition of the Inupiat people subject to drastic change. Critical factors requiring attention include subsistence-resource base and traditional land-use privileges. Moreover, Federal monies and programs are routinely provided other social groupings impacted by federally sponsored undertakings. The same principles must be applied in NPRA.

m. Social Well-Being

Controlled development which is responsive to Native concerns should consider two sides of Native well-being: on the one hand, perpetuation of kinship and subsistence patterns, and on the other, mitigation of social problems symptomatic of rapid change.

Kinship and subsistence. Modern Inupiat lifestyle is functionally based on subsistence, cash income, hunting and fishing camps, and permanent village habitation. The blend of traditional and modern in the contemporary Inupiat lifestyle is expressed in social structures revolving around the family and kinlike alliances. These social structures encourage cooperation and allow elders to transmit cultural and environmental knowledge through actions that center on subsistence.

Activities that take time away from subsistence and divide family and other kin groups will change the Inupiat lifestyle. Thus, the job that takes a father or mother from the village may provide cash for subsistence equipment, but it may also produce family estrangement or limit time for subsistence. Young people who leave the village for construction or clerical jobs associated with NPRA development may break their functional relations with the village. Isolation in camps or compounds associated with development may create social and individual problems that alienate young people from both their coworkers and their families. Such has been occurring in the Inupiat culture for the past 70 years; further development in NPRA can only exacerbate the situation.

If kinship is a pillar of Inupiat social structure, then social impacts must be judged against a standard that explicitly recognizes kinship factors. Open-range concepts, consolidation of development sites, and other mitigations dealing with the physical environment could be ineffective in preserving the traditional Inupiat lifestyle. Designing hiring practices that would seek to preserve family integrity, to recruit workers from the same village to work in the same development site, to enhance esteem of family leaders, and so on, are as important to the Inupiat cultural future as preserving caribou and controlling erosion. Without planning and action concepts sensitive to social factors, costly solutions to physical and biotic problems may fail.

Any large-scale development projects in NPRA could worsen race relations. Problems would be most serious for the Natives in the work camps that are isolated from the traditional communities and where they must work rather intensely and for relatively long periods with non-Natives. In these areas they would be a decided minority. For non-Natives, racial prejudice would be most serious in the traditional villages where they are the minority. One of the reasons race relations would worsen is that the incoming population will be predominantly male. A shortage of women could intensify feelings of prejudice among men.

Job competition could also increase racial tensions. Natives may feel that since the development has taken place on their lands, they should be given preferential treatment for jobs. Non-Natives would feel that such racially based hiring is unfair. If work camps are not the rule, competition for village housing could also heighten bad feelings since homeowners might be pressured to rent to a particular group and exclude others.

Development would also intensify the already serious problem of alcohol and drug abuse throughout the region. An increase in the number of jobs and an increase in the amount of money available to the population would make drugs and alcohol more affordable. An increase in personal frustration — among the Inupiat resulting from changes in subsistence and culture, and among transients resulting from feeling of isolation and separation — would tend to push some individuals toward more use of these agents. Increased drug and alcohol abuse would have several secondary effects. Their use has raised the incidence of accidents and suicides and deteriorated the general health of the population. Also, most crime in the region results from drug and alcohol abuse. Money spent on drugs and alcohol is not

Young people who leave home to take advantage of construction jobs may lose touch with traditional family and village life. (Grossmann-Granger Productions)

available to fund more wholesome activities, such as subsistence pursuits and home improvements.

n. Scientific Research

A considerable amount of scientific research has been conducted throughout northern Alaska, particularly in the past 30 years. The area is of particular interest to scientists, because of its wilderness qualities and the extremes of its physical and biological environment. Successful human operations in the Arctic often require costly modifications of traditional technologies. Ameliorating the conditions and understanding the natural processes in the Arctic are the primary purposes of scientific research in the region. In the past, most research in Arctic Alaska has been conducted at the Naval Arctic Research Laboratory near Barrow. This facility combines sophisticated laboratory techniques with arctic field conditions. In recent years, scientific interest has been moving away from Barrow, due in part to growing industrial and conservation interest in other parts of the region. Much of the current research conducted in the north is directly related to developmental interests. Science has benefited from the focus of public and industrial attention and money that development has brought to the area. Further development in NPRA would continue to stimulate national and scientific interest in the region. The cost of scientific research in the North Slope region has risen significantly in recent years, partly because of general inflationary trends both inside and outside the region. Additional development in the NPRA region would probably aggravate the already high costs of scientific activity there.

In the past, local residents have been able to participate in research only as laborers and guides. In recent years, however, Native people have expressed a desire to participate more meaningfully in arctic research. The Inupiat have suddenly become responsible for the administration of significant landholdings, are building new housing and schools, and are considering developing natural resources of the region. At the same time, they also want to maintain their traditional resources and lifestyle. As their region grows and as their realization of the necessity to conserve their natural resources increases, their need for firm scientific knowledge increases. Future development in the NPRA area will increase both the opportunities for and the desirability of Native participation in scientific research.

o. Population Centers

Impacts to various villages, enclaves, and camps largely depend on location of development sites.

Growth of settlements and disturbance or depletion of subsistence resources are expected. Also, great public exposure of the North Slope as a frontier for natural resources development will result.

Barrow. Barrow would almost certainly experience a greater degree of impact from development in the NPRA region than other villages. Barrow is the largest village in the North Slope Borough and serves as the governmental, trade, economic, and cultural center of the region. Tax monies flowing into the borough due to the expanded tax base and investment monies coming to ASRC would flow first to Barrow, and the greatest growth in government and Native corporations would also occur here.

Growth, stimulated by development of NPRA, would have a profound impact on Barrow's infrastructure and housing. Building sites in the area are already severely limited by land-ownership patterns and generally poor soils to the south and east of the village. Further growth would intensify the pressure on Federal agencies to relinquish lands to the village for building sites — particularly the National Weather Service, which occupies a 13-acre (5-hectare) tract of land in the center of the village, and the Naval Arctic Research Laboratory, which occupies potentially useable land to the north of Browerville, a suburb of Barrow. The housing shortage has been somewhat relieved recently by construction of several multifamily dwellings, and this trend may continue. Schools, public safety, transportation, and hospital facilities in Barrow are also already crowded. Further development would add to current demands for adequate community facilities.

Although Barrow is the most cosmopolitan village in the North Slope Borough, it would be a mistake to conclude that subsistence pursuits are no longer important here. Nearly all Native residents in Barrow participate in subsistence activities and, to varying degrees, depend on subsistence for their food. Increases in population would intensify pressures on local subsistence resources, making maintenance of the traditional culture more difficult.

Small villages. The impact of NPRA development on the area's small villages would be directly related to the proximity of the development relative to the villages. Villages along transportation corridors, roadways, or pipelines could experience moderate to severe impact. On the other hand, villages far from the development site would experience minimal impact, considerably less than that expected in Barrow. Increased borough tax revenues would make more funds available for improvements in the smaller villages. Also, the number of borough government jobs would to some extent benefit village residents. Some villages, particularly Point Hope, Wainwright, Anaktuvuk Pass, and Kaktovik, could experience a significant increase in tourism. The economic importance of cottage industries and other small businesses would rise in the villages, though at a slower rate than in Barrow.

Current growth pressures in Barrow would be increased by NPRA development. (Charles Sloan, U.S. Geological Survey)

The main impact in small villages would be on the subsistence resources and surrounding environs. Small villages west of Barrow, including Wainwright, Point Lay, and Point Hope, depend heavily on marine resources, and their well-being is tied to any conditions that would influence marine mammal and fish populations. These villages also rely on the Western Arctic Caribou Herd, and any development that affected these caribou would in turn affect village inhabitants. Atkasook and Nuiqsut are more oriented to inland subsistence resources than the coastal villages. Anaktuvuk Pass is the most dependent of all North Slope villages on inland resources. Therefore, development in the foothills and mountains provinces of NPRA would most affect these villages. Kaktovik is perhaps the most isolated of the borough villages, and it would probably experience the least impact from NPRA development. However, Kaktovik residents are highly dependent on marine mammal resources, many of which migrate past the northern boundary of NPRA.

Federal and industrial enclaves. Several enclaves housing military, industrial, and scientific operations and personnel are scattered throughout the region. Except for the Naval Arctic Research Laboratory, most of these centers are occupied by individuals who are working in the area for relatively brief periods of time; they are separated from their families and maintain residences outside the region. There are no plans at present to convert any of these enclaves into permanent villages.

The impact of NPRA development on these enclaves would be minimal. It might enhance the importance of military operations in northern Alaska by focusing public attention on increasing national security problems. Development in NPRA will increase the number of job opportunities available in the region and will tend to create competition for those jobs. Some residents are employed at the enclaves. Competition will drive up wages and operating expenses of enclave operations and intensify enclave security precautions.

Outlying camps. Many traditionally used outlying camps are located throughout the region. For the most part, they are infrequently or seasonally occupied by small groups of people from the villages during subsistence harvesting. Many of the camps are of extreme cultural and historic importance to these people. A few camps, particularly in the delta of the Colville River, are more or less permanently occupied by single-family groups.

Scientific research parties occupy field camps throughout the region, particularly during summer. Some field camps have been occupied for more than 20 years and have extensive research histories associated with them.

Culturally significant areas, like this cemetery near Point Hope, require protection.

NPRA development would bring an influx of transient workers. (Grossmann-Granger Productions)

Development in the NPRA region could affect at least some of these outlying camps. Development near a camp would change the environmental characteristics that originally prompted the camp's establishment. Identification of important camps and location of development remote from them would be highly desirable.

p. Mitigation of Social Impacts

The concept of environmental mitigation has evolved to a higher degree than the concept of social mitigation. As recently as 1972 and the final environmental impact statement on the trans-Alaska pipeline, treatment of socioeconomic impacts and mitigation was not fully or specifically addressed. Data and methods to gauge impacts to the human environment — socioeconomic and cultural changes — need further development. In the case of the North Slope and indigenous Inupiat culture, the affected human sector is unique in many respects. Use and occupation of the region spans 10,000 or more years. Cultural identity and a conservative tradition have not undergone dilution or assimilation characteristic of minority populations in more urban or industrialized areas. Actions and policies to alleviate adverse human impacts should consider the following: 1) continuation of Native subsistence patterns, 2) protection of culturally significant areas, 3) education on race relations, 4) controlled and moderately paced development, 5) cooperatively developed utilities, and 6) Native participation in planning and decisionmaking.

Social mitigation, as an integral part of planning, entails more than a "band-aid" approach to oversights of the human factor. It entails a basic choice to balance human and materialistic factors. For example, re-routing a pipeline or road away from a caribou calving area would benefit wildlife and subsistence values, increase development costs, but accomplish the project. The choice to include human considerations is a critical one. If a project is allowed to proceed on the grounds that economic factors are paramount, then no amount of social mitigation will alleviate the end result — truncation of the subsistence resource base and disrupted cultural patterns.

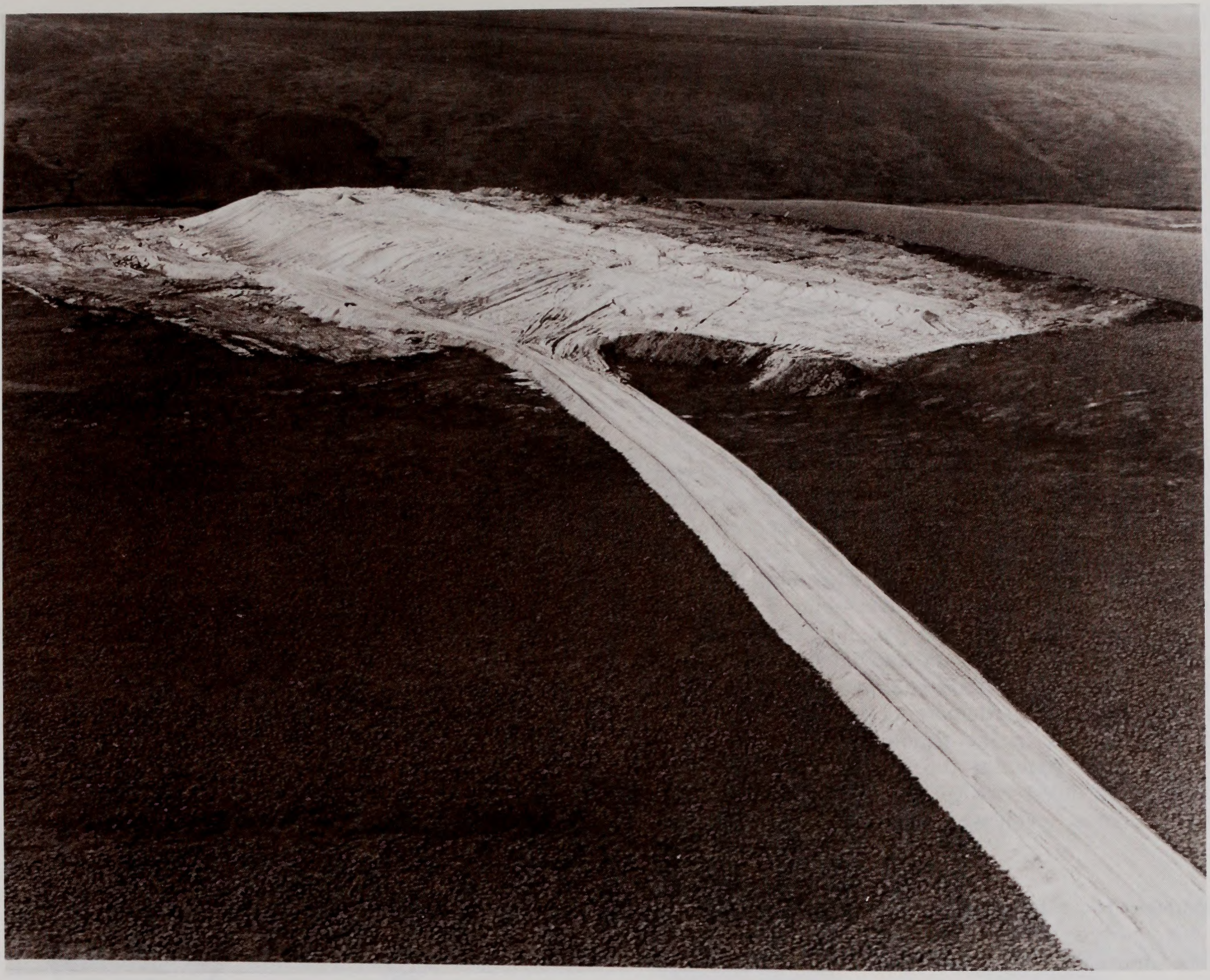
Continuation of Native subsistence patterns. By far the most compelling concern of most of the Native population in northern Alaska is the continued opportunity to harvest traditional subsistence products from the land. The cultural integrity of the Inupiat is very closely linked with the quality of the biological populations on which subsistence hunting and gathering depend. Since many subsistence wildlife species are migratory, industrial activity should be designed to interfere as little as possible with subsistence pursuits. Pipelines and roadways should be constructed and routes planned so as not to create barriers to the flow of migratory species. Furthermore, they should not separate hunters and gatherers from their subsistence resources. Other development facilities should be tightly centralized so as to minimize their interface with traditional activities.

It is widely held that oil and gas development-related activities conducted in the winter in northern Alaska will have minimal impact on subsistence activities, since many of the species either are not present in the area or are in a dormant state. However, detailed site-specific studies should be done before the effectiveness of seasonal separation of development and subsistence activities can be assumed.

Subsistence harvesting of wildlife populations could also be adversely affected if development results in large numbers of sports hunters, tourists, and similar "outsiders" having access to subsistence-resource populations. It is doubtful that wildlife populations could support both subsistence hunters and increases in these other consumptive uses. It may be necessary, therefore, to limit access to wildlife populations to those people who have traditionally used them. The impact of development on an individual's subsistence harvesting practices could be minimized if the industries design flexible work schedules and practices that allow Native workers relatively large blocks of time to pursue subsistence activities.

Protection of culturally significant areas. There are numerous sites throughout NPRA that are of particular importance to the Inupiat, e.g., sites of ancient villages, burial grounds, and seasonally occupied hunting and fishing camps. Areas of high cultural significance should be identified and protected early in the development scheme. It should also be noted that the Inupiat also value the wilderness character of the land. Esthetic values of significant lands must be maintained, as well as their physical integrity. Thus, development activities should be located far enough from culturally significant lands that they do not create serious noise problems or change the landscape. Finally, development activities should be organized so that access to

Local participation in the decisionmaking process is of utmost importance to successful planning. (C. D. Evans, AEIDC)



Construction activities, such as gravel removal and road building, could destroy wilderness and scenic values in NPRA. (J. C. LaBelle, AEIDC)

these culturally significant areas by the Natives is not altered or impeded.

Education on race relations. Problems of race relations in northern Alaska may be intense when development starts but may be relieved with time as members of both cultures become more tolerant and understanding. One way to minimize this problem is to initiate orientation programs.

Incoming industrial workers should receive some information concerning the Native culture prior to their arrival. Too often, newcomers have little knowledge of or regard for the Inupiat culture and its successful adaptation to the arctic environment. Conversely, the Inupiat often have little understanding of what the industrial culture is trying to accomplish on their lands. Thus, the cultural orientation process should flow in both directions.

Controlled and moderately paced development. Development in NPRA will increase the number of jobs and other economic opportunities in the region. In the past, most new business and employment opportunities have been filled by nonresidents, and although the percentage rate of unemployment in the region has decreased with economic activity (due to increases in the total number of people in the region), the number of Native residents actually seeking jobs before, during, and after the project has remained the same. This has created a great deal of bitterness in the resident populaton, and it is important that employers be encouraged in the future to hire locally whenever possible. Extensive occupational skills training programs will be necessary to prepare area residents for the anticipated employment opportunities. The Inupiat people could be further involved as investors in upcoming development projects through participation by the local regional corporation and various village corporations.

Cooperatively developed utilities. The influx of large numbers of people from outside the region to NPRA would place additional stress on existing, overtaxed regional and local infrastructures. Needed improvements should be identified early in the planning effort and absorbed as part of the costs of development. To the fullest extent possible, improvements and their costs should be shared by local interests and the developing industries. As an example, exploration and development companies often develop extensive communication networks which could also serve area residents. Duplicate efforts and facilities could thus be minimized. Other functions, such as public safety and waste disposal, might be handled more efficiently by the borough than by the industries.

Native participation in planning and decision-making. Another major concern of many residents of the North Slope Borough is a feeling that they do not have control over events taking place on their lands. To mitigate this feeling it will be necessary to maximize local participation. Residents should be urged to serve equally with other representatives on policy-making, decisionmaking, and regulatory boards.

Successfully developing a portion of NPRA in a way that will have minimum impact on the area's residents would require a fine balance that appropriately isolates the two populations in the sense of respect for social and cultural privacy, yet fully integrates in a functional relation those Native people who want to participate in the expanding industrial system. This would call for developing the area in a way that would maximize the number of options open to people. Thus, some individuals would be able to maintain a more traditional lifestyle, while others could choose to participate in the industrial society. If development in the region proceeds slowly, this would allow time for the people of the region to accept and digest change and to work changes into their unique, evolving culture. Specific impacts should be carefully anticipated and mitigated before problems become acute.

3. Wilderness, Scenery, and Recreation Values

a. General Impacts

Practically all of NPRA remains today in a primitive wilderness state. Any petroleum development will impact its wilderness, scenery, and recreation values. Introduced land uses, such as petroleum related development, are incompatible with the wilderness character of the basically undeveloped Reserve. Even if most development were limited to relatively small (local) parts of the Reserve, the associated impacts would be dispersed over large areas. This is primarily due to the treeless and relatively flat nature of most of the Reserve, where development cannot be conveniently hidden. Solitude, a primary ingredient of wilderness, is easily disturbed in the Arctic by development activities.

Many impacts to scenic values would be local and will be limited to the viewing distance permitted by topography. Impacts on recreation will depend on public access to development sites, roads, the number and location of airfields open to public use, and the degree to which all recreational opportunities are encouraged. However, recreational demands within NPRA are expected to be low for the foreseeable future.

Petroleum-related development is incompatible with the wilderness character of the Reserve.

Table 6. Wilderness, Scenery, and Recreation Impacts from Petroleum Development and Production

Source	Impacts	Magnitude[1]	Term[2]	Location[3]
Construction and operation (pads, mud pits, pump stations, powerplants, waste disposal facilities, camps, pipelines).	Alter wildnerness values	***	**	**
	Alter or destroy scenic values	***	***	**
	Impede recreational use	***	***	*/**
Roads and trails	Degrade wilderness values	***	**	**
	Alter or destroy scenic values	***	***	**
	Provide access for recreation; cause overuse of area.	***	***	***
Airstrips	Reduce wilderness values	***	***	**
	Provide recreation opportunities	***	***	***
	Alter scenic values	***	***	**
Material borrow sites, consumption of water.	Impair wilderness status	***	*	*/**
	Impede recreational use	***	***	***
	Alter scenic values	**	*	*
Presence and noise of humans associated with camps.	Destroy some wilderness characteristics.	**	**	**
	Impair scenic values	**	**	*
	Reduce hunting opportunities	**	**	*

1 ** = moderate; *** = major.
2 * = short; ** = intermediate; *** = long.
3 * = onsite; ** = local; *** = regional.

b. Activity-Specific Impacts

Following is a discussion of the wilderness, scenery, and recreation impacts associated with potential development and production of the petroleum resources of NPRA. These impacts are summarized in table 6.

i. Construction

All construction activities would largely destroy wilderness values and alter or destroy scenic values. Construction could reduce recreation values through degradation of the high-quality river environments. The activities could further reduce recreation values locally through overuse of the area by nonresident hunters and fishermen and through reduction of the fish and wildlife resources of the area.

The consumption of water or the siltation caused by construction may curtail certain primitive recreational opportunities during the summer season. Water use could lower the water level of rivers and lakes used for boating to a degree that renders them unfloatable. A second impact would be loss of fish and wildlife as a result of a severe water shortage or lack of water at critical periods. However, current practices should avoid impacts of this magnitude.

The construction of production sites, roads, and pipelines would essentially make the whole area or smaller portions no longer suitable for wilderness designation. If the roads were permanent and open for public use, the impact on wilderness would be lasting. The construction and operation of pipelines would have an impact similar to that of roads. Adequately reviewed design, onsite mitigation, and rehabilitation would greatly minimize adverse incursions on a wilderness setting.

The impacts created by material borrow sites and by the consumption of large quantities of water located within NPRA could adversely effect scenery and wilderness. The impact of gravel or sand removal would depend on whether the areas were restored either by nature or man. Visual-resource managment techniques can help alleviate impacts if applied during the planning stages.

The impact of increased human presence and noise associated with camps would adversely affect wilderness values by removing the opportunities for experiencing the solitude and serenity characteristic of wilderness. Spacing of access points or control of visitor use can help to preserve these attributes.

Construction impacts can generally be mitigated by avoiding critical areas of high scenic, wilderness, or recreation values. Crossing rivers at right angles where crossings are necessary and controlling riverflows to avoid low flows during times of peak recreational use are examples of techniques that could be used to accommodate development in such areas.

ii. Operation and Maintenance

Developed oil fields, pipelines, and roads would impact scenery, changing form, line, and color of landforms and water bodies, and vegetation. The same facilities in high-use areas and in areas where manmade changes are now evident would result in loss of present landscape character.

The operation of airstrips could have both adverse and beneficial impacts on wilderness values and recreation. A permanent, heavily used airstrip could alter or destroy wilderness values, but airstrips located at acceptable sites and to which access is controlled could enhance recreational uses of the area.

iii. Rehabilitation and Cleanup

Rehabilitation and cleanup could erase or at least mitigate many of the impacts associated with the construction and operation of petroleum development in NPRA. In some cases and in the long term, rehabilitation of the area could completely restore the wilderness, scenery, and recreation values of the area.

III. Environmental Impacts of Transportation and Distribution of Petroleum Produced in NPRA

As in the foregoing section on development and production impacts in NPRA, this section presents qualitative environmental impacts associated with conventions of petroleum development. Appendix C describes the current and standard practices for construction and operation of petroleum transportation facilities in the arctic environment. Appendix A provides a summary description of the affected environment.

In lieu of proposed projects and selected routes, three general illustrative corridors leading out of NPRA are considered. No map locations are inferred. Two connect to the existing TAPS trunkline; the third extends westward to the Bering Sea coastline.

The basis for qualitative impact analysis of transportation systems and modes is the corridor concept (Berger, 1977). Recent experience with TAPS and similar large-scale projects has indicated that impacts are not confined to the defined path of a pipeline. A corridor includes pipeline, roads, material borrow sites, pump stations, and terminal facilities; it requires a peak work force during construction and an operating work force during its lifetime. In an arctic frontier area, such as the North Slope, everything necessary to the project is brought in; many of these introduced things remain after project completion. Any utility corridor, particularly one to export oil or gas from a remote area to distribution points, carries primary, secondary, and cumulative impacts. Added segments or new corridors also bring about long-range growth and development and potential impacts; for instance, the potential exists to increase capacity of a trunkline by adding a parallel system or adding "loops" and feeder lines. It is also possible to use a corridor to link previously isolated areas to more populous or developed areas. Hence, the resource commitment of land area, gravel, and water necessary for a transportation corridor constitutes only a part of the overall impact to be expected.

A. General Impacts

The construction and operation of any transportation facility in Arctic Alaska must be based on the experience gained in the construction and initial operation of TAPS. Certain measures/policies on TAPS were undertaken to enhance the environment or eliminate, avoid, or mitigate the adverse effects of the construction and operation of the system. Similar mitigative action would also be initiated upon development of any of the alternative transportation systems for oil or gas from NPRA under consideration in this study.

Potential adverse impacts of a project are usually avoided or mitigated, consistent with engineering feasibility and cost. Primary potential regional and local impacts of construction and operation of a system would be initially mitigated by the site/route selection process and by the selection of specific construction techniques, process design criteria, and operational controls.

The construction and operation phases of a petroleum transportation system would, by law, be in accordance with all applicable Federal, State, and local codes and regulations. These are described in Appendix B. Adherence to these requirements would ensure impact mitigation of surface disturbance, noise levels, erosion, water pollution, air emissions, health and safety hazards, wildlife and aquatic resource conflicts, and social and cultural elements. Mitigation, however, does not imply total impact elimination. All construction and operational developments will have some unavoidable impacts.

Optimum mitigation requires strict adherence to and tight controls on compliance with construction and design specifications/stipulations and operational procedures. TAPS experience demonstrates that construction delays, lack of timely response to environmental problems, economic difficulties, and faulty management or work enforcement are common occurrences in large projects. Thus, the required tight controls over compliance with mitigative procedures may become compromised. If this occurs, then the overall level of impact would be increased and would therefore be incremental to the apparently unavoidable impacts.

The construction and operation of a petroleum transportation system in the Arctic region could be expected to result in certain unavoidable local and regional environmental impacts upon physical, biotic, and human resources. These unavoidable impacts which occur during the construction phase would be, for the most part, short term and transitory, while those associated with the operational life of the system would be long term in nature.

The majority of the construction-related unavoidable impacts is associated with surface disturbance. Other short-term but unavoidable impacts would be associated with authorized activities, which include instream construction, burning of wastes, discharge of sewage effluent, noise emissions from vehicles and blasting operations, and exhaust emission, all of which are in compliance with permits and standards. Other construction-related, unavoidable impacts would include erosion, siltation, accidental oil/fuel spills, man/animal interactions, socioeconomic conflicts (Native — non-Native), and esthetic impingement.

Long-term, unavoidable impacts are associated with the operational life of a system. The major unavoidable impacts could be:

- Interference with subsistence patterns.
- Interference with Native cultural and lifestyle values.
- The possibility of road access to regions previously inaccessible by road.
- Secondary development of the new system, i.e., mineral extraction, resource developments, fish and game harvests, and the like.
- Damage to land and water resulting from a major oil system failure.
- Long-term environmental degradation as a result of construction and operation of a transportation system.
- Wildlife habitat alteration.
- Commitment of gravel and water resources.

Lesser long-term impacts would include:

- Esthetic impingement.
- Restricted use of the system's land components and committed resources for the life of the project.

The baselines for the impact and mitigation discussion herein are the TAPS stipulations and experience; only residual impacts of the TAPS and potential new impacts relevant to the NPRA arctic environment are considered.

1. Pipelines

The need for local resources, such as gravel, in the construction of an elevated pipeline depends strongly on construction technique. Workpads require about 8,560 cubic yards of gravel per mile (5,320 cubic meters per kilometer). This implies the development of extra-corridor material sites and many material-site–corridor-access roads.

Revegetation needs stem from the restoration and revegetation of cut/fill operations along the corridor, played-out material sites, and access roads. Restoration/revegetation problems are attendant to transportation corridor development in the Arctic. Revegetation strategies involving introduced species have not been successful in the arctic areas of the TAPS.

The mobilization, construction, and demobilization of construction could require 5 years and a significant labor force. Depending upon the corridor selected, a major staging area could be required in the Bering/Chukchi Sea area or in Fairbanks, or both.

If the TAPS construction represents a valid parallel, the construction of either a gas or an oil pipeline may be accompanied by fuel spills on the order of 565 gallons per mile (1,326 liters per kilometer). The causes of spills, on the TAPS route, were vehicle accidents, fuel handling operations, construction activity, fuel distribution system failures, and construction equipment failures.

The 6-month startup of the TAPS resulted in spillage of 30,310 gallons (114,560 liters) of fuels. In addition, a spill of about 25,000 gallons (94,500 liters) of 40-percent methanol/water solution occurred during the hydrostatic testing of the fuel gas line. Presumably, both kinds of spills are possible during startup of either an oil or gas pipeline. In addition, four crude oil spills occurred during the startup of TAPS, totalling 54,645 gallons (206,560 liters); 42,000 gallons (159,000 liters) of this resulted from the failure of a buried valve attributed to third party intrusion, and 12,600 gallons (47,600 liters) spilled as a result of the explosion of pump station No. 8.

During the first full year of operation, August 1, 1977, to July 31, 1978, reported crude oil spillage amounted to 1,125 gallons (4,275 liters). In addition, sabotage of an elevated pipeline section resulted in a spill of 670,000 gallons (2,533,000 liters). While an elevated pipeline provides an "easier" target, it could be misleading to conclude that an elevated pipeline is more vulnerable to sabotage than a buried one.

In addition, based on data for August through November 1977, fuel spillage (vehicle, fuel handling, and the like) amounted to about 62 gallons per mile (145 liters per kilometer) per year. This amount may not be a good indication of typical maintenance activity for a pipeline because it includes the effects of continuing construction activity on the TAPS route. The following table summarizes the spillage for the TAPS on a per-mile basis. By comparison, statistical data for crude oil pipelines in the conterminous United States indicate an average spillage of about 39 gallons per mile (91 liters per kilometer) per year.

Spills, in Gallons Per Mile, for the Trans-Alaska Pipeline

	Construction 11/74-12/76	Startup 1/77-7/77	Operations 9/77-8/78
Fuels	565	37	62
Alcohol	—	31	—
Crude oil	—	68	839

The maximum design static spill for the TAPS was 2.1 million gallons, equivalent to 50,000 barrels of crude oil. These design criteria, terrain slope, and protection of sensitive environments dictated valve placements in light of P.L. 93-153, Title 1(h)(2):

> The Secretary * * * shall issue regulations or impose stipulations * * * which shall include * * * (D) requirements to protect the interests of individuals * * * who rely on the fish, wildlife, and biotic resources of the area for subsistence purposes.

None of the spills along TAPS appears to have been catastrophic. A contributing factor is that most spills have been terrestrial. Planned containment and cleanup activities were generally effective. In the Arctic coastal plain or on the shores of the Bering and Chukchi Seas, the situation could be significantly different. Mitigative actions could include the application of formal systems safety design techniques and a reappraisal of spill criteria.

In general, impacts caused by a rupture of buried pipeline parallel those of elevated pipelines.

The construction of a buried system in the Arctic, as the TAPS has demonstrated, requires extensive blasting in permafrost soils. Exhuming the system for reuse of the pipe at the end of the life cycle appears to be impractical.

2. Terminals

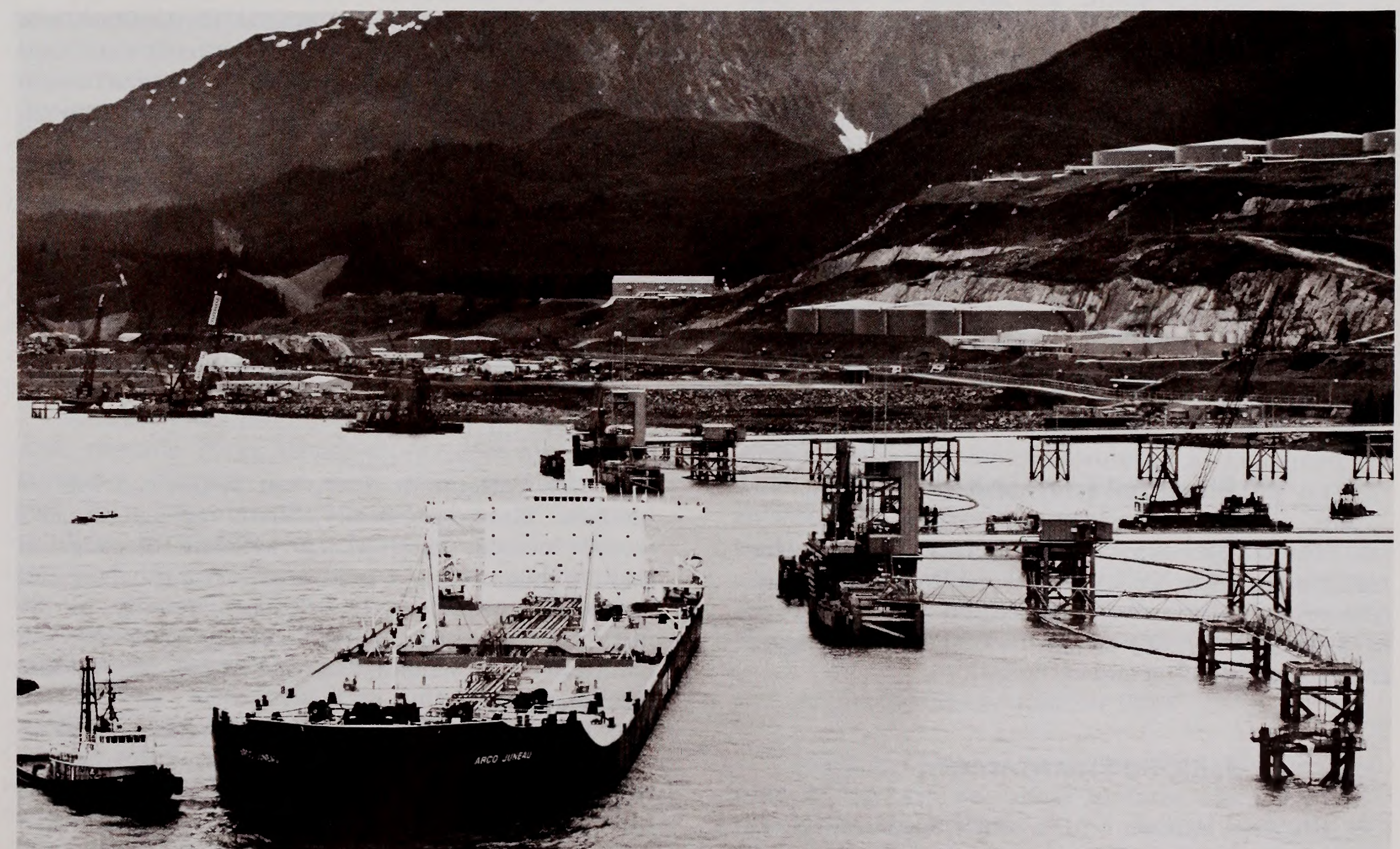
Transportation of oil or gas to the west could require the construction of a liquefaction/storage facility for gas and a storage facility for crude oil. If a pipeline mode were employed from NPRA, gas liquefaction and liquefied natural gas (LNG) storage facilities would be required at the terminal.

Local material needs for terminal and waterfront construction depend on many factors, including specific location, terminal throughput and product mix, and waterfront dredging as opposed to offshore mooring. The impacts of obtaining these materials would be highly localized.

Fuel spillages would undoubtedly occur during the construction of such a terminal. Data for spills during the construction of the TAPS Valdez terminal are scanty. However, there were no indications of significant environmental damage.

Oil spillage during oil terminal operations includes chronic and accidental sources. The major chronic source is a ballast water treatment plant. The crude oil burden to the environment of such a plant depends on discharge standards and the volume of ballast water processed. The significance of such a

Operation of industrial and transport facilities like these in Valdez would significantly increase the potential for oil spills. (Alyeska Pipeline Service Company)



burden is unknown for arctic waters. Mitigation includes the use of segregated ballast tankers or the treatment of ballast waters at existing nonarctic ballast water treatment plants. In addition to ballast oil spillage, accidental oil spills routinely occur at marine facilities. U.S. Coast Guard data indicate that 286 reported offshore/onshore bulk cargo transfer incidents at domestic marine facilities resulted in the spillage of 274,677 gallons or about 960 gallons per reported incident in 1976. Unfortunately, the spill frequency cannot be determined since the number of transfer operations is not given in the data source. However, data compiled for the period from 1970 through 1972 by the U.S. Coast Guard indicate that there was an average of one spill in about 180 transfer operations. The average quantity spilled was 150 barrels of oil. The operations at Valdez terminal are perhaps more indicative of a new oil terminal.

During the first 6 months of operation, the Valdez terminal handled 234 tankers. There was one reported spill incident every 12 transfers with about 37 gallons (140 liters) spilled per incident. The apparently higher incidence of spills at Valdez compared with the average for the United States could be attributed to the more diligent reporting of incidents at Valdez.

Analyses of Valdez operations indicate that many effective mitigative actions are possible with respect to equipment and procedures. However, terminal operations in general seem to lead to numerous oil sheens and slicks of unknown origin. At the Valdez terminal, the most significant spill incident category is the "unknown source" spill. The term "chasing sheens" indicates the degree of frustration shown by Alyeska Pipeline Service Company personnel in attempting to clean up the small spills of unknown origin. Control and cleanup of unknown-source spills have become very costly for the terminal and to the State of Alaska. The types of materials from these unknown-source spills vary from crude and lubricating oils to diesel fuel and asphalt. In most cases, the State of Alaska is utilizing the State Coastal Protection Fund to pay for the cleanup.

The design of oil tank farms includes diking systems to contain the contents of any or all tanks in the event of failure. In light of the sensitive nature of the ecosystems of the Bering/Chukchi Seas, the design of such containment systems should be reviewed from the standpoint of a common failure mode, i.e., methods of failure which could strike tank and dike simultaneously. Consideration should also be given to creating secondary containment systems, for example, by locating facility roads in an appropriate manner.

An oil/gas terminal would result in other effluents and emissions characteristic of such a facility. The impacts would be localized and mitigable by the application of Best Available Control Technology (BACT) rules [Title 40, Code of Federal Regulations, Part 52.01 (f)].

However, if gas is to be liquefied, there would be concern for the impacts of water withdrawals and thermal discharges. The liquefaction of natural gas requires the extraction of energy on the order of 400 Btu per thousand cubic feet (MCF) of gas. The making of 4,570,000 cubic feet of LNG — the capacity of one tanker — would require heat extraction and disposal of about 50 billion Btu's of energy. Water is commonly used for heat disposal. At a 20°F (6°C) increment, about 895 acre-feet (1,100,000 cubic meters) of cooling water would be required per LNG tanker load. The extraction of such water volumes from the Bering/Chukchi Seas and discharge of the heated volume in a flow-through system would result in impacts on aquatic biota of unknown but of perhaps significant magnitude. A closed-loop cooling system with secondary use of the hot water (e.g., to supplement local home heating needs) could reduce the biologic impacts.

The operation of a terminal in Arctic Alaska offers the opportunity for (or threat of) significant shifts in Native lifestyle. Employment opportunities might range from 100 to 1,000 jobs at the terminal. An industrially based community the size of, and with the needs of, Nome, Kotzebue, or Barrow could result from terminal development.

B. Regional Impacts

1. Physical Environment

The construction and operation of a transportation system from NPRA would result in some depletion of the existing regional natural resources, such as sand, gravel, and water, along with increased resource exploration and exploitation.

2. Biotic Environment

Regional impacts on the biotic environment are associated with interference with traditional animal migration patterns or disruption of fish and wildlife habitats. More specifically, these regional impacts would include: interference with or blockage of caribou migration and anadromous fish runs, impacts on peregrine falcons, loss of productivity in the marine environment, general animal disturbance or harassment, or increased harvest of fish and wildlife resources.

Placement of a pipeline and haul road transportation corridor within any of the land surrounding NPRA could interfere with the seasonal movements of the Western Arctic Caribou Herd; to a lesser extent, corridors exiting NPRA to the east could interfere with the movement of the Central Arctic Caribou Herd. Furthermore, in the past, the Western Herd apparently migrated farther east than at present, and such movements could recur in association with a population increase. Caribou from the Western or Central Herd are seasonally present in each of the general corridor areas. It is extremely important to the viability of each herd that the caribou be allowed to migrate seasonally to make efficient use of winter or summer ranges and reach their preferred calving grounds at the appropriate time each year. Interference with or blockage of traditional migration routes of caribou by pipelines or haul roads is one of the more serious impacts.

TAPS lies within the range of the Central Herd. Recent studies (Cameron and Whitten, 1976, 1977, 1978) indicate that, in general, caribou avoid the Prudhoe Bay area and the pipeline-haul road corridor, especially cow caribou with calves. The general reluctance of caribou, except for a few individuals, to cross the pipeline, even at specially constructed crossings, has fragmented the herd into east and west segments that move independently of each other. Local traffic and human activity within a corridor apparently represent equally serious or overriding impediments to movement, since avoidance of the corridor occurs irrespective of the pipe mode which would otherwise be encountered.

The north-south orientation of TAPS still allows each segment of the Central Herd access to both summer range on the coastal plain and winter range near the Brooks Range. However, any pipeline extending eastward to TAPS would interfere with similar movements of both the Central Herd and the Western Herd. If caribou from the Western Herd react to a pipeline and haul road corridor as the caribou from the Central Herd have to TAPS, loss of access to major portions of summer or winter range and fragmentation of the Western Herd are very likely consequences. This would have a severe impact on the northern Alaska regional ecosystem and adverse ramifications for subsistence harvest of caribou. Loss of access to parts of the traditional caribou range would lead not only to population reductions, due to the fact that small fragmented caribou subpopulations do not collectively achieve the same reproductive success as do large populations moving freely over large expanses of range, but also to failure of caribou to enter the customary hunting areas.

Anadromous fish, such as salmon, use most major regional rivers as migratory pathways. Many freshwater fish also use these same waterways to move from overwintering areas to summer habitats each year. If development of any corridor blocked or interfered with the passage of adult anadromous fish to upstream spawning areas, passage of young anadromous fish from upstream rearing areas to the ocean, or movement of freshwater fish to or from overwintering areas, fisheries impacts would be inevitable. Blockage of fish passage in the lower Colville River could result in the elimination of anadromous fish populations within most of the central North Slope region.

Some endangered arctic peregrine falcons nest in each general corridor area, but more nest along the Colville River than elsewhere. Impacts on peregrine falcons could include disturbance of breeding activities or disruption of critical habitat, which includes the habitats and populations of its prey species. Any impacts on the peregrine falcon population in northern Alaska would be of national significance because Alaska is one of the last breeding sites for this species.

Any major impact on the productivity of the marine environment of the Bering Strait or Chukchi Sea due to an oil tanker accident would be of major significance. These areas are important to the life cycles of many marine organisms, as well as seals, walrus, and whales (including the endangered bowhead whale).

General wildlife disturbances from any corridor development and possible wildlife harassment by workers and vehicles would be common impacts.

The noise, human activity, vehicle movement and low-flying aircraft associated with the construction and operation of any pipeline and haul road system would disturb some species of wildlife, such as large mammals and nesting waterbirds. Wildlife would tend to avoid areas of disturbance or harassment. Unless the wildlife can quickly adapt to disturbance, parts of the animals' normal range would remain unavailable due to avoidance, and declines in total regional populations could result. Wildlife cannot adapt to actual harassment, such as chasing with vehicles or aircraft; the end result of such active harassment is a lowering of an animal's chance of survival.

Increased sport and subsistence harvest of fish and wildlife resources is also possible. Opening of haul roads to general use would increase access to game species of northern Alaska for both subsistence and sport hunters. Although regulations may prevent hunting during construction, a total ban on hunting and fishing within the corridor would likely be difficult to enforce and cause hardship to subsistence users.

3. Human Environment

Impacts on cultural resources will vary in magnitude and duration, depending on the activity and accompanying mitigation. Archeological and historical sites, representing aboriginal use and various more recent eras, such as exploration and commercial whaling, may be subject to irretrievable loss due to construction activities. Traditional land use areas, evidence of Inupiat use and occupancy, as well as sites having spiritual importance but with no physical remains, require protection as relics of the past and, in many cases, as present-day subsistence sites.

a. Archeological and Historic Sites

Impacts to archeological sites in any corridors from NPRA will be similar to those identified previously within NPRA. Site location and density would depend on topography or geomorphology of the specific corridor discussed. For example, deposits of eolian sands would present the same sorts of problems and limitations for archeological site location and stability whether in or out of NPRA. Similarly, in mountainous terrain, resources, as well as human populations, would be channeled in such a way that predicted site locations would vary little from one corridor to the next. With this in mind, archeological sites can be broadly identified for each corridor by giving attention to the characteristic geomorphology, vegetation, resources and history of each, as well as to the planned system of export, and by drawing comparisons to similar characteristic features for sites within physiographic provinces of NPRA.

b. Subsistence

Any effects on the major resource animals will have to be compensated for either by specifically affected families or by a whole village. All subsistence hunters rely upon numerous resources. If one resource fails, others will be more heavily harvested. Some species may be able to temporarily withstand heavier harvests, but none can do so on a long-term basis.

There may not be any comprehensive method by which to assess local versus regional impacts on subsistence. In traditional Native culture, there are trading and sharing networks that involve more than one village. A village far from the impacted area may increase its harvests to share with the affected villages. There are also trade and sharing networks between village subsistence harvesters and wage-earning relatives in urban areas. The only constant in the situation is that each person must have a certain amount of food resources to survive. How that level is achieved and maintained will probably always be in a state of flux.

The mere presence of seasonal or permanent installations and personnel can result in slight population shifts or even the creation of a new village. Whether it be a pumping station maintenance crew or a permanent port facility, the opportunity for greater diversity of lifestyle will result in many subtle changes in Native community makeup. It is impossible at this time to predict how the regional Native culture will be altered in response to future changes. It may be said that some disruptive behavior will occur and that the subsistence lifestyle will be subjected to powerful influences of change. The magnitude or strength of these influences will be in proportion to the size of the industrial installations, their duration, and their proximity to the villages. Any shift, forced or induced, involving an increased reliance upon a cash-based economy effectively reduces the subsistence hunters' independence.

c. Socioeconomics

The intensity of socioeconomic impacts associated with transportation corridors out of NPRA will differ for each region and within regions. In the

Transportation corridors would significantly affect subsistence hunting and gathering activities.

Corridor development could result in development of extensive transportation facilities throughout northern Alaska. (Bureau of Land Management)

Arctic region, socioeconomic impacts caused by transportation corridors will be minor compared to those from construction and operation of NPRA petroleum fields. Outside of NPRA, transportation corridors will be the major source of NPRA development impact. The amount and kind of impact will vary with proximity of settlements to the corridor.

With these variables in mind, it is possible to anticipate impacts in several socioeconomic categories. Local subsistence practices may be affected by easier access to formerly remote areas and by the increased number of nonresident recreationists and hunters this attracts. More human intrusion and the corridors themselves will interfere with the basic productivity and migration patterns of many subsistence-resource species, particularly mammals and birds. Increases in human population will stimulate demand for housing (already in critically short supply in most villages) and health care, utilities, public safety, and educational facilities. Villages in or close to the corridor could suddenly have a land route to other regions of the State. The number of available jobs would increase dramatically in some areas, as would investment opportunities for Native regional and village corporations. Local government will benefit by the increase in taxable properties, incomes, and sales. Natives should be included in all planning phases of the operations so as to lessen impact.

The overall effect would be a further change in the Native lifestyle. Within a short time, the relative isolation from the Western society and economy would lessen, and this could exacerbate several extant social problems — race relations, alcohol and drug abuse, and crime.

Any corridor originating in NPRA would cross portions of the Arctic outside NPRA, extending the impacts from NPRA to broader areas of the region. They could pass near any of the four Arctic villages outside NPRA. Local pressures in these villages, both for and against the corridor, would be great. While inclusion would bring prosperity, it would also make maintenance of the traditional culture much more difficult.

Subsistence hunting and gathering would be significantly affected by any corridor. The same factors which make any route desirable for a corridor (through mountain passes and along rivers) also make it valuable to subsistence. Routes east out of NPRA across the Colville River would affect an extremely important area for fish and caribou migrations; in addition, this drainage contains the only significant population of moose north of the northern limit of trees. Because all of the important, commonly harvested subsistence species in NPRA depend on other regions for some of their life-cycle requirements, extending oil-related development beyond the

Future development could alter the pristine character of the arctic landscape. Shown above is the area south of Liberator Lake. (C. D. Evans, AEIDC)

boundaries of NPRA would directly affect larger areas of their habitat and, thus, indirectly impact the subsistence base of the peoples of the Arctic.

A corridor westward from NPRA would affect a larger percentage of the land than would one to the east. This general area was only indirectly impacted by construction of the trans-Alaska pipeline. Construction of corridors to move NPRA oil or gas in this region would introduce impacts similar to those in the Arctic region and would be viewed just as ambivalently by residents. Economic opportunities for area residents and opportunities for further developments by local governments would be enhanced by construction of any corridor, but subsistence activities would be reduced and preservation of traditional cultures would be threatened.

d. Wilderness, Scenery, and Recreation

The Alaskan Arctic, with a few exceptions, has a primitive character and is essentially wilderness. The arctic landscape has undergone little change caused by man. Virtually all arctic rivers are still clear and free flowing.

The development of oil fields and pipelines would adversely impact the wilderness quality of the area and could impact potential Wild Rivers, scenic areas, and recreational use and opportunities. Man-made structures can affect scenery or landscapes by changing line, form, color, or texture. Structures placed near a river could alter or destroy the attributes of the river area. Recreational opportunities could be lost if animal numbers or migration or distribution patterns were affected; there would be fewer opportunities to hunt, photograph, or view animals, particularly caribou.

This would be particularly true of a corridor westward from NPRA. Although the general area is more populated and shows more evidence of human activities, it is basically primitive and, in essence, wilderness. Recreational use of this general area is relatively high by Alaskan standards, and opportunities are many and varied. Sport hunting, fishing, backpacking, mountain climbing, canoeing, kayaking, powerboating, wildlife and landscape photography, and wildlife viewing are some of the recreational activities now enjoyed by local residents, other Alaskans, and out-of-State visitors.

C. Transportation Routes

1. From Alaska to the Conterminous United States

The transportation of oil and gas from an NPRA source out of Alaska could result in new or additional impacts in two areas of Alaska: those associated with the possible looping of TAPS to accommodate NPRA oil, and those associated with marine routes in the Bering Sea.

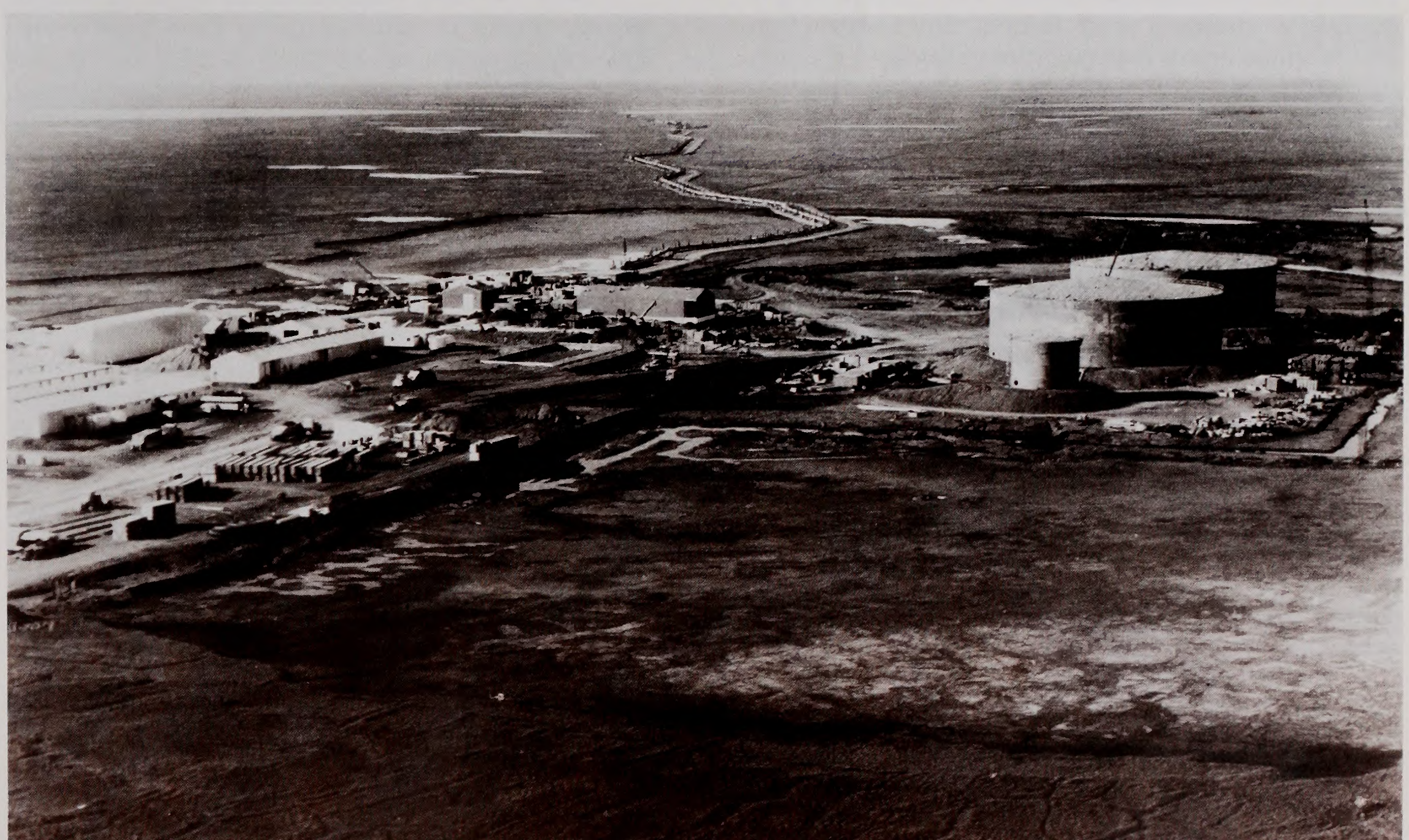
a. Looping of TAPS

Given sufficient production from NPRA, looping of TAPS to increase its capacity might be desirable under Interstate Commerce Commission regulations. As a common carrier, TAPS would be required to accept oil and gas produced from NPRA.

The maximum design capacity of TAPS is 2.0 million barrels per day (MMBD) with 12 pump stations in operation, or 1.6 MMBD with 8 pump stations in operation. However, since the pipeline startup with eight pump stations, the maximum throughput has been limited to 1.2 MMBD. This reduced throughput is the result of the crude oil characteristics, which have increased line pressure losses above the original design values. In an attempt to bring the pipeline up to design capacity without constructing additional pump stations, chemicals were added to the crude oil between pump stations 1 and 3 on April 1, 2, and 3, 1979, to reduce pipe friction loss. However, the addition of the chemical increased the throughput by only about 0.1 MMBD. Throughput will be increased to about 1.5 MMBD with the construction of the four additional pump stations and the use of chemical additives. Currently, Prudhoe Bay producers plan to utilize only 1.6 MMBD of the pipeline capacity. This would, in theory, leave available 0.4 MMBD capacity if four additional pump stations were completed.

If, however, the design capacity of 2.0 MMBD cannot be attained with the operation of 12 pump stations and the chemical additive friction reducer, it may be necessary to loop the pipeline to handle NPRA oil production. Looping consists of constructing a pipeline parallel to the existing pipeline between pump stations. The increased capacity of the two lines reduces the line friction losses, and the existing pump station can handle a greater throughput in the looped area. The looplines are added where the greatest line pressure drop occurs. For example, on TAPS, between pump stations 1 and 3 (station 2

If looping of the trans-Alaska pipeline is required to accommodate NPRA oil, additional pump stations like this one at Prudhoe Bay may be necessary. (Alyeska Pipeline Service Company)



In 1973 refined oil products were spilled in Cold Bay. Spills in arctic waters could be even more destructive because oil trapped under sea ice might be difficult to remove. (Environmental Protection Agency)

has not been constructed), the pressure drops from 1,100 to 25 pounds per square inch gage (lb/in^2g). That is, oil discharged at station 1 at 1,100 lb/in^2g is received at station 3 at 25 lb/in^2g. The construction of a loopline in this area might be considered if pump station 2 were not constructed to alleviate the pressure loss or if greater throughput were desired. Looping of the entire TAPS system may be required to provide any significant increase over present design capacity.

Impacts of looping would be primarily to the physical environment as a result of the construction of the parallel pipeline and limited to the width required for the pipeline. Existing work areas, pads, and other construction-related features would likely be used.

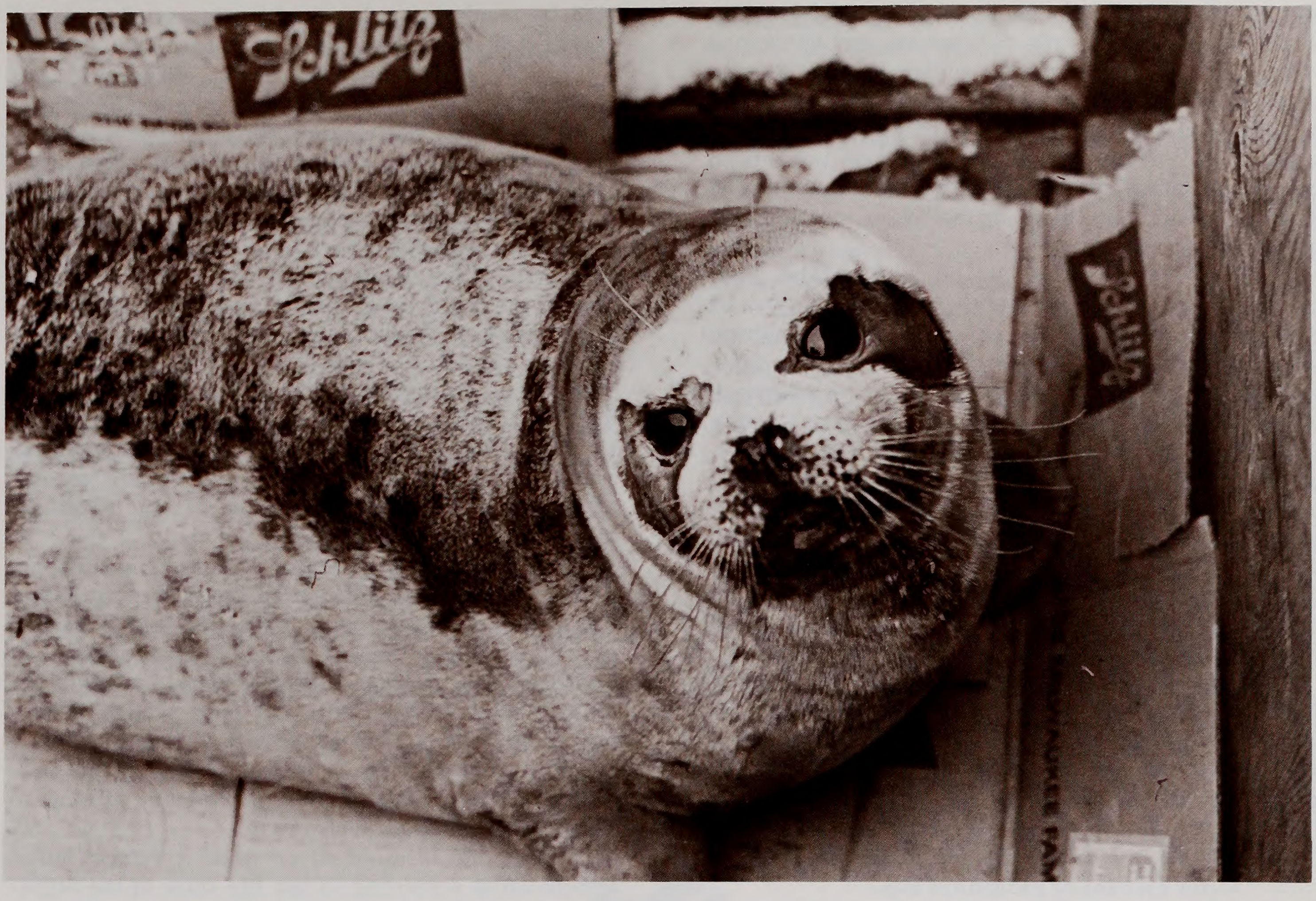
The major impact would be the significant use of gravel necessary for construction. Impacts to the biotic environment would be moderate, compared with the impacts of the construction of TAPS; the greatest effect would be loss of vegetation along the path of the new pipeline. Overall impacts to the human environment, as previously described under development and production impacts, could range from moderate to severe, depending upon the scheduled rate of construction. Experiences gained in the construction and operation of TAPS should help mitigate or avoid many of the major problems associated with construction. Detailed impacts associated with specific aspects of pipeline construction have been discussed previously.

b. Sea Routes

Even the most responsible operation of modern tankers results in minor impacts. Shipboard sewage and other wastes are normally treated before discharge. Solid wastes in many cases are compacted, stored, and disposed in appropriate landfills. Problems created by these activities are expected to be minor. Combustion emissions from tankers at sea would be of minor significance.

However, deliberate discharges of oily ballast and bilge water are a source of chronic oil spills that would be of concern in the Bering Sea. U.S. Coast Guard surveillance and "oil fingerprint" techniques should discourage surreptitious oil discharges. Other mitigation alternatives include the requirement for segregated ballast tankers and strict accountability for ballast water volumes of vessels seeking to service a terminal in the Bering Sea. Of major concern for Bering/Chukchi Sea oil transportation would be the possibility of a casualty and subsequent breakup of a tanker. Oil spilled on arctic waters does not spread into a thin film as it often does on calm, warmer waters. Therefore, the area covered by a tanker spill may be quite small, only a few square miles or kilometers. Hoult (1975) calculated that Prudhoe Bay crude oil when spilled on water under arctic conditions will spread to a thickness of approximately 0.4 inch (1 centimeter).

Prudhoe Bay crude oil and diesel oil have been experimentally injected under sea ice to determine



These photos show oiled animals found near Kodiak in 1967. An oil spill could be devastating to the marine environment. (Environmental Protection Agency)

the mechanism of entrapment of oil in or by ice. The results indicate that both oil types become entrapped most often by ice freezing under the oil. It also appears, however, that oil may be trapped by forming a matrix with the lower layer of the sea ice. The absence of currents may allow even large pockets to become so entrapped. Airborne radar systems, such as SLAR, should have little difficulty in locating and mapping oil trapped under ice.

Physical removal of an oil slick is the most positive means of dealing with a spill. The type of cleanup operation employed in the arctic marine environment will be largely dependent on the presence or absence of ice. The likelihood of oil migrating under sea ice is great. Oil trapped under pack ice may be difficult to remove immediately. Through the process of melting of the top surface and freezing of the bottom surface, oil trapped in multi-year ice may eventually appear at the ice surface. Oil trapped under ice should be removed if not entrapped by newly formed ice. Oil trapped under seasonal sea ice may be less difficult to contend with. By the summer it could be set free to float as a slick on the surface.

Mitigation of oil tanker impacts in the Bering/Chukchi Sea involves minimizing the probability of spills near critical areas, accepting that such spills will still be possible, and preparing effective contingency plans. Specifics include:

- Utilizing the best available above- and below-water systems as navigation aids.
- Establishing a network of ice stations to provide the ship's master updated information while en route.
- Including environmental considerations in tanker routing decisions.
- Conducting further experimental studies into the physical behavior of crude oil spilled into cold sea waters, including spills beneath ice.
- Conducting further research into the fate and biological effects of crude oil.
- Developing equipment and procedures to collect and remove under-ice spills.

In the event of a major spill, the immediate concern would be for marine life in the vicinity of the tanker. At the next level, concern would be for long-term toxic effects. Biodegradation of oil is brought about by bacterial oxidation of oil to carbon dioxide and water. An oil spill in the marine environment persists only when it is protected from bacterial action. The rate of microbial oxidation is affected by the kinds and abundance of microorganisms present, the availability of oxygen, the water temperature, and the extent of oil dispersion in water. In Cook Inlet, whose water is characterized by ambient summer surface water temperatures of 41°F (5°C), high nitrogen and phosphate levels, and turbulence generated by winds and tides, biodegradation of crude oil is essentially complete in 2 to 3 months.

Considerable question exists concerning the potential for biodegradation of oil by microorganisms in arctic waters. The location and season of a spill are the primary factors regarding biodegradation processes in the Arctic. Spills occurring near the shore during the ice-free season, where wave-generated turbulence is greatest, have been demonstrated to be biodegraded, but incompletely. Oil trapped beneath ice, however, is probably subject to insignificant biodegradation. Salinity-stratified water beneath the ice may inhibit the supply of oxygen necessary to oxidize oil. An estimated 320,000 gallons (1,200,000 liters or 1,200 cubic meters) of oxygen-saturated sea water is necessary to oxidize 1 gallon (3.7 liters) of crude oil. Crude oil under sea ice is not readily attacked by microorganisms due to the relatively small surface area of oil pockets.

Oil affects organisms physiologically and behaviorally through direct lethal toxicity; sublethal disruption of physiological processes and behavior; effects of direct coating by oil; incorporation of hydrocarbons, causing tainting and/or accumulation of hydrocarbons in food webs; and changes in biological habitats. Lethal toxicity is a function of the direct interference in cellular and subcellular processes by aromatic hydrocarbons. Phenolic substances and napthenic acids are also toxic.

The concentration of oil which produces lethal effects varies according to the life stage of the organism involved. The type and degree of oil weathering is also important. Exposure for a few hours to 1 to 100 milligrams per liter of total soluble aromatic hydrocarbon (SAD) derivatives results in the death of many adult marine organisms. Larvae of marine organisms are particularly sensitive to oil; concentrations of 0.1 milligram per liter of SAD may be lethal. Sublethal toxicity also affects survival. Responses of individual organisms include disrupted behavior, susceptibility to disease, reduced photosynthesis, reduced fertility, and abnormal development.

The effectiveness of cleanup operations in the Arctic is dependent upon the properties of the oil spill and the environmental conditions at the time of the spill. Treatment of oil spills may also be important in minimizing environmental damage. Various methods have been developed, and some of these are perhaps as damaging as the oil spill if utilized improperly. For example, chemical dispersants and emulsifiers are nearly as toxic (and, in some cases, more toxic) than oil.

Insofar as the human environment is concerned, spills would largely affect the coastal Native populations that depend upon the marine environment for subsistence. In effect, the surface of the ice can be viewed as a seasonal extension of the subsistence range. A recent review (Worl, 1977) of the relationship between ice conditions and the culture of the Tagiugmiut Eskimo is summarized here.

In the fall, new ice forms. The Eskimos return to their village from their summer dispersion to await the formation of slush ice, but little hunting is done at this time. From November to April, there is a solid ice pack. Seals are taken at their breathing holes in the ice or with seal nets under the ice. Polar bears on the ice pack are also hunted at this time. In the year's early months, tomcod, smelt, and crab are fished through the ice. From March through May offshore leads begin to open in the ice. Whaling crews move onto the pack ice to await the migratory bowhead whales. During this time, some beluga whales and migratory waterfowl are also hunted. In May and June, when seals come out at small ponds on the ice, the men hunt seals on the ice. Later, bearded seals and some walrus are hunted from behind walls of ice blocks used for camouflage. In July, the ice disappears and hunting activities shift onshore. The villagers disperse to summer camps along the coast, where fish and beluga whales are taken in nets. Others hunt birds and gather eggs at rookeries.

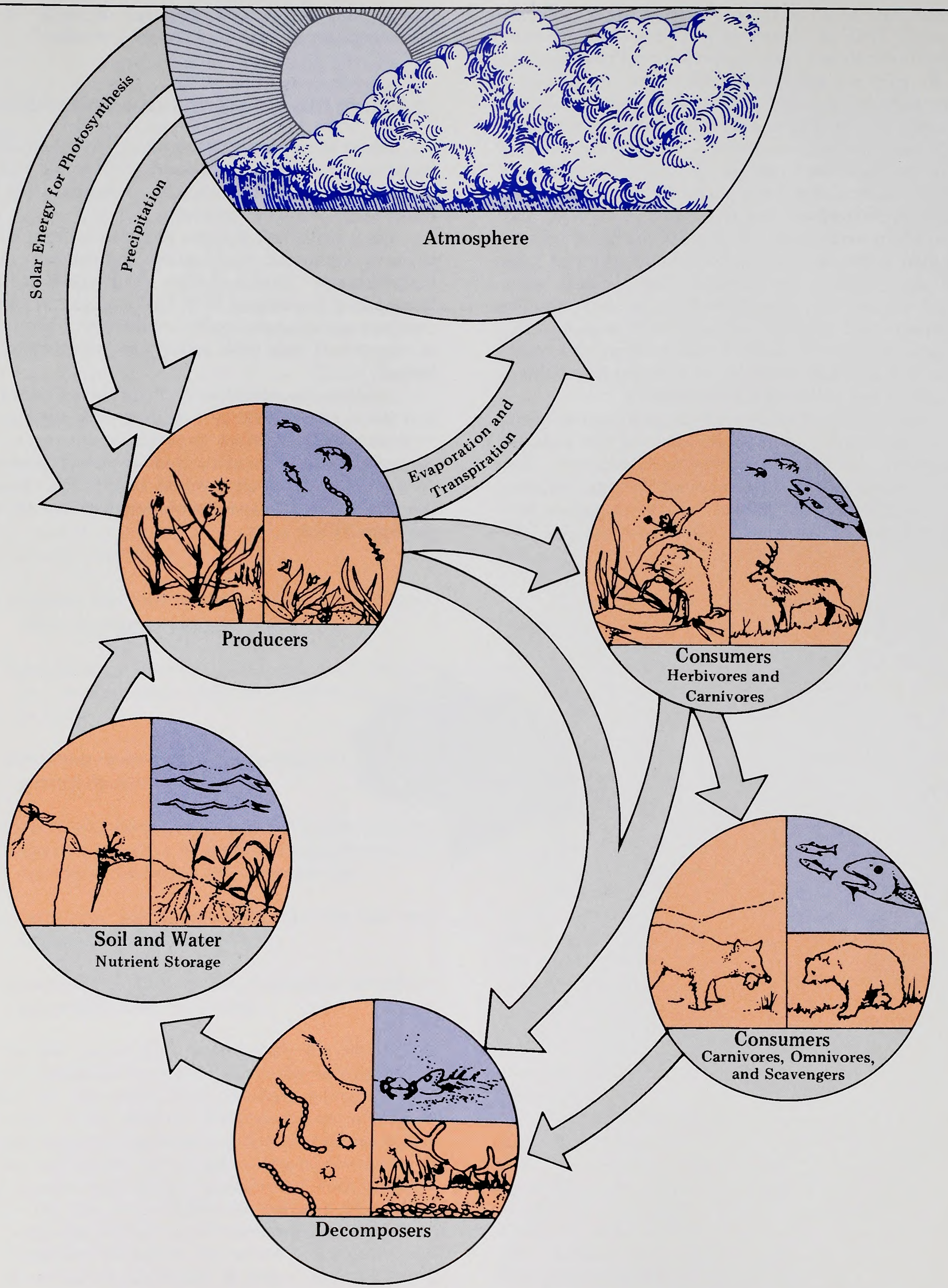
The impact of icebreakers in such regions needs to be carefully examined in light of the possible disruption of cultural subsistence patterns. The specific siting of any terminal must take into account the possible human impact of the location and seasonal use of associated shipping channels. The ramifications of chronic or large oil spills on the subsistence resource should also be considered.

2. Within the Conterminous United States

Since the transportation of oil/gas is basically in response to consumer demand, NPRA oil and gas availability would not increase transportation but rather displace foreign imports.

Anticipated oil and gas production from NPRA is minor compared to the needs and capacity of the conterminous United States distribution system. Incremental impacts of NPRA oil and gas on existing overland and overseas routes would be generated only to the extent that such activity is increased or prolonged.

Impacts associated with the proposed Alcan Gas and the Northern Tier or Sohio pipeline systems and with proposed terminal facilities on the west coast cannot be directly attributed to development in NPRA. Impacts, if any, would be through extended use of the facility to accommodate deliveries of oil or gas from NPRA.



Interrelationship between the living and nonliving environment.

IV. Special Land Values in NPRA

In the previous section, the general impacts resulting from the modes and techniques of development, production, transportation, and distribution of potential petroleum resources from NPRA have been described. This section discusses the relationship between the impacts of petroleum development and special land values identified by the NPRA 105(c) Land Use Study Team.

NPRA has been subdivided into 15 activity areas to facilitate the economic and environmental analyses. The NPRA Land Use Study has identified and described a number of significant resource values other than oil and gas for NPRA. For ready comparison, and to provide for analysis by activity areas, the activity areas have been superimposed upon the maps showing the distribution of resource values identified by the Land Use Study Team (figs. 3 through 14).

Caution, however, must be exercised in any analysis based on activity areas. A recurring theme in the many biological, sociological, and cultural analyses recently conducted on northern Alaska is that the entire region acts as a system. The culture of the Native people is organized around subsistence activities. Subsistence, in turn, is strongly dependent on migratory animals whose movements bring them, and the people dependent upon them, in contact with the entire region. The importance of a given area may change suddenly and unpredictably. For instance, calving in the Western Arctic Caribou Herd normally takes place in the foothills of the Utukok River drainage. However, in certain years, calving may shift to other areas where such activities do not normally occur. These areas, although used only infrequently, are of the utmost importance to the species. If animal behavior shifts, subsistence activities must shift similarly. Thus, the intensity of biological and cultural activity occurring in a specific part of the North Slope shifts dramatically in response to conditions which are poorly understood but regional in scope. Nontraditional developmental activities must recognize the importance of the interrelated separate elements of the "socioecosystem" throughout the Arctic. In general, dividing northern Alaska into discrete smaller parts should be avoided. Such subdivision may lead to recommendations of differential development as, for example, preserve area A intact, but develop area B intensely; this process ignores the complexity and underlying unity of the system.

It must be stressed that the subdivision of NPRA was done only to facilitate analysis. Such subdivisions have no ecological, cultural, or sociological significance.

A. Overall Considerations

As shown in figure 3, most of NPRA except parts of activity areas A and B in the north and activity areas M, N, and O in the south contain hypothetical coal resources. Significant areas of subeconomic bituminous coal resources have been identified, particularly in activity areas H, I, J, K, and L. According to the NPRA Land Use Study Team, there are some 13 billion tons of bituminous and about 97 billion tons of subbituminous coal in the category of "identified" coal resources on NPRA, while "undiscovered hypothetical resources" for the region are estimated at between 934 billion and 2.8 trillion tons. The development of a transportation network to accommodate petroleum development could significantly affect the potential for future utilization of this resource. Such utilization would obviously compound the overall impacts of resource development in the area.

The metallic and associated nonmetallic resources of the southern part of NPRA (fig. 3) presently include, but are not limited to, zinc, lead, silver, chromium, barium, fluorine, nickel, the platinum group, and copper. Occurrences of each of these in noteworthy concentrations has been verified in or adjacent to NPRA. Significant lead-zinc mineralized rock occurs at the surface in the southern foothills in activity areas N and O. Mineralized rock collected in the Drenchwater Creek area assayed to 34-percent lead and 49-percent zinc. As with the coal resource, the development of a transportation network to accommodate petroleum development in this area could benefit or enhance the potential for mineral resource exploitation.

The relation between some of the key wildlife resource values as identified by the NPRA Land Use Study Team and the petroleum activity areas is shown in figure 4.

All of activity area A, almost all of activity area B, over one-half of activity areas C and E, and parts of activity areas D, F, and G, are important to waterfowl and shorebirds, which have been recorded in densities as high as 400 shorebirds and 40 ducks per square mile (or 155 and 15 per square kilometer, respectively). In addition, about 60 percent of activity area B is critical for molting geese. Moose occur in significant numbers in the riparian habitat along the Colville River in activity area L, and in lesser numbers along the Colville River in activity areas H, K, N, and O. Significant fish habitat occurs in almost all of activity area A, in more than half of activity area B, in about one-third of activity areas E and F, and to a lesser extent in activity areas C, D, H, I, and J. Designation of critical habitat in a 15-mile (24-kilometer) radius around current or historic peregrine falcon nests could prohibit or greatly influence petroleum activity over 23 percent of NPRA. Most significantly affected would be those activity areas traversed by the Colville River.

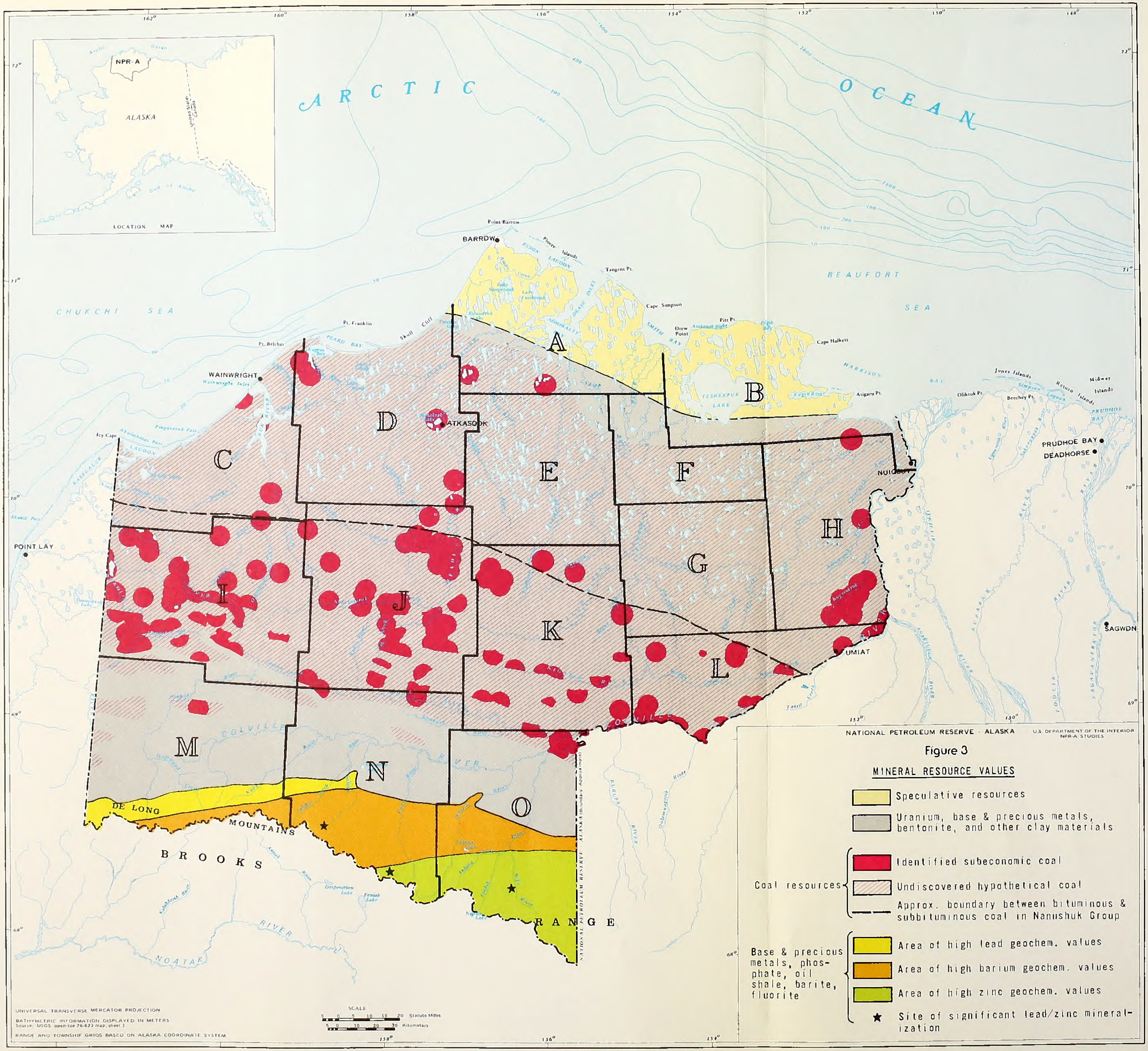
The entire area of NPRA is utilized by caribou and comprises about 30 percent of the total range of the Western Arctic Herd, as shown in figure 5. Seventy percent of the calving area of this herd is within NPRA, predominately in activity areas I, J, and M. All of activity areas A, B, D, and F and parts of activity areas C, E, and H comprise a major wintering zone for parts of this herd in recent years.

Present and potential land ownership in NPRA (fig. 6) would have little overall effect on petroleum development of the Reserve. Withdrawals of 474,570 acres (191,730 hectares) for Native village corporations are clustered around four villages and range from 5 to 10 percent of the areas of activity areas A, B, C, and D. More than 180 Native allotment applications have been made. While significant in number, they total only a small percentage of the NPRA area. However, land use for subsistence purposes encompasses essentially all of NPRA and much of the surrounding area, as shown in figures 7 through 9. Caribou are harvested extensively over the entire area. As shown in figure 7, at least 75 percent of NPRA is currently used for subsistence harvest of caribou. All of eight activity areas, A, B, C, D, E, F, H, and I, are used, as well as parts of the other seven activity areas. Ducks are harvested extensively in activity areas A, B, D, and E, and to a lesser extent in activity areas C, F, G, and J. Fish are harvested primarily in activity areas A, B, E, and F. As shown in figure 9, all of the area used for subsistence purposes by residents of Atkasook is within NPRA; about 95 percent of the area use by residents of Barrow is within NPRA, as is 20 percent of the area used by residents of Nuiqsut; 75 percent of the area is used by residents of Wainwright, and 50 percent of the area is used by residents of Point Lay.

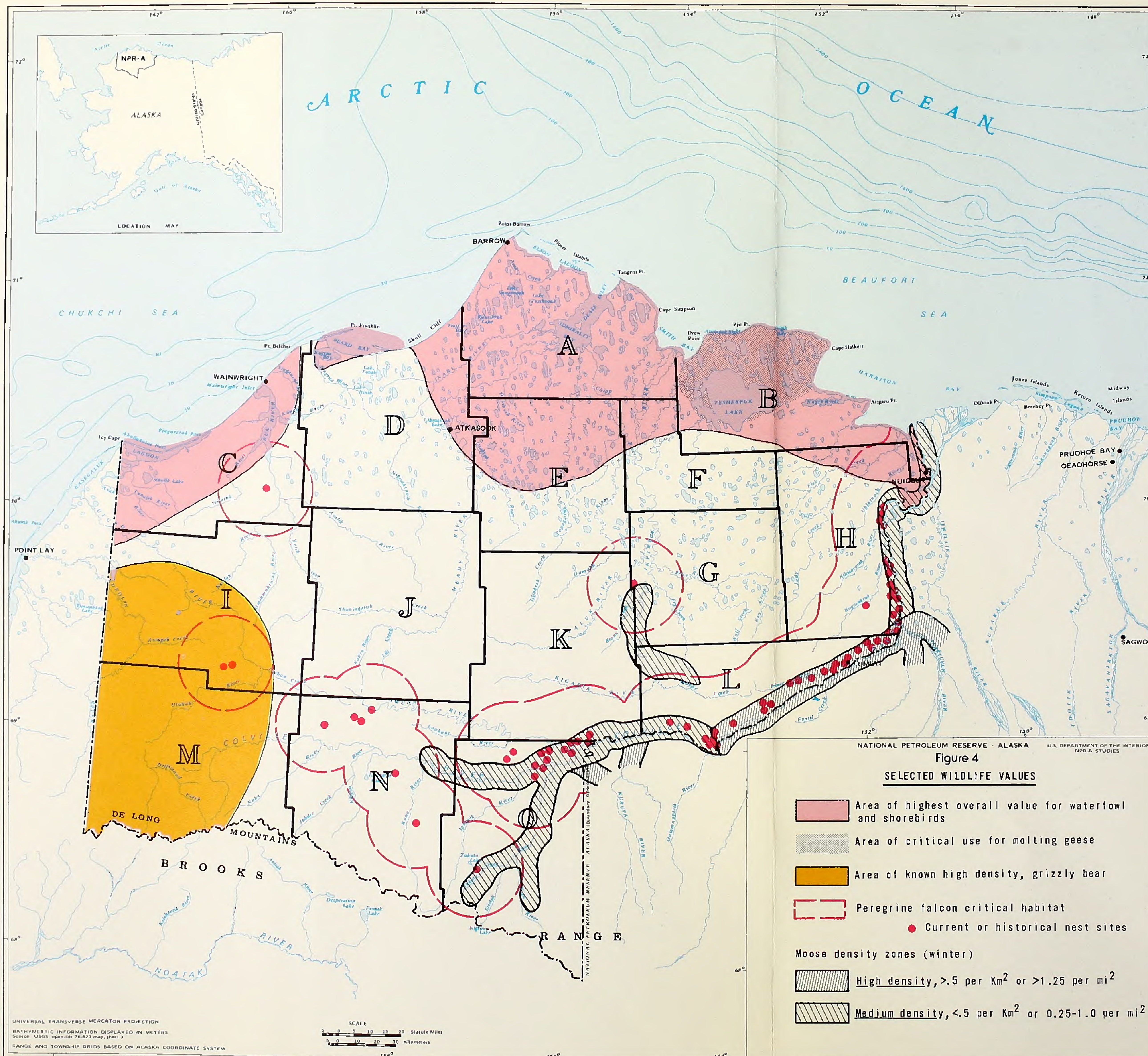
Areas of concern for cultural resources are shown in figures 10 and 11. Figure 10 shows the location of traditional land use sites inventoried by the North Slope Borough; figure 11 shows the location of cultural resource sites investigated as part of the NPRA Land Use Study and areas that have been nominated to the National Register of Historic Places. It must be stressed, however, that due to the size of the area and the paucity of archeological information upon which to base nominations, the process of finding and describing historic and archeological places in northern Alaska has just begun. Undoubtedly, many more historic and cultural sites of national and international significance exist in NPRA, although they have not yet been identified.

Additional areas of ecological or geological significance, and other features of scientific, educational, or historical value, as compiled by the NPRA Land Use Study Team, are shown in figure 12. With the exception of sites recommended as potential natural landmarks, which cover about 22 percent of the area, sites and areas designated are generally small and scattered. Actual designation of sites nominated for proposed ecological reserves, if based upon areas of the recommended natural landmark sites, would withdraw areas from development.

Although all of NPRA with the exception of areas around the several villages has wilderness characteristics, selected areas were identified by the NPRA Land Use Study Team as having significant wilderness attributes, as shown in figure 13. Major portions of all except three activity areas have high wilderness values. Recreational opportunities consist of waterfowl hunting, mainly in activity areas A, B, C, and D; big game hunting, mainly in activity areas L, M, N, and O; and hiking, backpacking, and floatboating in activity areas L, M, N, and O. Of significance to petroleum development are the recommendations for designation of major portions of the Colville River (from its headwaters to Umiat), the Nigu-Etivluk River (all of the Nigu and the Etivluk) and the Utukok River (from the south boundary of NPRA to within 25 miles (40 kilometers) of the west boundary) as Wild Rivers. Although recreational use of the area is very limited, opportunities for use exist, as shown in figure 14. Opportunities for waterfowl hunting exist in the northern part of NPRA, predominately in activity areas A, B, C, D, and H. Opportunities for big game hunting exist in activity areas M, N, and O, and in the southern parts of activity areas I, J, and K. The De Long Mountains in activity areas M, N, and O, although remote, offer excellent opportunities for backpacking and floatboating, as do the Colville, Utukok, and Nigu-Etivluk Rivers in activity areas I, L, M, N, and O. However, despite its large area and opportunities, NPRA currently receives less than 1 percent of the total recreational use in Alaska.



ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
LOCATION MAP
NPR-A
ALASKA
Point Barrow
BARROW
Tangent Pt.
Cape Simpson
Drew Point
Pitt Pt.
Cape Halkett
HARRISON BAY
Atigaru Pt.
Oliktok Pt.
Beechey Pt.
Jones Islands
Midway Islands
Return Islands
PRUDHOE BAY
DEADHORSE
SAGWON
UMIAT
NUIQSUT
TESHEKPUK LAKE
SMITH BAY
Pt. Franklin
Skull Cliff
Pt. Belcher
PEARD BAY
WAINWRIGHT
Icy Cape
ATKASOOK
POINT LAY
COLVILLE RIVER
DE LONG MOUNTAINS
BROOKS RANGE
NOATAK RIVER
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers
NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR NPR-A STUDIES
Figure 3
MINERAL RESOURCE VALUES
Speculative resources
Uranium, base & precious metals, bentonite, and other clay materials
Coal resources
Identified subeconomic coal
Undiscovered hypothetical coal
Approx. boundary between bituminous & subbituminous coal in Nanushuk Group
Base & precious metals, phosphate, oil shale, barite, fluorite
Area of high lead geochem. values
Area of high barium geochem. values
Area of high zinc geochem. values
Site of significant lead/zinc mineralization


NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure 4
SELECTED WILDLIFE VALUES
Area of highest overall value for waterfowl and shorebirds
Area of critical use for molting geese
Area of known high density, grizzly bear
Peregrine falcon critical habitat
Current or historical nest sites
Moose density zones (winter)
High density, >.5 per Km² or >1.25 per mi²
Medium density, <.5 per Km² or 0.25-1.0 per mi²
LOCATION MAP
NPR-A
ALASKA
ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
BARROW
Point Barrow
WAINWRIGHT
ATKASOOK
POINT LAY
PRUDHOE BAY
DEADHORSE
SAGWON
NUIQSUT
UMIAT
Icy Cape
Pt. Belcher
Pt. Franklin
Skull Cliff
Cape Simpson
Drew Point
Pitt Pt.
Cape Halkett
HARRISON BAY
TESHEKPUK LAKE
A
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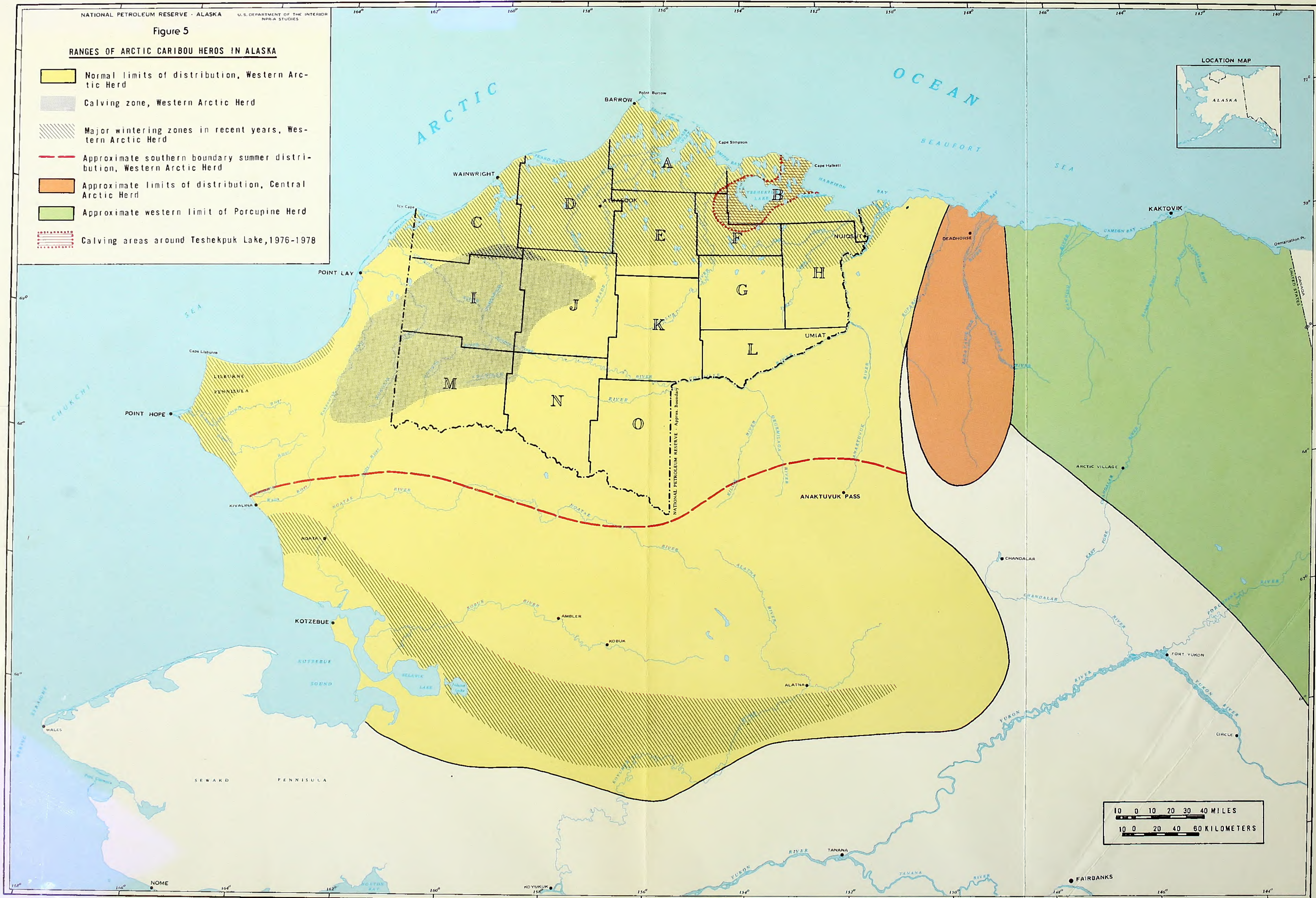
K
L
M
N
O
DE LONG MOUNTAINS
BROOKS RANGE
COLVILLE
NOATAK RIVER
NATIONAL PETROLEUM RESERVE - ALASKA (Boundary)
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers



NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure 5
RANGES OF ARCTIC CARIBOU HEROS IN ALASKA
Normal limits of distribution, Western Arctic Herd
Calving zone, Western Arctic Herd
Major wintering zones in recent years, Western Arctic Herd
Approximate southern boundary summer distribution, Western Arctic Herd
Approximate limits of distribution, Central Arctic Herd
Approximate western limit of Porcupine Herd
Calving areas around Teshekpuk Lake, 1976-1978
LOCATION MAP
ALASKA
ARCTIC
OCEAN
BEAUFORT
SEA
CHUKCHI
SEA
BARROW
Point Barrow
Cape Simpson
Cape Halkett
HARRISON
BAY
WAINWRIGHT
ATKASOOK
Icy Cape
POINT LAY
Cape Lisburne
LISBURNE
PENINSULA
POINT HOPE
KIVALINA
NOATAK
KOTZEBUE
KOTZEBUE
SOUND
SELAWIK
LAKE
AMBLER
KOBUK
ALATNA
ANAKTUVUK PASS
UMIAT
NUIQSUT
DEADHORSE
KAKTOVIK
Demarcation Pt.
CANADA
UNITED STATES
ARCTIC VILLAGE
CHANDALAR
FORT YUKON
CIRCLE
TANANA
FAIRBANKS
KOYUKUK
NOME
WALES
SEWARD
PENINSULA
NATIONAL PETROLEUM RESERVE - Approx. Boundary
A
B
C
D
E
F
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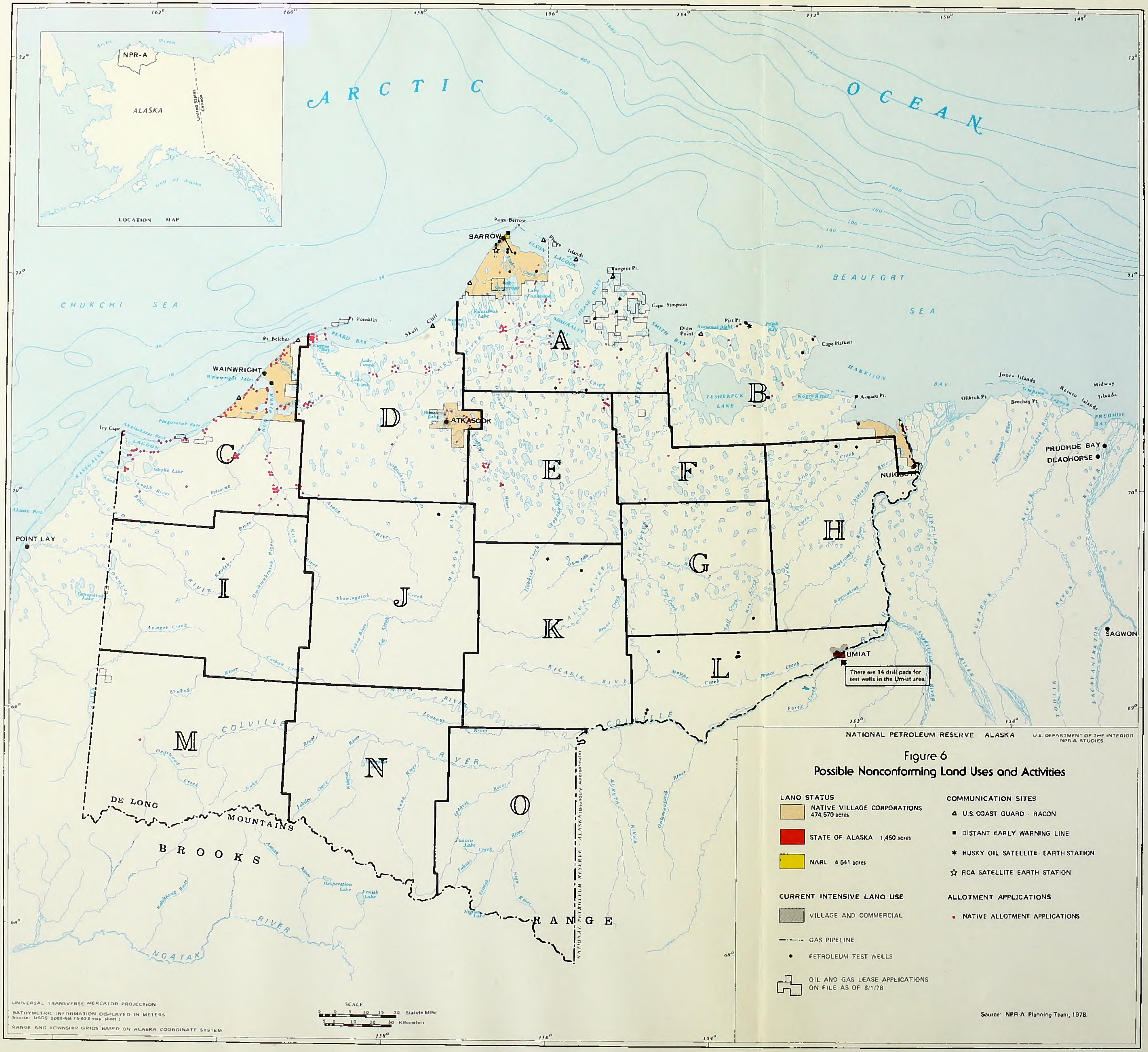
H
I
J
K
L
M
N
O
10 0 10 20 30 40 MILES
10 0 20 40 60 KILOMETERS



ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
LOCATION MAP
NPR-A
ALASKA
BARROW
Point Barrow
WAINWRIGHT
ATKASOOK
NUIQSUT
PRUDHOE BAY
DEADHORSE
POINT LAY
UMIAT
SAGWON
TESHEKPUK LAKE
Icy Cape
Pt. Belcher
Pt. Franklin
Cape Simpson
Cape Halkett
HARRISON BAY
Jones Islands
Return Islands
COLVILLE RIVER
DE LONG MOUNTAINS
BROOKS RANGE
NOATAK RIVER
NATIONAL PETROLEUM RESERVE - ALASKA (Boundary Approximate)
A
B
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O
There are 14 drill pads for test wells in the Umiat area.
NATIONAL PETROLEUM RESERVE · ALASKA
U.S. DEPARTMENT OF THE INTERIOR NPR-A STUDIES
Figure 6
Possible Nonconforming Land Uses and Activities
LAND STATUS
NATIVE VILLAGE CORPORATIONS 474,570 acres
STATE OF ALASKA 1,450 acres
NARL 4,541 acres
CURRENT INTENSIVE LAND USE
VILLAGE AND COMMERCIAL
GAS PIPELINE
PETROLEUM TEST WELLS
OIL AND GAS LEASE APPLICATIONS ON FILE AS OF 8/1/78
COMMUNICATION SITES
U.S. COAST GUARD · RACON
DISTANT EARLY WARNING LINE
HUSKY OIL SATELLITE · EARTH STATION
RCA SATELLITE EARTH STATION
ALLOTMENT APPLICATIONS
NATIVE ALLOTMENT APPLICATIONS
Source: NPR-A Planning Team, 1978.
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 75-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers

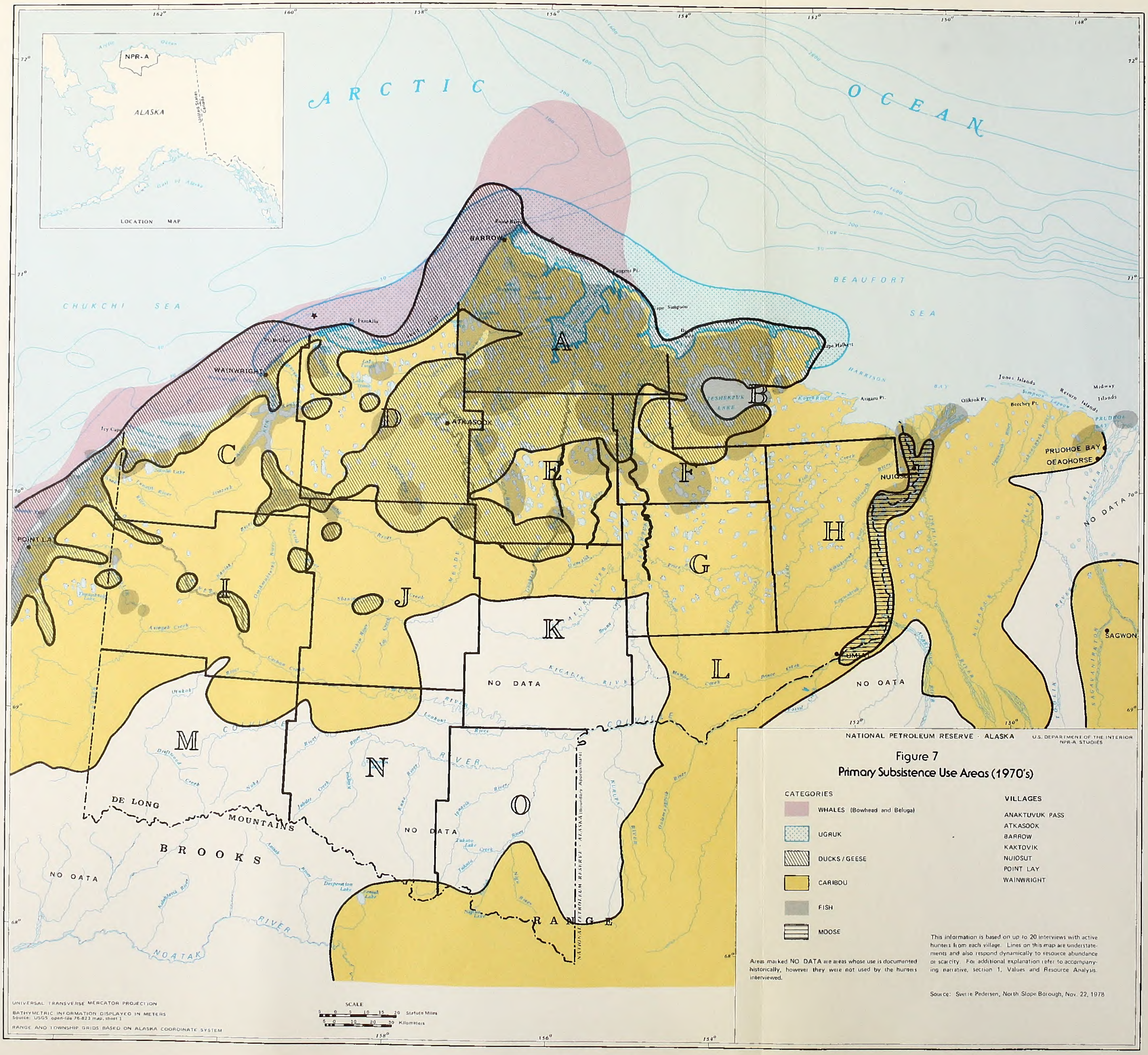


Figure 7
Primary Subsistence Use Areas (1970's)

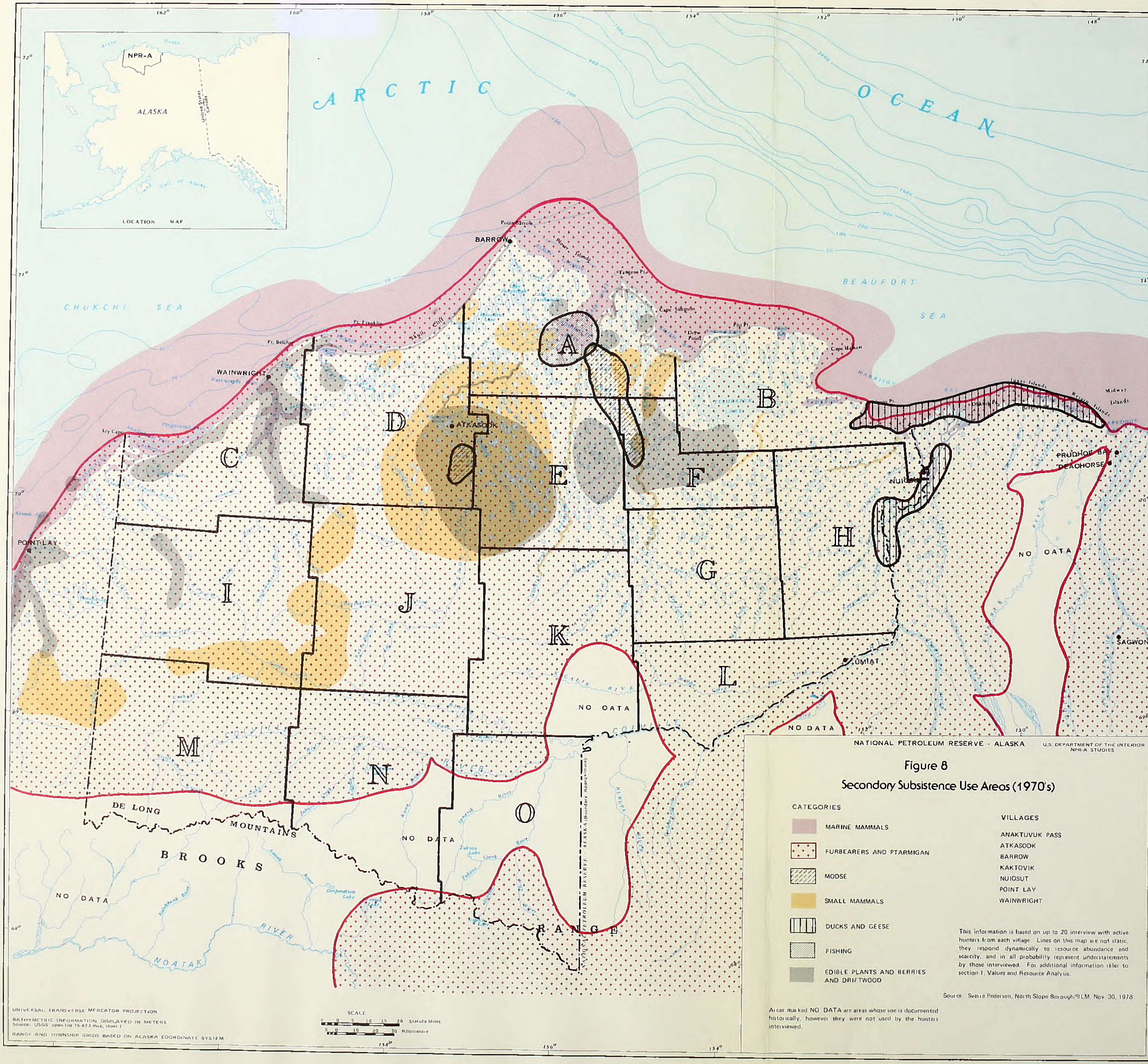
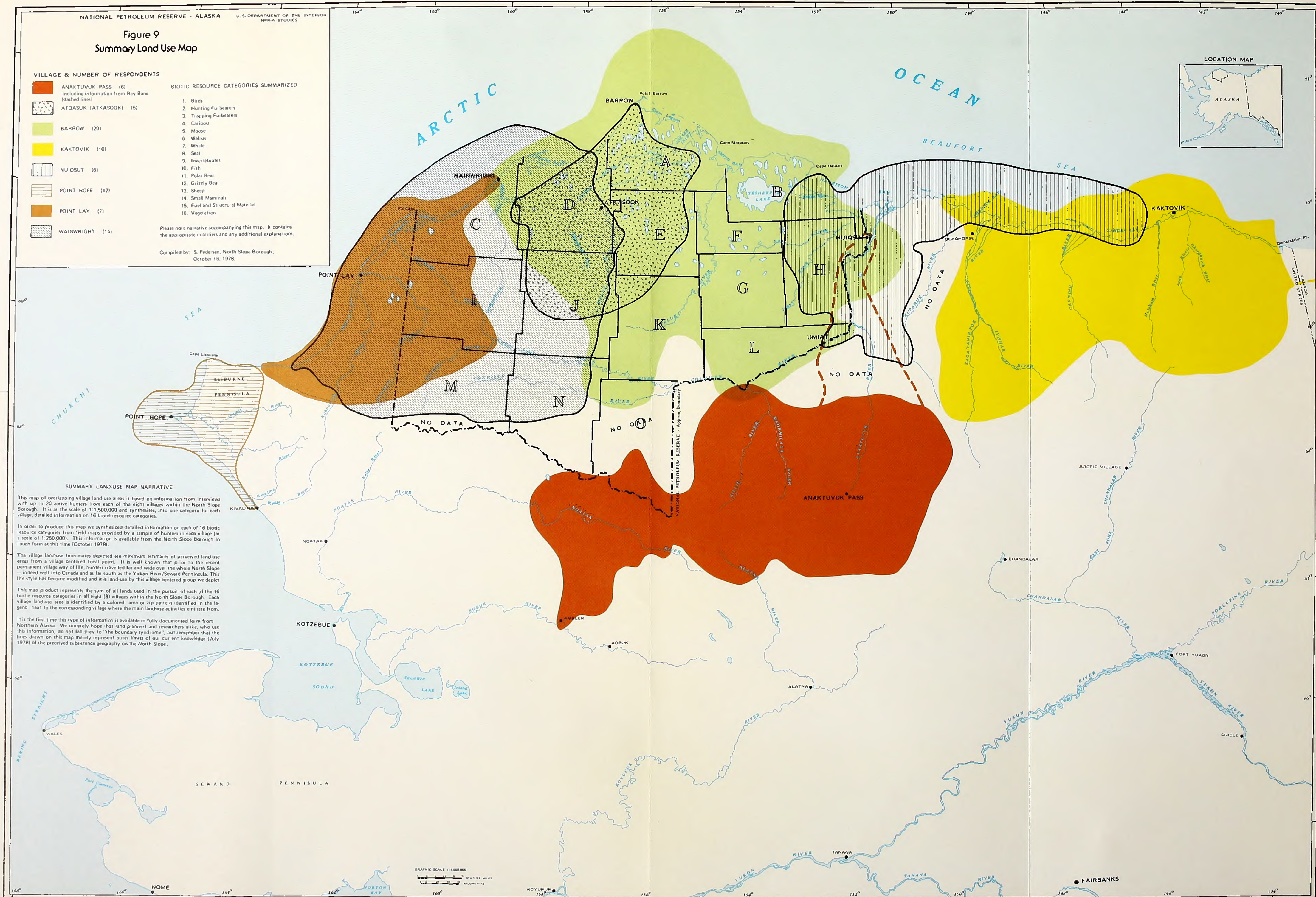
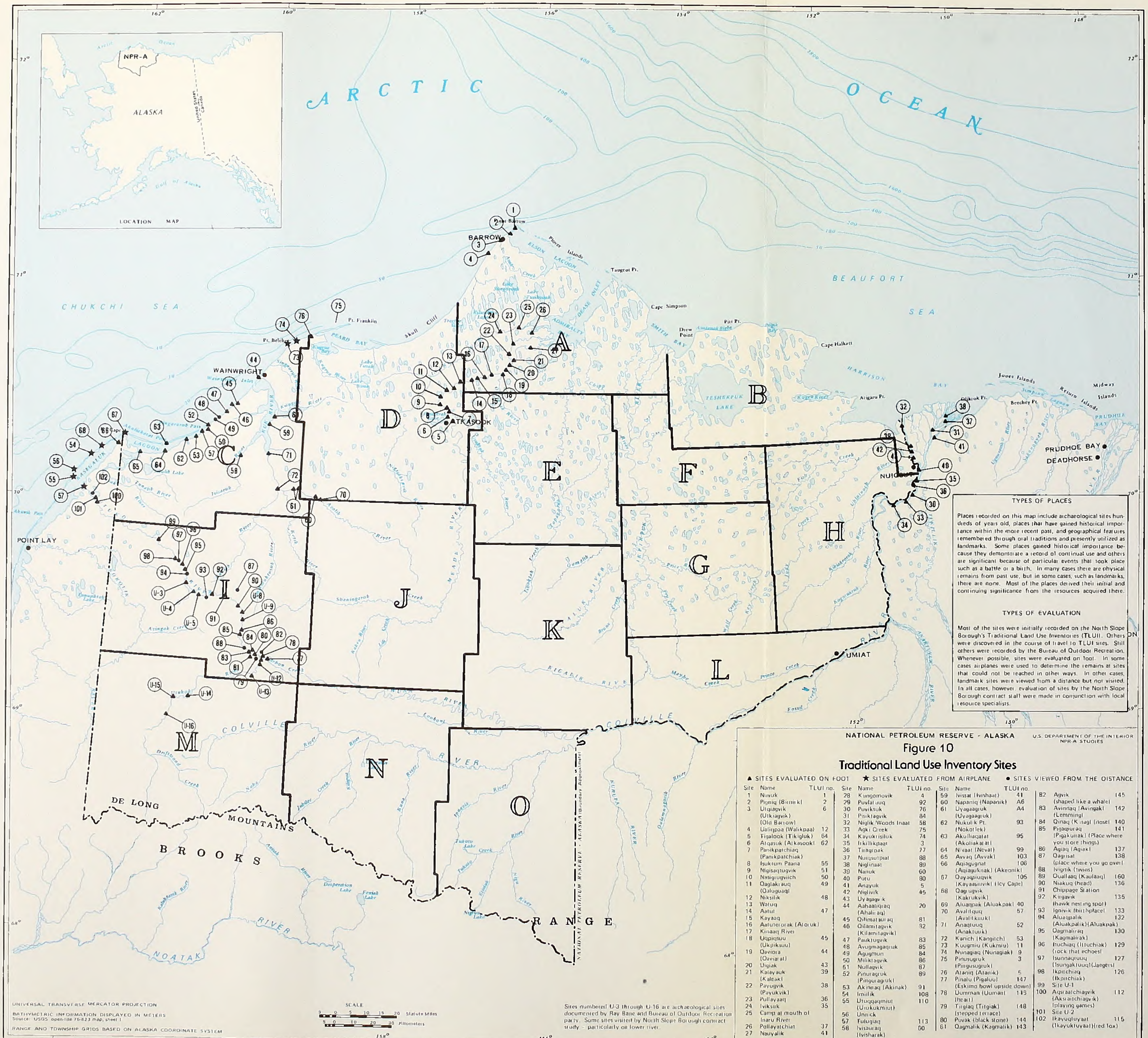


Figure 8

Secondary Subsistence Use Areas (1970's)


NATIONAL PETROLEUM RESERVE - ALASKA
U. S. DEPARTMENT OF THE INTERIOR NPR-A STUDIES
Figure 9
Summary Land Use Map
VILLAGE & NUMBER OF RESPONDENTS
ANAKTUVUK PASS (6) including information from Ray Bane (dashed lines)
ATQASUK (ATKASOOK) (5)
BARROW (20)
KAKTOVIK (10)
NUIQSUT (6)
POINT HOPE (12)
POINT LAY (7)
WAINWRIGHT (14)
BIOTIC RESOURCE CATEGORIES SUMMARIZED
1. Birds
2. Hunting Furbearers
3. Trapping Furbearers
4. Caribou
5. Moose
6. Walrus
7. Whale
8. Seal
9. Invertebrates
10. Fish
11. Polar Bear
12. Grizzly Bear
13. Sheep
14. Small Mammals
15. Fuel and Structural Materiel
16. Vegetation
Please note narrative accompanying this map. It contains the appropriate qualifiers and any additional explanations.
Compiled by: S. Pedersen, North Slope Borough, October 16, 1978.
SUMMARY LAND-USE MAP NARRATIVE
This map of overlapping village land-use areas is based on information from interviews with up to 20 active hunters from each of tha eight villages within the North Slope Borough. It is at the scale of 1:1,500,000 and synthesises, into one category for each village, detailed information on 16 biotic resource categories.
In order to produce this map we synthesized detailed information on each of 16 biotic resource categories from field maps provided by a sample of hunters in each village (at a scale of 1:250,000). This information is available from the North Slope Borough in rough form at this time (October 1978).
The village land-use boundaries depicted are minimum estimates of perceived land-use areas from a village centered focal point. It is well known that prior to the recent permanent village way of life, hunters travelled far and wide over the whole North Slope — indeed well into Canada and as far south as the Yukon River/Seward Penninsula. This life style has become modified and it is land-use by this village centered group we depict
This map product represents the sum of all lands used in the pursuit of each of the 16 biotic resource categories in all eight (8) villages within the North Slope Borough. Each village land-use area is identified by a colored area or zip pattern identified in the legend next to the corresponding village where the main land-use activities eminate from.
It is the first time this type of information is available in fully documented form from Northern Alaska. We sincerely hope that land planners and researchers alike, who use this information, do not fall prey to "the boundary syndrome", but remember that the lines drawn on this map merely represent outer limits of our current knowledge (July 1978) of the preceived subsistence geography on the North Slope.
LOCATION MAP
ALASKA
ARCTIC
OCEAN
BEAUFORT
SEA
CHUKCHI
SEA
BARROW
Point Barrow
Cape Simpson
Cape Halkett
TESHEKPUK LAKE
WAINWRIGHT
ATKASOOK
NUIQSUT
UMIAT
KAKTOVIK
DEADHORSE
Demarcation Pt.
POINT LAY
Cape Lisburne
LISBURNE PENINSULA
POINT HOPE
KIVALINA
NOATAK
KOTZEBUE
KOTZEBUE SOUND
SELAWIK LAKE
AMBLER
KOBUK
ALATNA
ANAKTUVUK PASS
ARCTIC VILLAGE
CHANDALAR
FORT YUKON
CIRCLE
TANANA
FAIRBANKS
KOYUKUK
NOME
NORTON BAY
WALES
BERING STRAIT
SEWARD PENNISULA
NATIONAL PETROLEUM RESERVE - Approx. Boundary
NO DATA
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
CANADA
UNITED STATES



TYPES OF PLACES

Places recorded on this map include archaeological sites hundreds of years old, places that have gained historical importance within the more recent past, and geographical features remembered through oral traditions and presently utilized as landmarks. Some places gained historical importance because they demonstrate a record of continual use and others are significant because of particular events that took place such as a battle or a birth. In many cases there are physical remains from past use, but in some cases, such as landmarks, there are none. Most of the places derived their initial and continuing significance from the resources acquired there.

TYPES OF EVALUATION

Most of the sites were initially recorded on the North Slope Borough's Traditional Land Use Inventories (TLUI). Others were discovered in the course of travel to TLUI sites. Still others were recorded by the Bureau of Outdoor Recreation. Whenever possible, sites were evaluated on foot. In some cases airplanes were used to determine the remains at sites that could not be reached in other ways. In other cases, landmark sites were viewed from a distance but not visited. In all cases, however, evaluation of sites by the North Slope Borough contract staff were made in conjunction with local resource specialists.

NATIONAL PETROLEUM RESERVE - ALASKA

U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES

Figure 10
Traditional Land Use Inventory Sites

▲ SITES EVALUATED ON FOOT ★ SITES EVALUATED FROM AIRPLANE ● SITES VIEWED FROM THE DISTANCE

Site	Name	TLUI no.
1	Nuvuk	1
2	Pigniq (Birnirk)	2
3	Utqiagvik (Utkiagvik) (Old Barrow)	6
4	Ualiqpaa (Walikpaa)	12
5	Tigalook (Tikigluk)	64
6	Atqasuk (Atkasook)	62
7	Panikpatchiaq (Panikpatchiak)	
8	Isuktum Paana	55
9	Nigisaqtugvik	51
10	Nasigrugviich	50
11	Qaglakrauq (Qaluguaq)	49
12	Niksilik	48
13	Waluq	
14	Aatut	47
15	Kayaaq	
16	Aaluterorak (Aloruk)	
17	Kinaaq River	
18	Uqpiqsuu (Ukpiksuu)	45
19	Qaviora (Qaviarat)	44
20	Uigiak	43
21	Kalayauk (Kaleak)	39
22	Payugvik (Payukvik)	38
23	Pullayaaq	36
24	Iviksuk	35
25	Camp at mouth of Inaru River	
26	Pollayatchiat	37
27	Nauyalik	41
28	Kungomovik	4
29	Puvlatuuq	92
30	Puviksuk	76
31	Pisiktagvik	84
32	Niglik/Woods Inaat	58
33	Agki Creek	75
34	Kayukrisiluk	74
35	Itkillikpaat	3
36	Tiragroak	77
37	Nuiqsutpiat	88
38	Niglinaat	89
39	Nanuk	60
40	Putu	80
41	Anayuk	5
42	Niglivik	45
43	Uyagagvik	
44	Aahaaliqraq (Ahaliraq)	20
45	Qitimataurаq	81
46	Qilamitagvik (Kilamitagvik)	82
47	Pauktugvik	83
48	Avugmagaqruk	85
49	Agugmun	84
50	Miliktagvik	86
51	Nullagvik	87
52	Pinuraqruk (Pingurагruk)	89
53	Akinnaq (Akinak)	91
54	Imiilik	108
55	Utuqqaqmiut (Utukukmiut)	110
56	Unnick	
57	Tulugiaq	113
58	Ivisauraq (Ivisharak)	60
59	Ivissat (Ivishaat)	41
60	Napaniq (Napanik)	A6
61	Uyagaagruk (Uyagaagruk)	A4
62	Nukulik Pt. (Nokotlek)	93
63	Akulliaqatat (Akoliakatat)	95
64	Nivaat (Nevat)	99
65	Avvaq (Avvak)	103
66	Aqiagugnat (Aqiaguknak) (Akeonik)	106
67	Qayaqsiuqvik (Kayaasiuvik) (Icy Cape)	105
68	Qagrugvik (Kakrukvik)	
69	Aluaqpak (Aluakpak)	40
70	Avalitquq (Avalitkuuk)	57
71	Anaqtuuq (Anaktuuk)	52
72	Kanich (Kangitch)	53
73	Kuugmiu (Kukmiu)	11
74	Nunagiaq (Nunagiak)	9
75	Pinusugruk (Pingusugruk)	3
76	Ataniq (Atanik)	5
77	Pinalu (Pigaluu) (Eskimo bowl upside down)	147
78	Uumman (Uuman) (heart)	115
79	Tirgiaq (Titgiak) (stepped terrace)	148
80	Puvak (black stone)	144
81	Qagmalik (Kagmalik)	143
82	Agvik (shaped like a whale)	145
83	Avinnaq (Avingak) (Lemming)	142
84	Qinaq (Kinag) (nose)	140
85	Pigaqiuraq (Pigakurrak) (Place where you store things)	141
86	Agiaq (Agiak)	137
87	Qagrisat (place where you go over)	138
88	Ivignik (twins)	
89	Quallaaq (Kaulaaq)	160
90	Niakuq (head)	136
91	Chippage Station	
92	Kirgavik (hawk nesting spot)	135
93	Ignivik (birthplace)	133
94	Aluaqpalik (Aluakpalik)(Aluakpak)	132
95	Qagmaliraq (Kagmalirak)	130
96	Iruchiaq (Ituchiak) (rock that echoes)	129
97	Isunnaqtuuq (Isungaktuuq)(Jaegers)	127
98	Ikpitchiaq (Ikpitchiak)	126
99	Site U-1	
100	Aqsraatchiagvik (Aksraitchiagvik) (playing games)	112
101	Site U-2	
102	Ikayuqtuyaat (Ikayuktuyaat)(red fox)	115

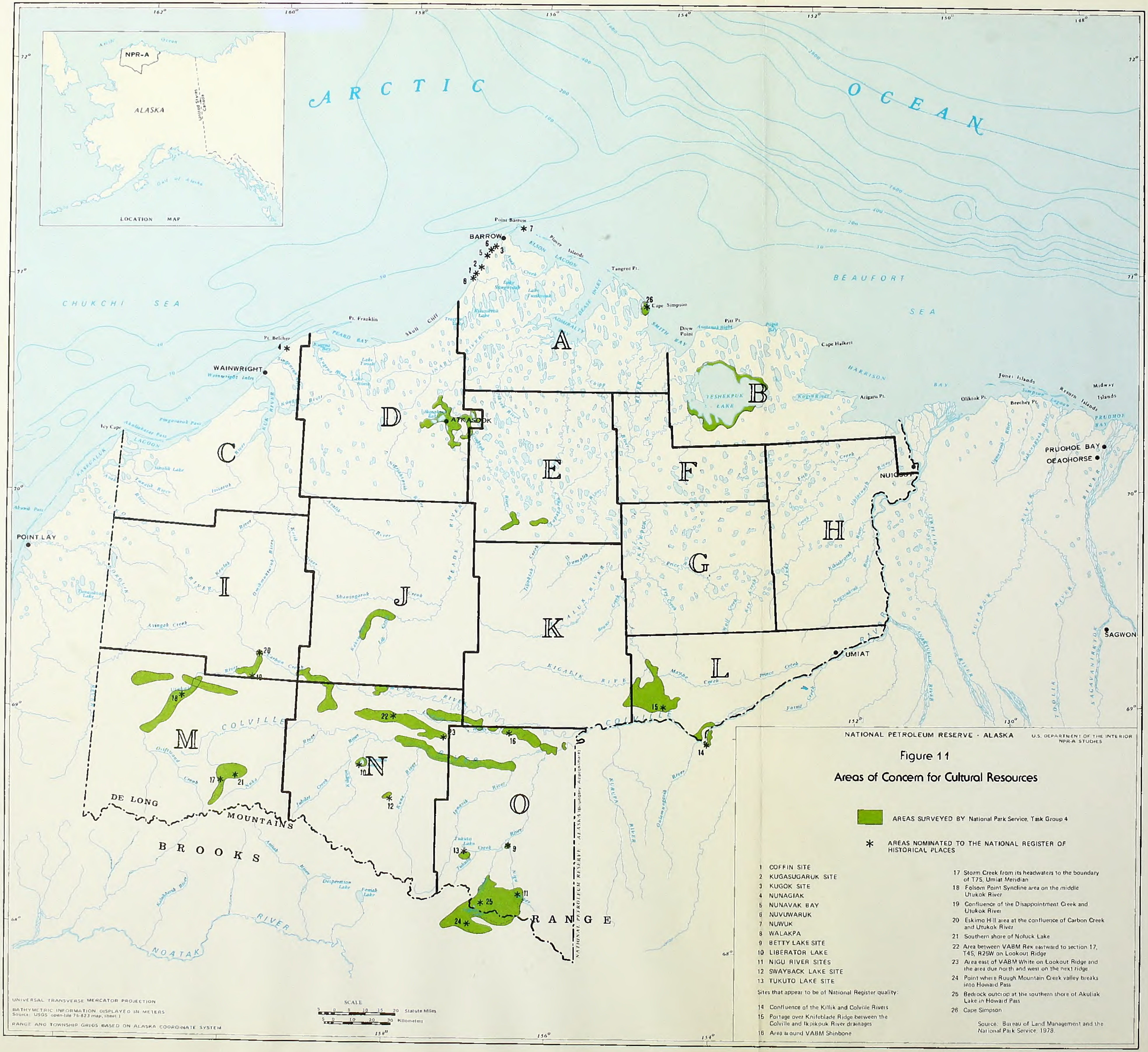
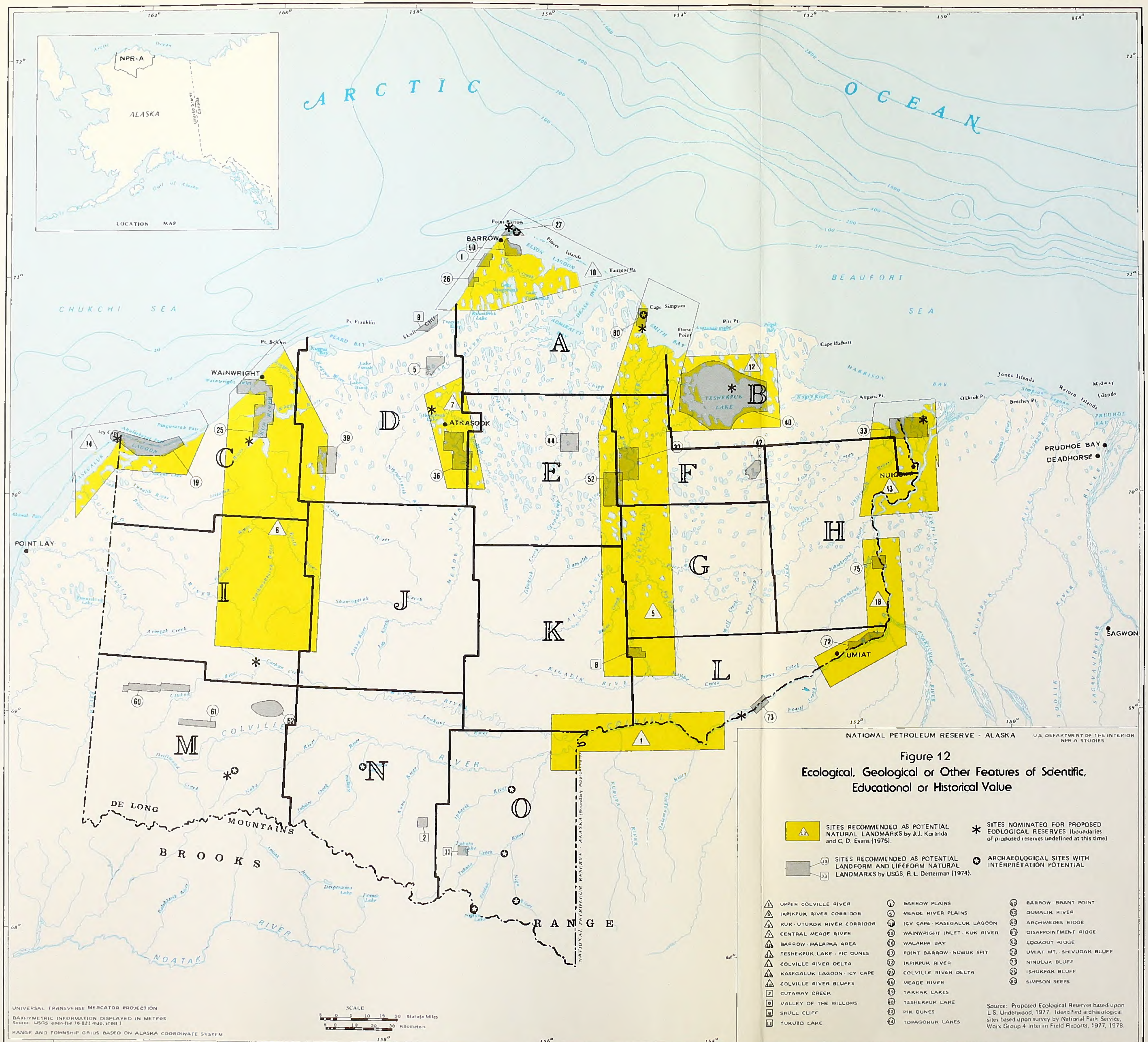


Figure 11
Areas of Concern for Cultural Resources


NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure 12
Ecological, Geological or Other Features of Scientific, Educationol or Historical Value
SITES RECOMMENDED AS POTENTIAL NATURAL LANDMARKS by J.J. Koranda and C. D. Evans (1975).
SITES NOMINATED FOR PROPOSED ECOLOGICAL RESERVES (boundaries of proposed reserves undefined at this time)
SITES RECOMMENDED AS POTENTIAL LANDFORM AND LIFEFORM NATURAL LANDMARKS by USGS, R.L. Detterman (1974).
ARCHAEOLOGICAL SITES WITH INTERPRETATION POTENTIAL
UPPER COLVILLE RIVER
IKPIKPUK RIVER CORRIDOR
KUK - UTUKOK RIVER CORRIDOR
CENTRAL MEADE RIVER
BARROW - WALAPKA AREA
TESHEKPUK LAKE - PIC DUNES
COLVILLE RIVER DELTA
KASEGALUK LAGOON - ICY CAPE
COLVILLE RIVER BLUFFS
CUTAWAY CREEK
VALLEY OF THE WILLOWS
SKULL CLIFF
TUKUTO LAKE
BARROW PLAINS
MEADE RIVER PLAINS
ICY CAPE - KASEGALUK LAGOON
WAINWRIGHT INLET - KUK RIVER
WALAKPA BAY
POINT BARROW - NUWUK SPIT
IKPIKPUK RIVER
COLVILLE RIVER DELTA
MEADE RIVER
TAKRAK LAKES
TESHEKPUK LAKE
PIK DUNES
TOPAGORUK LAKES
BARROW - BRANT POINT
OUMALIK RIVER
ARCHIMEDES RIDGE
DISAPPOINTMENT RIDGE
LOOKOUT RIDGE
UMIAT MT. - SHIVUGAK BLUFF
NINULUK BLUFF
ISHUKPAK BLUFF
SIMPSON SEEPS
Source: Proposed Ecological Reserves based upon L.S. Underwood, 1977. Identified archaeological sites based upon survey by National Park Service, Work Group 4 Interim Field Reports, 1977, 1978.
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers
LOCATION MAP
ALASKA
NPR-A
ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
BARROW
WAINWRIGHT
ATKASOOK
NUIQSUT
UMIAT
PRUDHOE BAY
DEADHORSE
SAGWON
POINT LAY
BROOKS RANGE
DE LONG MOUNTAINS
NATIONAL PETROLEUM RESERVE - ALASKA (Boundary Approximate)

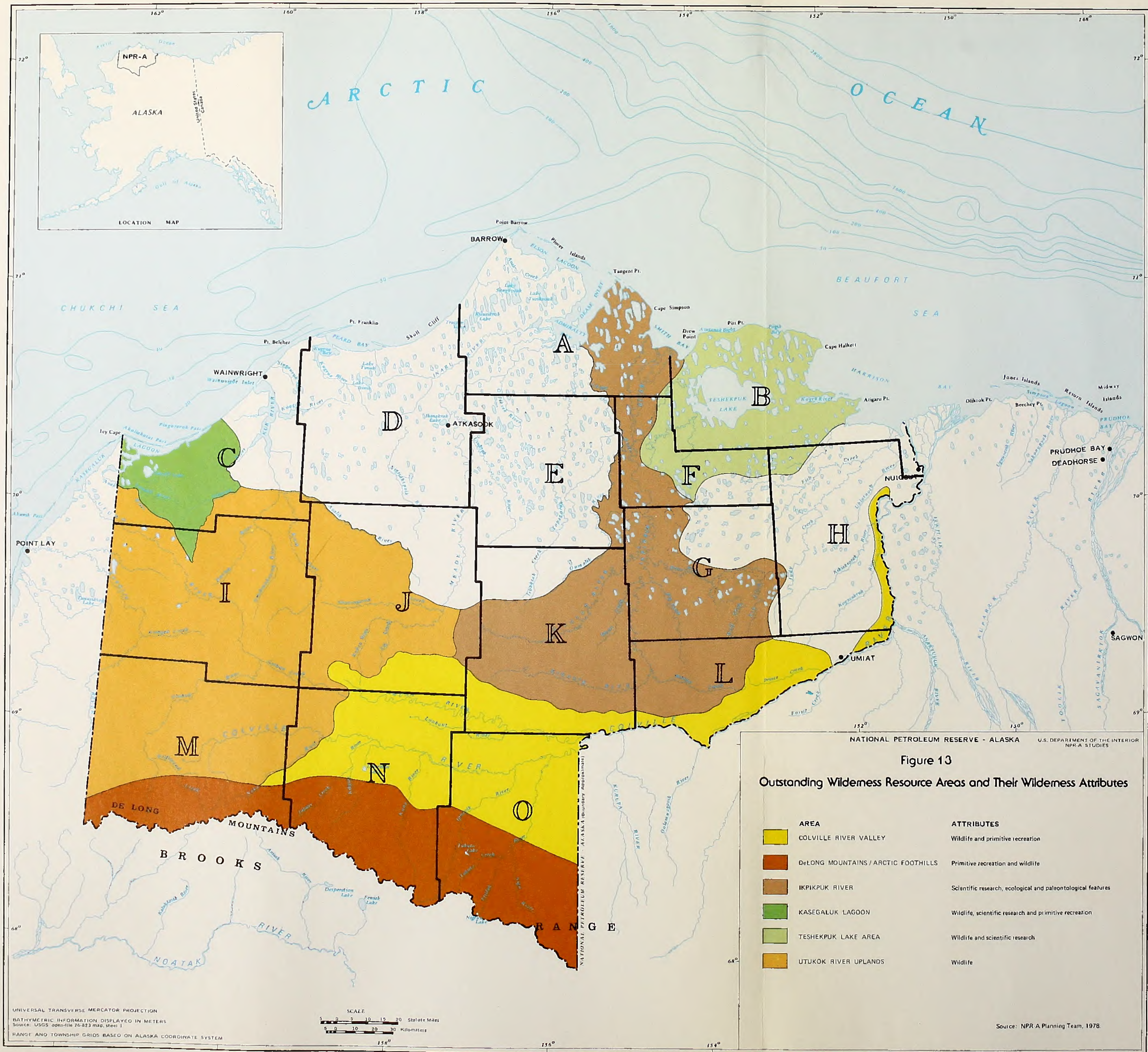
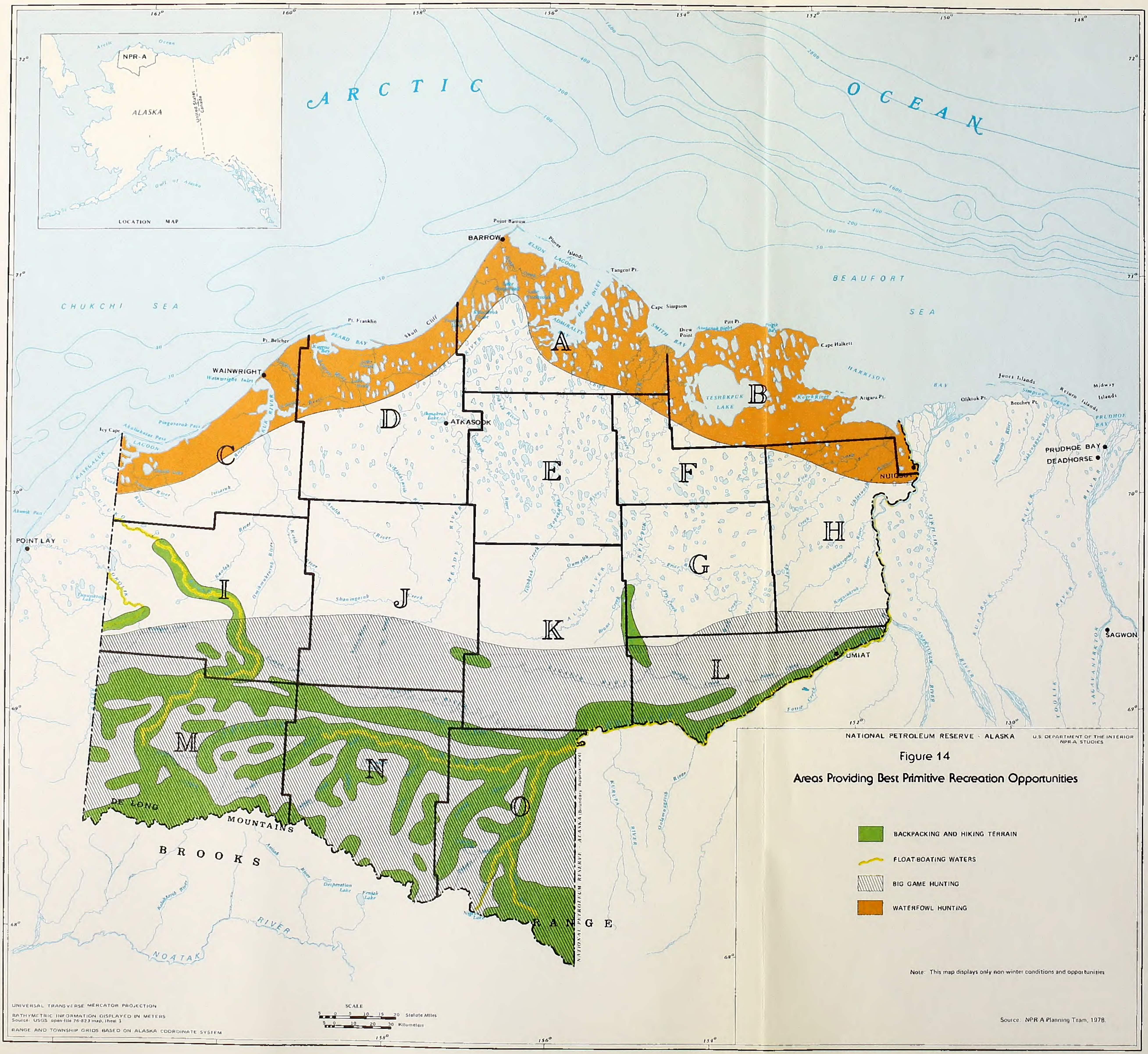


Figure 13

Outstanding Wilderness Resource Areas and Their Wilderness Attributes



NATIONAL PETROLEUM RESERVE · ALASKA

Figure 14

Areas Providing Best Primitive Recreation Opportunities

B. Petroleum Activity Areas

An analysis of land or resource values for each activity area provides a general approach to comparisons of areas. In this section, land values for each of the 15 activity areas are discussed. In addition to those values considered in the previous section, water and gravel — two resources in relatively short supply in NPRA — are also considered. The discussion on water and gravel assumes requirements based upon assumptions of the economic and policy study. For this evaluation, an average total requirement of 300 acre-feet (370,000 cubic meters) of water and 400 thousand cubic yards (11,300 cubic meters) of gravel is assumed for each moderate-sized field of 1.5 billion barrels of oil requiring 50 wells for development. These requirements could vary significantly with size of field, depth of wells, and physiography, and are used here only for purposes of general discussion of availability of the resources within each activity area. Values considered for each activity area include minerals other than petroleum; wildlife values; surface ownership; Native subsistence; archeologic and historic values, including traditional land use; ecological and geological features of scientific, educational, or historic value; and primitive recreation opportunities, visual values, and wilderness values. These land values are summarized by activity area in tables 7 and 8.

Activity area A contains limited coal deposits in its southwest corner. Water supplies are adequate to support development; however, saltwater intrusion in some lakes and streams limits the availability of fresh water along the coast. Moderate quantities of gravel are available from present beaches and offshore bars west of Barrow. Alluvial deposits near the mouths of the Meade, Topagoruk, and Ikpikpuk Rivers are thin and contain mostly sand.

The entire activity area has an abundance of waterbirds in summer. Average densities of shorebirds and ducks are more than three times the averages for the entire Reserve; about half of the approximately 5 million shorebirds using NPRA are found in this activity area. These high densities are particularly pronounced in the northern portion, where densities of shorebirds may exceed 400 per square mile (155

Table 7. Special Land Values by Activity Areas, in Percent

Resource Value	Activity Area														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Minerals:															
Uranium, base and precious metals, bentonite, and other clays.	35	25	100	100	100	100	100	100	100	100	100	100	80	60	45
Base and precious metals, phosphate, oil shale, barite, and fluorite.	—	—	—	—	—	—	—	—	—	—	—	—	20	40	55
Coal	25	15	100	100	95	85	100	100	95	100	100	100	10	10	5
Wildlife:[1]															
Caribou calving zone[2]	—	—	15	—	—	—	—	—	90	35	—	—	60	—	—
Caribou wintering area[2]	100	100	75	100	85	100	10	40	—	10	—	—	—	—	—
Caribou year-round use, Teshekpuk Herd.	—	50	—	—	—	10	—	—	—	—	—	—	—	—	—
Waterfowl and shorebirds	100	95	55	40	55	15	25	—	—	—	—	—	—	—	—
Molting geese	—	60	—	—	—	—	—	—	—	—	—	—	—	—	—
Grizzly bear	—	—	—	—	—	—	—	—	55	—	—	—	40	—	—
Primary subsistence:															
Caribou	100	100	100	100	100	100	95	100	100	85	35	80	30	15	25
Ducks	90	60	25	60	50	35	10	—	—	10	5	—	—	—	—
Fish	85	55	20	5	30	35	—	5	5	—	—	—	—	—	—
Wilderness attributes	25	95	65	—	10	45	65	5	100	70	90	95	100	100	100
Recreation:															
Waterfowl hunting	65	100	40	35	—	—	—	15	—	—	—	—	—	—	—
Big-game hunting	—	—	—	—	—	—	10	10	35	35	45	95	100	100	100
Hiking and backpacking	—	—	—	—	—	—	—	—	10	—	5	20	55	35	50

[1]Moose are present in the Colville and Etivluk River valleys.
[2]All of NPRA is within the normal range of the Western Arctic Herd of caribou.

Table 8. Ranges of Village Subsistence Activities, as a Percentage of Activity Area

Village	Activity Area															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Within NPRA[1]
Anaktuvuk Pass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Atkasook	90	—	—	80	70	—	—	—	—	50	—	—	—	—	—	100
Barrow	100	100	20	100	100	100	100	100	—	45	90	95	—	10	15	95
Nuiqsut	—	15	—	—	—	—	—	85	—	—	—	—	—	—	—	20
Point Lay	—	—	35	—	—	—	—	—	50	—	—	—	35	—	—	50
Wainwright	—	—	100	95	—	—	—	—	100	80	—	—	90	50	—	75

[1]Percent of overall subsistence range.
Percentages are approximate and are based on limited available information.

per square kilometer) and ducks average about 40 per square mile (15 per square kilometer). Offshore waters also provide habitat for the endangered bowhead whale and other marine mammals. The coastal area is used by female polar bears as denning habitat. Caribou utilize the entire activity area as both summer and winter range.

The NPRA Land Use Study considers barrier islands adjacent to the Reserve's coast worthy of full protection and designation as areas of critical environmental concern.

The activity area contains the largest village in the North Slope Borough — Barrow, the socioeconomic and political center for the entire region. Village lands occupy about 10 percent of the activity area. Development would bring economic opportunities, particularly employment, to village residents. Increased job opportunities might also be available to the residents of Wainwright, Atkasook, and Nuiqsut. Development, however, could also severely stress an already overburdened infrastructure in the Barrow area, particularly in the areas of housing, health care, public safety, and transportation.

The entire activity area is used for subsistence by Natives of Barrow. About 90 percent of the activity area is used by Natives of Atkasook and comprises about 30 percent of their present subsistence area. Main subsistence items are caribou, which are gathered over the entire activity area, and ducks and fish, which are gathered over almost all of the area.

Non-Federal surface ownership is limited to 161,280 acres (65,157 hectares) in the village of Barrow. In addition, the Naval Arctic Research Laboratory occupies 4,541 acres (1,834 hectares). Sixty-nine Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands, but some have been appealed.

Nearly 200 sites in the activity area are recorded in the North Slope Borough's Traditional Land Use Inventories (TLUI). Other similar sites undoubtedly exist. The Birnirk site is on the National Register of Historic Places. Seven additional sites in the activity area have been nominated; more may be deemed eligible. The Point Barrow and the Cape Simpson areas have been proposed as ecological reserves; the Point Barrow area has been identified by the NPRA Land Use Study Team as one of five unique ecologic areas in NPRA. About 25 percent of the area has outstanding wilderness attributes. Recreational opportunities include tourism in the Barrow area, waterfowl hunting, and wildlife (particularly birds) viewing.

Activity area B contains essentially no known mineral resources other than oil and gas. This activity area has ample water supplies; Teshekpuk Lake alone contains approximately 3 million acre-feet (3.7 billion cubic meters) of water. However, there is saltwater intrusion in some lakes and streams along the coast. Gravel suitable for pad construction could be obtained from buried marine terraces in the vicinity of Nuiqsut in the extreme eastern part of the area. Excavation, however, would require thawing of the gravel and removal of from 3 to 10 feet (1 to 3 meters) of overburden. Gravel is also available along the Colville River near the mouths of the Kikiakrorak and Kogosukruk Rivers, about 50 miles (80 kilometers) southeast of the area.

The Teshekpuk Lake area, one of the most significant fish and wildlife habitat areas in Arctic Alaska, comprises about three-fourths of this activity area. Compared with the remainder of NPRA, approximately six times the average density of geese, five times the average for whistling swans, three times the average for shorebirds, and twice the average for ducks and loons are found in the area. Teshekpuk Lake is extremely important to the entire Alaskan

Arctic as waterbird breeding, molting, and migration staging habitat. The large concentrations of white-fronted geese and brant utilizing the lakes, wetlands, and shorelines in about 60 percent of this area for molting may contain more than 10 percent of the North American populations of these species. During the molt, these birds are highly sensitive to disturbances and habitat alteration. A group of caribou, apparently distinct from the Western Arctic Herd, and known as the Teshekpuk Herd, remains in this activity area for all or most of the year. This herd of 3,000 to 4,000 caribou ranges over about 50 percent of the activity area and calves in parts of the activity areas adjacent to Teshekpuk Lake.

The Teshekpuk Lake area was given Special Area status in P.L. 94-258, and has been identified as an area of critical concern by the NPRA Land Use Study Team. Both the Teshekpuk Lake area and the Colville River Delta have been identified as unique ecologic areas by this study team. These areas are also extremely important to the subsistence culture of the area. The Colville River Delta supports subsistence and commercial fishing. The activity area contains the village of Nuiqsut in the Colville Delta, and the area is used extensively by Natives from Nuiqsut and Barrow for subsistence purposes. The entire area is currently used by Natives of Barrow, and about 15 percent of the area is used by Natives of Atkasook. The Teshekpuk Lake area also possesses outstanding wilderness values.

Non-Federal surface ownership within the activity area is limited to about 50,000 acres (20,200 hectares) at Nuiqsut (depending upon outcome of the disputed boundary of NPRA). Fifteen Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands but have been appealed.

More than 100 sites in the activity area are recorded in the North Slope Borough's Traditional Land Use Inventories. Both Teshekpuk Lake and the Colville Delta have been proposed as ecologic reserves. Sites of Historic Register quality have not been found but may exist. Almost the entire area possesses outstanding wilderness attributes, mainly associated with Teshekpuk Lake and its environs. Recreational opportunities include waterfowl hunting and wildlife viewing.

Activity area C is thought to contain subeconomic coal deposits and other (hypothetical) mineral resources. Water supplies are adequate except during late winter when the shallow lakes and rivers are frozen. Gravel for pad construction is available from the beaches and inland raised beaches in this activity area. Excavation from the inland raised beaches, however, would require thawing the gravel and removing from 3 to 10 feet (1 to 3 meters) of organic-rich overburden. Additional gravel is also available along the Utukok River about 5 miles (8 kilometers) south of the activity area.

Almost 55 percent of the activity area is significant as major waterbird habitat and contains the best example of a barrier island-lagoon system on the Chukchi Sea coast. The Icy Cape area is second only to the Teshekpuk Lake area as important habitat for geese, especially for black brant, which use the area as a migration staging area. Its overall value for migra-

Caribou remain in the Teshekpuk Lake area year-round. (Robert Lewellen)

Extensive bituminous and subbituminous coal deposits have been identified in NPRA. (U.S. Geological Survey)

tory birds is nearly as high as that of activity areas A and B. Cliff-nesting raptors are present in low densities along some rivers and at least one active peregrine falcon nest site has been located on the Kaolak River. Designation of a 15-mile (24-kilometer) radius around the identified nest would conflict with petroleum development in about 20 percent of the activity area. The entire area is used by caribou; about 15 percent of the area is within the recent calving grounds of the Western Arctic Herd, and about 75 percent of the activity area is used as winter range.

The activity area contains the village of Wainwright, and is relatively close to the villages of Atkasook and Barrow. These villages may realize increased economic opportunities, particularly to individuals in the event of petroleum development. Infrastructures in these villages might be adversely affected, especially their transportation facilities. The possibility and intensity of these effects would be dependent upon the actual location of development.

The activity area is important to subsistence. Caribou are regularly harvested over the entire activity area, and waterfowl and fish over about 60 percent of the area. The coast is important for marine mammal and waterfowl harvesting, particularly from Wainwright to Peard Bay. The Kuk River is important for subsistence fishing and as a traditional route for travel throughout the region. The entire activity area is currently used by Natives of Wainwright for subsistence, about 35 percent of the area by Natives of Point Lay, and about 20 percent of the area by Natives of Barrow.

Non-Federal surface ownership within this activity area is limited to 154,026 acres (62,226 hectares) within the village of Wainwright. This is about 10 percent of the activity area. One hundred nine Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands but have been appealed.

More than 100 sites in the activity area are recorded on the North Slope Borough's Traditional Land Use Inventories; more undoubtedly exist. Point Belcher has been nominated to the National Register of Historic Places. The barrier islands have been identified by the NPRA Land Use Study Team as needing full protection. Approximately 750 square miles (1,940 square kilometers) also has been identified by the study team as both a unique ecological area and an area of critical environmental concern. Both the Icy Cape area and the Kuk River area have been proposed as ecologic reserves. About 65 percent of the area possesses outstanding wilderness values. Kasegaluk Lagoon offers excellent recreation opportunities, including boating and wildlife viewing; excellent opportunities for waterfowl hunting exist over about 40 percent of the activity area.

Activity area D contains hypothetical and some subeconomic deposits of coal, but no other known mineral resources. Water availability is similar to that for activity area C; it is adequate except during late winter. Gravel resources are scarce within the activity area. Small amounts of poor quality occur in the western part. Gravel, however, is available from beach deposits at Point Belcher, about 5 miles (8 kilometers) to the west, and at Point Barrow, about 30 miles (48 kilometers) to the northeast.

About 40 percent of this activity area contains above-average densities of ducks, loons, and shorebirds. The Peard Bay area is particularly important to shorebirds and waterfowl during late summer-fall migration. Peard Bay also provides habitat for marine mammals; the coastal area receives some winter use by denning polar bears. In general, values associated with wildlife habitats decrease rapidly as one moves from the coastal area.

Caribou use the entire activity area as winter range and are dispersed here on summer range. Fisheries resources are not numerically large or diverse but are highly significant to subsistence users.

The activity area contains the village of Atkasook and is close to the villages of Wainwright, Barrow, and Point Lay. These villages might benefit economically from development within the area due to increased job opportunities and other related economic activities. The probability of development stressing existing infrastructure in these villages appears low, since exploration and development sites would probably be located away from these villages, and the development of independent facilities would be necessary.

The entire activity area is used extensively by Natives of Barrow and Wainwright for subsistence pursuits, and about 80 percent of the area by Natives of Atkasook. This is about 30 percent of the current

Development in certain areas of NPRA could further disrupt the habitat and reproductive success of the peregrine falcon, an endangered species. (John Burns, Alaska Department of Fish and Game)

Some villages, such as Wainwright, could expect limited economic opportunities from NPRA development. (C. D. Evans, AEIDC)

subsistence area used by Natives of Atkasook. It also contains the lower Meade River, which supports an extensive subsistence fishery. Caribou are harvested throughout late summer and winter, and about 60 percent of the area in the coastal region is utilized for harvesting waterfowl.

Non-Federal surface ownership is limited to 68,652 acres (27,735 hectares) at Atkasook. Fifty Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands but have been appealed.

Nine sites in the activity area are recorded in the North Slope Borough's Traditional Land Use Inventories; more likely exist. The central Meade River area has been proposed as an ecological reserve. Although much of the area is wilderness, it possesses few, if any, outstanding attributes. Recreational opportunities consist mainly of waterfowl hunting over about 35 percent of the area. Some archeological sites have been found, but none are of national significance.

Activity area E may contain mineral resources other than oil and gas. Water is readily available. Summer streamflow can be stored for winter use. The area contains numerous large, fairly deep lakes. Gravel resources are lacking in this area, but sand is abundant. The nearest sources of gravel are along the beaches and bars at Point Belcher and Point Barrow, about 70 miles (112 kilometers) north of the activity area, and along the Colville River, about 70 miles (112 kilometers) to the south. About 85 percent of the activity area has been used as winter range by the Western Arctic Caribou Herd in recent years, and some dispersed use occurs in summer. About 55 percent of the area provides good habitat for waterfowl and shorebirds.

Although this activity area contains no villages, it is close to Atkasook and relatively close to Barrow and Nuiqsut. Residents of these villages could expect some increased job opportunities and other related economic activities, if development were to occur. It is doubtful that development here would present any direct demands to the existing infrastructure of these villages, except perhaps in Atkasook.

About 70 percent of the activity area is currently utilized by Natives of Atkasook, and all of the area by Natives of Barrow for subsistence pursuits. Caribou are harvested over the entire activity area, ducks over about 50 percent of the area, and fish over about 30 percent of the area.

All surface is under Federal ownership. Twenty-one Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands but have been appealed.

There are more than 30 sites recorded in the North Slope Borough's Traditional Land Use Inventories; more sites are likely to exist. Only a small part of the activity area — about 10 percent — has outstanding wilderness attributes, and there are no outstanding recreational opportunities.

Activity area F contains hypothetical mineral resources other than oil and gas. Water is readily available. Summer streamflow can be stored for winter use. The area contains numerous large, fairly deep lakes. Gravel resources are lacking, but sand is abundant. The nearest sources of gravel are at Point Barrow, about 90 miles (144 kilometers) to the northwest, and along the Colville River, about 70 miles (112 kilometers) to the east.

About 15 percent of the activity area (in the north and northeast corner of the area) is within the important habitat around Teshekpuk Lake which supports high densities of waterfowl. The Teshekpuk Herd of caribou, which remains in the area year-round, ranges into about 10 percent of this activity area; the entire area is used as winter range by the Western Arctic Herd.

There are no villages in this activity area, but the area is relatively close to Barrow, Atkasook, and Nuiqsut. These villages might derive increased job opportunities from development in this area. Villagers could, conceivably, commute relatively easily between their villages and job sites. Development in this activity area would probably have only indirect negative effects on the area's infrastructure.

The entire activity area is used by Natives of Barrow for subsistence purposes. Caribou are harvested regularly over the entire activity area and ducks and fish over about 35 percent of the area. Areas along the Ikpikpuk and Chipp Rivers are heavily used.

All surface is under Federal ownership. Four Native allotment applications filed under the Native Allotment Act of 1906 have been rejected because of the reserved status of NPRA lands but have been appealed.

Although fewer than 20 sites in the activity area are recorded in the North Slope Borough's Traditional Land Use Inventories, more sites undoubtedly exist. About 45 percent of the activity area possesses outstanding wilderness attributes. However, recreational opportunities are limited. The activity area contains a significant section of the Ikpikpuk River corridor, which has been proposed as an ecologic reserve. Much of the activity area lies within Teshekpuk Special Area designated in P.L. 94-258.

Activy area G contains hypothetical deposits of mineral resources other than oil and gas. Water is available from deep lakes except in the southwest corner of the activity area. Some limited gravel resources are available along streams draining the foothills in the southern and western parts of this area. Generally, these gravel deposits are thin and not suitable for most uses. Gravel, however, is available along the Colville River, about 30 miles (48 kilometers) south of the activity area.

The wildlife resources are not outstanding. About 15 percent of the area is used by ducks and waterfowl. Some recent usage by moose has been recorded for the extreme southwest corner, and relatively diffuse summer and fall caribou migrations cross the area in a generally north-south pattern. One peregrine falcon nest has been located near the western boundary. Proposed designation of a 15-mile (24-kilometer) radius around the nest as critical habitat would affect about 20 percent of the area.

There are no villages in this activity area, but the area is relatively close to Barrow, Atkasook, and Nuiqsut. These villages might derive increased job opportunities from development in this area. Villagers could conceivably commute relatively easily between their villages and job sites. Development in this region would probably have only indirect negative effects on the area's infrastructure.

The entire activity area is used by Natives of Barrow for subsistence activities, although the intensity of the activities may be less than in adjacent areas. Caribou are harvested regularly, along with some fish and waterfowl.

All surface is under Federal ownership. One Native allotment application filed under the Native Allotment Act of 1906 has been rejected because of the reserved status of NPRA lands.

Although there are few sites in the activity area recorded in the North Slope Borough's Traditional Land Use Inventories, more sites undoubtedly exist. About 65 percent of the area has outstanding wilderness attributes. The entire western part of the area contains a major portion of the Ikpikpuk River corridor, which has been proposed as an ecologic reserve. Recreational opportunities include a potential for big-game hunting over about 10 percent of the area.

Activity area H may contain mineral resources other than oil and gas. Several subeconomic coal deposits have been identified, particularly in the southeastern corner of the area. Water is available throughout most of this activity area from numerous deep lakes. Adequate gravel resources occur along the Colville River on the eastern boundary. Additional gravel resources occur on river terraces in the vicinity of Nuiqsut, but excavation of this gravel would require thawing and removal of 3 to 10 feet (1 to 3 meters) of organic-rich overburden.

About 40 percent of this activity area is used as winter range by the Western Arctic Caribou Herd. Arctic fox and female polar bear make use of the excellent denning habitats in the Colville River Delta. The high-brush habitat along much of the Colville River on the eastern boundary provides for a moderate year-round density of moose. The river itself is an important summer habitat for many anadromous and resident fish species, and numerous deep pools along the channel provide valuable overwintering habitat for several species. The steep bluffs bordering the river on the west provide excellent habitat for cliff-nesting raptors. Eighteen peregrine falcon nest sites have been found along this stretch. Proposed designation of a 15-mile (24-kilometer) radius around each nest as critical habitat would affect more than 50 percent of the area.

The activity area contains no villages but is quite close to Nuiqsut. The residents of this village could experience increased economic opportunities if development occurred within this subregion. However, this village was reestablished in recent times by people coming from Barrow to preserve their Native culture. Development in this activity area would be very controversial.

The Colville River is an important area for arctic moose. (Grossmann-Granger Productions)

The activity area is utilized extensively by the people of Nuiqsut and Barrow for subsistence harvesting. Caribou are hunted throughout the activity area, particularly in late summer, early fall, and winter. Moose travel along the Colville River almost to Nuiqsut and are hunted extensively by residents of that village. The Colville River is extremely important in this activity area for production and subsistence harvest of fish. Many overwintering sites are located in this segment of the river and in many of the lakes throughout the region.

All surface is under Federal ownership. One Native allotment application filed under the Native Allotment Act of 1906 has been rejected because of the reserved status of NPRA lands but has been appealed. There are 12 sites in the activity area recorded in the North Slope Borough's Traditional Land Use Inventories; more sites undoubtedly exist. Two areas — the Colville River Delta and the Colville River bluffs — have been proposed as ecologic reserves. A small part of the northeast corner of the area falls within the Colville River Special Area as designated in P.L. 94-258. This same area is also part of the unique ecological area identified by the NPRA Land Use Study Team. The entire reach of the Colville River — comprising about 5 percent of the area — has outstanding wilderness values, and is suitable for float-boating. About 15 percent of the area in the northeast offers opportunities for waterfowl hunting, and about 10 percent of the area in the south offers opportunity for big-game hunting.

Activity area I contains hypothetical mineral resources other than oil and gas. Numerous subeconomic coal resource areas have been identified throughout the area. Water from lakes is quite limited in the southern and southeastern parts of the area, but large rivers, such as the Utukok, Kokolik and Koalak, have ample summer flows that could be stored for year-round use. Gravel resources are available from the flood plains and terraces of Utukok and Kokolik Rivers. Large quantities of frozen, sandy gravel are also present in the southwest corner of this area.

This activity area is a major part of the calving area of the Western Arctic Caribou Herd and is vital to the continued well-being of the herd. This calving area encompasses all of activity area I and extends into activity areas C, J, and M. Even minor development may prevent or delay caribou access to these calving grounds or cause significant disturbance to calving groups which would result in serious reduction of the herd. The southern half of the activity area also supports a population of as many as 100 grizzly bears. Numerous ptarmigan are present. At least two active peregrine falcon nests are present along the Utukok River; other cliff-nesting raptors also use the area. Proposed designation of a 15-mile (24-kilometer) radius around each nest as critical habitat would affect petroleum development in about 15 percent of the area.

Because this activity area contains a significant reach of the Utukok River and is the regular site for calving of the Western Arctic Herd of caribou, it is of extreme importance to all peoples of northern Alaska. It also contains the headwaters of the Colville River, where significant fish spawning and some overwintering occurs.

Wainwright and Point Lay, the closest traditional villages, could expect only a minimal increase in economic opportunity from development in this activity area because they are distant from the possible work sites. The entire activity area is used by Natives of Wainwright for subsistence harvest, and about 50 percent of the area by Natives of Point Lay. Lay.

All surface is under Federal ownership.

There are more than 20 sites in this activity area recorded in the North Slope Borough's Traditional Land Use Inventories; many more are known to exist, especially along the Utukok River. Two sites in the southeast corner have been nominated to the National Register of Historic Places. The upper part of the Kuk-Utukok River corridor, proposed as an ecologic reserve, is in this activity area. Most of the activity area is within the Utukok Special Area as designated in P.L. 94-258. The activity area also is a major part of a unique ecological area identified by the NPRA Land Use Study Team. The entire area possesses outstanding wilderness values. The upper three-fourths of the Utukok River has been recommended by the Administration for designation as a Wild River. Recreation opportunities include float-boating, big-game hunting over about 35 percent of the area, and hiking and backpacking over about 10 percent of the area.

Activity area J contains hypothetical deposits of minerals other than oil and gas. Numerous subeconomic coal deposits have been identified throughout the area. Water from lakes is very limited. The Meade and Avalik Rivers have ample summer flows that could be stored for year-round use. Gravel resources are lacking. Gravel is available, however, along the Utukok River about 40 miles (65 kilometers) to the west and along the Colville River about 25 miles (34 kilometers) to the south.

About 35 percent of this area is within the calving area of the Western Arctic Herd. The entire activity area receives some use by caribou during spring migrations and as summer range. Numerous ptarmigan are present. Some cliff-nesting raptors are present in the southern part of the area.

This activity area contains no villages and is relatively isolated from them. Thus, development would bring few economic opportunities to these villages. Travel to and from work sites and home villages would be difficult.

This activity area is not as extensively used for subsistence purposes as others, except in unusual years when game cannot to found elsewhere. About 80 percent of the area is used by Natives of Wainwright, about 50 percent by Natives of Atkasook, and about 45 percent by Natives of Barrow.

All land surface is under Federal ownership.

Although there are few sites in this activity area recorded in the North Slope Borough's Traditional Land Use Inventories, more sites likely exist.

The western part of this activity area is an extension of the Special Areas in activity area I. About 70 percent of the area possesses outstanding wilderness values, and about 35 percent offers recreational opportunities for big-game hunting.

Activity area K may contain mineral resources other than oil and gas; numerous subeconomic coal resource areas have been identified throughout the area. Water is available from lakes in the extreme northern part of the area. The Colville, Awuna, Kigalik and Titaluk Rivers have ample summer flows that could be stored for year-round use. Adequate gravel resources probably exist along the Colville River in this activity area. Additional gravels also occur along the Colville River to the east.

Caribou of the Western Arctic Herd utilize parts of the activity area as summer range. Numerous ptarmigan are present. Although no active peregrine falcon nests have been identified in this activity area, critical habitat zones based on a 15-mile (24-kilometer) radius around known nest sites in areas G, L, and O to the east and south would affect about 20 percent of this activity area. The activity area is relatively isolated from villages of the North Slope. About 90 percent of the area is occasionally used for subsistence hunting by Natives of Barrow. The Colville River in this activity area has important subsistence fisheries.

The land surface is under Federal ownership.

The section of the Colville River along the south boundary of this activity area is part of the Colville River Special Area designated in P.L. 94-258. It is also part of the area proposed as an ecological reserve, as well as part of the Colville River that has been recommended by the Administration for designation as a Wild River. About 90 percent of the area has outstanding wildlife attributes, and about 45 percent of the area offers recreational opportunities for big-game hunting. Limited opportunities for hiking and backpacking also exist, and the Colville River offers excellent opportunities for float-boating.

Activity area L may contain mineral resources other than oil and gas. Numerous subeconomic coal resource areas have been identified throughout the area. Water from lakes is very limited. Maybe Creek, Prince Creek, and the Colville River have summer flows that could be stored for year-round use. Abundant gravel resources are available along the Colville River.

The Colville River flood plain and adjacent areas support the highest moose density on NPRA, as well as a moderate density of wolves. The river is a major pathway for migrating fish and year-round habitat for resident species. Caribou utilize about 80 percent of the activity area as summer range. Numerous ptarmigan are present. The bluffs of the Colville River along the south boundary of this activity area contain a high density of rough-legged hawk, golden eagle, and gyrfalcon nest sites. There are at least 34 peregrine falcon nest sites in this reach of the river. Proposed designation of a 15-mile (24-kilometer) radius around each nest as critical habitat would affect more than 70 percent of the area.

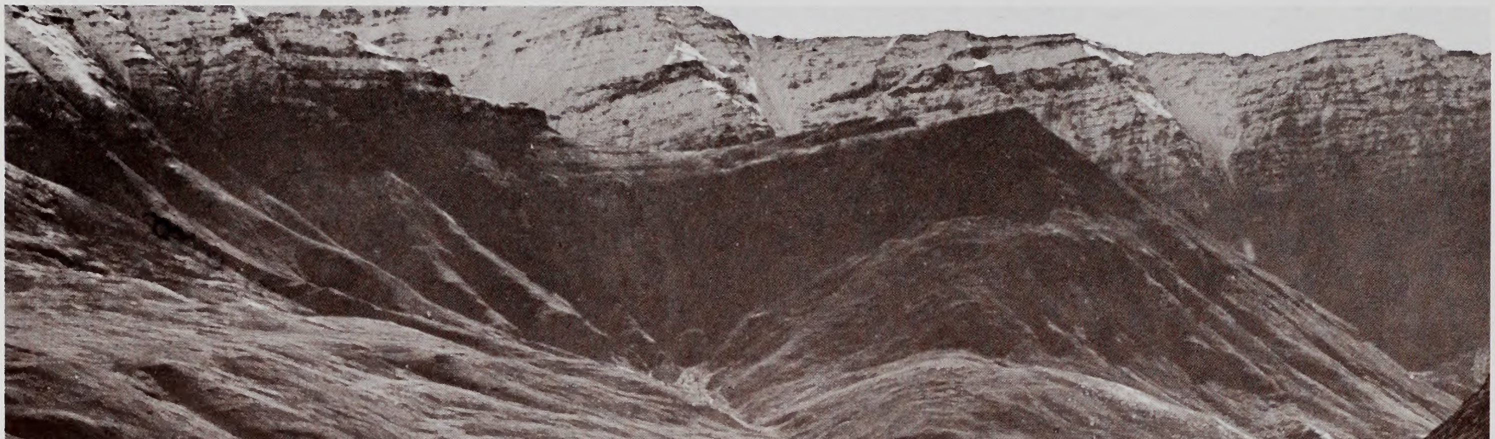
The activity area contains a nearly abandoned exploration camp at Umiat which has a functioning airport and could be utilized in the event of development. The activity area lies relatively close to the villages of Nuiqsut and Anaktuvuk Pass, and residents of these villages might experience some increase in job opportunities and development-related economic activities.

The activity area also contains a significant portion of the Colville River and is important to year-round subsistence fisheries. Residents of Barrow use almost the entire activity area extensively for subsistence activities. Residents of other villages utilize the area less intensely for trapping and furbearer hunting.

The land surface is under Federal ownership. One Native allotment application filed under the Native Allotment Act of 1906 has been rejected because of the reserved status of NPRA lands but has been appealed.

Although there are few sites in the activity area recorded in the North Slope Borough's Traditional Land Use Inventories, more sites undoubtedly exist. Approximately half of the activity area lies within the Colville River Special Area as designated in P.L. 94-258. This reach of the Colville River is also part of that are identified as a unique ecological area by the NPRA Land Use Study Team, as well as part of the river reach recommended by the Administration for designation as a Wild River. Parts of the river are included in two proposed ecologic reserves. Two sites in the activity area have been nominated to the National Register of Historic Places. The overall area,

Although the village of Anaktuvuk Pass is located outside NPRA, its residents utilize the area for subsistence purposes. (J. C. LaBelle, AEIDC)



especially along the Colville River, has outstanding wilderness value and is currently used for float-boating, hiking and backbacking, and big-game hunting.

Activity area M has good potential for both metallic and nonmetallic mineral resources; about 20 percent of the area has a high potential for lead and barium. Transportation facilities associated with petroleum development could facilitate development of these minerals. Water from lakes is very limited, but the Utukok, Nuka, and Colville Rivers have adequate summer flows that could be stored for year-round use. Large gravel resources occur along both the Utukok and the Colville Rivers in this activity area.

The activity area is very important to wildlife. About 60 percent of the activity area is part of the calving area for the Western Arctic Herd. The north-western portion in particular is heavily used by calving groups in most years. The southern two-thirds of the activity area is commonly heavily used by caribou during both precalving and postcalving migrations. Postcalving migration frequently involves rapid west-to-east movements by extremely large groups of animals, involving much of the entire population. This activity area ranks with activity area I in its importance to caribou. Grizzly bear are abundant in about 40 percent of the area. Numerous ptarmigan are present.

The De Long Mountains along the southern boundary of this activity area contain relatively low numbers of Dall sheep. These sheep, as well as wolves and other large mammals in the southern part of the activity area, have ranges extending into the Noatak National Monument. Designation of a 15-mile (24-kilometer) radius around peregrine falcon nesting sites in activity area I as critical habitat would affect about 12 percent of this activity area.

This activity area contains no traditional villages but is relatively close to Anaktuvuk Pass, where residents might experience some improved economic benefits from development.

About 90 percent of the activity area is currently used by the residents of Wainwright for subsistence purposes. Caribou, Dall sheep, grizzly bear, and moose, as well as furbearers and small game species, are regularly harvested throughout the area. Residents of Wainwright, Barrow, Point Lay, and Anaktuvuk Pass hunt this activity area occasionally in winter for fur-bearing animals.

The land surface is under Federal ownership. One Native allotment application filed under the Native Allotment Act of 1906 has been rejected because of the reserved status of NPRA lands but has been appealed.

Although there are no sites in this activity area recorded in the North Slope Borough's Traditional Land Use Inventories or on the National Register, such sites undoubtedly exist.

The northern half of this activity area is part of the Utukok River Special Area designated in P.L. 94-258. One site at Noluck Lake has been proposed as an ecologic reserve, and two sites in the area have been nominated to the National Register of Historic Places. The entire area possesses outstanding wilderness values and offers excellent recreational opportunities. Reaches of the Colville and Utukok Rivers in this activity area are included in recommendations of the Administration for designation of these two rivers as Wild Rivers. The De Long Mountains within this activity area offer some of the best recreation opportunities in NPRA, including backpacking, float-boating, camping, wildlife viewing, and big-game hunting.

Activity area N has a good potential for both metallic and nonmetallic mineral resources; about 40 percent of the area has a high potential for lead, zinc, and barium. Transportation facilities associated with petroleum development could facilitate development of these minerals. The Colville River has ample summer flow that could be stored for year-round use. Gravel resources are abundant along the Colville River and its tributaries.

Importance of this activity area for use by precalving and postcalving migrating caribou is similar to, but slightly less than for, activity area M.

The De Long Mountains along the southern boundary contain relatively low numbers of Dall sheep. These sheep, as well as wolves and other large mammals in the southern part of this activity area, have ranges extending into the Noatak National Monument. There are five known peregrine nesting sites in this activity area. Numerous ptarmigan are present. Designation of a 15-mile (24-kilometer) radius around these nesting sites as critical habitat would affect about 60 percent of the activity area.

This activity area contains no traditional villages but is relatively close to Anaktuvuk Pass and Point Lay, where residents might experience some economic benefits if development occurred in this subregion.

About half of the activity area is used by residents of Wainwright for subsistence purposes. Residents of Wainwright, Barrow, Point Lay, and Anaktuvuk Pass hunt this activity area infrequently in winter for fur-bearing animals.

The land surface is under Federal ownership.

Although there are few sites in this activity area recorded in the North Slope Borough's Traditional Land Use Inventories, more sites undoubtedly exist. The Colville River, which passes through this activity area, is part of the Colville River Special Area designated by P.L. 94-258, as well as part of that area identified as a unique ecological area by the NPRA Land Use Study Team. This reach of river is also included in the Administration recommendation for designation of the Colville River as a Wild River. Four sites in this activity area have been nominated to the National Register of Historic Places. The entire area possesses outstanding wilderness values and offers recreational opportunities for float-boating, backpacking, wildlife viewing, and big-game hunting.

Activity area O has a good potential for both metallic and nonmetallic mineral resources; about 55 percent of the area has a high potential for lead, zinc, and barium. The activity area includes one known area of significant lead-zinc mineralization. Transportation facilities associated with petroleum development could facilitate development of these minerals. Water is available from a few scattered lakes. The Colville, Nigu and Etivluk Rivers have ample summer flows that could be stored for year-round use. Gravel resources are abundant along the Colville River channel and its tributaries.

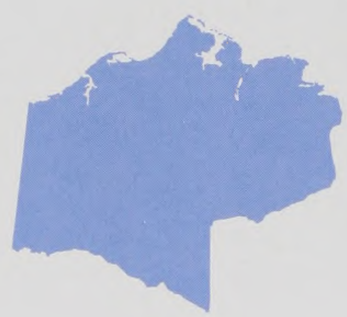
Caribou use this activity area each year during precalving and postcalving migrations through the mountain passes. Some caribou also use this activity area as summer range. Riparian areas along the Colville River comprise the major part of the winter moose habitat on NPRA, although densities of moose are not as high here as in portions of the Colville River in activity area L. Numerous ptarmigan are present. There are 15 known peregrine nesting sites in this activity area. Designation of a 15-mile (24-kilometer) radius around peregrine falcon nesting sites in area I as critical habitat would affect more than 60 percent of the area.

This activity area contains no traditional villages, but it is relatively close to Anaktuvuk Pass, where residents might experience some improved economic benefits if development were to occur in this activity area.

About 20 percent of the activity area is currently used by the residents of Anaktuvuk Pass for subsistence purposes. Caribou, Dall sheep, grizzly bear, and moose are regularly harvested throughout the activity area, as well as furbearers and small game species. Residents of Wainwright, Barrow, Point Lay, and Anaktuvuk Pass also utilize the activity area infrequently in winter for trapping fur-bearing animals.

The land surface is under Federal ownership.

The reach of the Colville River in this activity area is included in the Administration recommendation for designation of a major part of the Colville River as a Wild River. Five sites in this activity area have been nominated to the National Register of Historic Places. Additional sites for inclusion in the National Register or TLUI undoubtedly exist. The area possesses outstanding wilderness values. The De Long Mountains, Colville River, and the Nigu-Etivluk River in this activity area offer some of the best recreation opportunities in NPRA, including backpacking, float-boating, wildlife viewing, and sports hunting.



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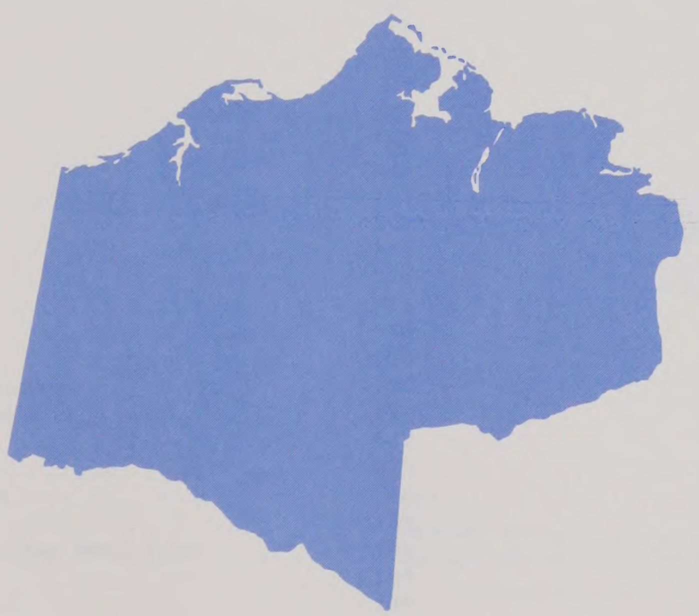
Appendix A

Description of the Environment



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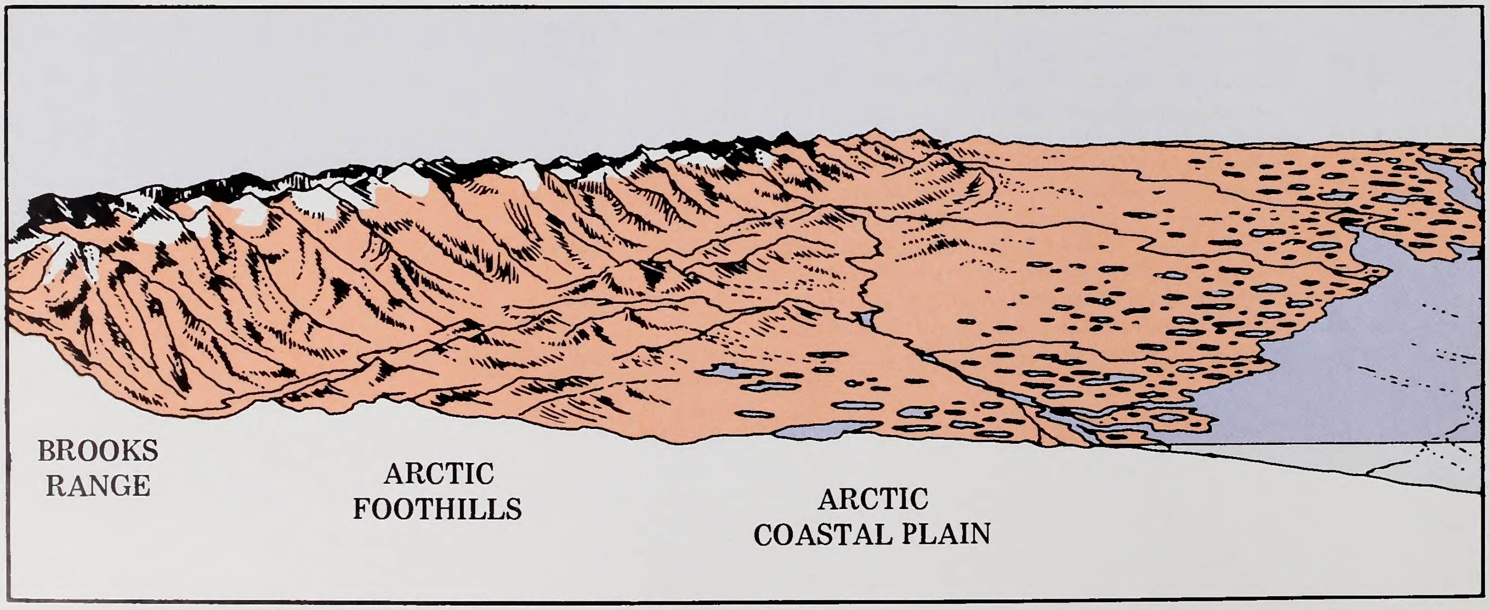
(*Insert map follows designated page)

Tables

NPRA encompasses the three major physiographic provinces illustrated below. (AEIDC)



I. National Petroleum Reserve in Alaska (NPRA)

The National Petroleum Reserve in Alaska (NPRA) is a 37,000-square-mile (95,800-square-kilometer) area of the North Slope, lying between the crest of the Brooks Range and the Arctic Ocean. The North Slope Native people, the Inupiat, inhabit and base their subsistence culture in this region. Barrow serves as the seat of the North Slope Borough and the Arctic Slope Regional Corporation. Near Barrow is the Naval Arctic Research Laboratory, a base for scientific research on the arctic environment. Prudhoe Bay and the trans-Alaska pipeline lie 60 miles (96 kilometers) east of the Reserve.

Because of the scale of the maps in this appendix, it is not possible to show all locations mentioned in the text. Places not shown may be located on the standard maps of the U.S. Geological Survey, or in the Dictionary of Alaska Place Names (Orth, 1967).

This description of the NPRA environment is based upon data from several key sources. It is an abbreviated description designed to provide an overview of the area. The principal references from which this description was compiled are 1) the Alaska Regional Profiles, Volume II, compiled by the Arctic Environmental Information and Data Center of the University of Alaska (1975), 2) the physical, ecological, and socioeconomic profiles compiled by the NPRA 105(c) Land Use Planning Team (1978a, b, c), and 3) the Field Studies prepared by the Work Groups of the NPRA 105(c) Task Force (drafts of 1977 and 1978 studies on file with the NPRA 105(c) Study Office in Anchorage; to be published in 1979).

A. Physical Environment

1. Physiography

NPRA encompasses three physiographic provinces — the Arctic Coastal Plain, the Foothills, and Brooks Range — as shown in figure A-1. The ice pack in the Arctic Ocean is also an important physiographic unit because of its bearing on the climate, marine fauna, and human population of the Reserve.

Ice normally covers the Beaufort Sea 10 months a year and frequently longer. The Beaufort Sea currents force the ice shoreward, producing a great expanse of shorefast ice in the winter. This ice pack extends the land boundary seaward for much of the ice-cover period.

Ice cover on the Chukchi Sea lasts 7 to 8 months each year. The north- and east-flowing currents keep the winter sea ice moving, resulting in areas of open water. These open waters provide favorable conditions for marine mammals; and they, in turn, are important to Natives who depend on these animals for subsistence.

In years of maximum sea-ice retreat, the polar pack lies well north and west of the Chukchi Sea coast but only 30 to 40 miles (48 to 65 kilometers) north of the Beaufort Sea coast. In some years, however, some shorefast ice remains throughout the summer.

Ice in both seas occurs in three major zones: 1) seasonally forming, but relatively stable landfast ice, 1 to 6 feet (0.3 to 2 meters) thick; 2) the offshore bank of ice known as the shear zone, 6 to 13 feet (2 to 4 meters) thick; and 3) the seasonal and multi-year pack ice, 6 to 12 feet (2 to about 4 meters) thick.

The Arctic coastal plain is an area of low relief comprising nearly half of NPRA. It extends inland from the beaches and sea cliffs along the Chukchi and Beaufort Seas to the base of the foothills at an altitude of about 500 feet (150 meters). Relief is provided by gentle rises that are erosional remnants of ancient wave-cut cliffs, by fresh and ancient riverbanks that are generally less than 40 feet (12 meters) high, and by pingos, ice-cored circular hills. Innumerable thaw lake basins lie as much as 30 feet (10 meters) below the general level of the plain. The principal rivers that flow across the plain are the Colville, Ikpikpuk, Topagoruk, Meade, Kuk, and Utukok. All except the Kuk flow in incised channels across most of the coastal plain and empty into the sea or an embayment through deltas. The Kuk River is a drowned estuary at the confluence of the Avalik and Kaolak Rivers.

The Foothills province is as much as 125 miles (200 kilometers) wide, extending as a band of hills between the Brooks Range and the coastal plain. East-trending tundra-covered ridges and broad valleys express the underlying broad folds in the bedrock. The Colville River flows east across the Foothills province; almost all the north-flowing streams from the Brooks Range are its tributaries. In the eastern part of NPRA the Colville flows northeast across the Foothills and Coastal Plain provinces, forming the eastern boundary of the Reserve. The Utukok and Kokolik Rivers are the only other rivers that flow across the Foothills province. Because of this pattern of stream valleys, little sand and gravel has been deposited in the northern foothills or on the coastal

Table A-1. Major Habitat Associations of Fish and Wildlife on or Adjacent to NPRA

Common Name	Scientific Name	Marine and Coastal	Tussock-Moist Tundra	Alpine Tundra	Wet Sedge Tundra	High Brush
Mammals						
Masked shrew	*Sorex cinereus*		●	●	●	
Arctic shrew	*S. arcticus*		●		●	●
Dusky shrew	*S. obscurus*		●			●
Hoary marmot	*Marmota caligata*			●		
Arctic ground squirrel	*Spermophilus parryii*		●	●		●
Brown lemming	*Lemmus sibiricus*		●		●	
Collared lemming	*Dicrostonyx torquatus*		●	?	●	
Northern red-backed vole	*Clethrionomys rutilus*		●	●		●
Tundra vole	*Microtus oeconomus*		●			●
Singing vole	*M. gregalis*			?		●
Gray wolf	*Canis lupus*		●	●		●
Arctic fox	*Alopex lagopus*	●			●	
Red fox	*Vulpes vulpes*		●	●		●
Grizzly bear	*Ursus arctos*		●	●		●
Polar bear	*U. maritimus*	●				
Ermine	*Mustela erminea*		●	●	●	●
Least weasel	*M. nivalis*		●	●	●	●
Wolverine	*Gulo gulo*		●	●		●
Caribou	*Rangifer tarandus*		●	●	●	●
Moose	*Alces alces*				●	●
Dall sheep	*Ovis dalli*			●		
Muskox	*Ovibos moschatus*		?			?
Tundra hare	*Lepus othus*		?			?
Beluga	*Delphinapterus leucas*	●				
Narwhal	*Monodon monoceros*	?				
Killer whale	*Orcinus orca*	?				
Harbor porpoise	*Phocoeana phocoena*	?				
Gray whale	*Eschrichtius robustus*	?				
Fin whale	*Balaenoptera physalus*	?				
Sei whale	*B. borealis*	?				
Little piked whale	*B. acutorostrata*	?				
Hump-backed whale	*Megaptera novaengliae*	?				
Bowhead whale	*Balaena mysticetus*	●				
Northern fur seal	*Callorhinus ursinus*	?				
Northern sea line	*Eumetopias jubata*	?				
Walrus	*Odobenus rosmarus*	●				
Harbor seal	*Phoca vitulina*	?				
Ribbon seal	*P. fasciata*	?				
Ringed seal	*P. hispida*	●				
Bearded seal	*Erignathus barbatus*	●				
Fish						
Arctic lamprey	*Lampetra japonica*		?	?	?	?
Arctic cisco	*Coregonus autumnalis*	●	●	●	●	●
Bering cisco	*C. laurettae*	●				
Broad whitefish	*C. nasus*		●	●	●	●
Humpback whitefish	*C. pidschian*		●	●	●	●

Table A-1. Major Habitat Associations of Fish and Wildlife on or Adjacent to NPRA (continued)

Common Name	Scientific Name	Marine and Coastal	Tussock-Moist Tundra	Alpine Tundra	Wet Sedge Tundra	High Brush
Fish (Continued)						
Least cisco	*C. sardinella*		•	•	•	•
Pink salmon	*Oncorhynchus gorbuscha*	•	•	•	•	•
Chum salmon	*O. keta*	•	•	•	•	•
Round whitefish	*Prosopium cylindraceum*		•	•		•
Arctic char	*Salvelinus alpinus*	•	•	•		•
Lake trout	*S. namaycush*		•	•	•	•
Inconnu	*Stenodus leucichtys*		?	?	?	?
Arctic grayling	*Thymallus arcticus*		•	•	•	•
Pond smelt	*Hypomesus olidus*		?	?	?	?
Capelin	*Mallotus villosus*	•				
Rainbow smelt	*Osmerus mordax*	•				
Alaska blackfish	*Dallia pectoralis*		•		•	
Northern pike	*Esoc lucius*		•	•	•	•
Longnose sucker	*Catostomus catostomus*		•	•		•
Arctic cod	*Boreogadus saida*	•				
Pacific cod	*Gadus macrocephalus*	•				
Burbot	*Lota lota*		•	•	•	•
Saffron cod	*Eleginus gracilis*	•				
Ninespine stickleback	*Pungitius pungitius*		•	•	•	•
Pacific sand lance	*Ammodytes hexapterus*	•				
Pacific ocean perch	*Sebastes alutus*	•				
Whitespotted greenling	*Hexagrammos stelleri*	•				
Pacific herring	*Clupea harengus pallasi*	•				
Slimy sculpin	*Cottus cognatus*		•	•	•	•
Fourhorn sculpin	*Myoxocephalus quadricornis*	•			•	
Striped seasnail	*Liparis liparis*	•				
Arctic flounder	*Liopsetta glacialis*	•			•	
Starry flounder	*Platichythys stellatus*	•				
Birds						
Yellow-billed loon	*Gavia adamisii*	•			•	
Arctic loon	*G. arctica*	•			•	
Red-throated loon	*G. stellata*	•			•	
Whistling swan	*Olor columbianus*				•	
White-fronted goose	*Anser albifrons*		•		•	
Black brant	*Branta bernicla*	•	•		•	
Canada goose	*B. canadensis*	•	•	•	•	•
Lesser snow goose	*Chen caorulescaens*	•	•		•	
Pintail	*Anas acuta*		•		•	
Mallard	*A. platyrhynchos*		•		•	
Green-winged teal	*A. crecca*		•		•	
American pidgeon	*A. americana*		•		•	
Shoveler	*A. clypeata*		•		•	
Oldsquaw	*Clangula hyemalis*	•	•		•	
Steller's eider	*Polysticta stelleri*	•	•		•	
King eider	*Somateria spectabilis*	•	•		•	
Common eider	*S. mollissima*	•	•		•	

Table A-1. Major Habitat Associations of Fish and Wildlife on or Adjacent to NPRA (continued)

Common Name	Scientific Name	Marine and Coastal	Tussock-Moist Tundra	Alpine Tundra	Wet Sedge Tundra	High Brush
		Birds (Continued)				
Spectacled eider	*S. fischeri*	●	●		●	
Red-breasted merganser	*Mergus serrator*	●	●		●	
Lesser scaup	*Aythya affinis*	●	●		●	
Greater scaup	*Aythya marila*	●	●		●	
Common scoter	*Melanitta nigra*	●	●		●	
Surf scoter	*M. perspicillata*	●	●		●	
Rough-legged hawk	*Buteo lagopus*			●		●
Golden eagle	*Aquila chrysaetos*			●		●
Gyrfalcon	*Falco rusticolus*			●		●
Peregrine falcon	*F. peregrinus*			●		●
Snowy owl	*Nyctea scandiaca*		●	●	●	
Short-eared owl	*Asio flammeus*			●		●
Willow ptarmigan	*Lagopus lagopus*		●		●	
Rock ptarmigan	*L. mutus*		●	●		
Sandhill crane	*Grus canadensis*		●		●	
Western sandpiper	*Calidris mauri*		●		●	
Semipalmated sandpiper	*C. pusilla*		●	●	●	
Baird's sandpiper	*C. bairdii*		●	●	●	
Pectoral sandpiper	*C. melanotos*		●		●	
Dunlin	*C. alpina*		●		●	
Semipalmated plover	*Charadrius semipalmatus*		●	●	●	●
American golden plover	*Pluvialis dominica*		●	●	●	
Black-bellied plover	*P. squatarola*		●	●	●	
Red phalarope	*Phalaropus fulicarius*	●	●		●	
Northern phalarope	*P. lobatus*	●	●		●	
Long-billed dowitcher	*Limnodromus acolopacous*		●		●	
Ruddy turnstone	*Arenaria interpres*		●	●	●	
Bar-tailed godwit	*Limosa lapponica*		●	●		
Whimbrel	*Numenius phaeopus*		●	●		
Common snipe	*Capella gallinago*		●		●	
Spotted sandpiper	*Actitis macularia*		●		●	
Buff-breasted sandpiper	*Tryngites subruficollis*		●		●	
Parasitic jaeger	*Stercorarius parasiticus*	●	●	●	●	●
Pomarine jaeger	*Stercorarius pomarinus*	●	●		●	
Long-tailed jaeger	*S. longicaudus*	●	●	●		
Glaucous gull	*Larus hyperboreus*	●	●		●	
Sabine's gull	*Xema sabini*	●	●		●	
Black-legged kittiwake	*Rissa tridactyla*	●	●		●	
Arctic tern	*Sterna paradisaea*	●	●		●	
Common raven	*Corvus corax*		●			●
Robin	*Turdus migratorius*		●			●
Grey-cheeked thrush	*Catharus minimum*		●			●
Wheatear	*Oenanthe oenanthe*		●			●
Bluethroat	*Luscinia avacica*		●			●
Arctic warbler	*Phylloscopus borealis*		●			●
Yellow wagtail	*Motacilla flava*		●	●		●
Water pipit	*Anthus spinoletta*		●	●		●

Table A-1. Major Habitat Associations of Fish and Wildlife on or Adjacent to NPRA (continued)

Common Name	Scientific Name	Marine and Coastal	Tussock-Moist Tundra	Alpine Tundra	Wet Sedge Tundra	High Brush
Birds (Continued)						
Northern shrike	*Lanius excubitor*		•			•
Wilson's warbler	*Wilsonia pusilla*		•			•
Hoary redpoll	*Carduelis hornemanni*		•	•		•
Savannah sparrow	*Passerculus sandwichensis*		•	•		•
Tree sparrow	*Spizella arborea*		•			•
White-crowned sparrow	*Zonotrichia leucophrys*		•			•
Fox sparrow	*Passerella iliaca*		•			•
Lapland longspur	*Calcarius lapponicus*		•	•		•
Snow bunting	*Plectrophenax nivalis*		•	•		•

plain. Most streams are braided and occupy broad flood plains. In winter these flood plains are normally covered by sheets of ice; spring ice jams in the channels frequently cause flooding, which, in turn, may cause gravel deposition.

North of the Colville River the east-trending hills are low, and the valleys are wide. Most of the streams flow east or west for long distances before cutting north through the hills and flowing onto the coastal plain. Numerous lakes lie north of the gradational boundary between the Foothills and the Coastal Plain provinces.

The Brooks Range province, which includes the De Long Mountains and the Central Brooks Range, extends 10 to 20 miles (16 to 32 kilometers) inside the NPRA southern boundary. Rugged terrain and steep mountain slopes characterize the Central Brooks Range, but broad valleys extend to the north. The entire area is north of treeline. Summit elevations are highest in the east, ranging from about 4,000 to 5,600 feet (1,200 to 1,700 meters). The eastern three-fourths of the province is drained by north-flowing tributaries of the Colville River. The western quarter of the province is drained by the Utukok and Kokolik Rivers.

2. Geology

a. Bedrock Geology

The geology of NPRA is shown in figure A-2. The rocks in the southern mountainous part of NPRA are mainly limestone, dolomite, chert, diabase, phyllite, sandstone, and conglomerate of Paleozoic age. They are part of the Brooks Range geanticline, which is characterized by uplifted, folded, and faulted rock structures.

The southern foothills of the range and the De Long Mountains encompass a geologic zone termed the disturbed belt. The main geological features are numerous shallow thrust faults in rocks of Paleozoic age and in wackes, shales, and conglomerates of Mesozoic age.

The rocks in the northern foothills are mainly wackes, sandstone, coals, and conglomerate of Cretaceous age, folded into broad Appalachian-type folds. The latter area is sometimes referred to as the Colville geosyncline.

Bedrock in the northern one-third of NPRA occupies a broad, structurally high zone formed mainly by the Barrow arch; this feature is oriented approximately northwest and encompasses other structural features including the Meade River arch, the Arctic platform and the Romanzof uplift. Bedrock is chiefly flat-lying sandstone, shale, siltstone and coal of the Nanushuk Group, which is exposed along the axis of the Meade River arch; and shale, siltstone, bentonitic clay, coal, and sandstone of the Colville Group, which occupies basins on either side of the Barrow arch. These stratigraphic groups, of Lower and Upper Cretaceous age, respectively, are discontinuously exposed along the Chukchi Sea coastline from Skull Cliff to near Icy Cape, on rivers west of the Meade River, and on the Colville River and two of its western tributaries. Bedrock is not exposed along the Beaufort Sea coast but is present about 100 feet (30 meters) below sea level at Barrow.

Bentonitic clay of the Colville Group is a swelling clay (montmorillonite). It is the major unstable unit in bedrock bluffs and is subject to debris flows and landsliding.

A more detailed summary of the bedrock geology within NPRA is given in the Environmental Impact Statement prepared by the U.S. Department of the Navy (1977).

b. Surficial Geology

The surficial geology of NPRA is shown in figure A-3.

Linear ridges, in the southern part of the arctic foothills south of the Colville River, stand above a rolling tundra plain. (J. C. LaBelle, AEIDC)

i. Mountains and Foothills

In middle or early Pleistocene time, a piedmont-type glacier covered a substantial portion of the northern slope of the western Brooks Range within NPRA and extended into the northern foothills of the range. Where the range peaks are at lower elevations in the west, the ice was more restricted in areal extent. The glacier did not extend into the lower areas west of the Utukok River drainage basin. Till deposited by this ice sheet has been extensively eroded, leaving resistant erratics scattered on bedrock. The abrasive action of the ice sheet produced the low, rounded hills and ridges and the broad valleys that extend north from the higher areas of the Brooks Range. Remnants of Pleistocene gravel outwash terraces, deposited by streams carrying meltwaters, are generally 100 to 200 feet (40 to 60 meters) above the present streams and rivers.

Remnant terraces are present along the major north-flowing tributaries of the Colville River, as well as along the Colville River itself. In earlier geologic times the Colville River extended as far west as Driftwood Creek, where ancestral Colville River terrace gravels are perched more than 500 feet (150 meters) above the present river valley. The geology and geomorphology of the Driftwood area indicate that the ancestral Colville River was cut off or beheaded once by the Kokolik River and subsequently by the Utukok River. In the future it may be beheaded again by a north-flowing tributary of Disappointment Creek.

Although not draining glaciated terrain, the Kokolik River is also bordered by similar gravel terraces. However, these alluvial terraces may have been derived from a beach gravel at the inland margin of the coastal plain at an elevation of 400 to 500 feet (120 to 150 meters).

Late Pleistocene glaciation is represented only in the southeast corner of NPRA, where ice reached down the Nigu River valley a short distance beyond the mountain front, and in the headwaters of Driftwood Creek, where two very small exposures of till are associated with fresh cirques. Most of the area on the range's north slope within NPRA was at elevations too low to nourish glaciers during Late Pleistocene time, and the area was probably in the precipitation shadow of a southerly moisture source.

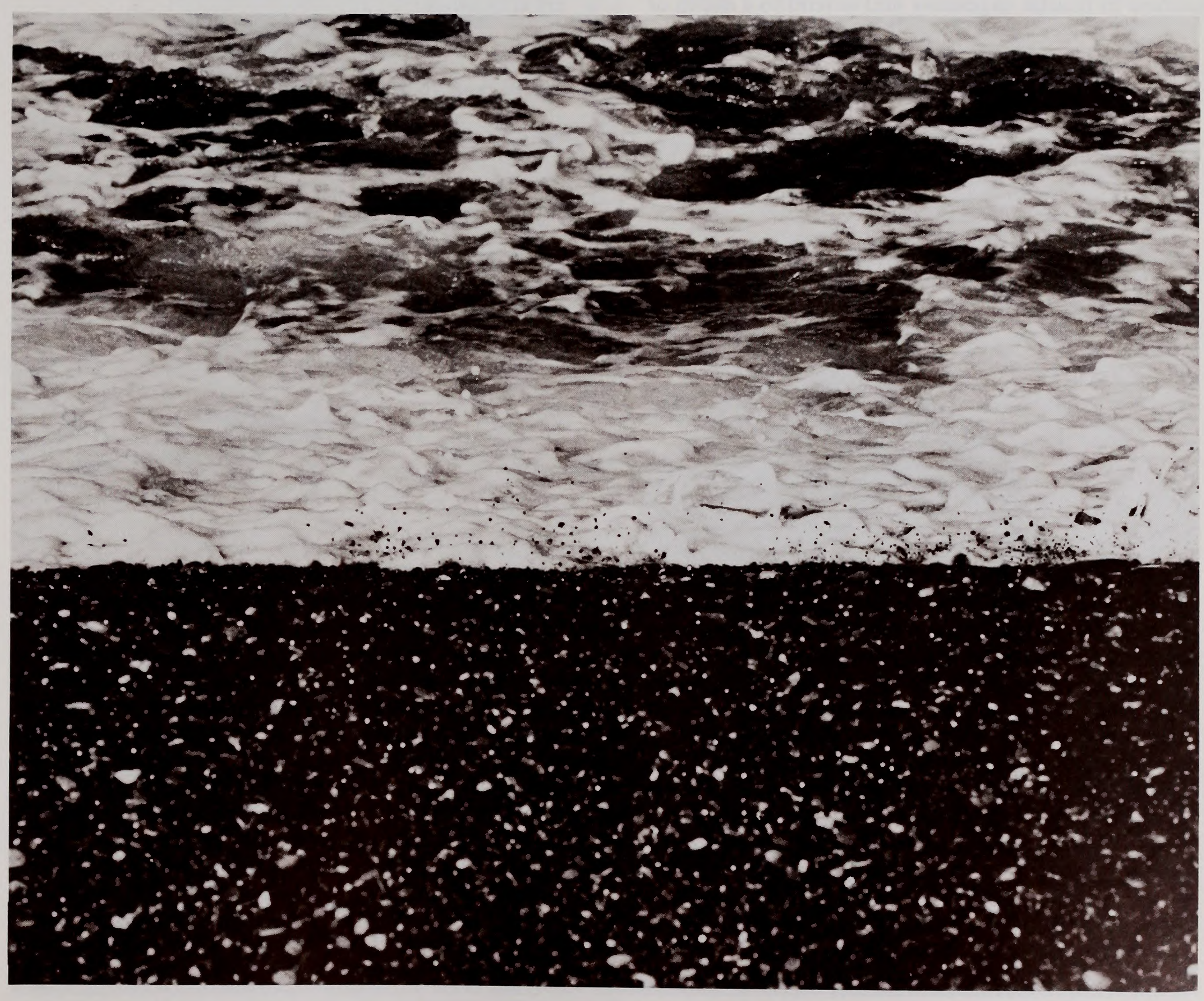
Surficial deposits are generally absent from much of the low foothills portion of NPRA north of the Colville River, except where they occur as a 3- to 10-foot (1- to 3-meter) thick weathered zone. The inland boundary of unconsolidated sediments of the coastal plain grades imperceptibly into the weathered zone of the low foothills. The contact zone is at an elevation of about 500 feet (150 meters) throughout much of the area. However, in the areas bounded by the Utukok and Meade Rivers, bedrock and the weathered zone are present at the surface with few coastal plain deposits north to an elevation low of about 100 feet (33 meters).

Landslide deposits are not common in the foothills in NPRA. However, talus and block rubble are found at the base of some of the high ridges and hogbacks, such as Meat Mountain. In the warmer months, earthflows, slumps, and soil and debris flows occur on riverbanks and on south-facing slopes. Solifluction, the creeping downslope movement of surface materials, occurs sporadically but is apparently not a dominant process in slope lowering as it is in areas south of the Brooks Range.

ii. Coastal Plain

The unconsolidated coastal plain deposits that lie unconformably on the Cretaceous bedrock include Pleistocene and Holocene alluvium of the modern stream valleys; the Pleistocene (and Pliocene?) marine, fluvial, and eolian sediments blanket the remainder of the coastal plain and comprise the Gubik Formation (Black, 1964; Gryc, Patton, and Payne, 1951). The oldest marine deposit is beach gravel that lies from 400 to 500 feet (120 to 150 meters) above sea level near longitude 162° W. near the upper (inland) limit of the upland silt. The upland silt is generally more than 150 feet (50 meters) above sea level and is as much as 130 feet (40 meters) thick. It forms a mantle over fluvial and marine deposits in valleys cut in bedrock and in many areas rests directly on bedrock (O'Sullivan, 1961).

The beaches of Icy Cape, Cape Franklin, and Point Barrow are significant gravel deposits along the NPRA coast. (J. C. LaBelle, AEIDC)



A large area of marine sand of nearshore origin occurs in the western part of the coastal plain (McCulloch, 1967), and eolian sand covers much of the eastern part of the Reserve (Carter and Robinson, 1978). The dunes were active within the last 11,000 years and were fed by east-northeast winds blowing sand from the Colville River flood plain. Dune sand is clean and pebble-free.

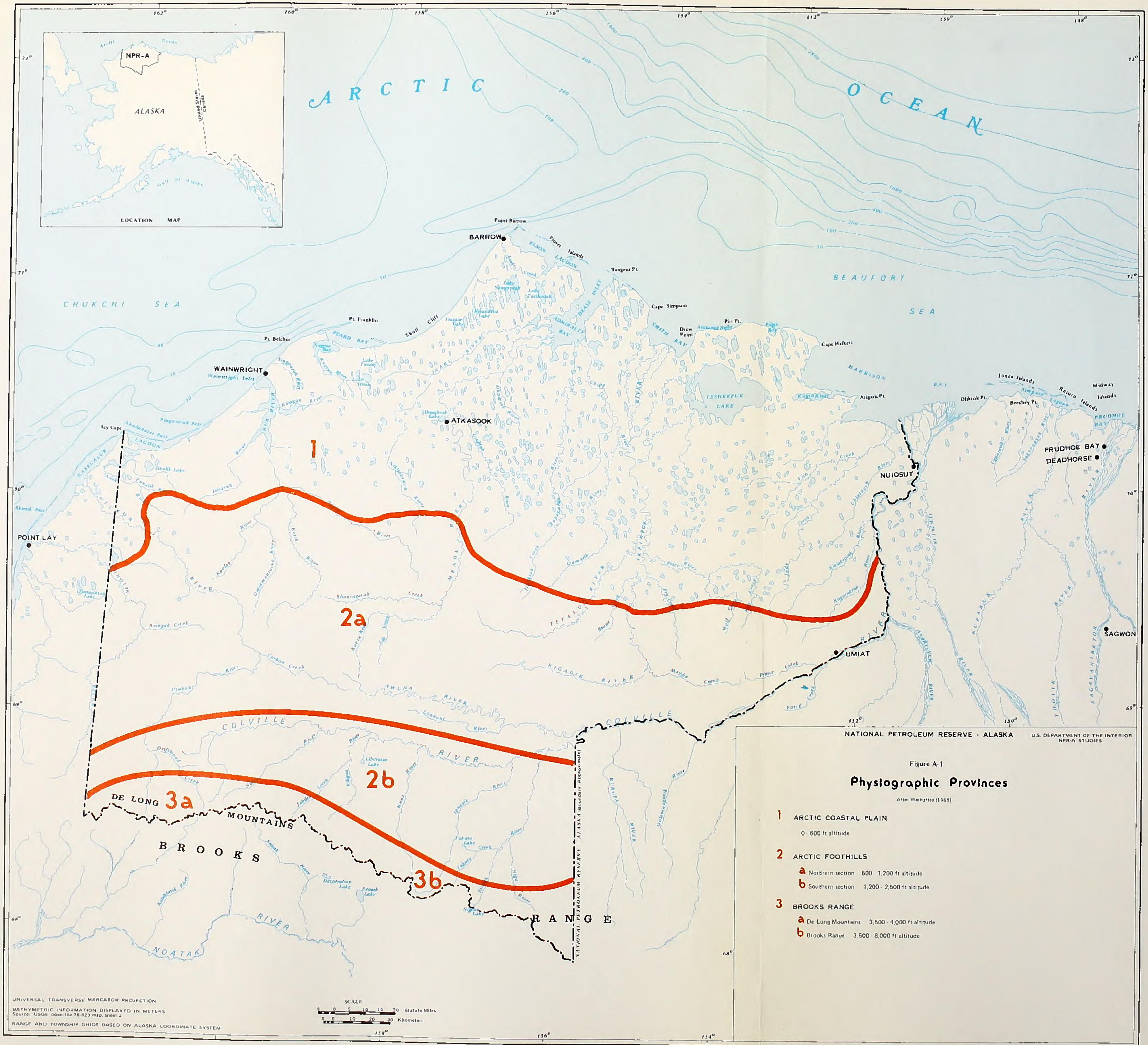
Nearshore deposits consist of clean to silty or clayey, fine to medium sand containing pebbles and granules of chert. In the western part of NPRA these deposits lie on both sides of a wave-cut scarp 65 feet (20 meters) above sea level a short distance inland from the Chukchi Sea coast and on either side of another scarp which lies farther inland at about 100 feet (30 meters) above sea level. East of Meade River, the marine sand is separated from eolian sand by a wave-cut scarp, the base of which is 65 to 80 feet (20 to 25 meters) above sea level. Still farther east, near the Colville River, the marine sand deposits have been reworked by streams that crossed the coastal plain before development of modern stream valleys.

Fine-grained marine deposits, consisting of sandy silt and clay, lie beneath younger marine deposits at Skull Cliff southwest of Barrow. East and southeast of Barrow, sandy silt and clay occur at the surface in coastal exposures and extend to a depth of about 50 feet (15 meters) near Cape Simpson. Sand and gravel beach deposits at Barrow can be traced southeastward and along the north shore of Teshekpuk Lake where they are as much as 43 feet (13 meters) above sea level landward of the sandy silt and clay unit.

The older and modern beaches of the Icy Cape, Cape Franklin, and Point Barrow areas, as well as the coastal islands and offshore bars, are the major sources of gravel along the coast. Elsewhere, coastal beach deposits are narrow and too thin to be a significant source of gravel.

Fluvial deposits bordering the large streams commonly consist of fine gravel and slabby sandstone where the streams enter the coastal plain. The gravel deposits are thin and generally do not exceed the scour depth of the rivers, either in the flood plain or on adjacent terraces. The gravel deposits extend only a few thousand feet beyond the foothills into the coastal plain. Commonly, the gravels are poorly sorted, and material sizes at a single location may range from large slabs to silt. In many areas the gravel comprises a thin armor that covers soft blue clay. The gravels contain much chert and coal, which are undesirable constituents of material to be used as concrete aggregate. Fluvial deposits at stream mouths are silty sands.

Barrier islands and spits characterize the coastline along the Bering and Chukchi Seas. (C. D. Evans, AEIDC)



NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure A-1
Physiographic Provinces
After Wahrhaftig (1965)
1 ARCTIC COASTAL PLAIN
0 - 600 ft altitude
2 ARCTIC FOOTHILLS
a Northern section 600 - 1,200 ft altitude
b Southern section 1,200 - 2,500 ft altitude
3 BROOKS RANGE
a De Long Mountains 3,500 - 4,000 ft altitude
b Brooks Range 3,500 - 8,000 ft altitude
ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
LOCATION MAP
NPR-A
ALASKA
BARROW
Point Barrow
WAINWRIGHT
ATKASOOK
POINT LAY
NUIQSUT
UMIAT
PRUDHOE BAY
DEADHORSE
SAGWON
TESHEKPUK LAKE
Icy Cape
Pt. Franklin
Pt. Belcher
Cape Simpson
Cape Halkett
Tangent Pt.
Drew Point
Pitt Pt.
Atigaru Pt.
Oliktok Pt.
Beechey Pt.
Jones Islands
Return Islands
Midway Islands
HARRISON BAY
PEARD BAY
SMITH BAY
ADMIRALTY BAY
ELSON LAGOON
Plover Islands
Skull Cliff
COLVILLE RIVER
DE LONG MOUNTAINS
BROOKS RANGE
NOATAK RIVER
KIGALIK RIVER
AWUNA RIVER
MEADE RIVER
NATIONAL PETROLEUM RESERVE - ALASKA (Boundary Approximate)
1
2a
2b
3a
3b
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
5 0 5 10 15 20 Statute Miles
5 0 10 20 30 Kilometers

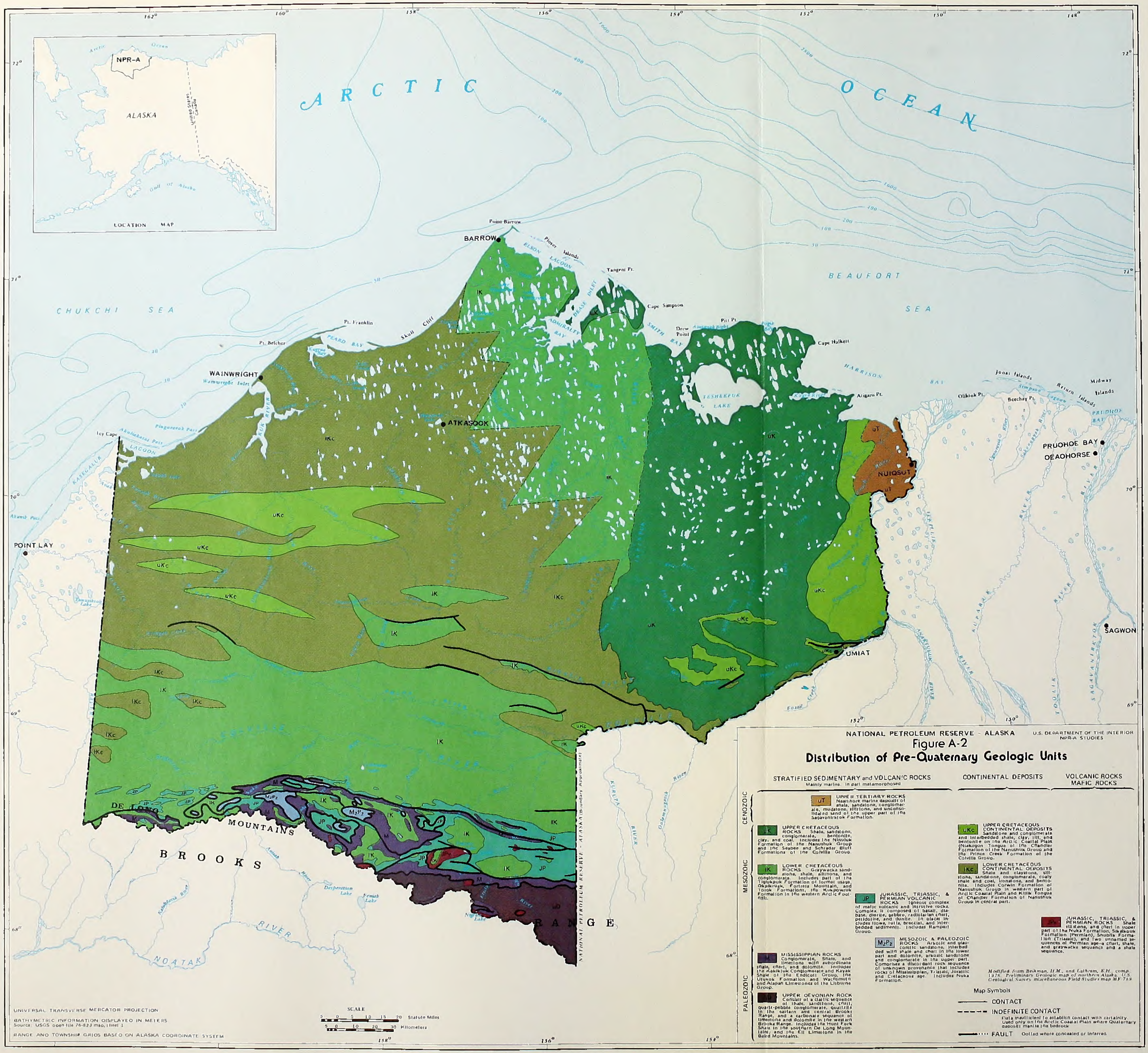


Figure A-2
Distribution of Pre-Quaternary Geologic Units

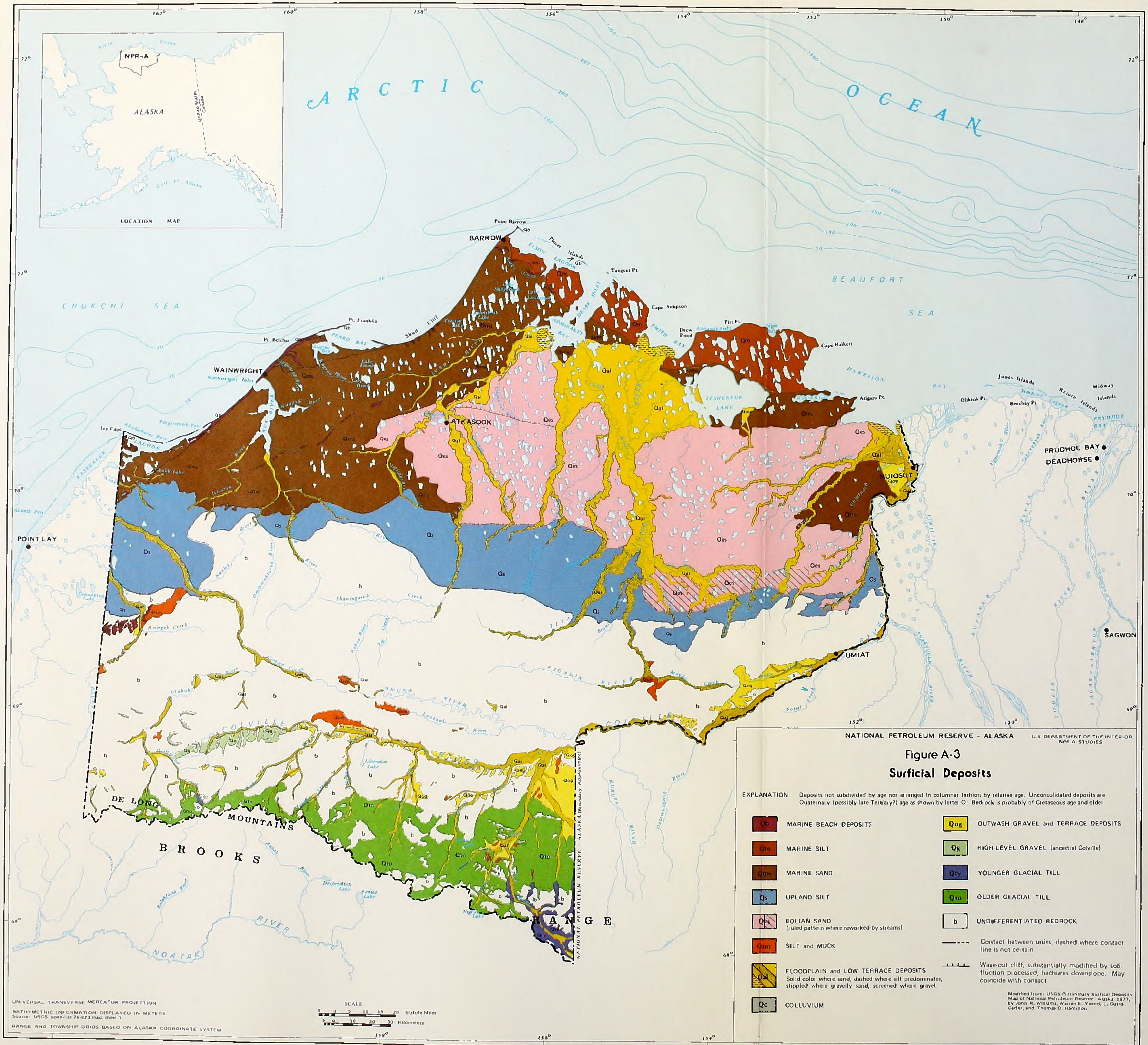
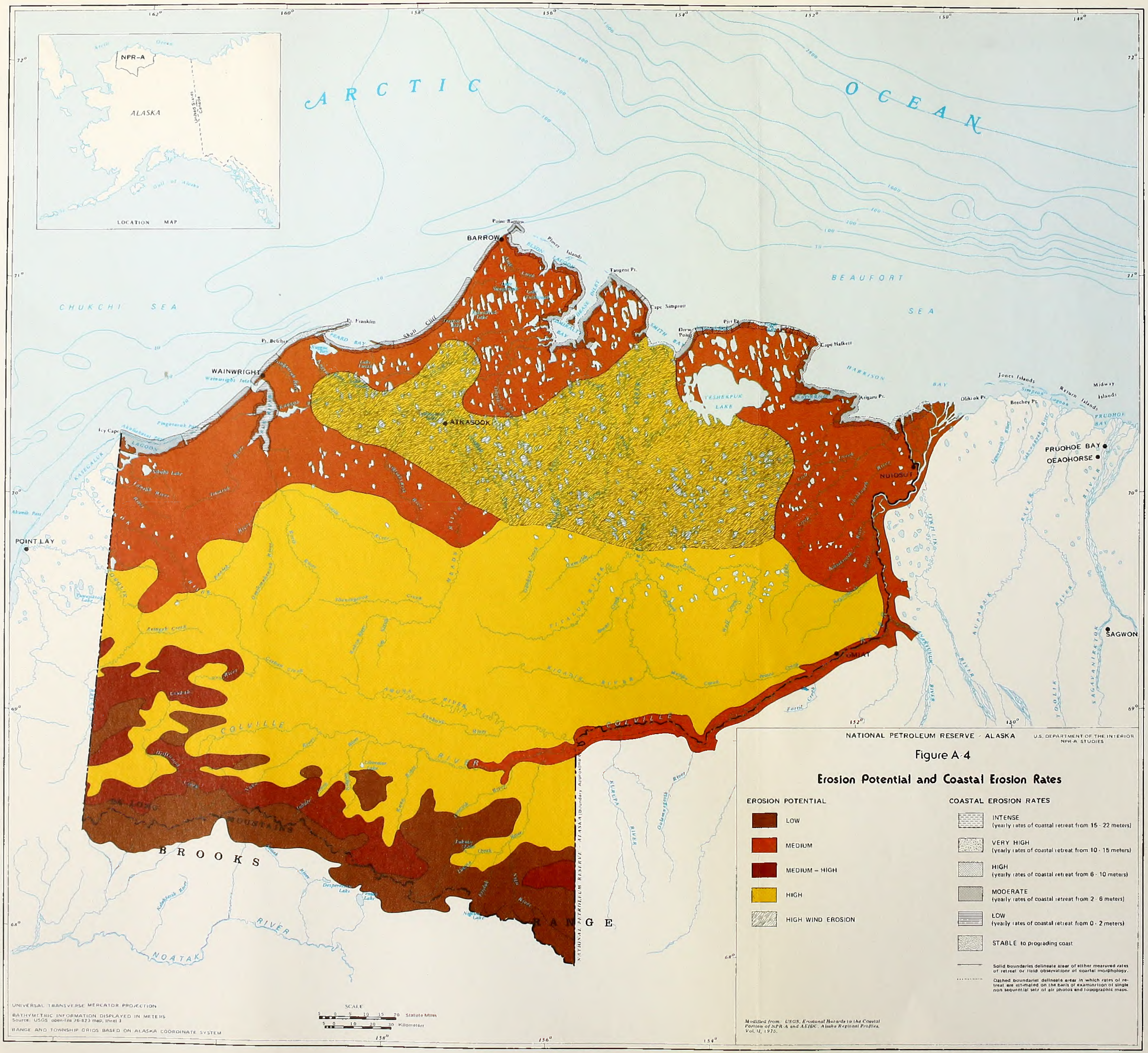


Figure A-3
Surficial Deposits


NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure A-4
Erosion Potential and Coastal Erosion Rates
EROSION POTENTIAL
LOW
MEDIUM
MEDIUM – HIGH
HIGH
HIGH WIND EROSION
COASTAL EROSION RATES
INTENSE
(yearly rates of coastal retreat from 15 - 22 meters)
VERY HIGH
(yearly rates of coastal retreat from 10 - 15 meters)
HIGH
(yearly rates of coastal retreat from 6 - 10 meters)
MODERATE
(yearly rates of coastal retreat from 2 - 6 meters)
LOW
(yearly rates of coastal retreat from 0 - 2 meters)
STABLE to prograding coast
Solid boundaries delineate areas of either measured rates of retreat or field observations of coastal morphology.
Dashed boundaries delineate areas in which rates of retreat are estimated on the basis of examination of single non sequential sets of air photos and topographic maps.
Modified from: USGS, Erosional Hazards to the Coastal Portion of NPR-A and AEIDC, Alaska Regional Profiles, Vol. II, 1975.
ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
NPR-A
ALASKA
LOCATION MAP
BARROW
WAINWRIGHT
ATKASOOK
TESHEKPUK LAKE
NUIQSUT
PRUDHOE BAY
DEADHORSE
POINT LAY
SAGWON
UMIAT
COLVILLE RIVER
BROOKS RANGE
NOATAK RIVER
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers

Ice-cored hills called pingos are the most prominent feature of the coastal plain. (J. C. LaBelle, AEIDC)

iii. Thaw Lake Cycle

Surficial deposits of the Alaskan Arctic coastal plain have been so extensively modified by the thaw lake cycle (Britton, 1967) that in many areas few, if any, residual surfaces remain. Most of the ground surface is underlain by silt, sand, and peat deposited during formation, enlargement, and drainage of these lakes. Sellman and others (1975) have classified the lakes of the coastal plain and have outlined their distribution and geomorphic implications. The lakes are rarely older than a few thousand years (Carson, 1968; Brown, 1965), and many are still unstable and in a continuing process of enlargement. Others have coalesced, and some have been drained by intercepting streams, lower lake basins, meandering streams, or retreating coastlines.

The thaw lake cycle is initiated by thaw of ice-rich permafrost as a result of disturbance of the thermal regime (including man's activities). Near Barrow the interstitial ice content (not including wedge ice) exceeds the natural void volume of the sediments down to a depth of about 30 feet (10 meters). Thawing is therefore accompanied by settlement, and a lake basin is created. For example, Hussey and Michelson (1966) found that in the Barrow area settlement resulting from thaw of the upper 20 feet (6 meters) of these sediments would be approximately 10 feet (3 meters) beneath the original (residual) surface, 4 feet (1.2 meters) beneath ancient drained thaw lake basins, 2 feet (0.7 meter) beneath recently drained thaw lake basins, and 0.3 foot (0.1 meter) beneath a present-day lake. Thus, after initial thaw settlement, the thaw lakes tend to expand laterally by thaw of the banks until the lake intercepts another basin, is drained by a stream, or passes into an older phase of the thaw lake cycle.

The lakes in the upland silt terrain in the southern part of the coastal plain, at about 100 to 500 feet (30 to 150 meters) above sea level, are smaller and less widespread than coastal plain lakes. Locally, the upland thaw lakes may be incised as much as 100 feet (30 meters) because of the presence of ground wedge ice in excess of the natural voids of the silt at greater depths. The ice content may reach 80 percent by volume of the sediments and result in thaw settlement approaching 60 percent of the original volume (Are, 1973). Lakes of the upland silt terrain also expand by thaw erosion of their banks of ice-rich silt, and expansion continues until the basin is drained by intercepting a stream or another lower basin.

iv. Permafrost

Except beneath deep lakes that do not freeze to the bottom and deep pools in larger streams, permafrost extends from the base of the active layer (1.5 to 6 feet (0.5 to 2 meters)) to as deep as 1,150 feet (350 meters). Exploratory drillholes in the Prudhoe Bay area reached the base of permafrost at depths as great as 1,970 feet (600 meters).

Exposures of permafrost are rare because only constant erosion will keep them visible. Along the shore of Beaufort Sea, spectacular ice wedges occupy the upper 30 feet (10 meters) of permafrost and have attracted scientific attention since the earliest explorations. The ice wedges are formed by thermal contraction cracking during the winter. Annual filling of the cracks with water and hoarfrost increases the amount of ice and expands the wedges (Lachenbruch, 1962). Other ice forms in the coastal plain include segregated ice and pingos. Most, if not all, of the pingos are ice-cored hills in drained, thaw lake basins.

Sellman and Brown (1973) found that in the Barrow area ice volumes in the upper 10 feet (3 meters) vary from massive wedge ice to barely visible segregated ice in excess of the volume of voids in the sediment. Ice content generally decreases with depth, and, in the coastal plain, equals the volume of voids at a depth of about 25 to 30 feet (8 to 10 meters).

v. Shoreline Changes

The coastlines of the Chukchi and Beaufort Seas differ in many characteristics. The Chukchi coastline is exposed to erosion by waves driven by westerly to southwesterly winds during late summer. Cyclonic storms in the fall cause a surge and waves 10 to 13 feet (3 to 4 meters) above sea level (Lewellen, 1976). The amount of erosion caused by the storm depends on the fetch of the wind, which, in turn, depends on the position of the arctic ice pack. In contrast, the Beaufort Sea coast is generally bordered by pack ice and is eroded by northeasterly winds of rather limited fetch.

The coastal bluffs along the Chukchi coast are composed of resistant bedrock over about 35 percent of the coastline. The coast includes large areas of stable to prograding shoreline near Icy Cape, in the area between Point Belcher and Point Franklin, and at Point Barrow. The Beaufort Sea coastline, however, is underlain mainly by marine silt, and silt and peat of thaw lake basins. The deposits probably contain much more ice than those of the Chukchi coast and are more easily eroded.

From Icy Cape to Peard Bay, the Chukchi shoreline is protected by offshore barrier bars and islands that are separated from shore by a narrow lagoon. The Beaufort Sea shoreline generally lacks the protection of islands and is open to erosion along many deep indentations in the coastline.

In general, the rate of erosion retreat on the Chukchi Sea coast is low to moderate, less than 20 feet (6 meters) per year, but on the Beaufort Sea coast erosion is moderate to intense, from 6 to 70 feet (2 to 22 meters) per year (fig. A-4). Most of the erosion of the Beaufort Sea coast involves steady undercutting during each open water season, but that of the Chukchi coast is accomplished mainly during major storms when the ice pack is far from shore. The most severe storm of record occurred on October 3, 1963, when water covered the Point Barrow Spit and threatened the Naval Arctic Research Laboratory and other installations on the spit. The surge from this storm was 9 feet (2.8 meters) above sea level at Point Barrow and the swashline was about 12 feet (3.7 meters) above sea level. The most severe attack of the waves was between Wainwright and Barrow, where the coast is unprotected by offshore islands (Hume and Schalk, 1967). During this one storm 20 times the annual longshore sediment transport of about 12,000 cubic yards (9,200 cubic meters) was recorded from the southwest to the Barrow Spit.

c. Geologic Problems

Major problems associated with geologic features and affecting potential development include: lack of adequate sources of conveniently located sound rock and gravel; swelling clay; permafrost terrain; coastal erosion; riverbank erosion; and deflation of eolian sand exposed to the action of wind.

i. Rock and Gravel Sources

Bedrock outcrops along the Chukchi coast, along rivers west of longitude 156° W., and along the Colville River consist of shale, siltstone, coal, clay, and sandstone. All but the sandstone are unsuitable for most engineering requirements, and the sandstone is of marginal quality for use as riprap and other construction purposes. Sand resources are abundant, but quantities of available sand are limited because exposures are generally localized in riverbanks and coastal bluffs beneath several feet or meters of frozen unconsolidated overburden.

Gravel resources are limited in quantity and occur in just a few areas, requiring long hauls to most construction projects. Gravel deposits are most commonly found in raised beaches, in offshore bar and island deposits, and inshore from the modern beaches near Barrow, Point Belcher, Point Franklin, north of Wainwright, and near Icy Cape. A discontinuous series of thin bar and beach deposits extends southeastward from Barrow to the north shore of Teshekpuk Lake and along the shoreline south of Wainwright. Fluvial gravel does not generally exceed the depth of scour and is commonly a thin armor on clay or coarser marine and eolian deposits. The Colville River has the largest gravel resources of the area in its flood plain and terrace deposits. In addition to being limited in quantity, the gravel there commonly contains coal and chert in quantities that would lower its effectiveness as concrete aggregate.

Although sand resources are abundant, for most surface courses and for many other uses, stabilization is required.

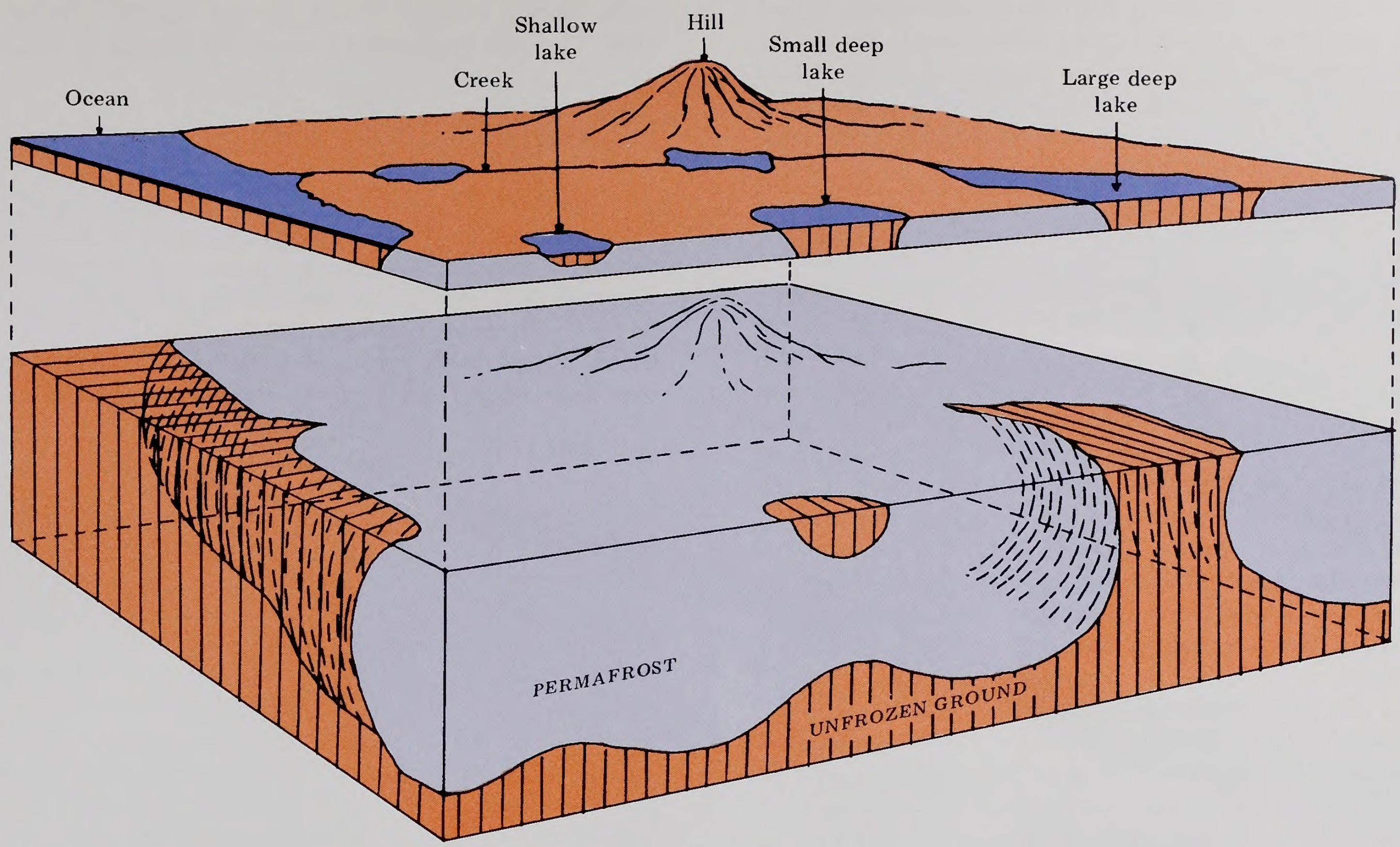
ii. Swelling Clay

The Colville Group contains bentonitic clay which swells when wet. These deposits form the debris flows at Umiat and are responsible for landsliding along rivers, such as in the Kuk River basin.

iii. Permafrost

The marine silt and the upland silt deposits are especially sensitive to thaw collapse because of their high content of segregated ice in addition to the usual wedge ice. The eolian sand deposits are expected to contain less segregated ice than the silt deposits, although the sand contains much wedge ice; however, test data are not yet available to support these conclusions. Until shown to be otherwise by exploratory drilling, all frozen unconsolidated deposits may be assumed to have an ice content that would cause differential settlement if permafrost were thawed during construction.

Disturbance of the thermal regime of permafrost may lead to subsidence in most areas where the



Illustrated here is the effect of surface features on the distribution of permafrost in the continuous permafrost zone. (U.S. Geological Survey)

ground ice content exceeds the volume of voids of the soils. Ground subsidence leads to formation of ponds, which, under certain conditions, can be expanded by thaw processes to thaw lakes. The thaw process, once initiated, is difficult and expensive to control.

iv. Coastal Erosion

Coastal erosion rates range from less than 20 feet (6 meters) per year on the Chukchi Sea coast to 6 to 70 feet (2 to 22 meters) per year on the Beaufort Sea coast (fig. A-4). Coastal installations would be faced with erosion problems, as well as potential impacts of excavation and erection of protective structures. Excavation could accelerate erosion, and protective structures retard or deflect coastal sediment transport.

v. Riverbank Erosion and Floods

Steep streambanks are actively undercut by streams, and channels commonly shift, especially in braided reaches. These activities could jeopardize construction in and adjacent to streams. Flooding of some of the smaller rivers is spectacular at breakup, and flood crests of 20 feet (6 meters) have been reported on the Avalik River and other streams. Breakup of the Colville River leads to floods that inundate much of its flood plain and delta.

vi. Wind Erosion

Disturbance of the vegetation cover in sandy areas, particularly in the dunes (Williams and others, 1977) results in rapid, severe wind erosion of exposed sand. Wind erosion potential is shown in figure A-4.

3. Climate

NPRA is within the Arctic climatic zone. The summers are characterized by cool maritime winds, frequent cloudiness, fog, light rain, and continuous light. The ocean moderates temperature extremes near the coast. In winter cloudiness decreases and very cold winds prevail. At Barrow, the sun remains below the horizon for more than 2 months. By mid-September a snow cover is usually present, increasing to a depth of 1 to 2 feet (30 to 70 centimeters) by March and April. The snow melts by June or July. Winter temperatures average -15°F to -25°F (-26°C to -32°C); however, winds frequently contribute to wind chill factors as low as -50°F (-46°C) and lower. The combination of darkness and extreme cold in winter makes outdoor work difficult and often hazardous.

a. Temperature

During most of the year, the Arctic is covered by a shallow layer of stable cold air. The warmest month of the short, cool summer is July; the average temperature then at Barrow is about 39°F (4°C). In February, Barrow's coldest month, the average temperature is about -20°F (-29°C). Inland temperatures are more extreme.

In the Arctic, the chill factor is more important than air temperature in evaluating temperature effect on biological systems. Strong winds coupled with low winter temperatures produce equivalent chill temperatures that require man to take extreme precautions outdoors and have caused animals to develop physiologic adaptations or migrate.

b. **Precipitation**

Precipitation over most of the Arctic coast is very light, usually less than 10 inches (25 centimeters) annually. In winter the cold air can hold little water vapor, and the ice cover slows oceanic evaporation. Rain accounts for the major part of precipitation, the greatest amount of which falls in July and August. Snow, however, may fall in every month and usually predominates beginning in September. Snow deeper than 1 foot (0.3 meter) persists for many days each winter throughout NPRA. However, almost continuous winds move and redistribute snow, causing bare or nearly bare ridge tops and drifted valleys.

On the coastal plain the soils are saturated with water throughout the summer. The surface wetness in this area, in spite of the low precipitation, results from low moisture loss by evaporation and low rates of infiltration because of permafrost.

The relative humidity in the Arctic is generally high; values average 60-90 percent throughout the year. The low temperature keeps the absolute humidity low.

c. **Wind**

Surface winds along the Arctic coast usually blow at a fairly constant rate year-round. At Barrow, calm conditions exist only 1.3 percent of the time. A general yearly average wind speed for the coastal zone is 15 to 20 miles per hour (24 to 32 kilometers per hour) at relatively exposed locations. Wind speeds over inland areas at low elevations are usually lower.

d. **Severe Storms**

Occasional intense storms have occurred in the area. The most disastrous storm recorded along the coast occurred October 3, 1963. The major causes of damage were erosion of the shoreline, sea water overflowing into a freshwater lake, flooding, and scattering of debris a mile or more inland. Salt water also damaged vegetation over large areas of the coastal tundra. The wave action was estimated to transport about 20 times the normal average annual sediment load. Winds of 55 miles per hour (88 kilometers per hour) were measured at Barrow.

Thermal erosion caused these ice-rich blocks to fall into the lower Colville River. Waves lapping against riverbanks and spring flooding accelerate permafrost thaw. (J. Walker)

During the great storm of October 1963, Point Barrow Spit was cut off from the mainland. (Robert Lewellen)

e. Cloud Cover

At Barrow and Umiat totally cloud covered skies occur during 58 and 54 percent of the year, respectively. Cloud cover is most prevalent in summer and autumn. Low ceilings are frequent during the summer and early autumn. The bases of the stratus clouds are frequently below 1,500 feet (475 meters).

f. Restrictions to Visibility

During the warmer months, fog frequently reduces visibility. Along the coast, fog may be expected to occur on at least 90 days each year. Oceanic and inland areas have relatively fewer days of fog.

In addition to fog, whiteouts and blowing snow associated with stormy winds can create conditions in which neither shadows, horizon, nor clouds are discernible. Under such conditions, senses of depth and orientation are lost, only very dark objects can be seen, and guide ropes may be necessary to assure safe movement from one place to another in settled areas.

g. Light

The Arctic receives an amount of annual sunlight equal to that in the lower latitudes. However, because the sun strikes the surface at a relatively low angle, much less energy is received. The northern Alaskan coast receives continuous sunlight in summer. In winter there is a long period of darkness. At Barrow, the sun is continuously above the horizon from May 10 to August 2 and below from November 18 to January 23.

In the winter when the sun is not more than 6° below the horizon, twilight permits many outdoor activities; artificial light is not needed. Due to the high reflectivity of the snow cover, some activities can be carried on under moonlit conditions.

h. Freezeup and Breakup

Freezeup on water bodies occurs in early to mid-September over much of NPRA. The average maximum thickness of both seasonal sea ice and freshwater ice at the end of the winter season is about 6 feet (2 meters). Breakup begins in late May inland and in June near the coast. Ice on deeper lakes frequently does not completely melt until mid-July. At Barrow, the ground-surface temperature is usually below freezing by late October and remains so until late June. During winter, frozen, snow-covered ground, rivers, and ocean facilitate heavy off-road traffic. During summer, such mobility is denied over much of the Coastal Plain and Foothills provinces, as well as offshore.

4. Water Resources

a. General Hydrology

The hydrology of NPRA is dominated by the cold, dry climate and permafrost. Streamflow essentially ceases during the long winter. Precipitation occurs mainly as snow from September to May and is stored in the snow pack until breakup, a dynamic flow period in late May and early June. Most of the annual runoff occurs in the brief 2- to 3-week breakup period. Ice jams and associated flooding occur on most streams at this time.

Thermal erosion of ice-rich siltbanks by streams leads to undercutting and rapid slumping in many areas of the coastal plain, particularly during breakup. Most of the sediment transported annually by streams moves during breakup.

On the Arctic coastal plain of NPRA, lakes, ponds and other wetlands cover about 30 percent of the surface. Most of the lakes are less than 6 feet (2 meters) deep and freeze to the bottom in winter. Teshekpuk Lake, third largest in Alaska, has a surface area of 315 square miles (815 square kilometers) and stores about 3 million acre-feet (nearly 5 billion cubic meters) of high-quality water. The area between Teshekpuk Lake and the foothills to the south is characterized by moderate relief and relatively deep lakes. Ice thickness on lakes and streams in NPRA can be as much as 8 feet (nearly 3 meters). Remnant pools of water are found beneath ice in lakes deeper than about 7 feet (about 2.3 meters) and in deep holes in the rivers.

Water in lakes and streams is of very high quality during the ice-free period. However, moderate suspended-sediment concentrations and associated turbidity occur in many streams during breakup and in shallow lakes agitated by wind. Concentrations of dissolved solids are very low except in the tidal zone of streams and in lakes that have been recently flooded by sea water or have a direct tidal connection. Water quality deteriorates under ice in winter because of freeze concentration of dissolved solids.

Ground water resources in NPRA are virtually nonexistent, owing to the widespread occurrence of permafrost. Ground water exists in thawed zones beneath deep lakes and pools in rivers that do not freeze to the bottom, but it is generally unsuitable for use because of high concentrations of dissolved solids. Ground water that occurs beneath permafrost in NPRA has been generally found to be too saline for use. There are no water wells in the Reserve.

Only two small springs were found in the Reserve during a 1977 water-quality assessment; these were near the mountains in the southern part of the Reserve.

Water supplies in the Reserve come primarily from lakes and to a lesser extent from streams. Snow and ice are commonly melted for water at times when other sources are not available.

b. Surface Water

Streamflow records were collected at the Colville, Meade, and Miguakiak Rivers and Nunavak Creek during the 1977 water year, but, in general, there is little information on the quantity of streamflow throughout the Reserve. The estimated mean annual runoff of NPRA averages about 0.5 cubic feet per second per square mile [$(ft^3/s)/mi^2$] or 0.005

During the spring thaw, river ice breaks up and is rapidly carried out to sea by swollen, flooding rivers. (Atlantic Richfield Company)

cubic meters per second per square kilometer [$(m^3/s)/km^2$]. In the northern part of NPRA runoff is about 0.3 $(ft^3/s)/mi^2$ [0.003 $(m^3/s)/km^2$] and increases to about 2 $(ft^3/s)/mi^2$ [0.02 $(m^3/s)/km^2$] on the southern boundary of the mountainous part of NPRA. Estimated mean annual runoff from NPRA outside the Colville basin is 14,000 cubic feet per second (ft^3/s) [392 cubic meters per second (m^3/s)] (Balding, 1976). Estimated mean annual runoff from the Colville for the 1977 water year is 16,000 ft^3/s (448 m^3/s).

The primary causes of floods in NPRA are rapid spring snowmelt or summer and fall rainstorms. During spring breakup between late May and early June, the height of the flood flow is significantly increased by the presence of ice jams. Peak discharge may occur at the maximum stage or on the falling recession. Flooding occurs on low-gradient streams along the Arctic coast from storm surges and discharge of streams draining large lakes, such as Miguakiak River, which drains Teshekpuk Lake. Strong winds and upstream flow from the Ikpikpuk River causes flooding along the Miguakiak River and Teshekpuk Lake. High persistent flow occurs in basins with large lakes where streams are supplied by lake storage. Maximum evident floods range from 7.1 to 80.5 $(ft^3/s)/mi^2$ [0.07 to 8 $(m^3/s)/km^2$] for large drainages in the Reserve (Childers, 1972). The estimated low monthly mean runoff in streams within NPRA is zero; flow beneath ice ceases during the late winter months. Low flows or no flow occur during periods of low precipitation in July and August on streams that have limited ground water or lake storage. In the unusually dry summer of 1977, streamflow was reduced to near zero in most of the streams in the Reserve by midsummer but increased with late summer rains.

c. Lakes

Lakes are the most conspicuous hydrologic feature in NPRA, comprising as much as 40 percent of the surface area. They range in size from less than an acre (0.4 hectare) up to Teshekpuk Lake which covers about 315 square miles (815 square kilometers).

Data obtained during a hydrologic reconnaissance in the summer of 1977 showed a grouping of deeper lakes south of Teshekpuk Lake (fig. A-5). Depths there range from 50 to 70 feet (16 to 23 meters). The deepest lake found in the Reserve is in the mountains near Howard Pass and is 121 feet (40 meters) deep. However, more than half the lakes sampled were less than 7 feet (about 2 meters) deep and probably either freeze to the bottom in winter or so nearly so that the remaining water contains substantially increased dissolved solids due to freeze concentration.

Teshekpuk Lake is divided into two basins, the smaller to the east. The average lake depth is about 20 feet (7 meters). A seismic crew reported a depth of 50 feet (16 meters) at one point near the west end of the lake, but this depth has not been verified.

Most of the surface water sampled in NPRA during the summer of 1977 was of excellent chemical quality. Specific conductance of water is a relative measure of the amount of dissolved solids contained. The only lakes in which high specific conductances were measured were those that were in direct tidal connection to the sea or had been contaminated by storm-driven sea waves.

Water clarity is affected by turbidity, and all shallow lakes in NPRA are subject to wind effects that stir up bottom sediments. The lakes with the greatest turbidity are the shallow coastal plain lakes from Point Barrow to the Colville Delta that are underlain by marine silts. Lakes of equivalent depth underlain by sand are much less turbid.

d. Ground Water

Widespread permafrost limits the occurrence of ground water in NPRA. There are no water wells within NPRA, and the wells nearest to the boundary are at the village of Anaktuvuk Pass and at the Cape Lisburne Air Force site.

Only two springs were found in NPRA during the summer of 1977 water-quality assessment.

About 40,000 seismic exploration shotholes have been drilled in NPRA to a nominal depth of 100 feet (33 meters). Water has been reported in a few of these holes, generally those close to streams or lakes. Shallow geophysical techniques were used in the summer of 1977 to evaluate the reported existence of a ground-water zone in seismic drill holes near Dogbone Lake, but evidence of such a zone could not be found.

Ground water has been found beneath permafrost in wells drilled for oil near Umiat but is generally too saline for use. Likewise, water that has been found in thaw zones beneath lakes has been found to be quite saline. The greatest potential for ground water in NPRA would be in thaw zones associated with the deep lakes south of Teshekpuk Lake and with the Colville River near Umiat, but wells would be difficult to develop in the fine-grained lake bottom sediments and would have very low yields.

e. Water Availability

The principal year-round source of water supply in NPRA is the lakes. Lake water is used by all the villages, Distant Early Warning Station sites (DEW-Line) and drilling sites. The only community where river water is the primary source is Umiat. Snow melters are commonly used to provide water for seismograph crews and drill crews. Villagers often melt lake ice or old sea ice when water from lakes is unavailable or inconvenient to use.

Water availability varies seasonally. Water is stored as snow or ice during mid to late winter and is available in maximum quantities in late spring and early summer.

Ground water has been found in association with river gravels near Umiat. It is not now a source of water for human consumption.

Esatkuat Lagoon supplies water for the city of Barrow, where water costs 16 cents per gallon. (Robert Lewellen)

Augmentation of existing water supplies can be managed in several ways. Because of the open terrain, winter snow cover, and persistent winds in NPRA, drift fences could be very effective in creating snow deposition, thereby increasing local water availability. Lake storage can be increased by deepening the lake basin and/or decreasing the depth of freezing using styrofoam mats or snow as insulators on the lake surface. Natural storage is very limited in rivers in NPRA but could be enhanced by removing gravel to form deep pits in the main river channel.

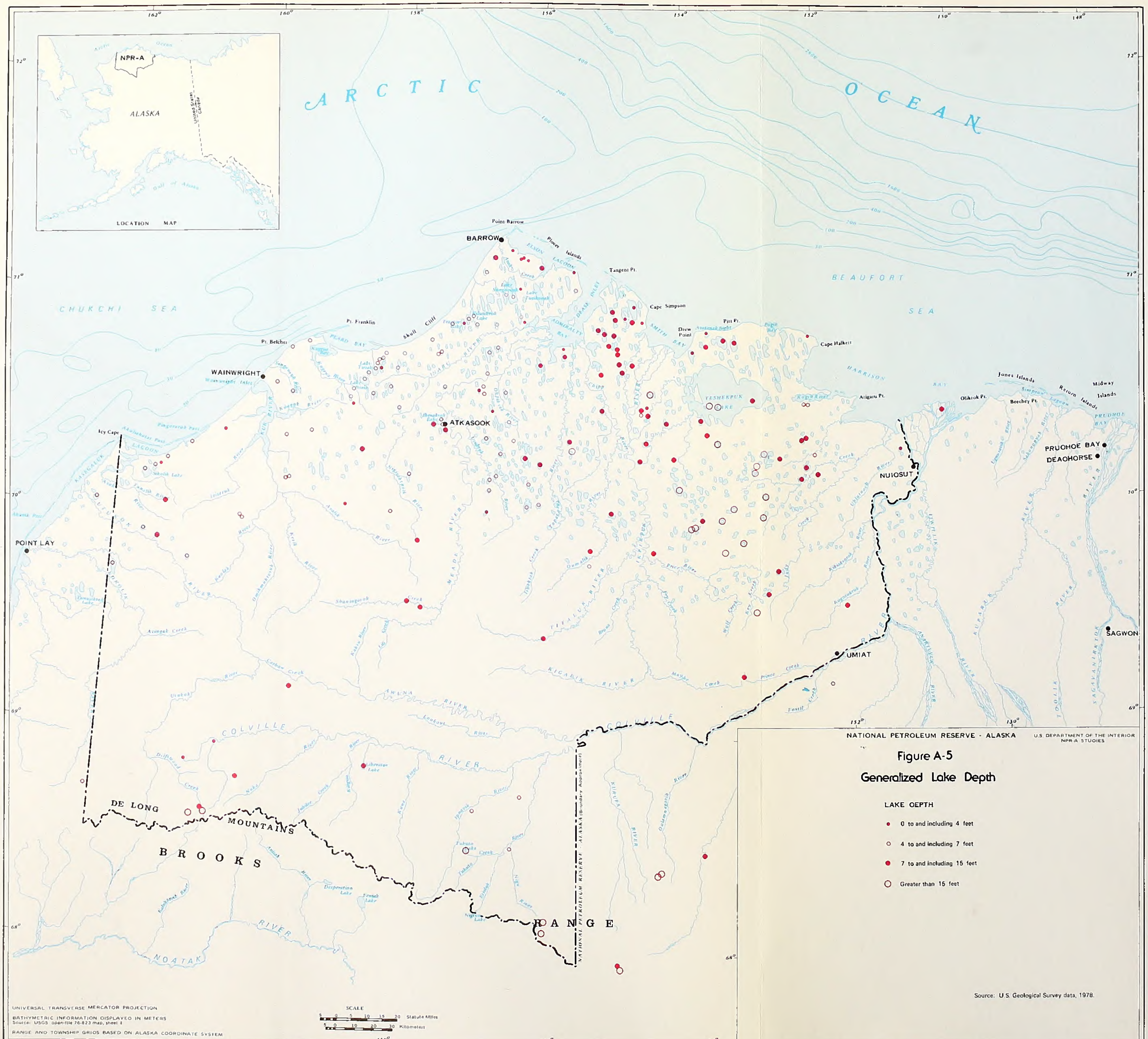
5. Environmental Quality

a. Air

Few air quality measurements have been made in NPRA; however, selected pollutants have been measured as part of research studies carried out at the Naval Arctic Research Laboratory (NARL) near Barrow. The amount of particulate matter in the air near NARL is very low (Cavanaugh, Schadt, and Robinson, 1969; Miller, 1975). In fact, some measurements of suspended particulates have reported zero micrograms per cubic meter. The particulate matter may be very high on occasion, particularly during dry summer periods, because of wind-borne dust from roads, beaches, sand bars, sand dunes, and other bare areas, such as riverbanks, flood plains, and dry lake beds. Carbon monoxide concentrations were quite low, ranging from 0.055 to 0.250 parts per million. Photochemical oxidants showed a maximum daily average concentration of 7.5 parts per hundred million (Cavanaugh, Schadt, and Robinson, 1969; Miller, 1975). Hydrocarbon concentrations are also very low. The effects of current human activities on air quality are minimal and are restricted mainly to the villages, drilling sites, and construction areas.

Smoke from tundra fires in NPRA and from tundra and forest fires to the south of NPRA was carried into and over the Reserve by southerly winds during the warm dry summer of 1977. Visibility was severely reduced in the southern half of the Reserve for about 2 weeks. In some areas, the ground was not visible from an altitude of 500 feet (152 meters), making air navigation difficult and hazardous. Such conditions represent rare cases of natural pollution.

Temperature inversions are relatively common throughout the Arctic in the winter, when there is a snow cover on the ground. Surface temperatures are colder than the air aloft, resulting in the colder air remaining near the ground as a stable mass. Air pollutants introduced near the ground surface tend to be trapped within the inversion layer. Prolonged periods with little or no wind cause stagnant air



NATIONAL PETROLEUM RESERVE - ALASKA

Figure A-5
Generalized Lake Depth

conditions, particularly where hills and ridges act as topographic obstructions to the flow of air. However, persistent moderate to strong winds on the coastal plain generally disperse pollutants produced.

Light winds prevail in some of the foothill sections of NPRA, particularly near Umiat and along the Colville River upstream from Umiat. The inversion level also tends to be closer to the ground in the foothills than on the coastal plain, and the potential for trapping pollutants and reducing air quality is greater there. However, the overall probability for air quality problems in NPRA is low.

b. Noise

Noise levels over most of NPRA are low and are mainly from natural sources. Wind noises are most noticeable in winter when wind velocities are high. Water-generated sounds consist of river currents and waves breaking on lake and ocean shores. A wide variety of animal sounds may be heard in NPRA.

Although NPRA is essentially a roadless area, snow machines and other all-terrain vehicles (ATV's) range widely during winter, as do ski-equipped aircraft. Equipment used for seismic exploration is also mobile and can reach most parts of NPRA over snow. In summer there is a substantial amount of motorboat travel on the major rivers and in the coastal lagoons.

Other manmade sounds in NPRA originate largely with aircraft and other mechanized vehicle use and are most concentrated in and near the villages. Aircraft at airfields can generate a great deal of noise. Turbo-prop aircraft as large as the Hercules C-130 are frequently used in the Arctic because of their short take-off and landing capabilities. Intense aviation activities now occur at Lonely and Umiat largely in support of exploration activities. Exploration drilling, construction activity, and fixed power sources also contribute to noise levels in NPRA.

Measurements made in 1976 at a drilling site at Teshekpuk Lake gave sound-level readings of 70 to 80 decibels at a distance to 50 feet (16 meters) decreasing to 6 dB(A) at a distance of one-half mile (0.8 kilometer), which is typical of the noise level in a small town or quiet suburb (U.S. Department of the Navy, 1977). The most noticeable sources were diesel engines running compressors and equipment.

c. Water

Although water in NPRA is essentially unpolluted by man's activities, its natural quality is quite variable. Suspended sediment is the most visible parameter affecting water quality in NPRA. Suspended-sediment concentrations are highest in the major streams and rivers during spring breakup and during periods of high summer flow. During low-flow periods, all the streams in NPRA are essentially clear. In 1977, concentration of suspended sediment in the Colville River near Nuiqsut ranged from 86 milligrams per liter during spring breakup to a low of 3 milligrams per liter in late July. By comparison, peak sediment concentrations in the Meade River and Miguakiak River were 155 and 107 milligrams per liter, respectively, during the summer of 1977. Sediment concentrations measured in a small tundra stream, Nunavak Creek near Barrow, ranged from 2 to 18 milligrams per liter.

Air traffic creates a great deal of noise. Hercules C-130's are frequently used in the Arctic because of short takeoff and landing capabilities. (Grossmann-Granger Productions)

Turbidity resulting from the suspension of sediment is also noticeable in many shallow lakes on the coastal plain; it is caused by wind and wave actions disturbing the bottom sediments. Turbidity is also noticeable in glacier-fed lakes in the Brooks Range and in many lakes that receive inflow from sediment-laden river floodwaters, particularly in the river deltas.

Color is another visible parameter affecting water quality in NPRA. The water in most rivers and lakes is virtually colorless, but highly colored water prevails in some of the small tundra streams and lakes. The color is mainly a result of high concentrations of total organic carbon, which has been measured at as much as 16 milligrams per liter.

Most lakes and streams in NPRA have low dissolved-solids concentrations during the open-water season and are basically a dilute calcium bicarbonate water of moderate hardness and slight alkalinity. Water in a number of lakes near the coast has comparatively high dissolved-solids contents, especially sodium chloride.

Water quality in lakes and streams is reduced in winter because of freeze concentration. The amount of concentration depends on the ratio of water to ice in a water body when maximum ice thickness is reached. Water under ice in deep lakes and deep pools in rivers retains relatively low concentrations of dissolved solids, but water in shallow lakes and river pools that freeze nearly to the bottom can become unpotable in late winter because of the concentration of dissolved solids.

Dissolved oxygen in water is essential to aquatic organisms and is at or near saturation in the lakes and streams of NPRA during summer. Dissolved oxygen levels can be severely depressed under ice cover in winter, owing to the lack of reaeration and the long dark period that limits photosynthetic activity. Low dissolved oxygen contents are most prevalent in the water bodies that freeze nearly to the bottom.

Because streamflow essentially ceases in NPRA during the winter, salt water invades major estuaries, such as the Colville Delta and the Kuk River Lagoon and extends as much as 31 miles (50 kilometers) upstream.

Ground water found beneath a lake at Barrow and beneath permafrost in oil test wells at Umiat was highly saline.

Natural oil seeps near Cape Simpson contaminate some tundra ponds, and a seep at the base of Umiat Mountain drains to the Colville River. Neither significantly alters the water quality except in a very local sense.

Few data are available regarding bacteria in water. Measurements made in the Meade River and adjacent lakes during spring breakup in 1978 found no or very few bacterial colonies. At Barrow, long-term testing of the water-supply lake at the Naval Arctic Research Laboratory (NARL) has also failed to find many bacteria, even though the lake is adjacent to the animal pens. It is likely that many surface waters in and near the villages are polluted by fecal bacteria because of the general absence of sewage and waste-water gathering and treatment facilities.

B. Biotic Environment

1. Ecosystems

The ecosystems of NPRA are categorized as low Arctic. The number of plant species and communities, as well as the diversity of associated animal species, increase inland from the northern edge of the coastal plain toward the Brooks Range. However, they then decrease in the mountains to very low values. The distribution of the ecosystems of NPRA is shown in figure A-6. Table A-1 lists the major habitat associations of fish and wildlife on or adjacent to NPRA.

NPRA can be divided into several ecological systems or zones having relatively distinct relationships and associated successional patterns and showing distinctive sensitivities and responses to disturbances. However, many birds and mammals, such as the caribou, move between and range beyond the boundaries of any given ecological system during the course of a year.

a. Marine and Coastal Zone

The marine environment within or adjacent to NPRA includes five types of habitat: shallow coastal marshes, especially along the Beaufort Sea; estuaries where fresh water from rivers enters the sea; brackish lagoons, protected bays, and inlets; shallow near-shore shelf areas, often subject to ice scouring; and the offshore Beaufort and Chukchi Seas.

Arctic rivers contribute virtually no fresh water or nutrients to the marine environment during the 9 or more months each year that these streams are frozen. In spring, the discharge of rivers causes a lowering in the nutrient concentrations in the upper levels of the marine environment near the river deltas. Productivity is lowered because of the limited nutrient content of water from snow and ice melt, dissolved oxygen concentrations are reduced by warmer fresh water entering the marine environment, and light penetration needed for photosynthesis is re-

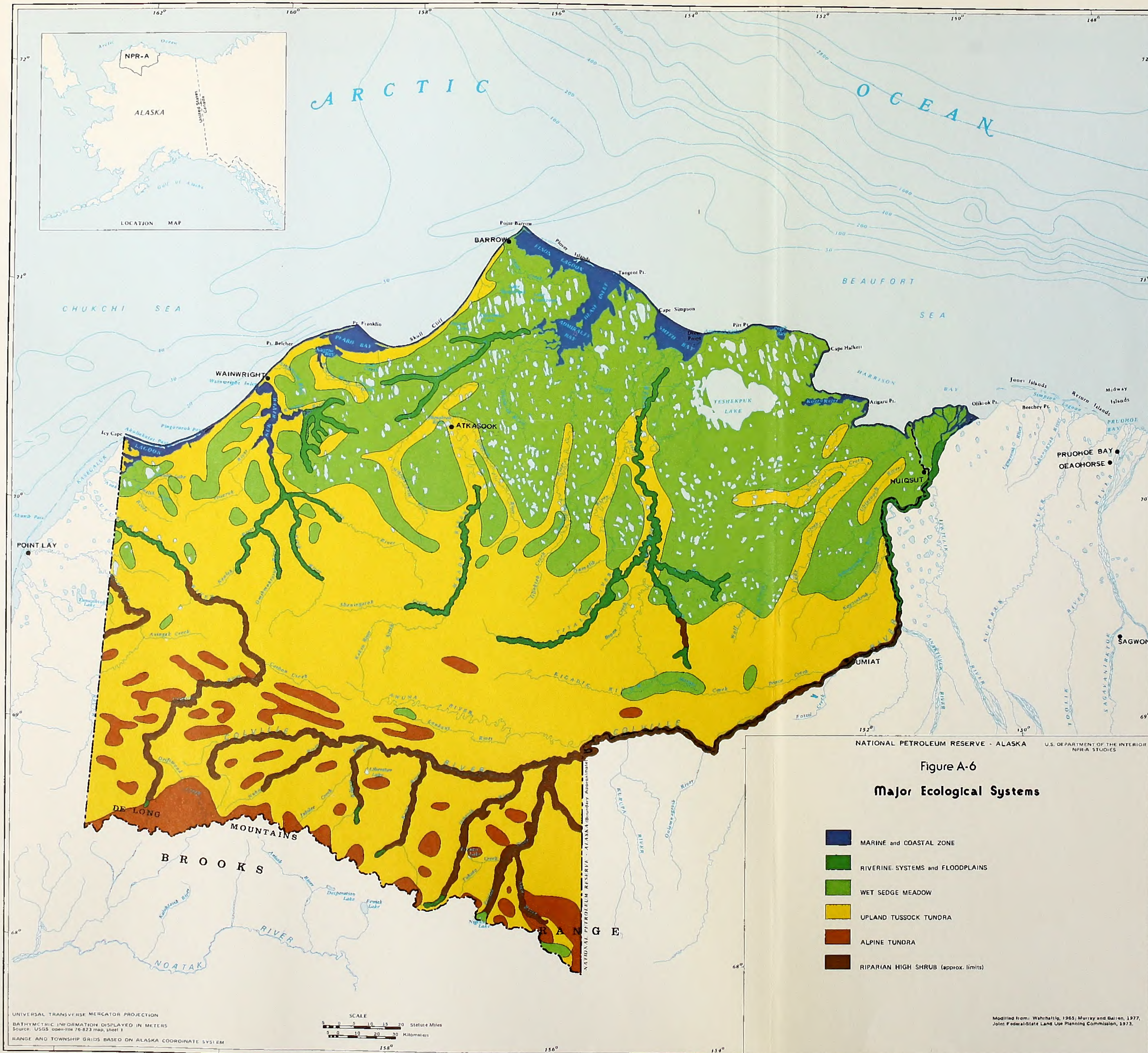


Figure A-6

Major Ecological Systems

duced by river-contributed turbidity. In contrast, in more temperate areas, spring runoff contributes high nutrient concentrations to a warmer ocean resulting in higher productivity and dissolved oxygen levels.

Plant life in deeper marine areas is restricted to phytoplankton. In a few locations, such as near Wainwright and in Peard Bay, algae grow in concentrations sufficient to form kelp beds. Concentrations of phytoplankton and other algae vary considerably due to conditions of sunlight, temperature, and nutrients.

Emergent grasses and sedges grow seasonally in brackish marsh ponds, and submergent plants grow in some protected lagoons. Common plant varieties are cotton grass, horsetail, marigold, foxtail, reed bent grass, alkali grass, sedges of the *Carex* genus, and grasses of the *Deschampsia* and *Dupontia* genera. The rigorous arctic environment of ice, low tidal amplitude, and soft, unstable beach sediments in intertidal areas restricts the variety of flora.

Two mammals, the polar bear and to a lesser extent the arctic fox, utilize both the landward and seaward portions of the NPRA coast. Polar bears frequent the mainland coast in winter, although they mainly obtain their food on the pack ice. Pregnant female polar bears construct maternity dens in areas of sufficient snow accumulation along coastal beaches below bluffs and riverbanks and on barrier islands. Some denning occurs on the pack ice. A significant number of arctic foxes spend the winter months along the coast and on the nearshore fast ice, where they feed on carrion and remains of polar bear kills and occasionally on ringed seal pups (National Oceanic and Atmospheric Administration, 1977).

The NPRA coast and protected nearshore waters are important to the life cycle of migratory waterfowl, shorebirds, gulls, and terns that are present from May through September. In general, the barrier island chains and the narrow beaches of the coast consistently support low numbers of nesting birds (Divoky, 1978). However, the barrier islands of Kasegaluk Lagoon are important breeding sites for arctic terns and eiders and are probably a major molting area for eiders and oldsquaw. Peard Bay and its barrier islands are known to be an important feeding and resting site. Smith Bay, the western portion of Harrison Bay, and the Colville River Delta provide valuable feeding and resting areas, although nesting on the Beaufort Sea coast is primarily on the mainland.

During spring when most of the NPRA coast is still covered with shorefast ice, migratory waterbirds utilize the coast as a navigational reference. Birds nesting on barrier islands, such as eiders, and inland nesting loons, oldsquaws, glaucous gulls and arctic terns utilize the barrier islands and protected bays and lagoons as resting areas but often feed in the open sea. In the postbreeding season, oldsquaws and brant gather in the protected bays and lagoons to feed on marine invertebrates and to rest on the barrier islands during their feather molt. Juvenile red phalaropes and Sabine's gulls, as well as other shorebirds and waterfowl, congregate on the barrier islands and bays to feed, molt, or stage for migration.

Polar bears are usually found on the sea ice, but females often return to land to bear their young in dens. (J. C. LaBelle, AEIDC)

In August and September, the shoreline of barrier islands has the highest density of birds of any of the Arctic coastal habitats; as many as 620 birds per mile (385 per kilometer) of shoreline are common. (Divoky, 1978).

True marine mammals in the marine environment include 10 species of whales and 6 species of seals. Of the marine mammals, only the walrus, ringed seal, bearded seal, and beluga could be considered common in the NPRA marine environment; they are most numerous during their spring and fall migration periods. Seals use barrier islands as resting areas, and ringed seal females have pups in snow lairs on the ice in nearshore areas during winter and spring.

There are fewer fish species in this marine environment than in temperate waters. Although knowledge of life history, abundance, and distribution of the fish life is limited, species diversity and abundance appear to be greater in the Chukchi Sea than in the Beaufort Sea. Of the 69 species believed to inhabit the marine environment near the Arctic coast, 13 species are anadromous. Some of the freshwater fish not considered to be anadromous may also enter brackish waters and estuaries.

Invertebrates include numerous types of protozoa, jellyfish, polychaetes, crustaceans, clams, sea stars, brittlestars, and sea cucumbers. Zooplankton in the area is dominated by copepods, and macrofauna is dominated by annelids, mollusks, and arthropods.

The type of vegetation present along the coast of NPRA is directly related to the amount of beach scouring by waves and ice in a given reach. Coastal beaches directly exposed to sea action are nearly devoid of vegetation. However, a large part of the Chukchi Sea coast and a smaller part of the Beaufort Sea coast in NPRA are protected from wave action and ice scour by chains of barrier islands lying as close as several hundred feet to several miles (a few tens of meters to 10 kilometers) from the mainland coast. These barrier islands receive the brunt of the scouring process and support very little vegetation. The mainland beaches thus sheltered on the landward sides of the bays, lagoons, inlets, and estuaries are able to support a greater abundance of vegetation.

The vegetation on the narrow, protected beaches of both the Chukchi and Beaufort Seas is similar to that reported for Walakpa Bay beaches by Potter (1972), although individual species may vary. Typical species at Walakpa Bay include: oysterleaf, arenaria, lyme grass, and alkali grass, with patches of scurvy grass, chickweeds, and tufted saxifrage. Some rare plants, such as *Draba adamsii*, occur near Barrow on an inland beach ridge and at Pitt Point (Lonely) (D. F. Murray, University of Alaska, written communication, August 1978).

b. Wet Sedge Meadows

The coastal plain, except for the river flood plains, is essentially a mosaic of small lakes and wet sedge meadows. About half of the coastal plain and one-fourth of the foothills are covered by wet sedge meadows. The peaty soil has a shallow active layer and is saturated throughout the summer. A nearly ubiquitous pattern of high- and low-centered ice-wedge polygons sometimes occurs even under some lakes. Several species of sedges, especially *Carex aquatilis* and cotton grass *Eriophorum angustilifolium*,

Ice-wedge polygons are distinctive features of the continuous permafrost zone. (Robert Lewellen)

The innumerable thaw lakes of the coastal plain provide important bird-nesting habitat. (C. D. Evans, AEIDC)

make up about three-quarters of the vegetation (Spetzman, 1959). Differences in the vegetative composition are related to the microrelief of the polygons. Many species of mosses grow in the understory, but lichens are abundant only in relatively dry habitats that collectively comprise a small portion of the area. Secondary species include other cotton grasses, louseworts, and buttercups in the wetter sites, and heather, purple mountain saxifrage, dwarf willows, and birch in the raised, drier habitats, such as the ridges on the polygon margins. Pendent grass *Arctophila fulva* is an important emergent species on the shorelines and in the shallow zones of ponds and lakes.

Plant consumption in wet sedge meadows is dominated by the brown lemming. Because the density of this species varies in a cyclic fashion over a period of 3 to 5 years, grazing pressure also varies in a cyclic fashion. Other herbivores, such as geese, collared lemmings, seed-eating birds, and caribou, are present but never achieve the high densities of the brown lemming nor do they undergo such dramatic changes in density. Arthropods of the wet sedge meadows are primarily saprovores, feeding mainly on products of decay and not extensively on live plant tissue. The terrestrial invertebrate fauna has few herbivores living above ground in the vegetation. Sawfly (Hymenoptera) and lepidopteran larvae occur on the few willows and other dicotyledonous plants (Bunnell, Maclean, and Brown, 1975).

Carnivores of the wet sedge meadows fall into two main classes: those that feed on invertebrates, mainly insect larvae and adults, and those that feed on brown lemmings, microtine rodents, and birds. Predators of tundra invertebrates are primarily birds, including several species of shorebirds, waterfowl, and some passerines, such as the Lapland longspur and snow bunting, during the breeding season. Major predators of lemmings include jaegers, snowy owls, short-eared owls, least weasels, ermine, and the arctic fox. Large mammalian carnivores (wolf, wolverine, grizzly bear) are uncommon in wet sedge meadows. Polar bears enter the terrestrial environment in significant numbers only for denning in winter by pregnant females.

Densities and reproductive success of the predators that depend on lemmings vary markedly from year to year, depending upon the stage of the lemming cycle in a given area. For example, pomarine jaegers may be absent in the Barrow area when the lemming cycle is at a low but may nest at high densities when the cycle highs occur. Similarly, snowy owls are unable to overwinter in the area except when lemming densities are relatively high. These specialized predators become rare or absent farther inland where species diversity of rodents increases.

The arctic fox population fluctuates more gradually in response to lemming cycles because foxes use other food. Arctic foxes prey on birds in summer, and they scavenge on bird and marine mammal carcasses along the coast and on the pack ice in winter.

Due to the poor drainage, damming effects of snow drifts, and low evaporation rates, large parts of the wet sedge meadows are flooded during early summer. These flooded areas are important for early production of diverse invertebrate populations, including fairy shrimp, springtails, snails, water fleas and midge larvae. These wetlands serve as the most important early summer feeding areas for a variety of waterfowl and shorebirds. Some shorebirds, especially plovers, continue to probe these areas later in summer after the surface water is reduced in extent. The most important such flooded areas lie in old drained lake basins (Bergman and others, 1977).

In the Coastal Plain province, the ecological relationships between terrestrial life and freshwater systems are extremely close and complex. Physical and ecological processes are constantly forming, reshaping, and draining in the freshwater ponds. An exchange of nutrients and energy between water and land is a central feature of the function of this ecosystem.

Plant life of the freshwater environment generally includes algae, other phytoplankton, emergent grasses, and sedges. Nearly all species of the freshwater phytoplankton are extremely small and are used as food by zooplankton and fish larvae. Phytoplankton production is low in deeper lakes. Emergent grasses and sedges occur along the banks of streams and around the edges of deeper lakes. Both submerged and emergent forms of aquatic seed plants occur in shallow ponds and lakes and may become quite dense by late in the growing season. Productivity of the thaw lakes is limited by low levels of phosphorus (Cornwall and Barsdate, 1977).

Zooplankton in the freshwater environment of NPRA is mainly composed of copepods, although other crustaceans, as well as rotifers, flagellates, and ciliates are present. Aquatic annelids and larvae of midges, mosquitoes, dragonflies, stoneflies, mayflies, and caddisflies are present and are important in the food web of fishes. Beetles, clams, and snails also occur in the streams and lakes. Fish found in freshwater ponds and lakes in this zone are listed in table A-l.

The annual freezing of lakes and streams to depths of about 6 feet (2 meters) strongly influences fish populations and species. Shallow lakes without outlets usually freeze to the bottom, and most are devoid of fish life. A few of these lakes contain ninespine stickleback and Alaska blackfish, which either overwinter in deeper holes or enter from the wet tundra marshes during the spring thaw period. Shallow lakes with outlets usually support larger populations in summer and as many as six species of fish. These fish either migrate from the lakes each winter prior to freezeup or are replaced each spring by new migrating fish. Deeper lakes, with or without permanent outlets, generally have substantial numbers and varieties of fish, especially if spawning substrate is present.

Most lakes in the western half of the coastal plain are thaw lakes less than 6 feet (2 meters) deep which freeze to the bottom by late winter. Of 32 lakes sampled during the 1977 field investigations (National Petroleum Reserve in Alaska Task Force, 1978d), fish were captured in only 17 lakes. Only four of these had species other than the ninespine stickleback. Apparently, tiny ninespine sticklebacks overwinter in the marine environment, rather than in small holes in the lake bottoms, and return to the thaw lakes through standing water found in the wet tundra during spring breakup. Probably most lakes in the area are without fish life for 8 or more months each year. A few deeper lakes there support resident fish populations.

On many of the smaller streams, flows are greatly reduced during the summer. Fish are then largely restricted to a series of ponds in the stream channel. Fish populations may be isolated in these ponds except when streamflow is sufficient to fill a connecting channelway.

Lake water clarity varies considerably on NPRA. Winds often keep the lakes turbid. The effects of this turbidity on the aquatic environment are probably adverse. However, in nearly all lakes observed, sunlight does reach the lake bottom, permitting production of phytoplankton, especially algae.

The reproductive success of many bird species in the Arctic is intimately tied to productivity of tundra ponds and lakes. Tundra ponds too shallow to support fish populations nevertheless play key roles in the ecology of the coastal plain. They produce vast numbers of invertebrates on which waterbirds feed.

c. **Upland Tussock Tundra**

Upland tussock tundra is the most abundant vegetation type on NPRA, covering a significant portion of the coastal plain, especially the southern part, most of the foothills zone, and portions of the mountain zone up to altitudes of about 3,000 feet (1,000 meters). In spite of its prevalence, this type of tundra has only recently become the subject of intensive ecologic study, and less is known about upland tundra than the wet sedge meadow type.

The dominant plant species in upland tussock tundra is the tussock-forming cotton grass, *Eriophorum vaginatum.* Individual tussocks are typically 1 1/2 feet (15 to 30 centimeters) in both diameter and height, separated by troughs about 1 foot (30 centimeters) wide. Scattered among and on the tussocks are secondary species, including grasses, sedges, and dwarf shrubs. Several different forbs also occur. Along margins of streams dissecting upland tussock tundra, willows as high as 3 feet (1 meter) occur. Lichens are more abundant here than in wet meadows, especially in association with the drier tussock communities. A broad range of variation exists in this zone, grading from nearly pure cotton grass stands to stands dominated by an overstory of low shrubs. In some areas, high-center polygons occur with tussocks in the centers and wet sedge meadow vegetation in the troughs between the polygons.

The accumulation of snow between tussocks provides a favorable environment for small rodents. The presence of exposed tussock and hummock tops provides opportunities for caribou winter foraging; particularly important are lichens and vascular plants associated with the tussocks. The exposed or thinly covered dark tussock tops warm rapidly in the spring

Cotton grass is the dominant plant species in upland tussock tundra. It provides favorable habitat for lemmings and other small rodents and forage for caribou in the spring. (O. E. Cote, AEIDC)

under the influence of increasing solar radiation in the longer days. Cotton grass begins to flower in early May on the most favorable sites and is the first new growth of the year on the Arctic Slope. Most of the adult female segment of the Western Arctic Herd of caribou takes advantage of this event by converging on the foothills of NPRA in May of each year. Floral parts and new growth of cotton grass are the major food items available immediately prior to and during the calving period. The calving grounds correspond to a zone where snow deposition and melt patterns normally make available a vast exposure of new-growth cotton grass at the appropriate time (Lent, 1966). Toward the end of the calving period (in early June), new growth of prostrate shrubs and certain forbs begins, also taking advantage of the tussock microenvironment, and use of these species by caribou becomes more common.

Small mammals associated with upland tussock tundra are the tundra vole, red-backed vole, arctic shrew, and ground squirrel (table A-l). Under some conditions, densities of small mammals in tussock communities can approach those in the wet sedge meadows in the coastal plain. The densities and productivity of bird and mammalian predators dependent on these rodents also fluctuate severely.

Large carnivores generally are more abundant in tussock tundra than in the wet sedge meadows. Wolf densities approximate one per 150 square miles (388 square kilometers), but wolves are locally more abundant where caribou are present. During the winter months when caribou are absent, wolves are also absent because alternative prey species are lacking. During the caribou calving season, wolves are tied closely to den sites, some of which occur in the tussock tundra areas. Grizzly bears occur in the tussock tundra and associated river valley and dry tundra ridges. Bears use a variety of food sources. Caribou provide a supplemental food source which is obtained mostly through scavenging.

Wolverine also are present, but little is known about their numbers or food habits.

The tussock community, particularly the associated low heath shrubs, could provide important range for muskoxen on NPRA as it has to the expanding muskox population reintroduced on the Arctic National Wildlife Range and near Point Hope. A few muskoxen were seen along the coastal part of NPRA during 1977.

Birds associated with tussock tundra include willow and rock ptarmigan, whimbrels, buff-breasted sandpipers, parasitic and longtailed jaegers, and the ubiquitous Lapland longspur. Peregrine falcons, rough-legged hawks, and gyrfalcons all forage over this vegetation type. Several thousand ptarmigan were observed over the eastern portion of the caribou

Flood plains of major river systems support a high brush community, which represents a distinct ecological system. Willows up to 25 feet provide browse for moose. (J. C. LaBelle, AEIDC)

calving grounds in mid-May 1962; their average density was approximately 50 per square mile (20 per square kilometer).

Waterfowl use lakes in the tussock tundra. Prevalent species include pintails, green-winged teal, oldsquaws, and greater scaup. Other species which breed mainly in the coastal zone, such as white-fronted geese, use the tussock tundra and river valleys during migration.

d. Riverine Systems and Flood Plains

The flood plains of the major rivers on NPRA are distinct and diverse ecological systems that dissect and interact with the upland systems. Flood plains are usually several times wider than their active stream channels. Incised streams and cut-banks are common. Oxbow lakes and associated emergent vegetation and wet sedge meadows are interspersed with higher terraces, especially in the foothills.

The most distinctive riparian vegetation type in the foothills and mountain zones is the shrub thicket. Tall shrub stands are found along much of the Colville River and its major tributaries and along parts of the Utukok and Ikpikpuk Rivers. The dominant species are willows (*Salix alaxensis* and *S. arbusculoides*) and alder (*Alnus crispa*). Willows up to 25 feet (8 meters) tall occur. These take several decades to develop. Almost pure stands of willow occur on alluvial deposits and low terraces.

The riparian shrub vegetation exists in narrow bands passing through the other types and provides an important edge effect which promotes species diversity. Thus, many bird species associated with wet and lake habitats are found in the flood plains even where these pass through the drier habitats of the foothills and mountain zones. Caribou and moose also use the bars and the active river channels to escape insects.

Moose are dependent upon the riparian high shrubs of the Colville River and its major tributaries. Even in summer, moose rarely move out of the river valley; moose observed by Mould (1977) had not moved farther than 12 miles (19 kilometers) from the river in summer, and all were in the flood plain during winter. In general, the size of arctic moose population is proportional to the amount of riparian habitat available. Appropriate areas of the Colville River drainage have been recommended for designation as critical habitat for moose.

In most years, caribou enter the Colville River drainage in large numbers during the summer months, feeding on new growth of shrubs and emergent vegetation as they move to and from the tundra or alpine areas. This use of vegetation likely does not significantly affect availability of browse for moose.

Muskoxen and tundra hare formerly occupied riparian shrub areas. Although the extirpation of muskoxen has been attributed primarily to hunting, it is not known to what extent natural changes in the ecology of the area might also have been involved in the loss of these two species. Both are known to utilize shrub communities elsewhere in their range.

River bars are used by many bird species, especially migrating geese in late summer, for resting, drying and sunning; the bars are also important to peregrine falcons.

Cliffs and bluffs near riparian habitats along the Colville, Utukok, and other rivers provide major nesting areas for peregrine falcons. This endangered species uses a variety of cliff types and substrates, especially in the Colville drainage. Their aeries are relatively accessible to humans; most nest sites can be reached without the aid of ropes. To some extent, gyrfalcons, rough-legged hawks, ravens, and golden eagles compete with peregrines for nesting sites.

Peregrines prey primarily on passerines (thrushes, warblers, and tree sparrows) that are dependent upon the high, dense, riparian shrub habitats. Peregrines also prey on birds of the low, open shrub communities (yellow wagtails) and tundra habitats (jaegers, shorebirds and snipe). Gyrfalcons are probably less dependent on riparian habitats, feeding largely on ptarmigan, rodents, such as lemmings and ground squirrels, and waterfowl. Rough-legged hawks show a strong preference for mammalian prey from a variety of habitats.

The peregrine falcon population in and around NPRA has declined dramatically since the 1950's. Present numbers are about 25 percent of those previously breeding in the area. On the Colville River the decline has been greater in upriver areas and tributaries than in areas downriver from Umiat, even though nesting substrates on the lower river appear less suitable. Prey availability and hunting conditions may be better on downstream areas, and a shift of remaining peregrines to these areas may coincide with the decline (White and Cade, 1975).

The overall decline in peregrines has been attributed to the physiological effects of accumulated organochlorine pesticide residues. Tundra-nesting peregrines winter far to the south and pass through some of the most heavily polluted areas in the Western Hemisphere. As predators at the top of a food chain, peregrines concentrate the pesticide residues. In contrast, gyrfalcons and rough-legged hawks do not migrate to heavily contaminated areas and have not suffered declines (Cade and others, 1971). The decreased number of peregrines may already have had some ecological ramifications in NPRA. White and Cade (1971) suggest that northern shrikes have increased and are now a major predator of passerines in shrub thickets.

The willow ptarmigan is by far the most abundant of the two ptarmigan species along the Colville River drainage. These birds nest at the edges of lowland dwarf shrub communities and are also frequently seen in tussock tundra. Presumably ptarmigan make greater use of the high shrub vegetation in winter when snow covers lower growth forms.

The river valleys, in general, and the high shrub communities in particular, provide for a great variety of life on a year-round basis. The availability of several alternative prey species and remains for scavenging attract large carnivores, particularly in the winter months. River valleys also provide good denning sites, especially for bears. The red fox is a dominant carnivore of smaller prey in this environment.

Twenty-four species of fish are believed to occur in NPRA riverine systems, but only 19 species were identified during the field investigations (National Petroleum Reserve in Alaska Task Force, 1978d). Since all streams and rivers freeze in the winter, fish either migrate to the estuaries or overwinter in the deep holes in lakes and rivers.

Salmonid species, such as char, whitefish, and cisco, found in NPRA in 1977 and 1978 were studied during upstream migration and spawning activities. Those populations may reflect higher numbers than can be supported for long periods by the available food supply. A high percentage of the fish captured had empty stomachs. Of those fish actively feeding, food items included caddisfly and chironomid larvae, terrestrial and aquatic beetles, aerial insects, snails, bivalves, amphipods, plankton, and ninespine stickleback.

e. Alpine Tundra (Fell-Fields)

The vegetation of the mountainous zone of NPRA is complex and variable and is influenced by a number of factors including bedrock type, degree of soil accumulation, slope exposure, drainage, snow cover, and altitude. Because of the relatively low altitudes of passes in the western and central Brooks Range, the areas of alpine tundra are discontinuous, being broken by tongues of riparian shrubs and associated meadows and tussock vegetation that extend in some places to the crest of the range.

True alpine tundra is found predominantly in drier sites. Mountain avens and other mat-forming species, lichens, and mosses are the dominant plants. The *Dryas*-lichen dry meadow generally occurs in the zone between 2,000 and 4,000 feet (600 and 1,200 meters). Ericaceous shrubs, especially *Cassiope tetragona*, are common in somewhat moister sites and where snow persists well into summer. Above 4,500 feet (1,500 meters), large barren expanses of substrate are common.

Dryas-dominated dry tundra meadows are also found on ridgetops, such as the long east-trending ridges in the Foothills province, and on other areas having shallow, coarse soils, such as rubble slopes. Fruticose lichens are a conspicuous component of this vegetation. *Dryas*-dominated communities also occur on dry, rocky slopes in stripes or "steps."

Locally, the activities of ground squirrels greatly alter the composition of this vegetation type. Their feeding is often directed at *Dryas* root systems, and this can lead to small-scale erosion. Ground squirrel burrowing activities cause formation of small "islands" of low willows, other shrubs, and grasses on the mounds of excavated dirt mixed with droppings.

Other rodents also live in the fell-fields. For example, marmots are found only in the alpine tundra. The singing vole is common at altitudes of about 4,000 feet (1,300 meters) and occurs in close association with *Cassiope*. Red-backed voles and collared lemmings also occur in the alpine tundra, as does the arctic shrew.

All large mammals of NPRA are only partly dependent upon alpine tundra because of their seasonal dependence upon other ecological types. Caribou, for example, use mountain meadows and ridgetops primarily for feeding on new green growth and flowering parts of herbs in summer and on

Ground squirrels feed on *Dryas* root systems, causing small-scale erosion that alters the composition of alpine tundra. (Marilyn Warren)

lichens in winter and spring. All the large carnivores inhabit the alpine tundra, but typically the red fox and the wolf are the most common species. Wolverine probably den in snow drifts associated with fell-fields. Wolves are more common in alpine areas and associated river headwaters areas than elsewhere in NPRA; densities of up to one wolf per 60 square miles (155 square kilometers) are reported. Den sites are probably relatively common in this zone. Grizzly bears commonly den in the ridge and upper foothill areas.

Dall sheep utilize the alpine tundra, moving upslope or downslope seasonally in response to snow accumulation and melting and the presence of green vegetation. Plant communities associated with rock outcrops and talus slopes provide important forage in conjunction with escape opportunities (Summerfield, 1974). In spring, the sheep forage low in the river valleys, where new growth is available. They are probably most vulnerable to predation at this time. The Dall sheep is apparently the only large mammal in NPRA that is presently confined to the Brooks Range province.

About 50 species of birds regularly breed in the alpine zone of Arctic Alaska. Passerines are especially prevalent, and they comprise more than 20 of the 50 species. However, relatively few species actually breed in the dry alpine tundra. The use of the alpine passes of the Brooks Range by birds migrating to and from the Arctic coastal tundra has been well documented. Willow ptarmigan in particular make heavy use of these passes; up to 50,000 have been reported moving northward each May through Anaktuvuk Pass.

Lakes in the alpine tundra are of glacial origin and are larger and deeper than most coastal thaw lakes. Lakes surveyed during 1977 ranged in surface area from 64 to 1,097 acres (25 to 443 hectares) and averaged 18 feet (about 5 meters) in depth; winter ice thickness on foothill lakes may reach about 8 feet (2.4 meters). Fish species diversity was low, with old fish dominant, indicating low fishing pressure and slow growth rates. Fish species commonly found in foothill and alpine lakes were lake trout, grayling, round whitefish, burbot, ninespine stickleback, and slimy sculpin. Least cisco were found in several lakes, and broad whitefish were found in one. Diets of the lake fish were similar to those of fish in the riverine systems, except that lake trout and burbot had eaten mostly small fish (least cisco, round whitefish, slimy sculpin, grayling, and ninespine stickleback) and lake trout had also eaten voles.

2. Unique Ecological Areas

Several broad areas within NPRA have unique ecological attributes. The Teshekpuk Lake, Utukok

Figure A-7
Unique Ecological Areas

uplands, and Colville River Bluff areas have been classified as special areas deserving protection under P.L. 94-258 as recorded in the *Federal Register* (43 CFR 2361, May 31, 1977). These areas and the Colville River Delta, Point Barrow area, and Icy Cape were also identified by Underwood (1977) in his recommendations on an ecological reserve system for Alaska. Most of these areas represent large tracts of fish and wildlife habitat. However, the Point Barrow area encompasses several small tracts which have a history as sites for ecological research. The Icy Cape area includes both research and habitat sites. These generalized areas are shown in figure A-7.

a. Teshekpuk Lake Area

The Teshekpuk Lake area is conspicuous for its large, uniformly oriented lakes. Several of these lakes range from 4 to 8 square miles (10 to 20 square kilometers) in surface area. Most are shallow, probably less than 10 feet (3 meters) deep. These lakes have developed and continue to change through thaw erosion processes unique to the Arctic. Many large lakes in this region have been incorporated into the sea by coastal erosion and now appear as bays and inlets. Wetland areas are dominated by a shoreline zone of *Carex aquatilis* in shallow ponds and lakes, grading to *Arctophila fulva* in deeper zones.

During the summer months, the most conspicuous faunal elements of the Teshekpuk Lake area, other than mosquitoes, are caribou and molting geese. The large lakes from the Kogru River northwest to Drew Point and south from the coast to Teshekpuk Lake attract thousands of geese and black brant from the U.S.S.R., Canada, and the conterminous United States during the annual molt. King and Hodges (1977) estimated that a total of 31,900 Canada geese, white-fronted geese, and lesser snow geese used this area for molting during July 1977. There are no other known areas of comparable molting concentrations in the North American or eastern Siberian Arctic. The large size of the lakes, which provide protection from predators, and the proximity to the coast are likely factors for this concentration, as is the traditional use of certain feeding areas along preferred nutrient-rich shorelines.

In late June and July considerable numbers of cow caribou with calves migrate through the large lake region north and east of Teshekpuk Lake. This area apparently provides relief from insects. The Teshekpuk Lake area is important for both summering and wintering caribou and is also used year-round by the Teshekpuk Herd of 3,000 to 4,000 caribou.

Large flocks of phalaropes gather in this area during late July prior to migration. A mass gathering and subsequent dispersal of thousands of juvenile Lapland longspurs was recorded in late July 1977, but its significance is not clear.

b. Delta of the Colville River

The Colville River Delta is the largest in Arctic Alaska. It presents a unique combination of physiographic features, including extensive sand dunes and

The coastal plain comprises nearly half of NPRA. The Ikpikpuk is a typical river flowing across this flat terrain. (U.S. Geological Survey)

The Colville River Delta presents a unique combination of physiographic features. It is important for spawning and overwintering fish and supports the only commercial fishing operation on the Arctic Slope. (J. C. LaBelle, AEIDC)

"perched" ponds in a relatively small area. The delta is important to fish for both spawning and overwintering habitat (Kogl and Schell, 1975). The extensive well-drained sites provide for unusually high numbers of burrowing mammals, notably ground squirrel and arctic foxes. There is also a relatively high concentration of polar bear denning sites. Numerous bird species are present, and the area is particularly important for whistling swans. Seals reportedly enter the delta and lower reaches of the Colville River.

The delta also supports the Reserve's only commercial fishing operation; as many as 60,000 whitefish and cisco are harvested there annually.

c. **Utukok Uplands**

The Utukok uplands extend from the Kokolik River eastward to upper Carbon Creek in the Foothills province of NPRA. Central to its ecological importance is the presence of abundant tussock tundra coincident with a zone of thin snow cover and early melt. The thin snow cover, normally less than 10 inches (25 centimeters) thick, extends in a zone southward across the southwest corner of NPRA, and encompasses the Western Arctic Caribou Herd's calving grounds. A predominance of cotton grass tussocks with few associated shrubs occurs in this area, and this probably increases its significance to caribou.

Because of the early snowmelt and greening of vegetation, the area is of critical significance to most migratory birds during spring movements to the coast, to caribou, and probably to ptarmigan. The concentrations of herbivores, in turn, support more large carnivores (grizzly bears and wolverine) than can be found elsewhere in the Alaskan Arctic. The dry alpine tundra on ridges also has less snow cover than comparable areas to the east and becomes green earlier, providing forage for caribou, as well as other herbivores, early in summer. However, the thin snow cover and relatively dry upland conditions make the area particularly susceptible to terrain damage.

d. **Colville River, Bluffs, and High Shrub Zone**

This riverine area has a high density of nests of peregrine falcons and gyrfalcons. It also contains the most extensive and well-developed tall shrub vegetation in the Alaskan Arctic. This vegetation supports the largest concentration of moose north of the coniferous forest zone in North America. Fish resources are probably the most numerous of the North Slope.

e. **Point Barrow Area**

The Point Barrow area possesses the extremes attainable in Alaska for many ecological properties and phenomena. Certain sites in the area are vitally important because of their long history of ecological research performed by the Naval Arctic Research Laboratory.

f. Icy Cape

The Icy Cape area provides the best example of a system of barrier islands, protected lagoons, and shorelines within the Chukchi Sea sector of the Arctic coastline. High densities of waterbirds and gulls have been noted, and the area is second only to the Teshekpuk area in importance to geese. The cape and adjacent waters are identified as an important area for migrating shorebirds. The area has also been used as a research site for the study of coastal erosion processes (Underwood, 1977).

3. Wildlife

There are about 40 species of mammals, 30 species of fish, and numerous birds which occur in the Arctic region. Many of these are found on NPRA and constitute its main renewable resource. This resource has sustained the Native populations for centuries and continues to supply a significant portion of their food requirements today. Migratory birds using NPRA are of high national and international significance.

a. Land Mammals

Some 20 species of terrestrial mammals occur regularly and breed on NPRA. Many of these have direct economic importance or recreational and scientific value. Several, notably grizzly bears, wolverine, caribou, and moose, occur in NPRA in numbers apparently unsurpassed in other Alaskan Arctic areas.

i. Caribou

The caribou in northwestern Alaska, known as the Western Arctic Herd, range over about 140,000 square miles (362,600 square kilometers). Patterns of habitat use shift from season to season and vary from year to year. The large carnivores of the Arctic depend upon caribou through both predation and scavenging. Similarly, man, in both prehistoric and historic times, has depended upon caribou for meat and other products. As a migratory animal, caribou link the tundra ecosystem with other ecosystems, specifically the taiga, forest-tundra, and alpine areas south of the Brooks Range crest. The well-being of caribou depends on freedom of movement to areas of favorable snow conditions, vegetative phenology, and insect relief. Generalized caribou movements are shown in figure A-8.

At all seasons, ranges outside of NPRA are utilized by some individuals and are apparently necessary for the maintenance of a large caribou population in northwest Alaska. Wintering areas south of the Brooks Range have always been used when the population was large (Murie, 1935; Lent, 1966).

Since at least the 1940's, the majority of caribou in this herd have normally wintered south of the Brooks Range. Lichen-rich ranges, primarily tussock-heath communities, and tussock meadows and forest edges receive the heaviest use. Parts of the lower Kobuk drainage and the Selawik basin are heavily used almost every year. Utilization of the Noatak drainage, upper Kobuk drainage, and areas south of the Kobuk drainage appears to vary greatly in intensity and locale from year to year. Ranges south of the Endicott Mountains in the central Brooks Range have generally received less use in the 1970's than in the prior decade. Almost every year part of the herd remains in winter on the Arctic coastal plain. The part remaining has ranged from about 15 percent in 1960-61 (Lent, 1966) to nearly all of the herd in 1957 (Olson, 1959), to about 50 percent in recent winters (National Petroleum Reserve in Alaska Task Force, 1978d).

Caribou wintering south of the Brooks Range generally start northward in late March. They travel across open habitats and enter NPRA through passes in the Brooks Range (Howard Pass, Killik Pass, and the heads of the Nimiuktuk and Kugururok Rivers and Trail Creek), or they enter along the southern foothills from the west end of the De Long Mountains. By early May most of the pregnant females of the population have entered the tussock tundra of the foothills. They move onto the calving areas by mid or late May. The relative degree of use of these various routes varies greatly from year to year, and occasionally some females do not reach the traditional calving ground by calving time. These variations are attributed mainly to variations in snow depth and timing of melt from year to year. Evidently, the same general calving area has been used at least since the nineteenth century (Lent, 1966; Skoog, 1968). During the calving period from late May to mid-June, females feed on the new growth of the *Eriophorum* tussock tundra in the northern foothills. Males are spread from the winter ranges to the southern foothills.

Immediately after calving in late June and early July, the caribou usually form large, dense, rapidly moving aggregations of many thousands of animals. These concentrations normally move southwest and into the southern foothills west of NPRA or they move directly west into the coastal uplands of the Pitmegea and Ipewik Rivers. In either case, the animals, including males that mix in with the females at this time, are using dry upland tundra where greening vegetation is available. In July, large groups move eastward near the crest of the De Long Mountains. In some years, the eastward movement is farther north, bringing animals directly back to the northern foothills and into the coastal tundra. In years when the main body moves east out of the mountains, there is frequently a northward movement of caribou through the Colville drainage into the Meade and Ikpikpuk drainages. Some animals may move directly from the mountains south into the Noatak drainage (Lent, 1966). Woody browse species, primarily willows, are important foods during the summer months in many areas.

Southern movements in late August and September take most of the caribou south of NPRA along routes similar to those used in spring. By November, after the rut, the caribou generally occupy winter ranges. Generalized caribou use zones in

NPRA are shown in figure 7 of the environmental analysis.

"Resident" caribou populations have reportedly been identified along the western Arctic coast of Alaska. White and others (1975) suggested that there is a resident population of about 300 caribou in the drainages of the lower Sagavanirktok and Kuparuk Rivers that is distinct from the migratory animals entering the area in summer. Resident groups have been tentatively identified in the Teshekpuk Lake and Wainwright-Kuk Inlet areas on NPRA. Estimates of numbers in these groups vary but range over 2,000 for Teshekpuk and 1,000 for Wainwright. The status of the Wainwright group is particularly uncertain since calving was not observed there prior to 1976. Whether the same individuals remain in these areas year to year or whether certain individuals migrate in some years but not in others remains a question.

The total Western Arctic Herd population has been estimated at 156,000 in 1961, 175,000 to 200,000 in 1962 (Lent, 1966), and 242,000 in 1970 (Alaska Department of Fish and Game, 1976). By 1975, the Department of Fish and Game believed that the population had dropped to 60,000 at most. In 1977, the population showed an apparent increase to between 65,000 and 75,000 (Alaska Department of Fish and Game, 1977). Although all the figures are estimates of varying accuracy, they show that the Western Arctic Caribou Herd, which had been increasing throughout the latter half of this century, reached a peak in about 1970 and by 1975 had declined substantially. Whether this decline has now been arrested is uncertain at present. Population fluctuations of similar or greater magnitude have occurred in the past in northwestern Alaska and elsewhere in Alaska and Canada. Theories advanced to explain such major declines have fallen into three basic categories: 1) declines are caused by deterioration of winter range resulting either from overgrazing or excessive burning and destruction of climax vegetation due to fires; 2) declines are caused by major shifts in ranges and transfer of large numbers of animals from one population to another; and 3) declines are caused by excessive hunting often acting in conjunction with natural predation pressure.

ii Moose

Approximately 1,800 moose occupy the North Slope region. At least two-thirds of this number are found in the riparian habitats of the central Colville River and its tributaries. Moose are present in lower numbers throughout the Colville River drainage (fig. A-9). However, during the summer, moose are occasionally found at other places in NPRA.

iii Dall Sheep

Dall sheep are present in the southern part of NPRA near the crest of the Brooks Range (fig. A-9). There are no data on population levels or trends. Dall sheep are sensitive to low-level aircraft overflights.

iv. Grizzly Bear

The southwestern part of NPRA contains the highest known grizzly bear density on the Arctic

Moose are common in the riparian habitat of the Colville River and its tributaries. (Robert Belous, National Park Service)

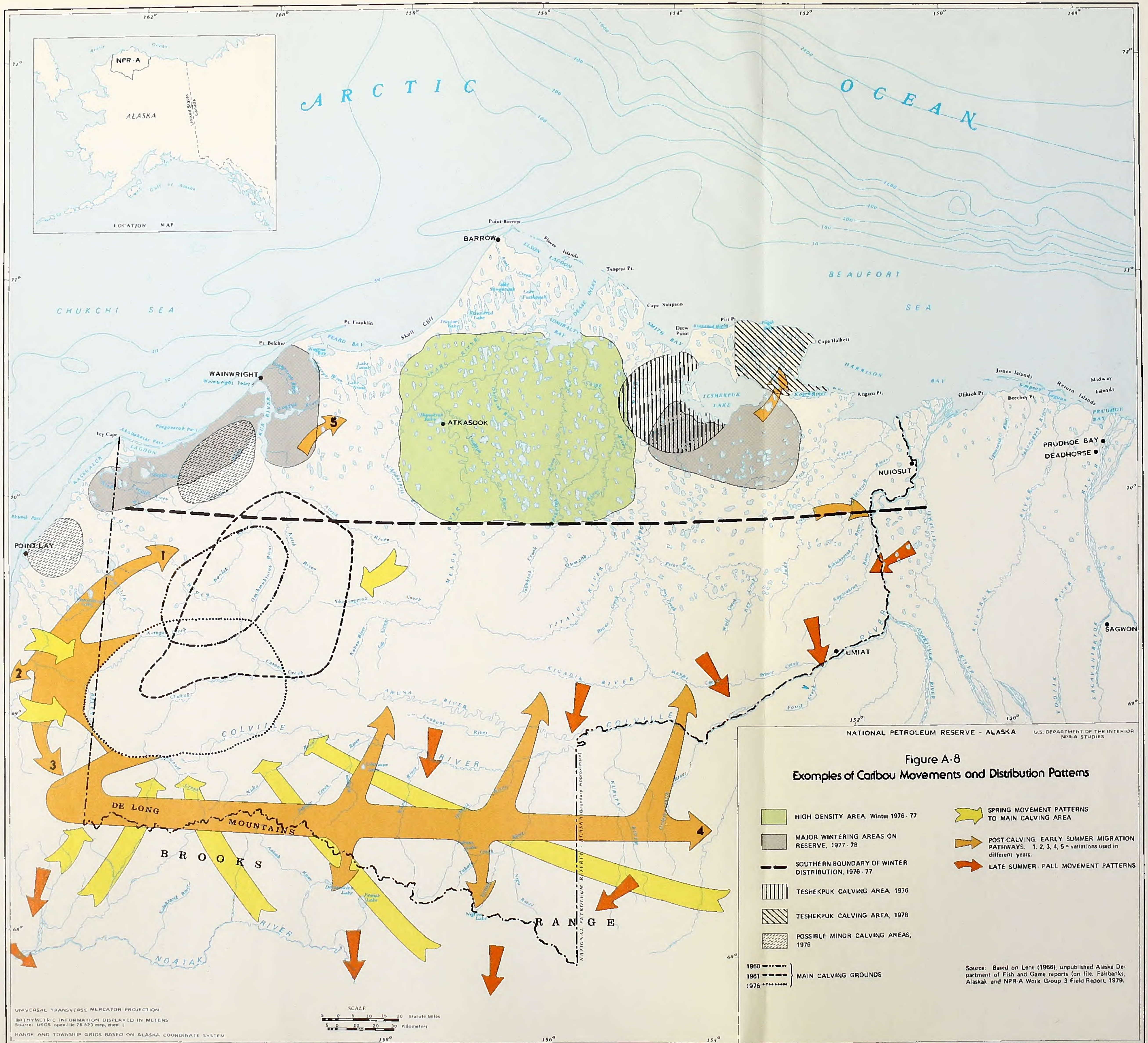


Figure A-8
Examples of Caribou Movements and Distribution Patterns

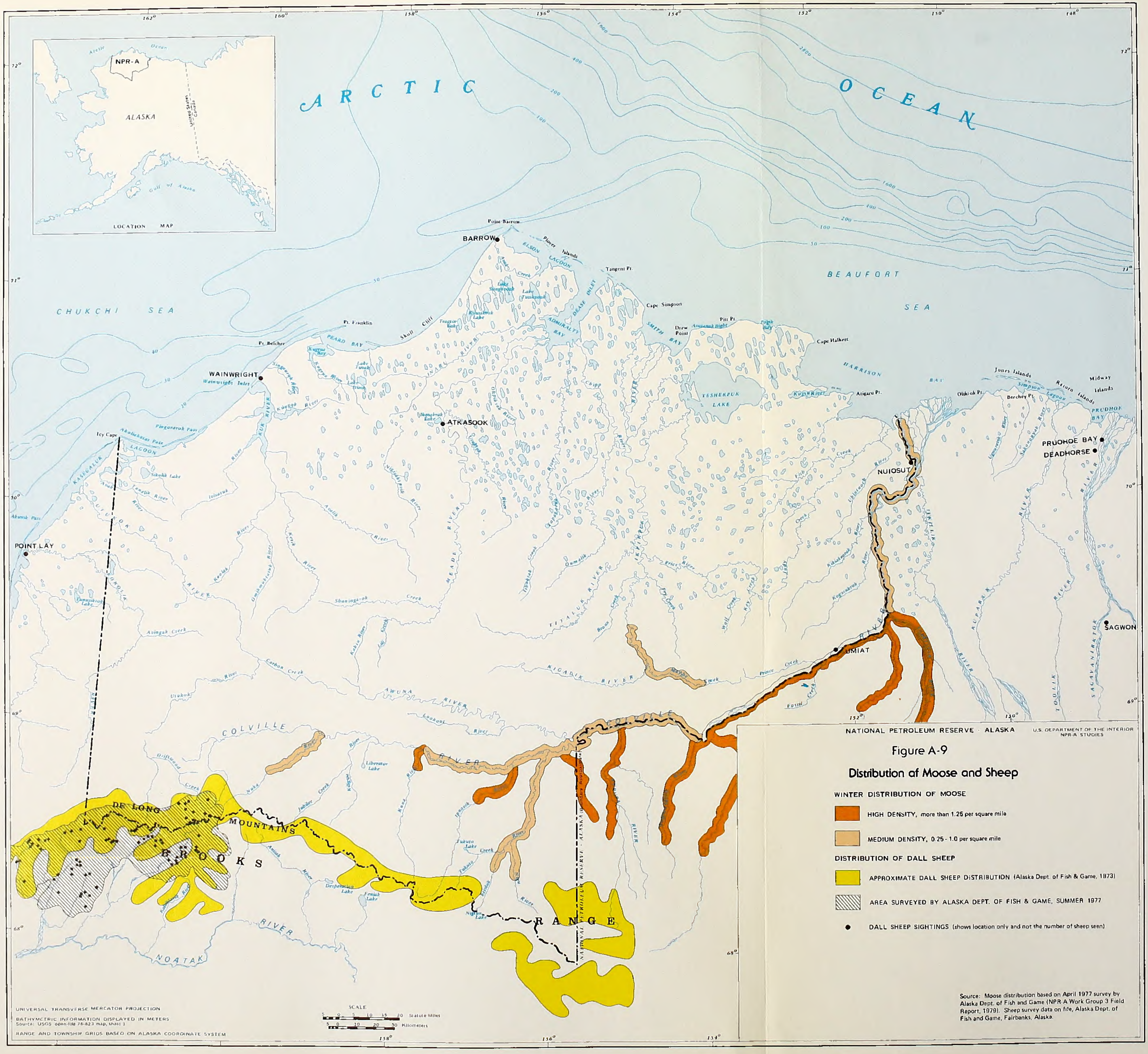


Figure A-9

Distribution of Moose and Sheep

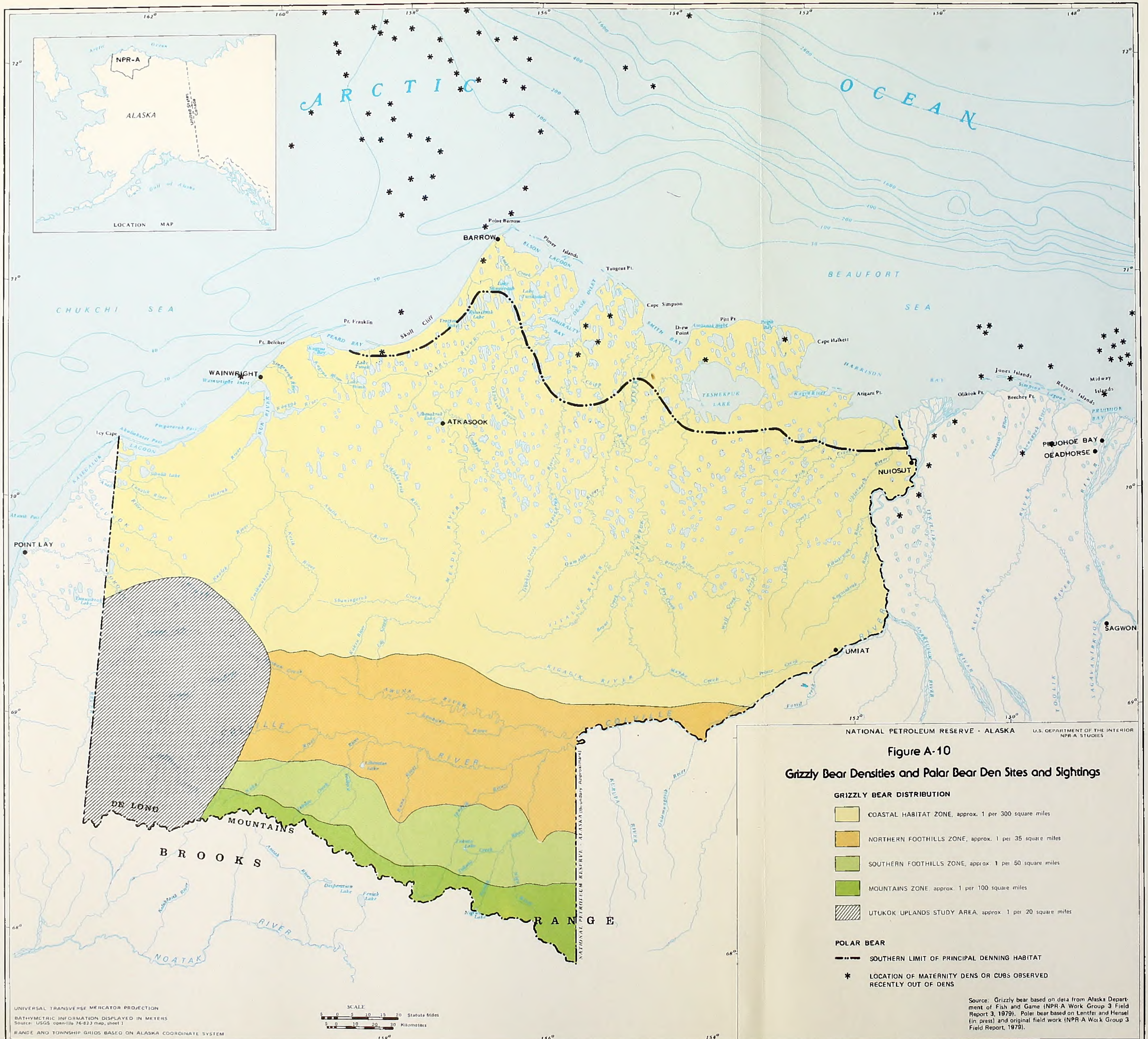


Figure A-10
Grizzly Bear Densities and Polar Bear Den Sites and Sightings

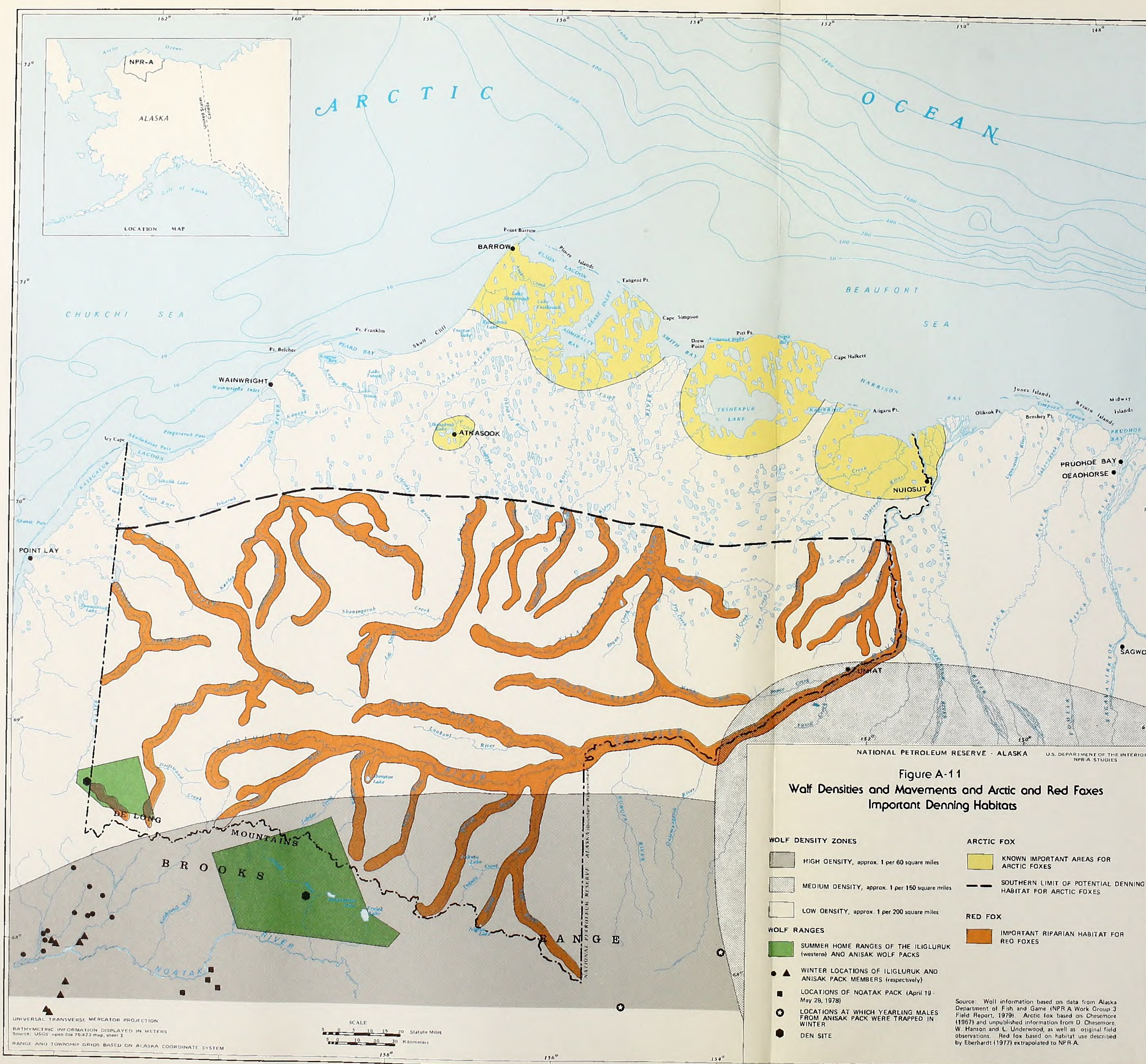
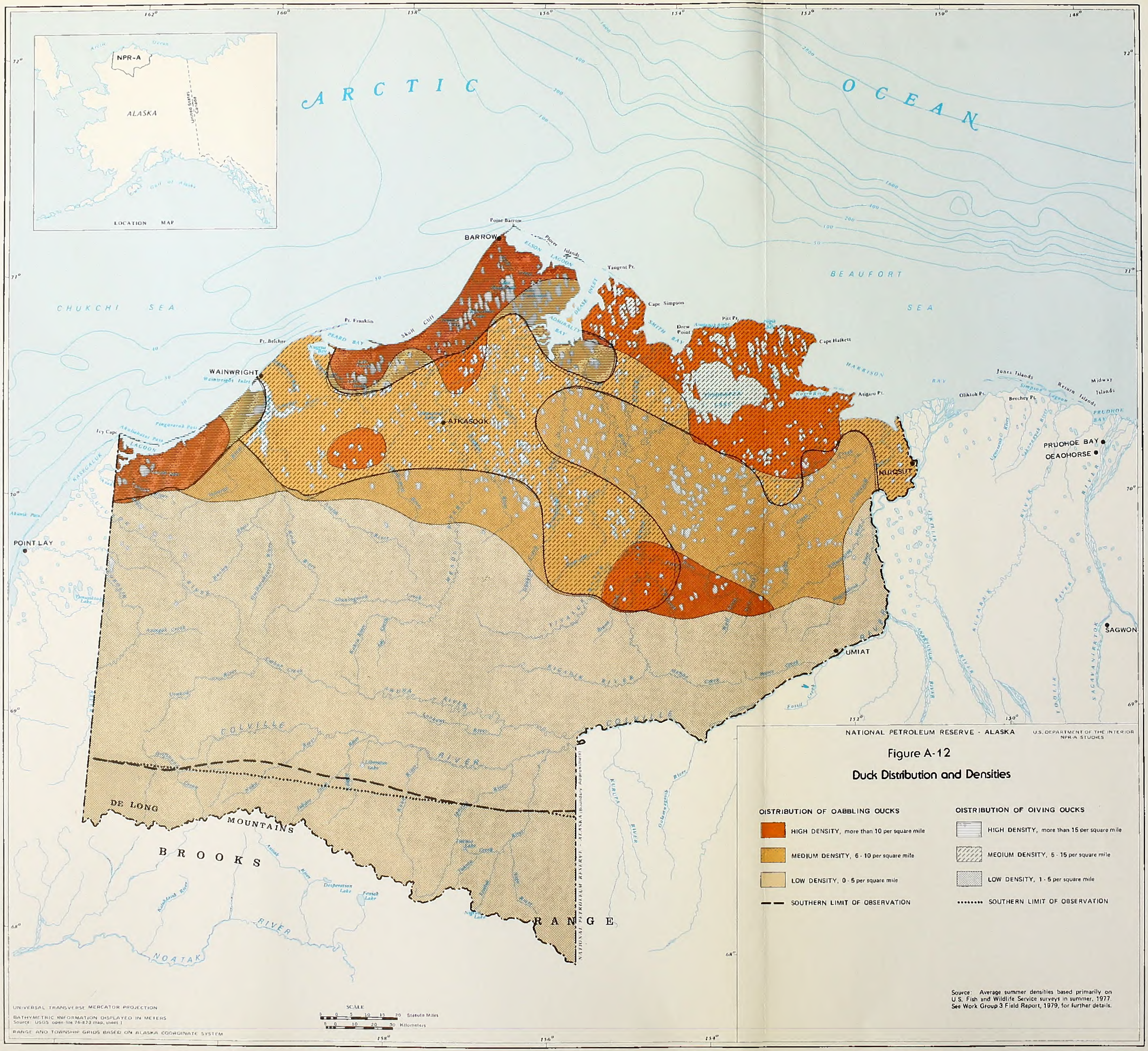


Figure A-11
Wolf Densities and Movements and Arctic and Red Foxes Important Denning Habitats



NPR-A
ALASKA
LOCATION MAP
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
Point Barrow
BARROW
ELSON LAGOON
Plover Islands
Tangent Pt.
Cape Simpson
SMITH BAY
Drew Point
Pitt Pt.
Cape Halkett
HARRISON BAY
Pt. Franklin
Skull Cliff
PEARD BAY
Pt. Belcher
WAINWRIGHT
Wainwright Inlet
ATKASOOK
Icy Cape
KASEGALUK LAGOON
Jones Islands
Return Islands
Midway Islands
Oliktok Pt.
Beechey Pt.
Atigaru Pt.
PRUDHOE BAY
NUIQSUT
POINT LAY
UMIAT
SAGWON
COLVILLE
RIVER
DE LONG
MOUNTAINS
BROOKS
RANGE
NOATAK
NATIONAL PETROLEUM RESERVE - ALASKA (Boundary Approximate)
NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure A-12
Duck Distribution and Densities
OISTRIBUTION OF OABBLING OUCKS
HIGH DENSITY, more than 10 per square mile
MEDIUM DENSITY, 6 - 10 per square mile
LOW DENSITY, 0 - 5 per square mile
SOUTHERN LIMIT OF OBSERVATION
OISTRIBUTION OF OIVING OUCKS
HIGH DENSITY, more than 15 per square mile
MEOIUM DENSITY, 5 - 15 per square mile
LOW DENSITY, 1 - 5 per square mile
SOUTHERN LIMIT OF OBSERVATION
Source: Average summer densities based primarily on U.S. Fish and Wildlife Service surveys in summer, 1977. See Work Group 3 Field Report, 1979, for further details.
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
5 0 5 10 15 20 Statute Miles
5 0 10 20 30 Kilometers

Coastal plains host an abundance of nesting shorebirds each year. (Atlantic Richfield Company)

Slope of Alaska; bear productivity is also greatest in this area. These population characteristics are believed to be associated with caribou calving grounds (fig. A-10). Grizzly bears are also commonly associated with the major river valleys of NPRA. Concentrations of human activities, such as oil development and resulting garbage, have been known to attract bears and may cause human-bear conflicts.

v. Wolf

Wolves are not prevalent in NPRA; their density ranges from one wolf per 60 square miles (155 square kilometers) in the southern portion (in the vicinity of upper Noatak, upper Kobuk, upper Killik, and Nigu Rivers), to one wolf per 150 square miles (388 square kilometers) in the southeastern portion of NPRA, and to one wolf per 200 square miles (517 square kilometers) on the coastal plain. Caribou are the major prey.

vi. Wolverine

Although wolverines have often been observed in the southern portion of NPRA and adjacent areas, the size of the wolverine population on the Arctic Slope is unknown. The denning period is January to May, and most denning occurs in tussock and alpine tundra habitats.

vii. Arctic Fox

Arctic foxes are most commonly found on the coastal plain (fig. A-11). The arctic fox populations of northern Alaska are cyclic, their peaks and lows occurring about every 4 years in association with the highs and lows of the lemming population. Garbage and deliberate feeding associated with increased human occupancy in the coastal plain can attract arctic foxes (Milke, 1977). This can lead to damage to facilities, health hazards (rabies), pressures for fox controls, and increased local predation on nesting birds.

viii. Red Fox

Red foxes can be found throughout the Arctic Slope of Alaska (fig. A-11) but are most common along major rivers. No red fox population data are available for NPRA.

ix. Polar Bear

From October through April female polar bears utilize both the Chukchi and Beaufort seacoasts, including the barrier islands, for maternity dens (fig. A-10). At other times of the year, polar bears are mainly restricted to the pack ice and are not found in the coastal zone.

x. Muskox

Native muskoxen populations on the Arctic Slope had been exterminated by the late 1800's. In 1969, muskoxen were reintroduced both in the Arctic National Wildlife Range and near Point Hope. Although a few have been seen in NPRA, the present population status within NPRA is not known.

b. Birds

i. Ducks

Several species of ducks utilize NPRA during summer (fig. A-12). In general, the highest density of diving ducks has been recorded within 60 miles (96 kilometers) inland from the coast between Smith Bay on the east and Peard Bay on the west and within 10 miles (16 kilometers) inland from Wainwright to Icy Cape. The highest density of dabbling ducks has been recorded within 30 miles (48 kilometers) inland from the coast. These high density areas represent the main nesting, resting, and feeding habitat for both groups, but other parts of the coastal plain also support significant duck populations. Approximately 90 percent of all duck breeding in NPRA occurs within 19,000 square miles (49,200 square kilometers) of habitat located north of a line generally from 20 miles (32 kilometers) south of Icy Cape east to approximately 40 miles (64 kilometers) north of Umiat along the Colville River. An estimated 500,000 ducks use NPRA during summer. Significant use areas for both groups include Teshekpuk Lake and most of the marine coastal zone and barrier island-lagoon systems. Shallow wetlands or ponds that freeze to the bottom are sites of important production of invertebrates that are eaten by waterfowl in the summer.

ii Geese

Four species of geese are known to regularly use the coastal plain of NPRA: white-fronted geese, brant, Canada geese, and lesser snow geese (fig. A-13). The estimated populations of geese utilizing NPRA in summer are: white-fronted geese — 53,900 (27 percent of the North American population); brant — 22,075 (11 percent of the world population); Canada geese — 30,000 (1 percent of the North American or 12 percent of the Alaskan population); and lesser snow geese — 397 (0.07 percent of the Pacific flyway population). No large goose nesting colonies exist on NPRA, but nesting sites are scattered over the coastal plain. The white-fronted goose is the most common breeder but is not a colony nester. Highest densities of geese occur in the Teshekpuk Lake and Icy Cape areas. The Teshekpuk Lake area is especially important to geese during the annual molt and attracts thousands of geese. The entire nonbreeding segment of brant from nesting areas north of the Bering Strait — from Canada, Alaska, and Siberia — molts here. This intensive usage is unique to the Arctic coastal plain of Alaska.

iii Loons

The species of loons utilizing NPRA are arctic, red-throated, and yellow-billed. Of the three, the arctic loon was the most common and the yellow-billed least common in 1977. A 20- to 30-mile (32- to 48-kilometer) band extending west from the Colville River Delta to Peard Bay and then southwestward along the coast to Icy Cape contains the highest density of loons (fig. A-14). The population of loons on NPRA is approximately 75,000, including young of the year. Other areas which seem to be heavily used by loons include the Koluktak Lake area, including Price River, and an area approximately 50 miles (80 kilometers) long by 20 miles (32 kilometers) wide and 20 miles (32 kilometers) south of Atkasook. The coastal zone is especially important during spring and fall migration.

iv Whistling Swans

About 4,200 whistling swans were found on the coastal plain of NPRA during September 1977. Highest swan densities occurred southeast of Teshekpuk Lake and east to the Colville River and in the Colville River Delta itself. Swans are easily disturbed by human activities.

The long-tailed jaeger is one of the most graceful birds in the Arctic. (Marilyn Warren)

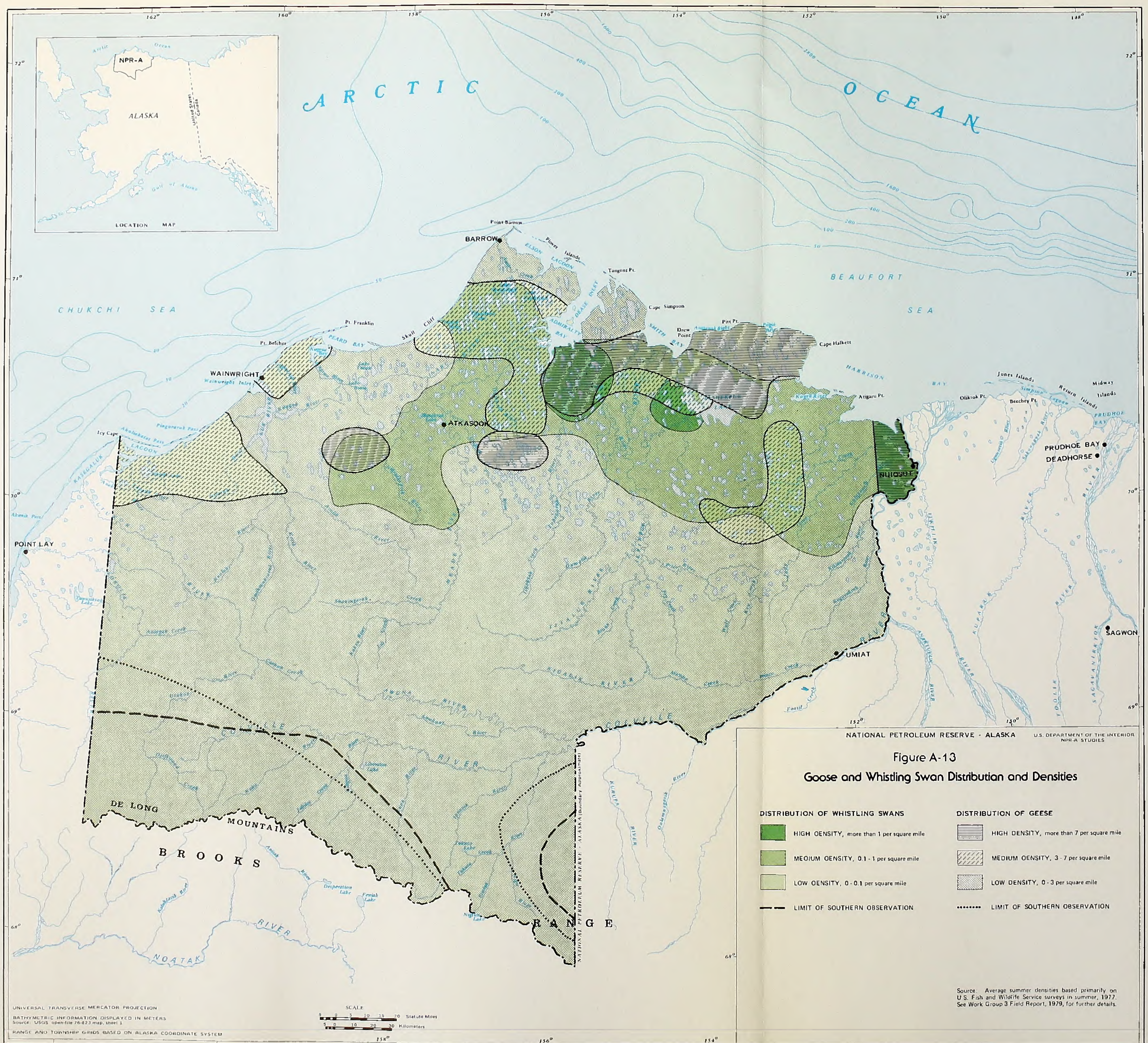


Figure A-13
Goose and Whistling Swan Distribution and Densities

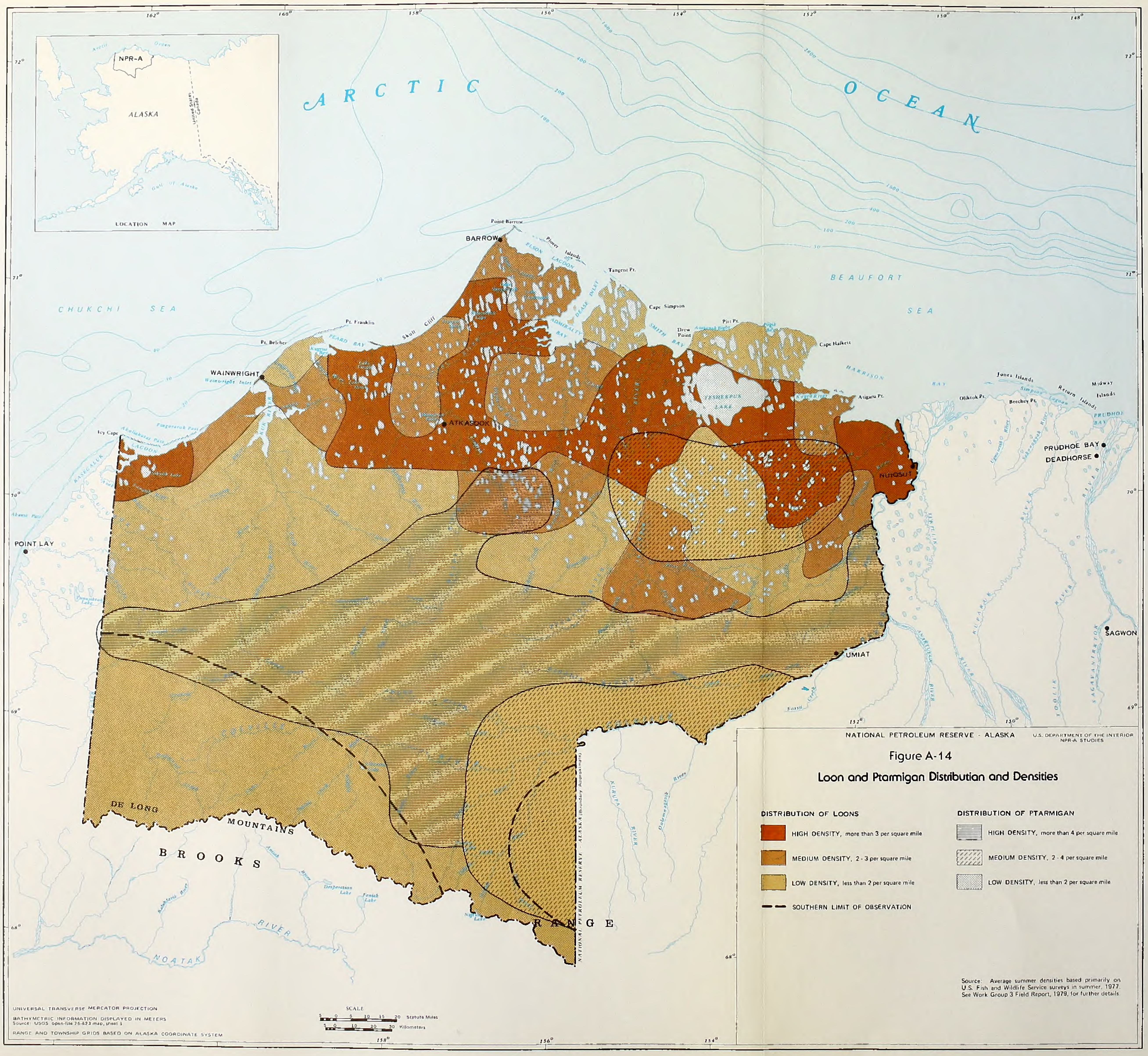
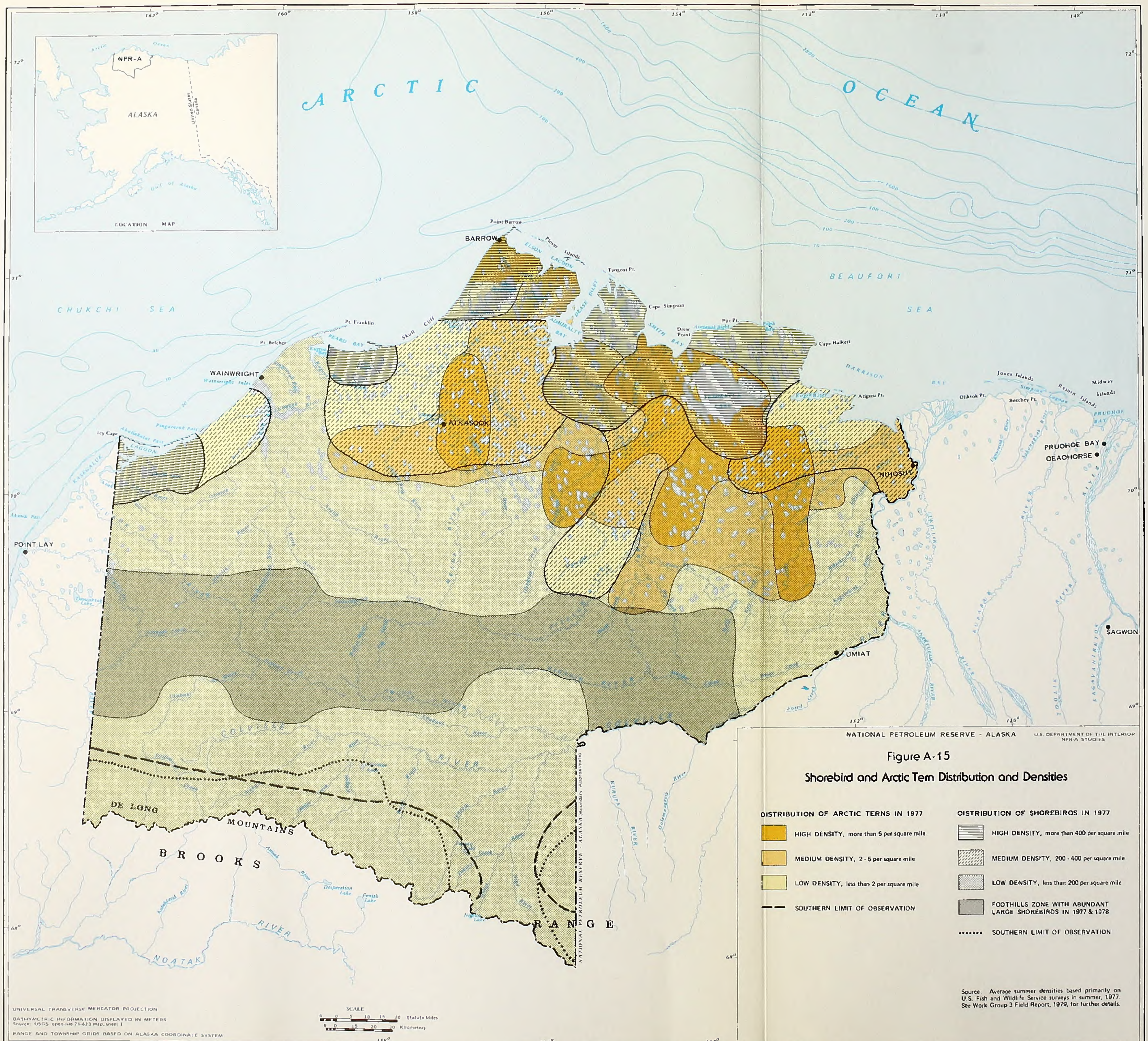


Figure A-14

Loon and Ptarmigan Distribution and Densities



NATIONAL PETROLEUM RESERVE - ALASKA
U.S. DEPARTMENT OF THE INTERIOR
NPR-A STUDIES
Figure A-15
Shorebird and Arctic Tern Distribution and Densities
DISTRIBUTION OF ARCTIC TERNS IN 1977
HIGH DENSITY, more than 5 per square mile
MEDIUM DENSITY, 2 - 5 per square mile
LOW DENSITY, less than 2 per square mile
SOUTHERN LIMIT OF OBSERVATION
OISTRIBUTION OF SHOREBIROS IN 1977
HIGH DENSITY, more than 400 per square mile
MEDIUM DENSITY, 200 - 400 per square mile
LOW DENSITY, less than 200 per square mile
FOOTHILLS ZONE WITH ABUNDANT LARGE SHOREBIROS IN 1977 & 1978
SOUTHERN LIMIT OF OBSERVATION
Source: Average summer densities based primarily on U.S. Fish and Wildlife Service surveys in summer, 1977. See Work Group 3 Field Report, 1979, for further details.
ARCTIC OCEAN
CHUKCHI SEA
BEAUFORT SEA
LOCATION MAP
ALASKA
NPR-A
BARROW
Point Barrow
WAINWRIGHT
ATKASOOK
NUIQSUT
POINT LAY
UMIAT
SAGWON
PRUDHOE BAY
DEADHORSE
Cape Simpson
Cape Halkett
Pt. Franklin
Pt. Belcher
Icy Cape
COLVILLE RIVER
DE LONG MOUNTAINS
BROOKS RANGE
NOATAK
NATIONAL PETROLEUM RESERVE ALASKA (Boundary Approximate)
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
BATHYMETRIC INFORMATION DISPLAYED IN METERS
Source: USGS open-file 76-823 map, sheet 1
RANGE AND TOWNSHIP GRIDS BASED ON ALASKA COORDINATE SYSTEM
SCALE
Statute Miles
Kilometers

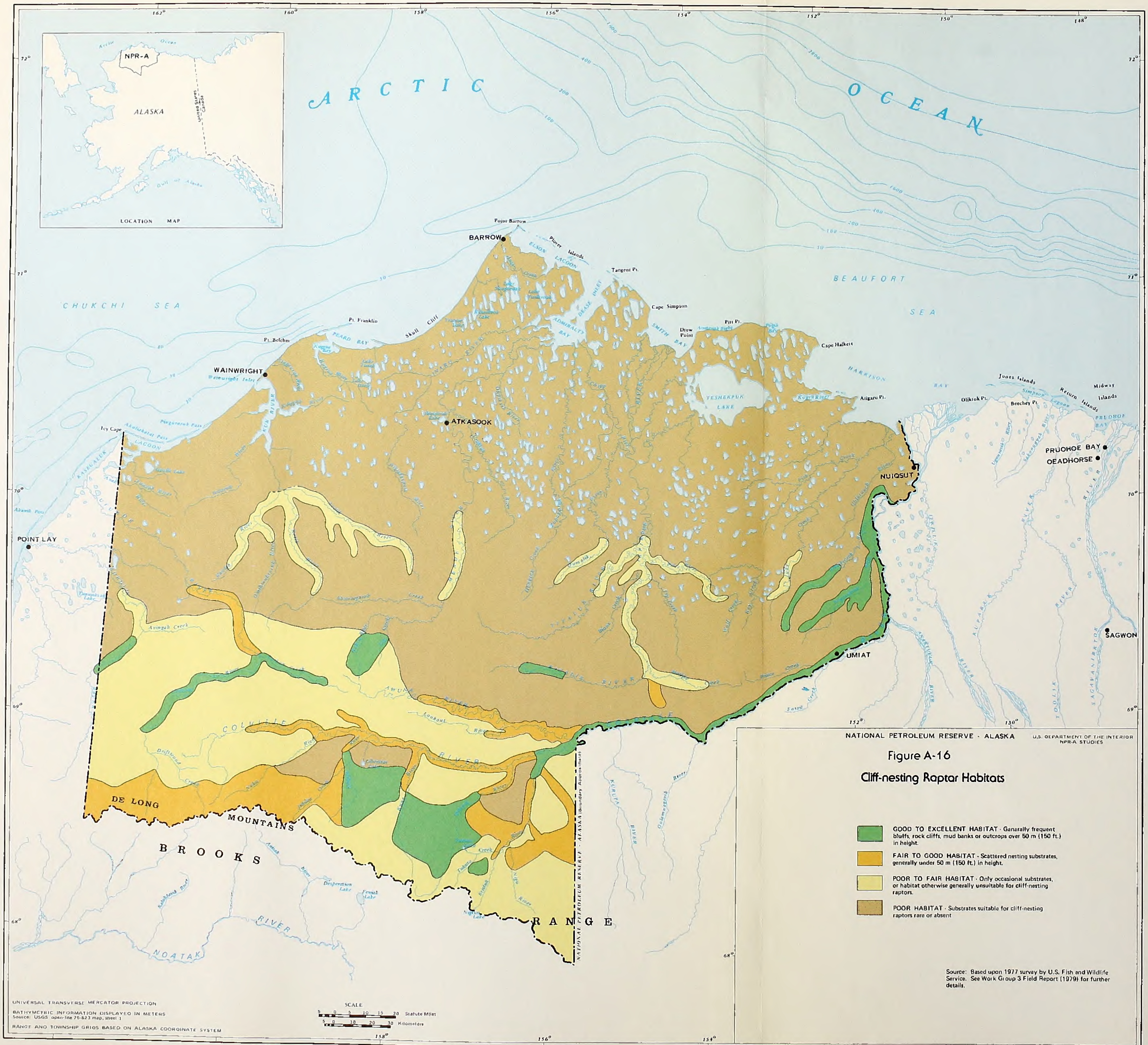


Figure A-16

Cliff-nesting Raptor Habitats

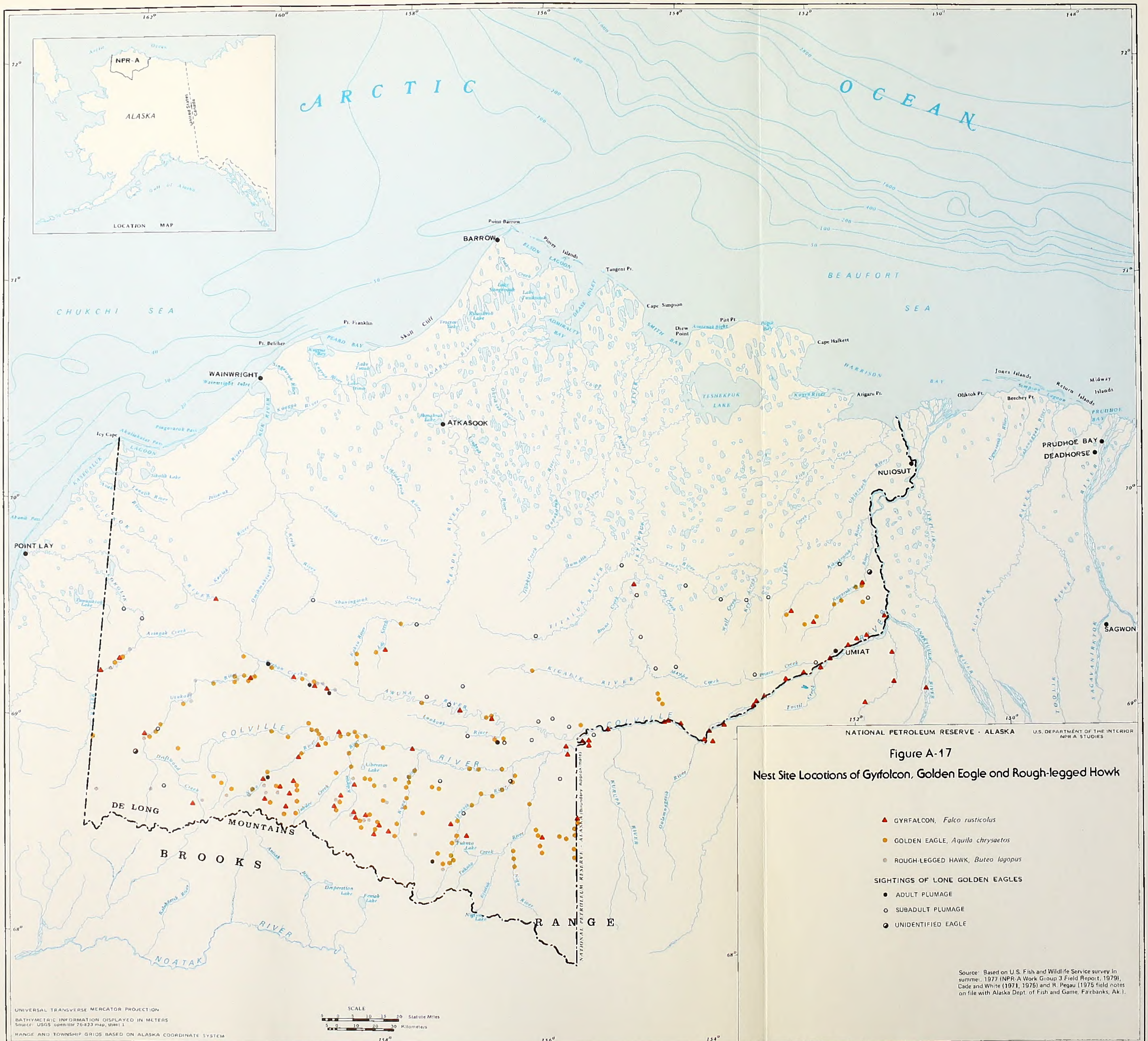


Figure A-17
Nest Site Locotions of Gyrfolcon, Golden Eogle ond Rough-legged Howk

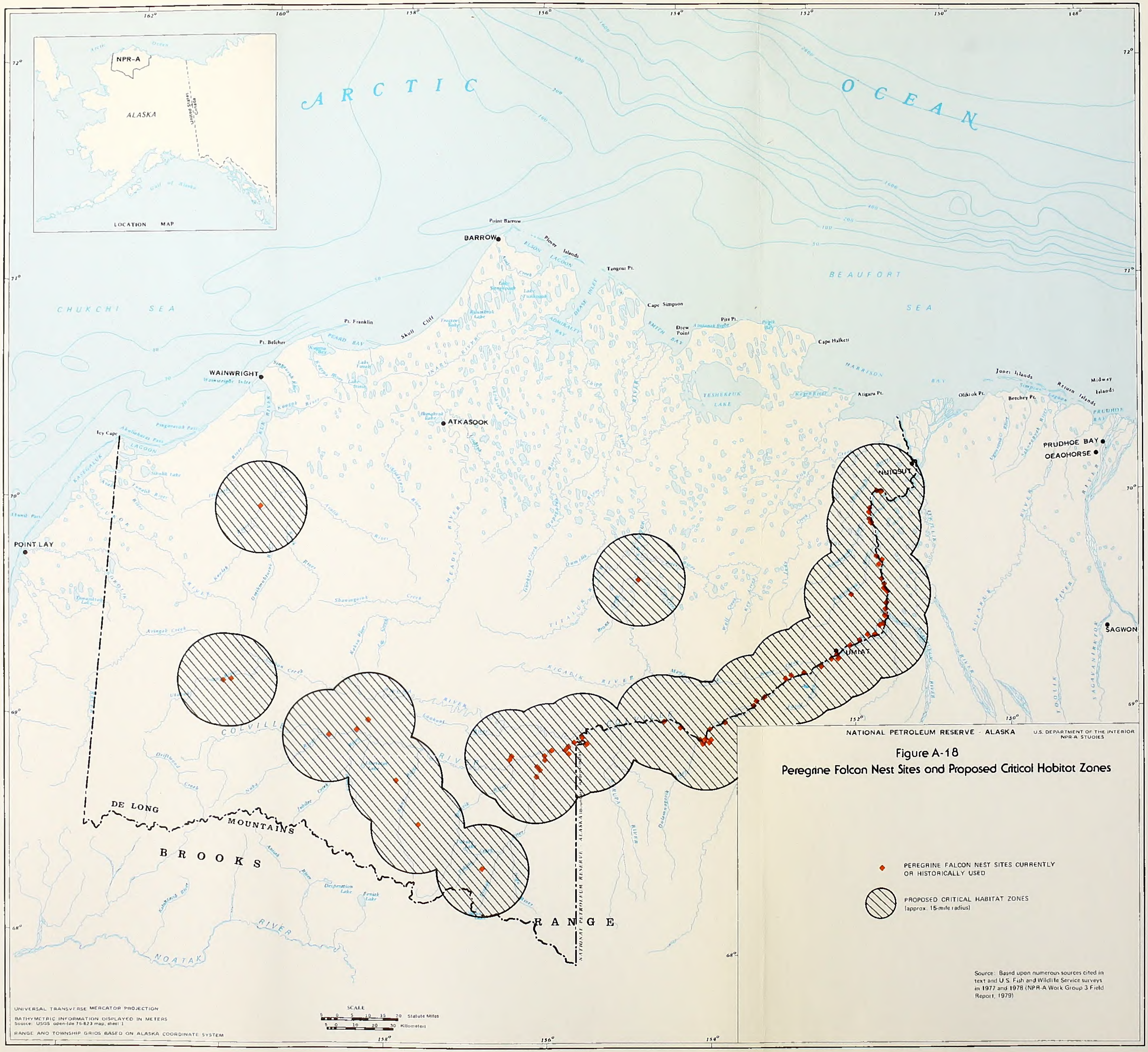


Figure A-18
Peregrine Falcon Nest Sites and Proposed Critical Habitat Zones

v. Shorebirds

The total population of shorebirds in NPRA during summer is approximately 5,700,000. The more abundant shorebirds include pectoral sandpiper, red phalarope, dunlin, northern phalarope, and semipalmated sandpiper. Shorebird density in NPRA is greatest within a zone up to 20 miles (32 kilometers) from the coast (fig. A-15). Nearshore waters and shorelines of waterways are of primary importance for feeding and migration. However, wetlands surrounding river delta systems may produce more shorebirds than other areas. Because of low breeding densities, breeding habitat is spread out and diverse. The coastal shoreline and the Teshekpuk Lake area are extremely important as staging areas for fall migration for red and northern phalaropes. A few shorebird species, notably godwits and whimbrels, are apparently more common in tussock tundra areas of the foothills than on the coastal plain.

vi. Raptors

The golden eagle, gyrfalcon, rough-legged hawk, snowy owl, and short-eared owl are all present on NPRA (fig. A-16). The endangered arctic peregrine falcon is also present but is discussed separately. Golden eagles nest in the foothills and Brooks Range; gyrfalcons nest in the cliffs along rivers or on isolated upland cliffs; rough-legged hawks nest on cliffs along rivers and some off-river sites; and owls nest in the open tundra. These raptors prey upon small rodents, ptarmigan, and other birds, and their populations and distribution vary with the availability of prey. Snowy owl population peaks are directly related to those of the lemming. Known nest sites (except for owls) are shown in figure A-17.

vii. Gulls, Terns, and Jaegers

Fifteen species of gulls, one species of tern, and three species of jaegers are present on NPRA during the summer. In 1977, there were an estimated 24,000 gulls, 100,000 terns, and 146,000 jaegers in NPRA. This group occupies diverse habitats, with pingos, spits, islands, and lagoons commonly used.

viii. Ptarmigan

Two species of ptarmigan, willow and rock, are present on NPRA all year. The maximum population estimate for NPRA in 1977 was 300,000. Willow ptarmigan are found mainly in the foothills and occasionally on the coastal plain, and rock ptarmigan are found mainly in the alpine tundra and barren areas of the Brooks Range.

ix. Passerines

The passerines comprise a diverse grouping of birds estimated to have reached a population in NPRA of 15 million birds in 1977. The only passerines that remain year-round on NPRA are ravens, snow buntings, and a few Lapland longspurs. Passerine densities greater than 500 birds per square mile (310 per square kilometer) were noted within 20 miles (32 kilometers) of Point Barrow and in other areas of the southern foothills and Brooks Range. These birds commonly use low shrubs and willows in the foothills and diverse habitats along waterways.

c. Marine Mammals

True marine mammals of the Chukchi or Beaufort Seas off NPRA include 10 species of whales — beluga, narwhal, killer whale, harbor porpoise, gray whale, fin whale, sei whale, hump-backed whale, little piked whale, and bowhead whale; six species of seals — northern fur seal, Steller sea lion, harbor seal, ribbon seal, ringed seal, and bearded seal; and the walrus. Of these, only the walrus, ringed seal, bearded seal, and beluga are common in the NPRA marine zone. The latter two species are most numerous during their spring and fall migration periods. Five species of whales are classified as endangered species; these are discussed in a separate section of this report.

d. Fisheries

The distribution and abundance of fish in the freshwater environment of NPRA is poorly defined. To date, 19 freshwater and anadromous species have been identified (table A-1). Ice on lakes and streams severely reduces available overwintering habitat. Thus, resident fish are restricted to those lakes and rivers that do not freeze to bottom in winter.

NPRA can be divided into several fishery habitat units corresponding to its physiographic provinces. The nearshore marine and coastal zone contains marine and anadromous species including arctic char, arctic cisco, fourhorn sculpin, arctic cod, and arctic and starry flounder. Seasonal abundance of fish along the coast is related to anadromous fish migrations to and from spawning locations, feeding areas, and overwintering sites.

Coastal plain lakes studied contained least and arctic cisco, broad and humpback whitefish, grayling, lake trout, slimy sculpin, Alaska blackfish, burbot, northern pike, and ninespine stickleback. Rivers draining only the coastal plain contain least cisco, humpback and broad whitefish, pink and chum salmon, grayling, ninespine stickleback, slimy and fourhorn sculpin, and arctic flounder.

The northern foothills contain most of the major drainages of NPRA, including the Colville, Utukok, and Kokolik Rivers. All freshwater species known for NPRA with the exception of the Alaska blackfish and the northern pike are found in these rivers. In the southern foothills and the Brooks Range, grayling, arctic char, lake trout, round and broad whitefish, least cisco, slimy sculpin, ninespine stickleback, burbot, and longnose sucker were found.

During the open-water season, waters that are likely to be inhabited by fish have inlets or outlets, adequate depth, and suitable substrate for spawning. Population diversity and size are greater in waters that possess all three of these characteristics and smaller where one or more is absent. Anadromous species require all three characteristics, particularly access. Shallow lakes feeding streams can be used for

Walrus are abundant in the marine environment of the Chukchi Sea and are most numerous during their spring and fall migration periods. (John Burns, Alaska Department of Fish and Game)

spawning but freeze during the winter, precluding their use as overwintering habitat. However, many deep lakes that are isolated from flowing streams support resident fish populations, and lakes without spawning or overwintering habitat may provide migratory links to other areas.

4. Endangered or Threatened Species

The endangered or threatened animals and plants which may occur on or adjacent to NPRA are listed in table A-2. Under the Endangered Species Act of 1973, any action carried out, funded, or regulated by a Federal agency that could damage endangered species, populations, or their critical habitats requires consultation with either the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (USFWS). The NMFS regulates activities that may affect marine mammals, and the USFWS safeguards the birds and plants listed. At present, there are no established guidelines identifying permissible or prohibited activities.

a. Marine Mammals

The whales listed in table A-2 are baleen whales that migrate into or through the NPRA area each spring and migrate south with or before the advancing ice in fall. The bowhead whale is harvested by the Natives of NPRA.

b. Eskimo Curlew

The Eskimo curlew may be extinct. However, possible sightings have been made within the last 2 years south of NPRA. If present, the Eskimo curlew probably nests in the coastal zone.

c. Arctic Peregrine Falcon

Most of the migratory arctic peregrine falcon population of the North Slope breeds within NPRA. Their nests are on bluffs and rocky outcrops and at the base of rocky faces above talus slopes along the Colville River and its major tributaries, such as the Etivluk, Oolamnagavik, Killik, Chandler, Utukok, Kaolak Rivers, and perhaps the Ikpikpuk River (fig. A-18). NPRA contains only the reproductive or summer habitat of the peregrine. The Colville River Special Area has been designated for protection of peregrine falcons (*Federal Register*, vol. 42, no. 107, p. 23720-28724).

d. Plants

Table A-2 lists one endangered plant species, *Smelowskia borealis* var. *villosa* (no common name),

Table A-2. Endangered (E) or Threatened (T) Animals and Plants which are Known to Occur or May Occur on or Adjacent to NPRA

Common Name	Scientific Name	Classification	Habitat
Marine mammals:			
Bowhead whale	*Balaena mysticetus*	E	Marine and coastal zone.
Fin whale	*Balaenoptera physalus*	E	Marine and coastal zone.
Sei whale	*B. borealis*	E	Marine and coastal zone.
Hump-backed whale	*Megaptera novaeangliae*	E	Marine and coastal zone.
Gray whale	*Eschrichtius gibbosus*	E	Marine and coastal zone.
Birds:			
Eskimo curlew[1]	*Numenius borealis*	E	Coastal zone and foothills.
Arctic peregrine falcon	*Falco peregrinus tundrius*	E	River bluffs, escarpments (fig. A-18).
Plants:			
No common name	*Smelowskia borealis* var. *villosa*	E	Alpine tundra (fell-fields).
Arctic bladderpod	*Lesquerella arctica* var. *scammanae*	T	Alpine tundra (fell-fields).
No common name	*Oxytropis kokrinensis*	T	Alpine tundra (fell-fields).

[1] This species may be extinct.
Sources: Ayensu and DeFilipps, 1978; *Federal Register*, July 14, 1977, vol. 42, no. 135, p. 36420-36431.

and two threatened plant species, *Lesquerella arctica* var. *scammanae* (arctic bladderpod) and *Oxytropis kokrinensis* (no common name). All three of these plants are known to be associated with dry, rocky tundra areas that are present in the foothills and Brooks Range areas of NPRA; however, no specimens of any of the three plants have ever been collected from NPRA.

C. Human Environment

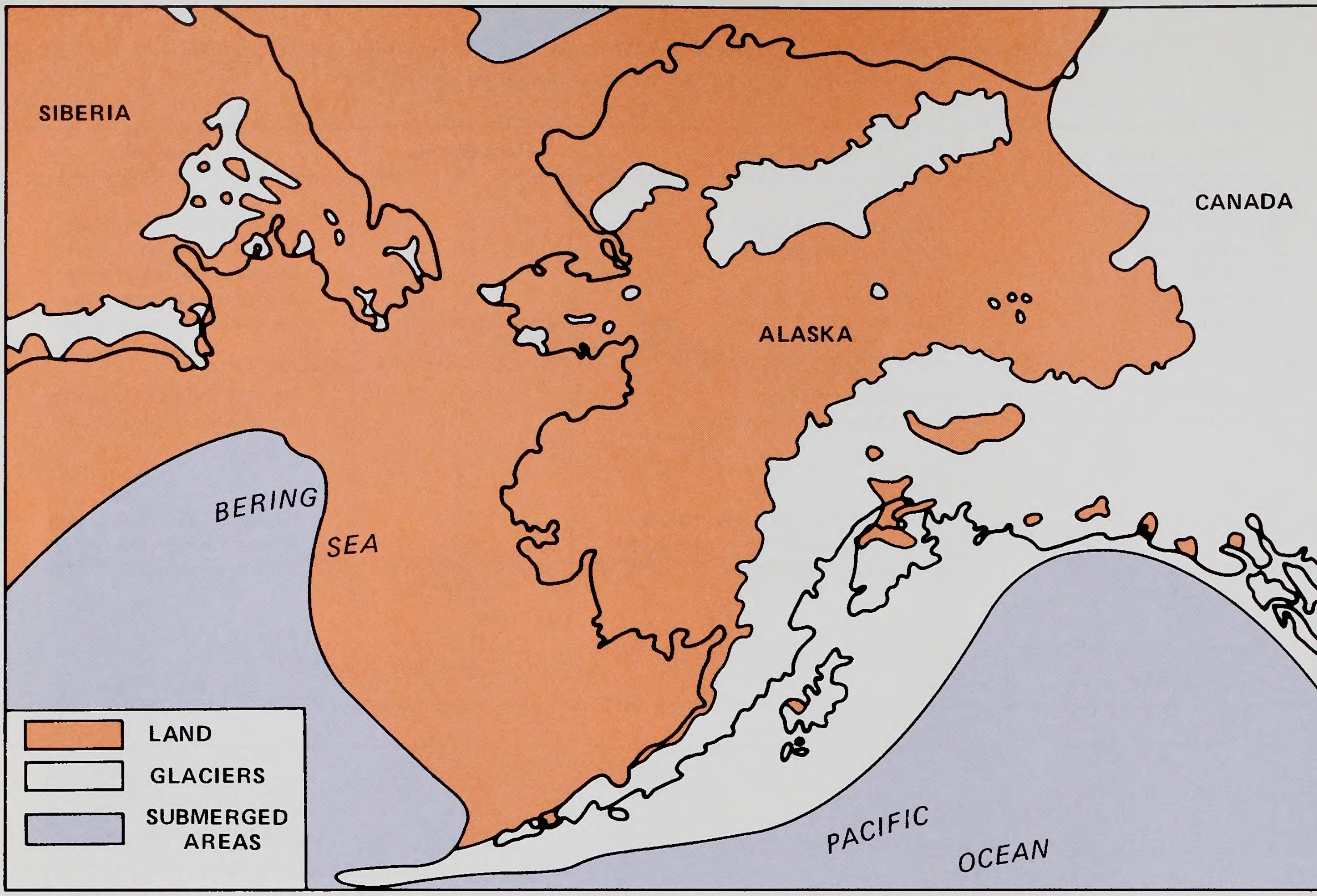
Human environment is a collective term for the areas of human use and activity, for what is manmade and introduced into the natural environment, and for humanly held values tied to the land and its resources. The manmade resource base includes Native settlements, military and industrial facilities, and the transportation and power network. Social sectors include the permanent Native population, and non-Native transient, military and industrial personnel, civil servants, and specialized professionals. A wide range of kinds of values is associated with the natural environment; for example, the Inupiat may view it as a subsistence base, while people beyond the NPRA area or outside Alaska may feel that wilderness, recreation, or scenic values of the environment are paramount.

The historic and contemporary periods are summarized here to focus on the continuum of traditional land use patterns and on introduced changes and responses to changes. The economic base of the region is a mix of cash income and subsistence at the individual's level. At the borough or regional government level, the economic base is industrial and personal property, as well as government programs. The human environment of the North Slope is an inextricable mix of the past and present, of indigenous and introduced influences.

1. Archeology and History

a. Archeological Significance and Potential of the North Slope

The first people of Alaska migrated from Asia across land now inundated by the Bering Sea. This Bering Land Bridge or Beringia, an area of thousands of square miles or square kilometers, existed during several geologic periods including one about 40,000 years ago and another between 28,000 and 10,000 years ago. The western North Slope is the eastern margin of the former land bridge. Archeological remains which may be found there are likely to be extremely important in reconstructing the history.



At the height of the Wisconsin glaciation, the Bering Land Bridge provided access to the New World. (AEIDC)

Prior to the recent research conducted for the P.L. 94-258 Land Use Study and the BLM surface surveillance activities, knowledge of the cultural resources in NPRA was limited. Until the 1970's archeological excavations and surveys were primarily carried out on the coast and on the major rivers near the coast. These surveys have indicated high potential for archeological resources along the Arctic coast from Kotzebue Sound to Demarcation Point. The coastal shallows may contain important clues to Eskimo prehistory (Nielson, 1977). Older sites along the coast may have been flooded by rising sea level. Inland, archeological resources commonly occur in elevated areas that commmand a view of the surrounding terrain, such as on the crests of ridges, hilltops, and knolls. However, recent work indicates that they also occur along the banks and terraces of rivers and streams, lakeshores, flood plains, or at river confluences (National Petroleum Reserve in Alaska Work Group 4, 1979).

When migration across Beringia into the New World first occurred is uncertain and is presently being addressed by several research projects. NPRA lies east of the land bridge and undoubtedly was used by the early immigrants. Several archeological sites along the Utukok River near Driftwood contain fluted projectile points that were assigned ages in excess of 15,000 years based on dates of similar material found in the Great Plains (Humphrey, 1970). Thus far, no sites in NPRA with chronological control contain material as old as 10,000 years. Many of the sites on the foothill ridgetops are simply clusters of lithic debris lying on the surface of the ground. Some may date back 17,000-27,000 years, but at present there is no reliable dating technique to determine the exact age of these sites.

It is generally believed that Eskimo culture in Alaska first became established in the Bering Strait area, spreading north and south from there. The Thule phase, from which modern Eskimo culture is derived, moved across northern Alaska and Canada to Greenland about A.D. 1200, then — if current thinking is correct — swung back upon itself a few centuries later, producing the remarkable homogeneity of language and lifestyle that distinguishes the Inupiat of the Arctic (National Petroleum Reserve in Alaska Task Force, 1978c).

The area including NPRA has been continuously occupied for the past 8,000 years. Many sites contain artifacts representative of the Paleo-Arctic (8,000–5,000 B.C.) and more recent cultural traditions. At some sites in the foothills along the major rivers, pit house depressions of the protohistoric and early historic period (1600 to 1890's) are conspicuous. Some of these sites and surrounding areas are still used as camping areas by subsistence hunters and travelers.

Most of the archeological sites in NPRA have been found at the surface or at less than 1 foot (30 centimeters) below the surface. Exposed areas where sites are easily detected do not develop a soil mantle because they are subject to wind and water erosion. Geologic studies indicate very few areas have aggraded or are aggrading on the Reserve; therefore, probability of the existence of deeply stratified sites is low. One notable exception is the site on Kinyiksukvik Lake in the Howard Pass area, where the earliest cultural material occurs 3 feet (1 meter) below the surface.

Identification of cultural (including archeological) resources is being done by the National Park Service (NPS), as part of the NPRA land use study, and by the Commission on History and Culture of the North Slope Borough. All of the sites inventoried by the NPS survey crews have been evaluated for inclusion on the National Register of Historic Places. Those that qualify are or will be nominated to the register. A few sites listed on the Traditional Land Use Inventory (TLUI) compiled by the North Slope Borough have been visited and evaluated for nomination to the national register.

The two identification programs have different emphases. The NPS is surveying to determine the age, number, distribution, and condition of a sampling of sites in specific environmental zones. Sites listed in the TLUI are those now used or used within the oral history-memory of the present inhabitants. Many of the sites in both programs have little or no significance as individual sites, but viewed in a regional context, they have scientific and economic importance as part of a yearly subsistence pattern.

As noted above, the significance of any site is relative. Very few sites in NPRA are so extensive or have such visible remains as to be of unquestionable national significance. As the inventory of sites and the knowledge of culture history increases, the scientific value of a particular site changes. Although it is impossible to predict what new technologies will assist archeologists in the future, past experience has shown that as the data base increases, so does the number of hypotheses to be tested. Thus, a site that today would not warrant expenditure of time and money may become an important scientific resource.

To date, several significant archeologic sites have been identified in NPRA. The Birnirk site near Barrow is the only entry on the National Register of Historic Places that is located in NPRA. However, as a

Cultural resources, such as this old house site on the Chukchi Sea, are being identified by the Historical Commission of the North Slope Borough and the National Park Service as part of the NPRA land use study. (Bureau of Land Management)

result of the National Park Service archeological surveys of 1977 and 1978 and Bureau of Land Management archival research into previously reported sites, the sites or areas discussed below are being recommended to the keeper of the National Register of Historic Places for inclusion on the register.

In and near Barrow seven sites represent 7,500 years of occupation. They are the Coffin, Kugasugaruk, Kugok, Nunavak Bay, Nuvuwaruk, Nuwuk, and Walakpa sites. At Point Belcher, northeast of Wainwright, the Nunagiak site represents 1,000 years of occupation, from the Late Birnirk to modern Eskimo traditions.

The interior foothills and mountain areas were also intensively occupied for a long period of time. Sites situated on Betty, Liberator, Noluck, Swayback, Tukuto, Kiingyak, and Akuliak Lakes have been periodically occupied in the past. Their most obvious cultural features are late prehistoric/historic villages indicated by house and cache pits. Small clusters of flakes around lakes indicate much longer but less intense occupation along the lakeshore than at the villages.

Inyorurak Pass in the Brooks Range contains a series of sites that center around Kinyiksukvik Lake. Occupation along the shore was concentrated in three areas that could be called villages. Test excavations along the shore indicated human use of the area possibly occurred 8,000 to 10,000 years ago. Caribou drive fences, hunting lookout sites, isolated stone tent rings, hearths, and locational cairns are scattered throughout the valley.

Near the confluence of the Killik and Colville Rivers are a variety of hunting sites representing many cultural traditions and a village or camp associated with the historic or protohistoric Eskimo. The two rivers were travel routes used by man and caribou in their seasonal rounds. The village and associated sites represent a part of the subsistence pattern of the historic inland Eskimo.

Along the middle section of the Colville River is "VABM Shinbone," a 10-acre (4-hectare) hilltop used repeatedly for centuries as a lookout station and butchering area by aboriginal hunters.

The portage over Knifeblade Ridge, which separates the Colville River drainage from the Ikpikpuk River drainage, has been a major travel route from the interior to the coast. Sites along this route indicate that travel patterns span several thousand years. The area is also historically important because the first U.S. Navy overland exploration party from the Noatak River to Point Barrow was guided over the portage.

The area where the Utukok River transects the east-trending foothills ridge system is a natural crossroad. The many sites in the area demonstrate human use of the area from perhaps as early as 8,000 B.C. to the present. Several archeologists consider this a prime target area for discovering sites that may date back 22,000-27,000 years.

The inventories of the National Park Service, Bureau of Land Management, and North Slope Borough will be incorporated into the Alaska Heritage Resources Inventory that is maintained by the State of Alaska.

The Native residents' view of a site's significance has a more economic urgency. Most of the sites or areas listed on the TLUI are or have been used for subsistence activities. No study has been conducted to determine how a perceived threat of damage or loss of potential food sources has affected the subsistence harvester. It is known that proposed changes in management policy on hunting of caribou have resulted in subsistence hunters changing their yearly hunting cycle to bag their meat supply before the new policies were instituted. Because the caribou thus taken were not in prime condition, more than the usual number was harvested as hunters tried to protect themselves from a shortfall of meat. At the same time, changes in access, whether by law or by biological necessity, will likely cause shifts to other areas known through personal or family experience or through oral tradition. (It is seldom that an unknown area is exploited, as such actions may be too risky in terms of productivity.) Such activity is commonplace, and it is this type of adaptability, mental and social, that gives rise to the information contained in the TLUI. Such changes in hunting behavior will also affect the significance of a use area because its traditional use is modified.

The cultural changes as a result of perceived threats are not quantifiable, and the ways in which the changes impact specific sites are unpredictable. One detectable change has been the decrease of food sharing between traditional sharers. While hospitality to visitors remains generous, gifts of food when guests leave have decreased in size or have been eliminated altogether because of the fear that some change in laws or exploration activity in the subsistence area will decrease the expected harvest. Such depletion of game has already occurred with caribou and with whales. It is to this real depletion of resource supply, and not to the fear of it, that people have reacted by limiting sharing. Such action has given rise to a number of responses, such as increased barter for resources between the coastal and inland communities and between families who concentrate on different resources or who live in different communities.

b. Aboriginal Period

The Eskimos were the only aboriginal population to simultaneously occupy both the Old and the New World. They are related to other northeastern Siberian groups called Arctic or Siberian Mongoloids (Laughlin, 1963). The Eskimo population can be subdivided into Yupik and Inupiat. The Inupiat are the current Native residents of Alaska's North Slope. The Yupik presently inhabit the west coast of Alaska in the northwest and Bering Strait coastal areas. Related to the Eskimo are the Aleuts, who live in the southern portions of the Alaska Peninsula and the Aleutian Chain. Distinct from the Eskimos are the Indians or Athabascans who live in the extensive interior of Alaska.

From prehistoric times, two complementary adaptations have been evident among the Eskimo of

Commercial whalers, such as these photographed in 1898, not only depleted the area's food resources but also introduced liquor, firearms, disease, and Christianity. (Naval Arctic Research Laboratory Library)

north Alaska. The Tareumiut, or people of the sea, lived in many small settlements scattered along the coast. Though these people hunted land animals, such as the caribou, and fished in inland waters, they were dependent primarily on the products of sea-mammal hunting. In contrast, the Nunamiut, or people of the land, lived a nomadic life in the interior. They gained their livelihood primarily from hunting caribou, following the migrations of these animals throughout the north Alaskan region (Spencer, 1959). The Tareumiut and Nunamiut are viewed as different expressions of the same culture. Their hunting specializations represented a division of labor that allowed full use of the area's diverse resources. And, through a lively trade that evidenced their interdependence, they shared the products of marine and terrestrial environments (Worl, 1977).

c. Historic Periods

Contact with Western civilization has caused drastic changes among the northern Eskimo. However, throughout various eras of commercial exploitation and proselytizing, the historic Eskimo response has been to adapt but to maintain cultural identity.

Following are major historic periods from contact in the 1700's to post-World War II:

Exploration	1778 to 1912
Commercial whaling	1860 to 1910
Fur trapping	1900 to 1950
Reindeer herding	1897 to 1950
Military construction	1946 to 1953

Beginning with Captain James Cook's search for the Northwest Passage in 1778, when he sailed through the Bering Strait as far north as Icy Cape, a series of British and Russian exploring expeditions passed by or touched briefly on the north Alaska coast. These early expeditions expanded geographic knowledge and produced invaluable ethnographic data. But beyond incidental trade and a number of encounters, both friendly and hostile, between the Natives and their visitors, these early contacts had little direct impact on the Inupiat. Nevertheless, the early voyages through 1838 and the more intensive probes that followed in the 1840's paved the way for the economic exploitation of the Arctic. At this time the Natives of this region were seen as a potential market for trade goods and as cultural curiosities. More important, the early explorers let the world know that the bowhead whale summered in the waters off the north Alaska coast, and by the 1860's, commercial whaling in the Arctic was intensive.

The onset of commercial whaling was the beginning of prolonged contact of irregular intensity between Westerners and Eskimos. Steamship whaling and shore-based whaling stations made it possible for crews to overwinter in the Arctic. Baleen was in high demand for corset stays, skirt hoops, and buggy whips; whale oil was also exported. In addition, walruses were taken for oil and ivory tusks. Caribou were killed to feed the wintering crews; each ship required more than 10,000 pounds of caribou a year (Bockstoce, 1977).

The movement of the inland Eskimo, or Nunamiut, to the coast was a significant consequence of this period. Their decline has been attributed to the cessation of trade with the coastal Eskimo (Spencer, 1959) and to a declining caribou population (Gubser, 1965). Starvation and disease killed most of the Nunamiut. Both the inland and coastal Eskimo populations were decimated by epidemic diseases.

Secondary effects with wide-ranging and long-term impacts of commercial whaling activities include introduction of trade in liquor and firearms, formal schooling, and Christianity. In the 1890's, the Federal Council of Churches largely apportioned the North Slope region to the Presbyterian missionaries.

Intensive trapping for fox and other furbearers for trade and cash was a departure from and erosion of communal life which revolved around the subsistence whale hunt. At the end of the commercial whaling era, whales and walrus were both drastically depleted, and difficulty in capturing enough for subsistence purposes has been noted (Bockstoce, 1977). This, coupled with the presence of trading posts and traders, and the economic boom being experienced in fur prices made for easy economic transition into the fur trade for the Inupiat, who were skilled at securing fox from the arctic environment with a minimum of supporting infrastructure, such as cash, towns, and services.

Reindeer herding was introduced to stem the effects of a declining caribou population and to provide a basis for a commercial economy. Ownership and pastoral management of a natural resource was an introduced concept that did not remain a permanent feature of the Inupiat socioeconomic system. Throughout the reindeer herding period, hunting, fishing, and trapping remained the major Inupiat preoccupations. Reindeer herding declined as a result of several factors, among them, predation from caribou, competition for herders from the increasing military construction, such as DEWLine and NARL, and a lack of a real market for reindeer, except within local communities.

During and after World War II, the strategic location of the North Slope became evident. Lands in northern Alaska were withdrawn by public land order in 1943 (rescinded in 1960). In the 1950's, a string of DEWLine sites was constructed for defense. At about the same time, Arctic Contractors was conducting exploration activities within Naval Petroleum Reserve No. 4. Inupiat labor was intermittently used, and cash wages lent financial support to the whaling crews, ensuring a continued share in the whale and walrus catch for the laborers.

d. Cultural Resources

The human record, evident and potential remnants of the past, goes back thousands of years. Aboriginal remains, historical sites associated with camp life and Western contact, and presently used traditional use areas indicate the kinds and extent of cultural resources on the North Slope.

The North Slope Borough Traditional Land Use Inventory has identified hundreds of culturally significant sites, like this sealer's hut on Cross Island. (C. D. Evans, AEIDC)

Historic preservation — inventory and protection of archeological and historic sites — is carried out at the Federal, State, and local levels. As noted, four sites in the North Slope Borough are presently listed on the National Register of Historic Places. The State of Alaska maintains the Alaska Heritage Resources Inventory. The North Slope Borough, particularly its Commission on History and Culture, maintains a Traditional Land Use Inventory (TLUI). Hundreds of sites are listed on the TLUI, and more are expected as the inventory continues. Most sites are located along the coast, river systems, caribou migration routes, and aboriginal trade routes. Sites include cabins, graves, sod-house ruins, fishing, trapping, and hunting areas, cellars, and other sites which are commonly regarded as significant. The TLUI indicates the kinds and extent of cultural resources on the North Slope and the continuum of traditional land use patterns held by the resident Inupiat.

2. Contemporary Period

Unprecedented political development, gaining momentum in the 1960's and continuing today, characterizes the contemporary era of Inupiat history. The political process is evident at each village and throughout the region. Every individual is affected, and most of the residents are actively involved. The region is becoming an integral part of State and national concerns by virtue of its natural resources. It is not unusual for a village elder or whale hunter to go to Anchorage or Washington, D.C., or abroad to represent Inupiat interests. The North Slope Borough maintains a liaison office in Washington, D.C., and in Anchorage.

a. Village Councils

Traditional forms of Inupiat self-government rest on kinship and territorial occupation. Whaling captains' associations and local town councils are organized on a traditional basis. A regionwide government was organized under the Indian Reorganization Act (IRA) of 1971; other government entities are incorporated under State laws. The IRA acknowledges Federal recognition of tribal governments, while incorporation under State laws confers certain legal powers depending on class status. By means of ordinances and "unwritten ordinances," village councils conduct external and traditional affairs. Social control is often extended, by the councils, to individual and interpersonal conflicts and toward the resolution of Inupiat and Tanik (non-Inupiat, white) affairs.

b. Regional Affairs

The political evolution of regional organizations and memberships among Alaska Natives requires a broad interpretation of the term "tribe." In contemporary terms, regional organizations include: regional associations, regional IRA governments, profit-making corporations under Public Law (P.L.) 92-203, and municipal governments (Worl, 1976). The organizations for the North Slope region are as follows:

Organization	Establishment Date
Arctic Slope Native Association (ASNA)	1966
Inupiat Community of the Arctic Slope (ICAS)	1971
Arctic Slope Regional Corporation (ASRC)	1972
North Slope Borough (NSB)	1972

The objective of ASNA was to resolve the aboriginal land claims of the Inupiat which encompassed all of the North Slope. Following compromise and codification into law, ASRC and village corporations were established under P.L. 92-203, the Alaska Native Claims Settlement Act (ANCSA). The ICAS and NSB now cooperatively contract to administer Bureau of Indian Affairs (BIA) and Indian Health Service (IHS) programs for education, health, business, and social services.

Other landmark political developments are the Inupiat Paitot (People's Heritage), the *Edwardsen* vs. *Morton* case (renamed *U.S.* vs. *ARCO et al.*), and the Inuit Circumpolar Conference (ICC). In 1961, the Inupiat Paitot convened to deal with problems common to northern and northwestern Eskimo. Major issues were: the right to hunt eider ducks (precipitated by a "Duck-In," a mass demonstration against migratory bird treaties between the United States and Canada and Mexico); opposition to Project Chariot, a proposed nuclear blast by the Atomic Energy Commission to provide a deep-water port at Cape Thompson; construction of high schools so that school-age Inupiat would not have to leave home for education; and provision of employment opportunities for Eskimos by contractors who normally imported their labor forces. The *Edwardsen* vs. *Morton* case involved Charles Etok Edwardsen, Jr., and numerous defendants, including the Federal and State governments and multinational oil companies. Edwardsen and other Inupiat filed a class action suit against Secretary of the Interior Rogers C. B. Morton, contesting that all land dispositions and petroleum development activities on the North Slope prior to the 1971 settlement act were invalid. In 1977, the case was dismissed. The ICC convened in the summer of 1977; delegates from Canada, Greenland, and Alaska met and passed 17 resolutions on Arctic policy, focusing on offshore resources. The Coastal Zone Management Newsletter, published by the North Slope Borough, provides a current chronicle of Inuit circumpolar affairs (National Petroleum Reserve in Alaska Task Force, 1978c).

Recent Inupiat regional affairs are marked by two major political developments: first, the passage of ANCSA (P.L. 92-203) of 1971, a land and cash settlement provided through regional and village corporations; and second, the political unification of the Inupiat and other Alaska Natives through participation and membership in various regional organizations.

This photo taken in 1898 shows inland hunters with a catch of wild fowl. (Naval Arctic Research Laboratory)

3. Populations and Settlements

a. Early Settlement Patterns

During the aboriginal period, the Tareumiut (coastal) and Nunamiut (inland) populations moved and settled in patterns responding to ecological factors, such as the availability of food sources. Although the Tareumiut may be generally described as sedentary, living in permanent and satellite villages along the coast, they also seasonally settled miles out on the ocean ice, along the sea coast and rivers, and at many inland places. The Nunamiut were largely nomadic and ranged widely throughout tundra plain and mountains. Nomadic camps were seasonally used for hunting and foraging. Coastal and inland people met at designated places to trade skins, whale and caribou products, and European ware, such as tobacco and knives. These summer fairs were occasions for economic and social exchange, serving to enhance subsistence values, and resulted in a sense of solidarity and homogeneity.

b. Historical and Contemporary Population Trends and Settlement Patterns

Two broad observations can be made on population and settlements in the Arctic Slope region: first, an increase in the resident population is largely due to an increase in Eskimo birth rate and greater life expectancy and to an influx of social services and white-collar personnel; and second, sedentary and seasonal patterns are modified by available market goods and cash jobs.

Barrow's population grew 500 percent between 1939 and 1970, and its facilities and services now accommodate regional Native affairs and nearby scientific research at the Naval Arctic Research Laboratory. Today, the Barrow population exceeds 2,000, over half of the total resident borough population (table A-3).

Three traditional Native communities were reestablished during the 1970's — Atkasook, Nuiqsut, and Point Lay. These communities have a combined population of about 300, comprised mainly of emigrants from Barrow who are seeking to return to a more traditional way of life.

Since 1970 the population composition of the North Slope Borough has changed dramatically. Non-Natives outnumber Natives when residents and personnel associated with military and petroleum activities are considered in the total. Although traditional communities are still almost entirely comprised of Inupiat, non-Natives (whites) fill professional job openings, mostly as teachers.

The age and sex composition of the North Slope population is fundamentally unlike national norms. The Alaska population is younger and comprises more men than the national population. The median age of the North Slope population is still lower, and there is also a greater percentage of males here than in the State as a whole. This departure from age and sex norms is also evident in both the traditional communities and at Prudhoe Bay/Deadhorse, where there is a significant number of working-age men (National Petroleum Reserve in Alaska Task Force, 1978c). Following are census data for 1970:

	Median Age	Percentage Male	Percentage Female
North Slope Borough	18.7	57.2	42.8
State of Alaska	22.9	54.3	45.6
United States	28.0	49.0	51.0

Future population trends are difficult to predict. The University of Alaska's Institute of Social and Economic Research (ISER) (1977) has projected a growth of about 2 percent annually for the villages of northern Alaska, and further growth related to the construction of a natural gas pipeline from Prudhoe in the early 1980's. Other large-scale projects, such as development of NPRA lands, would have an increased effect, so far ungaged.

4. Subsistence

The Inupiat people of Arctic Alaska continue to use the land, sea, and ice for subsistence hunting, fishing, and gathering to support their traditional way of life. Before contact with Western cultures, Inupiat survival was based solely on subsistence. Beginning in the 1850's, a series of commercial, military, and industrial incursions dramatically altered the Inupiat world and their responses to it. Recently, Alaska statehood, ANCSA, and intensive mineral exploration and development have imposed a new regime in the land and people of the Arctic. The Inupiat have ceased being ethnological objects and have entered the arena of international economics and politics; the land on which they have lived for centuries is no longer considered barren and worthless to a world in need of minerals and fuels (Hanrahan and Gruenstein, 1977).

Throughout history, the Inupiat have retained strong ties to their homeland, where human use was patterned according to custom rather than Western laws of ownership. The Inupiat have adopted many elements of Western technology and economy into their lifestyle, but the great majority continue to participate in subsistence activities as hunters, sponsors, and sharers of the hunt. The Inupiat have made it clear that this is both necessary and preferred for economic, social, and cultural reasons (Arnold, 1976; Worl, 1978).

Continuation of this lifestyle is the preeminent Native concern in Alaska (University of Alaska, ISER, 1977). It precipitated the scattered filings that became the Native claims movement leading to ANCSA. It was also the principal consideration of Congress when it inserted the Native dependence/livelihood clause in Section 105(c) of the Naval Petroleum Reserves Production Act of 1976 (Arnold, 1976).

A number of premises are prerequisite to interpretations of subsistence data and are discussed in

Table A-3. **Population Estimates, North Slope Borough Region, 1939-77**

Community	1939	1950	1960	1970	Jan. 1974	Jan. 1975	July 1975	Dec. 1975	July 1976	Jan. 1977	July 1977
Traditional communities:[1]											
Anaktuvuk Pass	—	66	35	99	134	134	129	129	150	150	151
Atkasook (Meade River)	78	49	30	—	—	—	—	—	—	—	86
Barrow	363	951	1,314	2,152	2,163	2,163	2,141	2,107	2,294	2,294	2,220
Kaktovik	13	46	120	123	141	141	119	119	123	123	134
Nuiqsut	89	—	—	—	145	145	149	149	152	152	157
Point Hope	257	264	324	386	404	404	384	403	408	408	412
Point Lay	117	75	—	—	27	27	48	48	51	51	54
Wainwright	341	227	253	315	354	354	341	344	357	394	398
Subtotal	1,258	1,678	2,076	3,075	3,368	3,368	3,311	3,299	3,535	3,572	3,612
Oil and gas/pipeline camps:[2]											
Prudhoe Bay/Deadhorse area	NA[3]	NA	NA	279	927	3,158	5,022	5,531	8,801	7,765	5,318
NPRA	NA	NA	NA	3	5	5	5	5	55	505	33
Subtotal	—	—	—	282	932	3,163	5,027	5,536	8,856	8,270	5,351
Military stations:[4]											
Cape Lisburne	—	—	NA	83	112	112	112	112	112	112	92
DEWLine	—	—	NA	111	111	111	111	111	111	111	108
Subtotal	—	—	—	194	223	223	223	223	223	223	200
Total	—	—	—	3,551	4,523	6,754	8,561	9,058	12,614	12,065	9,163

[1]Population for traditional communities since 1970 based on actual counts or Borough Planning Department estimates. The estimates for Barrow appear low. In the opinion of Alaska Consultants, Inc., the community's population was at least 2,700 persons.
[2]Population for oil/gas and pipeline camps since 1970 provided to the North Slope Borough by industry groups. Estimates for NPRA from January 1974 through December 1975 provided by the U.S. Geological Survey.
[3]Not available.
[4]Population for Cape Lisburne since 1970 provided to the North Slope Borough by the U.S. Air Force. Population for DEWLine stations (excluding POW-Main) provided to the North Slope Borough by the U.S. Air Force and by FELEIC Services, Inc., for the period December 1975 through July 1977. DEWLine populations back through 1970 assumed by Alaska Consultants, Inc., to be at December 1975 level.

Source: U.S. Census; North Slope Borough.

North Slope Borough studies (Schneider and Bowers, 1977; Schneider and Brown, 1978) and other Arctic literature. These are:

1. Subsistence is practiced in this region exclusively by Native people. Current studies by the borough identify no other subsisters in the region, though there is one white-operated commercial fishery at the mouth of the Colville River. (This Native exclusivity is unique in Alaska to the Arctic region because of the rigors of this northern environment and the special skills required for survival and productive hunting.)

2. Subsistence in some form, however modified by future events, will continue as a functional and cultural imperative of the Inupiat.

3. The evolving culture of the Inupiat is both dynamic and conservative. It is bound neither to stall at some prior level nor disappear through assimilation, emigration, or some other progression that seems to affect other minority cultures. The Inupiat have a direction of their own.

4. The adaptive response of the Inupiat to a changing environment is a part of a vital culture — valuable to the Inupiat because it allows retention of core elements of their way of life in a fast changing world and to others because it perpetuates cultural diversity.

5. Perpetuation of Inupiat culture depends on retention of a resource base that can support the subsistence option for those Inupiat who choose it. Subsistence — through language, environmental knowledge, hunting skills, and social/ceremonial networks that involve essentially the whole society — keeps traditional culture patterns operating and, therefore, alive.

a. Resource and Patterns of Use

Native use of natural resources can be related to three ecological zones: the ice, littoral or nearshore, and inland zones. Descriptions by Larsen and Rainey

(1948), Sonnenfeld (1957), and Spencer (1959) have featured coastal and inland subsisters as distinct and interdependent for the exchange of whale and caribou products. Current description by Worl (1977) makes these distinctions less discrete and, further, distinguishes the northern coastal Inupiat for successfully harvesting the ice environment. Sonnenfeld described sea ice as an extension of both land and sea, and pointed out the advantageous use of open-water leads in shorefast and pack ice to locate the migrating whales and seals.

The arctic environment has yielded a diversity of plants and animals for food, clothing, fuel, building materials, crafts, and other basic needs. Subsistence use calls for ingenious interpretation and use of the natural world — wide-ranging hunting and trapping, seasonal hunting and fishing, and occasional shifts to secondary resources (such as fish and small mammals) when primary resources (such as caribou) are scarce. Table A-4 lists various plant and animal resources used by northern Alaska Natives.

Many subsistence resources are migratory, arriving in northern Alaska or along the coast in spring. Some migrants reside in the region throughout the summer (all terrestrial mammals and waterfowl, some marine mammals), but many marine mammals travel farther north or east to summering areas, then return along similar routes in fall. Some mammals, such as ringed seals and caribou, migrate relatively short distances and are absent from the region only briefly. Some caribou winter in the Cape Thompson-De Long Mountains area, along the coast in the Point Lay-Icy Cape area, and in the Harrison Bay-lower Colville River area. Certain resources, including small mammals and ptarmigan, are nonmigratory and are available year-round. Seals and caribou, in particular, form the historical cornerstones of livelihood among northern Alaska villagers. Whales are of utmost significance for food, social, and religious purposes, but seals have been the long-term dependable sea mammal resource. Caribou, a dietary mainstay, have undergone major fluctuations in population that historically controlled inland populations by causing emigration and starvation. Present regional village locations along the coast — Anaktuvuk Pass being a notable exception — reflect the lack of dependability of caribou as a sole resource.

Villages are strategically located, intersecting the courses of migrating marine or terrestrial species where they occur in great numbers. Point Hope and Barrow, for instance, are situated on narrow land masses projecting into the ocean. Hunters are thus close to the sea ice leads used by bowhead and beluga whales, seals, walrus, and waterfowl during their northward spring and southward fall migrations. Anaktuvuk Pass is in a pass in the Brooks Range through which numbers of caribou migrate each spring and fall.

The extensive land areas lying between villages and stretching south toward the mountains deserve special mention. Seasonal changes and wildlife population changes dictate subsistence use of virtually all of the North Slope region to insure survival of the Inupiat inhabitants. Hunted animals, such as caribou, are wide ranging. Fish camps on the coast and along inland rivers are used for one or more seasons of the year. Traplines are characteristically remote and far flung. Birds use almost all of the area for seasonal

Seals are often harvested as subsistence hunters await the arrival of whales. (C. D. Evans, AEIDC)

Table A-4. Subsistence Resources, Arctic Slope Region

Category	Common Name	Eskimo Name	Scientific Name
Big game	Bear (black)	iggaġriq	*Ursus americanus*
	Bear (grizzly)	akłaq	*U. arctos*
	Caribou	tuttu	*Rangifer tarandus*
	Moose	tiniika	*Alces alces*
	Sheep (Dall)	imniaq	*Ovis dalli*
Marine mammals	Bear (polar)	nanuq	*Ursus maritimus*
	Seal (bearded)	ugruk	*Erignathus barbatus*
	Seal (harbor)	qasigiaq	*Phoca vitulina*
	Seal (ring) (hair)	natchiq	*P. hispida*
	Walrus	aiviq	*Odobenus rosmarus*
	Whale (beluga)	qilalugaq	*Delphinapterus leucas*
	Whale (bowhead)	aġviq	*Balaena mysticetus*
	Whale (gray)	aġviġluaq	*Eschrichtius robustus*
Small game and furbearers	Fox (arctic)	tiġiganniaq	*Alopex lagopus*
	Fox (red)	kayuqtuq	*Vulpes vulpes*
	Linx	niutuiyiq	*Lynx canadensis*
	Marmot (hoary)	siksrikpak	*Marmota boweri*
	Mink	itiġiaqpak	*Mustela vison*
	Porcupine	qinaġluk	*Erithizon dorsatum*
	Squirrel (arctic ground)	siksrik	*Spermophilus parryii*
	Ermine	itiġiaq	*Mustela erminea*
	Wolf	amaġuq	*Canis lupus*
	Wolverine	qavvik	*Gulo gulo*
Waterfowl and birds	Black brant	niġliñġaq	*Branta bernicla*
	Crane	tatirgak	*Grus canadensis*
	Eider (king)	kiŋalik	*Somateria spectabilis*
	Eider (common)	amauligruaq	*S. mollissima*
	Eider (Steller's)	igniqauqtuq	*Polysticta stelleri*
	Eider (spectacled)	qavaasuk	*Somateria fischeri*
	Goose (Canada)	iqsraġutilik	*Branta canadensis*
	Goose (snow)	kaŋuq	*Chem caerulescens*
	Goose (white-fronted)	niglivialuk	*Anser albifrons*
	Loon	tuullik	*Gavia*
	Murre	adpa	*Uria aalge*
	Oldsquaw	aaqhaaliq	*Clangula hyemalis*
	Owl (snowy)	ukpik	*Nyctea scandiaca*
	Pintail	kurugaq	*Anas acuta*
	Ptarmigan	aqargiq	*Lagopus lagopus*
Fish (Ikaliuk)	Blackfish	iłuuqiñiq	*Dallia pectoralis*
	Char (arctic)	iqalukpik	*Salvelinus alpinus*
	Cod (ling) (burbot)	tittaaliq	*Lota lota*
	Cod (tom) (arctic cod)	iqalugaq	*Boreogadus saida*
	Crab (Tanner)	puyyugiaq	*Chinocetes opilio*
	Flounder (arctic)	nataaġnaq	*Liopsetta glacialis*
	Grayling (arctic)	sulukpaugaq	*Thymallus arcticus*
	Herring (Pacific)	uqsruqtuuq	*Clupea harengus pallasi*
	Pike (northern)	siulik	*Esox lucius*
	Salmon (chum)	iqalugruaq	*Oncorhyncus keta*
	Salmon (pink)		*O. gorbuscha*
	Smelt (rainbow)	iłhuaġniq	*Osmerus mordox*
	Sucker (longnose)	milugiaq	*Catastomus catastomus*
	Trout (lake)	iqaluaqpak	*Salvelinus namaycush*
	Whitefish:	quptik	
	Arctic cisco	iqalusaaq	*Coregonus autumnalis*
	Bering cisco	qaaktaq	*C. laurettae*
	Broad whitefish	anaakłiq	*C. nasus*
	Humpback whitefish	pikuktuuq	*C. pidschian*
	Least cisco		*C. sardinella*
	Round whitefish		*Prosopium cylindraceum*
Berries	Blueberries	asiaq	*Vaccinium uliginosum*
	Cranberries	kimmiŋñaq	*V. vitis-idaea*
	Crowberries	paunġaq	*Empetrum nigrum*
	Salmonberries	aqpik	*Rubus chaemorus*

Category	Common Name	Eskimo Name	Scientific Name
Greens/roots	Grassroots		*Parrya nudicaulis*
	Sourdock (wild spinach)	masu	*Rumex arcticus*
	Willow leaves	quaġaq	*Salix*
Vegetables (wild)	Celery	iiguusiq	*Angelica lucida*
	Eskimo potato	utqi	*Hedysarum alpinum*
	Rhubarb	quŋulliq	*Oxyria digyna*

Table A-4. Subsistence Resources, Arctic Slope Region (continued)

The Eskimo names are from the North Slope Inupiat Language Commission, and represent the Barrow dialect.

activities. Entire river valleys, such as the John, and lakes, such as Iniakuk, are habitually used. Besides travel between villages for visiting and sharing, it is not unusual for hunters to make long trips, even in winter conditions.

Coastal communities differ little in the types of resources available. However, there are differences in dependable access to them and in the abundance of each species that is available. In Kaktovik, for instance, bowhead whales are hunted only in the fall, though they migrate past the village in late spring. Access is difficult during spring, so hunters wait until fall when conditions are better. Both Wainwright and Point Lay lie within striking distance of the migratory path of bowhead whales, but their access is poor because of constantly moving ice in spring. Icy Cape was a preferred whaling site but has not been used recently because it is a considerable distance from both permanent communities. Wainwright villagers now take whales off the coast north of the village where the leads are favorable.

Seals, ducks, geese, fish, and most terrestrial game are available to coastal villagers throughout the region; it is mainly in numbers harvested and timing of harvest that villages differ. The arrival of northward migrating resources is successively later in spring in the northern and eastern villages. Thus, hunting of bearded seals is latest at Kaktovik where breakup is latest. In fall the pattern is reversed, and Point Hope sees the passing of southward migrating coastal resources last of all the North Slope Borough villages.

Though coastal communities basically rely on the assemblage of marine resources, caribou have always been an important secondary source of meat. Some coastal dwellers pursue terrestrial species more today than in the past because snow machines enable hunters to travel faster and farther than before.

Widely distributed furbearers have provided garment material and also cash. Resident small mammals and terrestrial birds are abundant throughout the coastal district, and their use today is more a matter of personal taste than of regional difference.

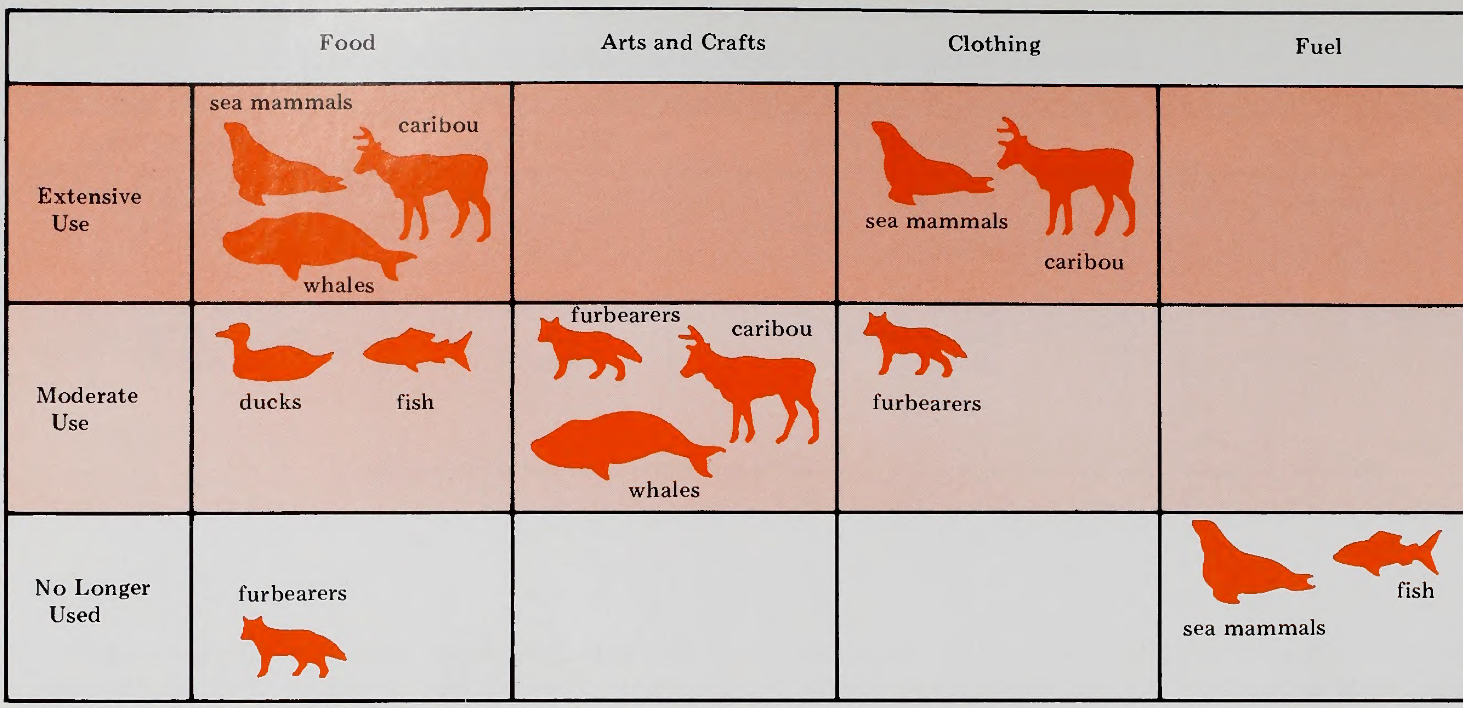
Kaktovik is the only regional village that harvests sheep annually. The proximity of mountains to Kaktovik permits its villagers relatively easy access to sheep. The greatest diversity of fish resources is harvested by Barrow residents, whereas Kaktovik is rather impoverished in this respect. Whether this is due to fishing methods and intensity or to availability is not clear, but the contrast points out important differences in subsistence patterns.

Nuiqsut, a recently resettled village on the Colville Delta, shares both inland and coastal traits in its food resource patterns. Because of comparatively limited pursuit of marine mammals and heavy reliance on fish and big game, it is considered to be an inland-type community. If caribou hunting continues to be limited, these hunters may turn their attention to intensive pursuit of marine mammals in Harrison Bay. Or they may acquire marine products through associations in those areas where they are plentiful — that is, by trade, seasonally moving to those areas for hunting, or outright purchase of the necessary products.

Anaktuvuk Pass is at present the only village solely dependent on inland resources. Marine resources are available by way of sharing arrangements with coastal villages. The variety of terrestrial species utilized by these villagers is only slightly greater than that of the wide-ranging coastal hunters. Caribou supply basic sustenance and are absolutely vital to the health and well-being of the people and the community. Furbearers are harvested in greater numbers here than in any of the other villages. Small mammals, such as marmots and hares, are harvested by Anaktuvuk Pass villagers but rarely elsewhere. Fish are also utilized. Sheep and moose are also pursued, particularly when caribou hunting is unproductive or restricted, as it has been recently.

Today, only the Colville Delta supports commercial exploitation of a natural food resource. Whitefish abound here in fall and early winter, and subsistence as well as commercial catches are regionally significant. Perhaps other sites in northern Alaska could support commercial endeavors, but no others now exist.

Throughout northern Alaska, greens, roots, vegetables, and berries are gathered from spring through fall. Many plants are eaten raw or cooked



Subsistence resources are used in varying degrees for multiple purposes. (AEIDC)

immediately. Others are stored in barrels or preserved as jams or in seal oil for later use as desserts and additives to meat dishes. Historically, the inland people made greater use of plant foods than did the coastal people. In all villages today, berries are the most important plant food gathered, and favored berrying areas are used every year (Spencer, 1959).

Use of many plant products has declined in favor of imported utility articles and construction materials, but driftwood and sod blocks continue to be used for some building purposes, such as insulation, outbuildings, and camp shelters. Anaktuvuk Pass villagers have access to forest products in the upper John River drainage, including spruce trees, which are used today primarily for construction of sleds (Bane and Nelson, 1977).

Though fuel oil has largely replaced use of willows for fuel in the villages, willows are still used to heat hunting and trapping tent camps throughout the winter. Coal from the surface or in shallow deposits is also used for fuel at Wainwright and Atkasook.

The subsistence harvest of a typical family in the North Slope Borough is given in table A-5.

b. Subsistence Values

The values attached to the more salient natural resources are elusive to many who are not part of the northern Eskimo society. To those who are native to the Arctic Slope, subsistence values evoke powerful feelings. Subsistence as a way of life offers more than the essentials for survival; it also offers community sharing and prestige, group risk in taking and recovery, physical and mental fitness, feasting, and trading. The Inupiat believe their cultural survival is based on a direct and intimate relationship with their environment (Worl, 1978).

Cultural expressions surrounding whaling illustrate subsistence values well. The umalik, or whaling captain, is considered a leader, provider, and esteemed member of the community. Muktuk — choice strips of whale skin and fat — and meat are shared at feasts, such as the Whale's Tail ceremony, Nalukatak (captain's feast), and introduced holidays, such as Thanksgiving and Christmas. Whaling is thus the nucleus of important cultural features of Inupiat society.

Eskimo dances frequently imitate animal movements, and carvings reveal an intimate knowledge of animal form and behavior. These expressions, and associated values, are another part of the cultural content of Inupiat society. The relationship between the Inupiat and their environment is based on several thousand years of cultural evolution. The persistence of their culture has been attributed to their tenacity in maintaining this relationship (Worl, 1978).

c. Subsistence Issues

Current subsistence issues are the petroleum development impacts, the bowhead whaling ban, and caribou "crisis" (Worl, 1978). These issues were precipitated by decisions made outside regional and local jurisdiction.

In 1969, the State of Alaska held a $900-million oil lease sale on Prudhoe Bay. In 1973, the U.S. Congress authorized construction of the Trans-Alaska Pipeline System to transport Prudhoe oil. In 1976, Congress passed the Naval Petroleum Reserves Production Act, authorizing production in three reserves and exploration of the fourth reserve (NPRA). Exploration activities entail drilling 26 exploration wells, running thousands of miles of seismic lines, and construction of support facilities. Also, the Alaska Natural Gas Transportation Act of 1976 authorized a

Table A-5. Subsistence Harvest by a Typical Family, North Slope Borough

Subsistence Resource	Average Number Taken	Notes
Caribou	34.2	This number represents the harvest before the caribou decline.
Oogruk (bearded seal)	3.0	
Walrus	1.8	
Seal	2.8	Figure is probably low.
Fowl	85.4	Fowl includes black brant, eiders, geese, ptarmigan, and oldsquaws.
Fox	15.9	Foxes are trapped for their fur.
Fish	(500 lbs)	Estimated; fish is eaten fried, frozen, and dried.
Polar bear	.4	Polar bear is generally shared through the extended family.
Bowhead whale	(200 lbs)	Both bowhead and beluga whales are hunted by crews and are shared communally. Bowhead whale figures are preregulation.

Wainwright is taken as being the typical village. The typical family has six members and an annual income of $10,621.31.
Source: North Slope Borough Planning Department, 1977, unpublished survey responses.

Although whales are of utmost significance for food, social, and religious purposes, seals have been the long-term dependable sea mammal resource. (Sea Grant)

Subsistence harvests are preserved by drying on racks. (W. Dietrich)

natural gas pipeline from Prudhoe through parts of Canada to the conterminous States. The gas pipeline system, exploration in the Arctic National Wildlife Range to the east of NPRA, and as yet undetermined land use of NPRA represent events which will affect the North Slope region.

In 1976, the Alaska Fish and Game Department imposed a quota on subsistence caribou hunting, and the State court enjoined all caribou hunting during ensuing litigation. In the summer of 1977, the International Whaling Commission (IWC) proposed a ban on subsistence hunting of the bowhead whale. The North Slope inhabitants' response to the outside decisions affecting their lives has been to create regional regulating bodies which could serve as counterparts — for negotiating and liaison purposes — to State, Federal and international bodies. For example, the Alaska Eskimo Whaling Commission — comprised of community whaling captains — was formed in response to the ban imposed by the International Whaling Commission. Also, the Fish and Game Management Committee and the Environmental Protection Office — within the NSB government — respond to caribou and petroleum development issues precipitated by State or Federal action.

5. Socioeconomics

Today, the North Slope regional economy is a mix of subsistence, cash employment, regional corporation and borough finances, and government programs. Recently, as a direct consequence of land claims settlement and Prudhoe Bay development, the North Slope Borough has gained access to corporate finances, government programs, and multinational affairs.

The Alaska Native Claims Settlement Act provided for 44 million acres (17 million hectares) in fee simple and $1 billion in cash, plus interest, over 20 years. The Arctic Slope Regional Corporation is entitled to roughly 1/12 of the total conveyance; control of land, i.e., carrying out the act, is the first priority of all of the Native corporations (Arctic Slope Regional Corporation, 1977).

The Prudhoe Bay oil field development represents an investment of nearly $3 billion. The assessed value of taxable property at Prudhoe is $2.2 billion, from which the State of Alaska raises over $200 million annually in property taxes, and from which the North Slope Borough received $13.5 million in 1976. On a yearly basis, Prudhoe generates over 98 percent of the region's revenue and about one-half of the borough's budget. The other half comes from various State revenue sharing programs (Hopson, 1976).

Contrasted with public finances is another aspect of the economy which cannot be ascertained or measured as succinctly — that is, individual subsistence and cash employment. Individual persons, partners, and families continue to rely on subsistence as a dependable and satisfying way to meet their basic needs. By means of sharing and sponsorship, they can pool their resources to obtain the necessary combination of hardware, cash, and time to hunt and fish. The following is a brief description of current patterns as described by Worl (1978):

> The subsistence participant may alternate between subsistence activities and cash employment. This method can take various forms, with the subsistence participant working seasonally, part time, or on a temporary job.
>
> The subsistence participant may receive financial support from one or more relatives, a spouse, or a hunting partner. A common pattern is for the wife to seek employment while the husband devotes the greater part of his time to subsistence-related activities. It is also common for a woman to be financial sponsor for her brother's or father's subsistence or whaling activities. The sponsor may provide cash directly to the subsistence participant, or he or she may furnish equipment and supplies in exchange for sharing in the subsistence harvest. A financial sponsor may establish reciprocal relations with one or more hunters.
>
> The subsistence participant may sell or trade his surplus products for other subsistence goods or trade for other items, such as ammunition or gasoline. The object of exchanging Native products is not related to actual harvest or production expenditures but to an informal determination of the level the community members can afford. By-products or raw materials from the harvested resource may be used directly by the subsistence participant or his wife for cash income from the sale of arts and crafts or Inupiat clothing or footwear. Raw material, such as baleen, furs, or bones, may be sold or traded directly to a craftsman. The arts and crafts cottage industry is an important source of cash income.
>
> A subsistence trapper may sell his furs to commercial buyers, but there is also a significant internal traffic in furs used for production of Inupiat clothing.

a. Government

Government on various levels — village, borough, State, and Federal — consitutes the biggest public sector within the North Slope region. The State of Alaska and the Federal Government have provided programs in health, education, and welfare and funds through revenue sharing and other means. Most of the State support for these programs comes from the Prudhoe development. Increased Federal support is likely if NPRA is similarly developed.

Dancing is an integral part of Inupiat ceremonies. Nuiqsut villagers celebrate their successful move. (J. C. LaBelle, AEIDC)

Modern equipment, like the outboard motor, has become important in subsistence activities and has fostered dependence on a source of cash income. (Robert Belous, National Park Service)

i. North Slope Borough

The North Slope Borough has served as an effective vehicle for political control and direction. It is the largest regional municipality in the United States. Its land base covers approximately 88,000 square miles (228,000 square kilometers). Its population is relatively small but growing; the regional total is more than 9,000, of which about 4,000 are Natives. The borough has a mayor, elected to a 3-year term, and a seven-member assembly. There is also a seven-member school board. The borough is a home-rule borough and has all legislative powers not prohibited by State law or its charter. Mandatory powers for a first-class borough are taxation, education, and planning, platting, and zoning. The following powers were transferred to the borough in an election held in April 1974:

- Streets and sidewalks
- Sewers and sewage treatment
- Watercourse and flood-control facilities
- Health services and hospital facilities
- Telephone systems
- Light, power, and heating utilities
- Transportation systems
- Water
- Libraries
- Garbage and solid waste collection and disposal services and facilities
- Housing and urban renewal, rehabilitation, and development
- Preservation, protection, and maintenance of historic sites, buildings, and monuments.

Areawide police powers were assumed after a July 1976 election. The borough established a service area at Deadhorse by ordinance in 1975 to provide solid waste, sewer, and water services. Separate and cooperative fire and emergency services are available in communities and bases, such as NARL.

The Capital Improvements Program (CIP) — a plan to provide each community with basic life, health, and safety support — is the greatest undertaking by the borough government. High-priority CIP projects are electric power generation, health clinics, sewage disposal, safe water sources, and year-round airstrips. Other CIP projects include housing, schools, and community service centers. When basic needs are adequately met, libraries and museums will be planned.

Including its most recent bond sale (1977), the North Slope Borough has sold a total of $85.1 million in general obligation bonds. However, the total amount of bonds authorized by Ordinance 77-10 for all purposes for the CIP ending FY 1982-83 is $131,577,000. The largest single sale took place in 1977 when $51.1 million in general obligation bonds were sold. This issue included $23 million for school facilities; $7.6 million for housing; $7.8 million for roads; $5.5 million for light, power, and heating systems; $5.5 million for sanitary facilities at Deadhorse; and lesser amounts for water, sewer, airport, and sanitary facilities and urban development. The status of the CIP is shown in table A-6.

The borough CIP was substantially amended in 1977. In September 1976 the North Slope Borough restricted its construction work in the CIP to 19 priority projects because of litigation over the borough's ability to collect taxes in excess of $1,500 per capita.

Property taxes are by far the most significant source of borough revenue. The State assessor's office lists the full value of real, personal, and oil and gas property in the borough as of January 1, 1977, at more than $3.5 billion; oil and gas property accounted for about 93 percent of this total. While the borough has the power to levy real and personal taxes of up to 30 mills, it is unable to do so because under Title 43.56 of the Alaska Statutes, local government is limited to a tax of $1,500 per capita.

Title 29.53.055 of the Alaska Statutes states that there is no limit on taxes levied or pledged to pay or secure payment of the principal and interest on bonds. However, this assertion is currently being challenged in the State Supreme Court. The North Slope Borough claims that the statutory limits on local government taxation do not apply to debt service, but only to operating revenues. An unfavorable decision to the borough would severly limit revenues necessary for its capital improvement program.

The borough mill rate in FY 1978 was set at 7.52 mills. This included a tax at the rate of 2.12 mills which is the subject of debt service litigation. In addition, the borough reinstituted a 3-percent consumer sales tax on all sales made within the borough in FY 1978. Other sources of borough revenue are the State and Federal Governments, mainly for health and education programs, and State revenue-sharing funds. In addition, the borough collects miscellaneous revenues, such as earnings from interest, its teacher, lunch, and housing program, and athletic gate admission charges. The general revenues collected by the North Slope Borough are shown in table A-7.

In addition to these boroughwide revenue sources, Barrow, Wainwright, and Point Hope levy local sales taxes. Barrow voted a ban on alcoholic beverages as of January 1978, cutting off the city's largest profit-making enterprise — the city-owned liquor store. Most villages have transferred their

Table A-6. Status of Capital Improvements Program to be Funded by Bonds Authorized and to be Authorized as per North Slope Borough Ordinance 77-1 for FY 1974-83
(Amounts given in thousands of dollars to the nearest thousand)

	Total Bond Program FY 1974-83	Total Bonds Authorized	Bonds Sold	Contracts or Other Obligations as of May 3, 1977
Education	$47,313	$40,000	$40,000	$21,797
Roads	18,221	18,111	11,200	7,126
Housing	37,043	13,792	13,700	12,958
Water facilities	215	186	100	26
Sewer facilities	560	386	375	2
Airports	882	667	175	58
Urban development	1,430	1,230	1,230	1,132
Light, power, and heating systems	7,297	6,944	5,550	2,265
Public safety	1,800	127	—	—
Sanitary facilities	15,951	12,770	12,770	12,500
Communications	540	540	—	—
Health facilities	325	—	—	—
Total	$131,577	$94,753	$85,100	$57,864

Information from Alaska Consultants, Inc., 1978.

Table A-7. General Revenue, By Source, for the North Slope Borough, FY 1973–78

Source	Fiscal Year 1973	1974	1975	1976	1977	1978
General property taxes, including penalties, interest, and charges	$418	$3,548	$5,501	$6,884	[a]$18,220	[b]$26,556
Sales taxes, including penalties and interest	37	1,040	1,181	—	—	240
State	69	1,376	2,295	5,342	5,302	6,839
Federal	27	31	1,767	1,270	1,883	2,091
Miscellaneous revenues	—	168	975	2,138	892	2,034
Total	$551	$6,163	$11,719	$15,634	$26,297	$37,760

[a]Includes a tax at the rate of 2.62 mills ($4,631,000) which is the subject of litigation.
[b]Includes a tax at the rate of 2.12 mills ($7,634,000) which is the subject of litigation.

General revenue includes all cash receipts except for enterprise funds. Amounts given in thousands of dollars to the nearest thousand. Information from Peat Marwick Mitchell and Co. (1978).

public works responsibility to the borough, thus minimizing their need for local funds.

ii. Arctic Slope Regional Corporation

The Alaska Native Claims Settlement Act (ANCSA) of 1971 created 13 regional and hundreds of village corporations throughout Alaska. In the North Slope region ANCSA established the Arctic Slope Regional Corporation (ASRC) and village corporations in Kaktovik, Anaktuvuk Pass, Barrow, Wainwright, Point Lay, Atkasook, Nuiqsut, and Point Hope. The primary purposes of the regional corporation are: 1) to receive and disburse money made available under ANCSA; 2) to select, own, and manage land made available under ANCSA; and 3) to conduct business for profit for the benefit of corporation shareholders. A total of 3,900 ASRC shareholders have been identified.

Since its creation, ASRC has made numerous investments and has formed six subsidiary corporations. In June 1977 the total assets of the corporation exceeded $12 million. Activities of the village corporations have varied from village to village. Many have taken over the operation of village stores and the sale of fuel to the general public. Some have formed joint ventures with ASRC.

iii. Local Government

Local village governments are unincorporated and have first- or second-class designation. The village council is the most important feature of local government. It oversees domestic affairs and acts as liaison between the village and the borough and between the village and the outside world. Through the village and borough governments, many people participate in all affairs affecting regional Native life.

Barrow is the only first-class city in the North Slope Borough, having achieved this status in 1974. Second-class cities include Anaktuvuk Pass, Kaktovik, Nuiqsut, and Wainwright. Atkasook, Point Lay, Point Hope, and Prudhoe Bay/Deadhorse are unincorporated communities.

b. Existing Development

Most of the North Slope region remains undeveloped. However, since the 1950's there has been a marked increase in base facilities separate from village growth. Scattered development has occurred along the coast and at strategic locations inland, associated with military or industrial bases or scientific research stations. Evidence of past petroleum exploration and defunct military installations does not decay or recover at normal rates in cold, dry, permafrost conditions. Development is clearly visible from the air, from elevated vantage points, or at long distances across the flat plains.

i. Transportation

In NPRA, transportation routes by air, waterways, and overland interconnect villages, bases, and population centers, such as Fairbanks and Anchorage. However, the land network, as in most of Alaska, is rudimentary.

Air transportation routes in northern Alaska are shown in figure A-19. Commercial jets (Wien Air Alaska) serve Barrow and Deadhorse daily; other communities are served by less frequent flights. Air taxi services are available at Barrow and Kaktovik for intraregional service. The U.S. Air Force contracts Wien to fly to three DEWLine sites, as well as to Kaktovik (Barter Island DEW), Barrow (NARL), Wainwright, and Point Lay. Public use is on a space-available basis. Airport facilities are grouped into two categories: 1) those operated and maintained by the Federal Government and for restricted use and 2) State and other public airports serving most villages (Hewitt V. Lounsbury and Associates, 1975).

The airports operated by the U.S. Air Force or Navy are generally well maintained and better able to handle large aircraft under adverse weather conditions than are public airports at most villages. Airport facilities located at active and deactivated DEWLine stations along the Arctic coast were constructed in the 1950's. Of the 17 original sites, 7 are in active military use, 4 are being used for research, 2 are logistical bases for exploration of petroleum resources, and the remainder are abandoned.

Federal air facilities are located at Cape Lisburne, Point Lay, Wainwright, Barrow (NARL), Lonely, Camden Bay, Demarcation Point, Cape Sabine, Cape Simpson, Point McIntyre, Peard Bay, Kogru Inlet, and Flaxman Island.

Public air facilities are located at Anaktuvuk Pass, Atkasook, Barrow, Deadhorse, Kaktovik, Nuiqsut, Point Lay, and Wainwright.

Marine transportation along the Arctic coast is controlled by seasonal ice conditions and shallow nearshore waters. The coast is usually ice free from about mid-July to near the end of September. Because there are no deepwater ports, cargo from ocean-going ships and barges is offloaded at sea onto lightering vessels. Barrow continues to serve as a major Arctic port — for sailing ships and steamships during the 1800's, for liberty ships during World War II, and for ocean-going barges today. The old liberty ship *North Star III*, operated by the Bureau of Indian Affairs, makes a once-a-year delivery at various northwestern and Arctic ports. Pacific Alaska Lines and Arctic Lighterage, both divisions of Crowley Maritime, make supplemental deliveries. Deliveries to service NPRA exploration and other military and industrial activities are also received at Barrow.

Delivery to Prudhoe Bay also requires lightering of freight from 6 miles (10 kilometers) offshore to port facilities. There are two unloading docks and a gravel causeway. Adjacent to the causeway is a 25-acre (10-hectare) gravel-pad storage area. Three heavy cranes are stationed at the docks for unloading cargo. A road connects the port to the main camp facilities and airport and to the Deadhorse Airport.

Since oil development began at Prudhoe Bay, ocean-going cargo deliveries to the Arctic coast have increased from 5,714 short tons in 1968 to 91,089 short tons in 1969 to 175,000 short tons in 1970. Cargo associated with petroleum development activities in the region includes fuel and fuel tanks, construction equipment, drilling mud, pipe, casing, prefabricated housing, and modular development camps. Most ports of embarcation are in Washington State or California; Seattle is the the primary port for Alaska cargo. A relatively small portion of ocean freight comes from intrastate ports, such as Anchorage.

Land transportation is limited to the trans-Alaska pipeline and parallel haul road. There are no

Airport facilities at DEWLine stations are used by military, scientific, and industrial aircraft and by the public during emergencies. (J. C. LaBelle, AEIDC)

major interconnecting overland routes on the North Slope. However, nearly every village and base facility has an internal, gravel or dirt road system that links it with an airport or ocean port. Residents use motor bikes, three-wheeled all-terrain vehicles, cars or trucks in summer, and consistently rely on snow machines for hunting and travelling to other villages in winter. Winter trails — some established during oil exploration or postwar construction — and historic trails continue to be used.

Barrow has a well developed road system of about 15 miles (24 kilometers) linking the village to NARL, Emaiksoun Lake, the gas field, scientific sites, and Point Barrow.

Prudhoe Bay/Deadhorse has an extensive, high-quality gravel road system which links the Deadhorse Airport, the Prudhoe Bay facility, the various drill pads, storage and dump sites. It is connected to the State highway system by the North Slope haul road.

The pipeline haul road — 200 miles (320 kilometers) of which lies within the region — has precipitated an unresolved issue. The issue is restricted versus public use and associated interests and concerns, such as access, recreation potential, induced growth, pipeline security, and village integrity. The haul road was originally built by the pipeline owners parallel to the oil pipeline for its construction and maintenance. The agreement under which the haul road was built required the State of Alaska to obtain the necessary construction permits from the Federal Government and also required the Alyeska Pipeline Service Company to build the road to secondary highway standards. By agreement between Alyeska and the State, possession of the road was turned over to the State in October 1978.

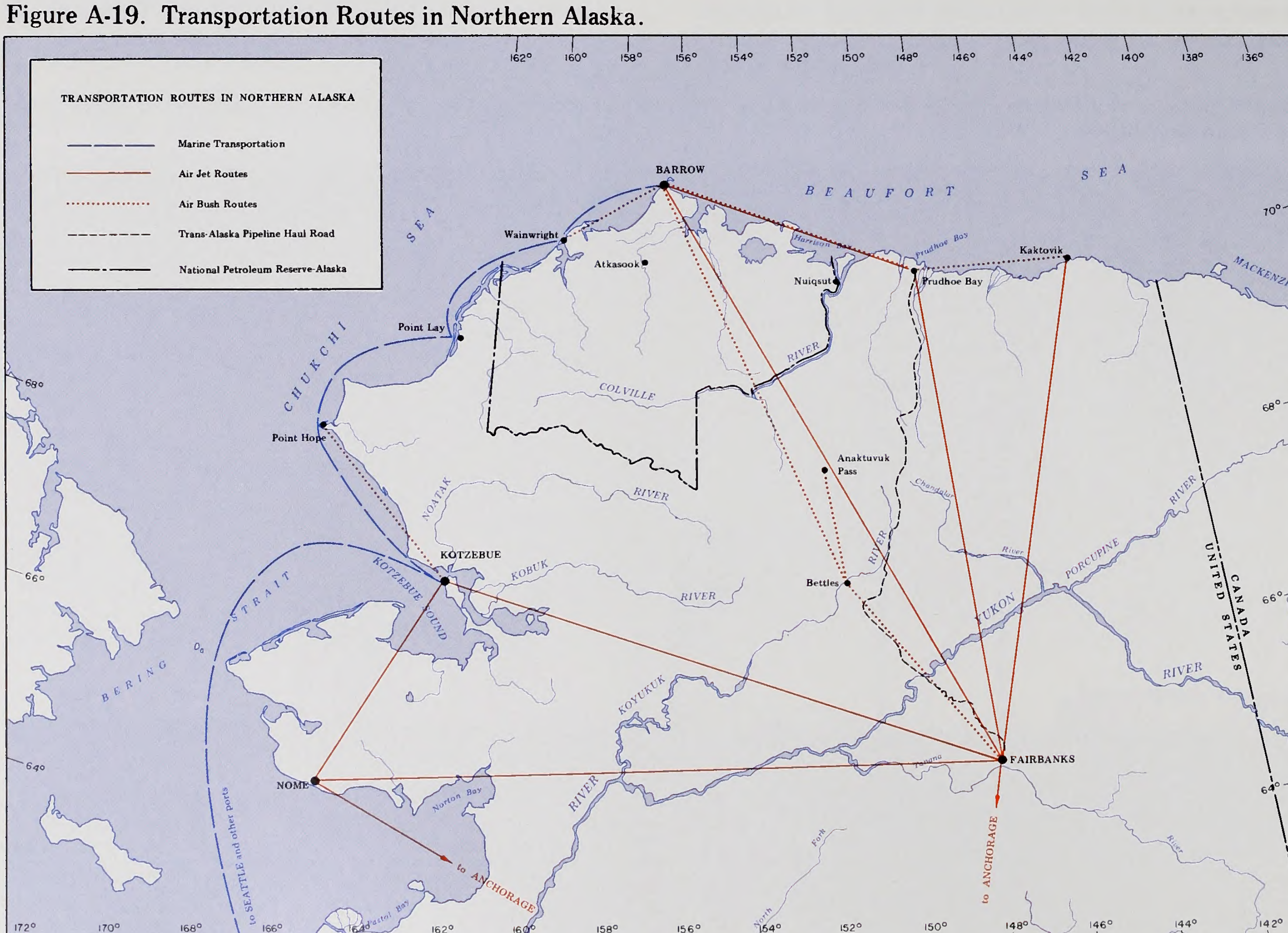
ii. Communication

Communication facilities are operated by the State and Federal Governments for civil aviation and national defense installations and by private companies, such as RCA and Wien Air Alaska, for public use. Until recently, radio and radio-telephone were the primary communications systems serving individual communities. However, the construction of telecommunications satellite earth stations at Barrow, Anaktuvuk Pass, Cape Lisburne, and Prudhoe Bay has brought long-distance telephone service to some otherwise isolated locations, and more are planned. Citizen-band (CB) radios are a common form of communication between whaling camps and boats hunting sea mammals, and some CB transmission between villages exists.

Communications in the Arctic provide telephone service via telecommunications satellite, military defense through DEWLine radar sites, and special communications for oil exploration and development activities.

Satellite telecommunications were established throughout Alaska in 1971 by RCA Alascom. This

Figure A-19. Transportation Routes in Northern Alaska.



Phone service to villages is provided by a telecommunications satellite system. (U.S. Geological Survey)

supplies are typically imported and high priced. In all villages except Barrow, small diesel generators [30 to 100 kilowatt (kW)] provide electricity, and oil and propane are burned for heat and cooking. Household and subsistence fuel use amounts to large quantities of oil and gasoline at high unit prices. Heating oil costs average $1.25 per gallon (3.78 liters), and gasoline ranges from $1.35 to $2.40 per gallon (National Petroleum Reserve in Alaska Task Force, 1978c). Undeveloped subbituminous coal reserves exist near Atkasook and Wainwright. A wind-power project is proposed by the borough for Point Lay.

The South Barrow gas field supplies Barrow and the NARL base. The city of Barrow receives gas-generated power and natural gas from a locally controlled utility company formed in the 1960's. The main generator is a 2,500-kW unit; normal electrical loads average between 1,000 and 1,500 kW. Natural gas lines to Barrow houses are makeshift and potentially unsafe, consisting of surplus pipe mounted on fuel drums that have been cut in half.

The operators of the South Barrow gas field have estimated that remaining reserves will be exhausted by the mid-1980's, according to current and telecommunications satellite provides two types of phone service: PHS, connecting public health facilities with regional hospitals, and MTS, message toll service for public use. Public dial phones in villages are usually located at a store or office building and controlled by an attendant. In addition to public use, stations carry private circuits for the Public Broadcasting System, the Alaska Native Health Service, and teletype and telex use.

DEWLine stations were established by the Air Force in the 1950's to provide intermediate radar detection of foreign aircraft. More sophisticated systems have largely replaced the DEW system.

The DEWLine Station at Lonely also serves base camp for the ongoing petroleum exploration in NPRA. Plans for modern communications include an RCA transportable earth station. Communication links are also planned between the earth stations and seven telephone repeater stations in NPRA. Included in the enclosed loop system is a repeater station at the deactivated Cape Simpson DEWLine site.

iii. Power and Fuel

Despite the real and potential reserves of oil, natural gas, and coal in the region, local energy projected use. Current NPRA exploration includes an effort to locate more natural gas for the Barrow area.

At Prudhoe Bay, SOHIO-BP Alaska and Atlantic Richfield (ARCO) provide power and fuel by an agreement with all the developers. The central powerplant presently has an installed capacity of 100 megawatts, although plans call for this capacity to be increased to 140 megawatts around 1980. Power is delivered to the operating facilities via 69-kilovolt transmission lines.

There is presently no central utility service at Deadhorse. The largest powerplant has a 1,900-kW generating capacity. An 800-kW plant to accommodate new water and sewer utilities is currently planned by the NSB.

iv. Water and Waste Disposal

None of the North Slope communities have "standard" water systems. The large majority of residents obtain their water by hauling water or ice from nearby lakes and streams. Water pollution is a critical problem at the source and at the point of use in most communities.

Water consumption varies from an estimated 10 gallons (37 liters) per person per day in Barrow to 2 gallons (7 liters) per person per day in smaller communities. In contrast, water use at DEWLine stations averages 47 gallons (177 liters) per day and at NARL in Barrow, 125 gallons (472 liters) per day.

Sewage is generally disposed of by "honey bucket." Human wastes are collected in plastic bags or barrels and hauled to a community dump. Water wastes from cooking and washing drain through pipes from the dwelling to the ground nearby.

Water and waste disposal is managed by more efficient and sanitary methods at industrial complexes. In the Prudhoe Bay area, both ARCO and SOHIO-BP Alaska have developed their own systems. ARCO pumps water directly from the Sagavanirktok River to its operations center during the summer months. The company has a 138-million-gallon (521-million-liter) reservoir which is filled during the summer. According to company officials, water use averages about 1 million gallons (4 million liters) per day.

SOHIO-BP Alaska obtains most of its water from the Kuparuk River and Big Lake. The two reservoirs on the Kuparuk River have a combined usable capacity of 42 million gallons (158 million liters), and a much smaller reservoir on Big Lake adjacent to the company's operations center has a capacity of 3 million gallons (11 million liters). Styrofoam floats covering the surface and heated Water circulated through the Big Lake Reservoir during the winter months prevent the water from freezing.

ARCO and SOHIO-BP Alaska maintain separate sewage and solid waste disposal systems. ARCO's operations center and its main construction camp have secondary sewage treatment systems; the effluent is piped to a holding lagoon. Overflow from the lagoon is discharged into the Arctic Ocean. Burnable solid waste is incinerated at each facility, while non-burnable wastes are hauled by truck to a landfill in a sand dune area east of the ARCO base camp. Similar facilities are provided by SOHIO-BP Alaska.

At Deadhorse, the Northwest Alaska Native Association Service Company manages by contract

Table A-8. North Slope Borough Community Dwelling Unit Count, 1977

Village	Total	Dwelling Units: Vacant	Dwelling Units: Occupied
Anaktuvuk Pass	49	5	44
Atkasook	[a]N/A	N/A	N/A
Barrow	386	36	350
Kaktovik	37	3	34
Nuiqsut	[b]41	N/A	N/A
Point Hope	69	N/A	N/A
Point Lay	[c]8	[c]2	[c]6
Wainwright	96	18	[b]78

[a]Not applicable.
[b]Figures from Alaska Consultants, Inc., 1977.
[c]Figures from Dupere and Associates, Inc., 1974.

From University of Alaska, Institute of Social and Economic Research, 1977.

Sod houses, like this one in Barrow, are being replaced by modern housing. (Robert Lewellen)

both water and waste disposal, as well as one of the camps. Most service companies based in the Deadhorse area obtain water from Colleen Lake, near the airport. The State has authorized the use of 267,000 gallons (1 million liters) of water per day from this source. The oil-field operators, service companies, and the State have requested the borough to establish centralized utilities at Deadhorse.

The borough has complied and has planned improvements, such as a water purification plant, a water storage reservoir, a solid waste incinerator, and a sewage treatment plant.

v. Housing

Throughout the villages, houses are generally overcrowded, poorly insulated, and without basic utilities (National Petroleum Reserve in Alaska Task Force, 1978c). Many dwellings need to be renovated or replaced. Despite a high vacancy rate, there is a shortage of adequate houses.

The typical house is small and costly to build and to heat. The average house in Barrow is about 630 square feet (58 square meters) (Dupere and Associates, Inc., 1974). Older houses in Wainwright and other villages measure between 250 and 500 square feet (23 and 46 square meters). Houses in Barrow have the region's highest ratio of space to occupants. The cost of building low-income public housing on the North Slope is 2.3 times that in Anchorage.

Programs under the Bureau of Indian Affairs, Farmers Home Administration, and the Alaska State Housing Authority provide financing and construction for improved housing. Most new units are prefabricated and shipped by barge. The Arctic Slope Regional Corporation has sponsored new housing at recent resettlements at Nuiqsut, Atkasook, and Point Lay.

Information on housing for the villages is shown in table A-8.

vi. Military, Industrial, and Scientific Base Facilities

Base facilities, separate from Native villages, include Prudhoe/Deadhorse, NARL, and DEWLine facilities. These bases are self-supporting and have all necessary housing, utilities, and supplies.

The Prudhoe Bay area is an industrial enclave in a region that is otherwise nonindustrial in character. Development and land use are necessarily dispersed because of the size of the field, which occupies nearly 400 square miles (1,000 square kilometers). The area is divided into numerous leases held by 16 oil companies and the Deadhorse Airport lands which belong to the State. Operation of the oil fields is divided between ARCO and SOHIO-BP Alaska; the former is responsible for the eastern half of the field and the latter for the western half.

NARL lies approximately 4 miles (6 kilometers) northeast of Barrow. It began in 1947 as a small adjunct to the original exploration base camp of Naval Petroleum Reserve No. 4. Since that time, NARL has been expanded to include the entire camp. NARL conducts research on the arctic environment and provides necessary logistical support. Facilities occupy 4,540 acres (1,834 hectares) and include housing and laboratory buildings and a 5,000-foot (1,500-meter) airstrip and air terminal facilities. The Navy has contracted the University of Alaska to operate the laboratory. Most research and support personnel are civilians.

Active DEWLine stations are located at Cape Lisburne, Point Lay, Wainwright, Barrow, Lonely (Pitt Point), Oliktok, and Barter Island. Inactive stations are located at Cape Sabine, Icy Cape, Peard Bay, Cape Simpson, Kogru Inlet, Point McIntyre, Camden Bay, Flaxman Island, Humphrey Point, and Demarcation Bay. Current NPRA exploration activities are based at Lonely.

c. Health and Social Services

The primary social service provided to community residents is health care. The U.S. Public Health Service (USPHS) — directly through staff and indirectly by leasing — provides health services and facilities. The State and local governments provide cooperative services, particularly to outlying areas. More than other social services, medical and dental care is a basic service that requires improvement to meet community needs.

The USPHS operates a 14-bed hospital in Barrow and provides itinerant medical and dental care to outlying villages. However, residents of Anaktuvuk Pass and Point Hope are served by other facilities. The Barrow Service Unit Hospital primarily provides outpatient clinical care. General clinic is held every weekday afternoon, while mornings are reserved for both inpatient care and specialty clinics for outpatients. The hospital is staffed by three doctors, a dentist, nurses, and support personnel. Specialists from the Alaska Native Medical Center in Anchorage or private physicians under contract are periodically brought to the hospital to conduct special clinics.

During FY 1976, the Barrow hospital received a total of 23,393 outpatient visits, 14 percent more than in FY 1975 and an extraordinarily large number in relation to the region's population. More than half of the visits in FY 1976 were first visits, with the remainder classified as continued treatment. USPHS statistics indicate that the leading reasons for outpatient visits were upper respiratory problems, accidents, and injuries, acute otitis media, alcoholism, influenza and pneumonia, strep throat, diseases of the teeth and gums, schizophrenia and other psychoses, exzema, urticaria and skin allergies, and laboratory tests.

During FY 1976, the Barrow Hospital had an average daily patient load of 3.9 persons, down from an average of 8.5 patients recorded in FY 1968. In

The U.S. Public Health Service operates this hospital in Barrow and provides health services to outlying villages.

FY 1976 a total of 1,520 inpatient days were logged at the hospital. The leading causes of hospitalization were influenza, accidents and injuries, deliveries, chronic otitis media, alcohol abuse, upper respiratory problems, infected skin and abrasions, functional psychoses, active pulmonary tuberculosis, and inflammatory diseases of the central nervous system.

The Alaska Department of Health and Social Services operates the Barrow Health Center with a normal staff of two State public health nurses and a borough community health aide. The staff makes frequent visits to outlying villages.

The North Slope Borough operates a system of health clinics staffed by health aides in all regional villages. Most village clinics are staffed by one primary aide and an alternate; Point Hope and Wainwright have two primary aides and an alternate. Those in Kaktovik, Nuiqsut, Point Hope, and Wainwright are held in buildings originally designed for other uses, those in Anaktuvuk Pass and Atkasook are located in school buildings, and the clinic in Point Lay is in the health aide's home. The borough plans to replace all clinic buildings in the region in the near future; however, in Point Hope the city government has obtained an Economic Development Administration grant to build its own facility. All of these clinics will be leased by the USPHS under its Village-Built Clinic Program.

In Barrow, the North Slope Borough is planning to supplement the USPHS program. The planned facility will house health administration and social service offices, as well as a senior citizens' center. Areas of planned improvement by the borough include dental care, mental health, alcoholic detoxification and rehabilitation, and optometric care.

Outside of the traditional communities, health facilities and services in the region are limited. At Cape Lisburne the Air Force has a medic, but cases requiring more than first-aid care are evacuated out of the region. The DEWLine stations also have no more than first-aid capabilities. In the Prudhoe Bay area many of the contractor camps have first-aid stations. In addition, ARCO has a well-equipped clinic at its main base camp. This facility is staffed full time by a physician and two assistants. SOHIO-BP Alaska has two medical facilities — one at its base camp and one at its construction camp No. 2 — each staffed by a licensed physician's assistant or nurse practitioner. Direct telephone lines connect these facilities to doctors in Anchorage. Persons requiring more than primary care are transported to hospitals elsewhere, usually in Fairbanks or Anchorage.

d. Subsistence and Cash Economy

The present mix of subsistence and cash is a means toward an end. The prevailing choice in lifestyle for the Arctic Slope Inupiat is to perpetuate their traditions in their homeland with necessary adaptations to the modern age.

Subsistence has been the proven means to ensure Inupiat survival. Between economic "boom" eras — associated with commercial whaling, fur trapping, and military and petroleum development — the means to survival has been subsistence. Subsistence provides food, particularly meat, and other items for clothing and shelter. Even today, there are no community stores which could provide all the basic supplies or food necessary for survival. Cash alone cannot support the Native communities.

Cash employment is now a necessary counterpart to subsistence. In historical periods, contract hunting and trapping in exchange for European goods and cash modified the Inupiat subsistence and intraregional trading patterns. In the contemporary period, the economic modification is in terms of Inupiat labor for cash. Present and future modifications — as expressed in borough and corporate planning — include Inupiat construction and industrial services and expertise.

The composition of the employed sector in the North Slope involves two identified populations — Native residents and non-Native immigrants. Generally, non-Natives fill highly skilled jobs associated with social services or industrial projects. Natives have been employed intermittently for general labor. Recently, job-training programs by government and industry have improved the skill levels of the Native population. The labor force characteristics from the Barrow area are shown in table A-9.

According to the State of Alaska, the three principal employment sectors for NPRA in 1976 were contract construction, mining or petroleum development — including operation of the Prudhoe/Deadhorse complex — and government. The mining sector was associated with camps outside traditional villages. The construction sector was associated with both villages and other bases. The government sector was located in villages, particularly Barrow.

Job opportunities have increased greatly in the 1970's, largely expanding the civilian resident labor force. The local government sector increased from 37 positions in 1970 to more than 640 positions in 1976. Most of these borough positions were filled in the traditional villages and serve the Native population directly (Alaska Consultants, Inc., 1977).

Unemployment rates for the region have been as high as 20 percent in recent years — lower in Barrow and higher in outlying villages. Cash employment often conflicts with subsistence. For example, the increase in job openings in April and May coincides with the spring whaling season. Many residents feel that flexible though irregular employment is not disadvantageous because this allows time for subsistence activities (University of Alaska, ISER, 1977). The borough allows flexible work schedules which are compatible with subsistence activities (National Petroleum Reserve in Alaska Task Force, 1978c).

Income patterns of the Native population and the immigrant population on the North Slope differ considerably. Although the average annual wage for the region in 1976 exceeded $46,000 — due to the trans-Alaska pipeline construction — income distribution in 1973 indicated that more than one-third of all regional family incomes were below poverty level (Dupere and Associates, 1973). Available data indicate that median family incomes are currently increasing (Alaska Consultants, Inc., 1977). Median

Table A-9. Labor Force Characteristics, Barrow Labor Area[1]

	1970	1971	1972	1973	1974	1975	1976
Civilian resident labor force (annual average):							
Percent of labor force	11.0	13.7	11.8	9.9	8.1	6.0	3.6
Range	6.1-18.8	7.2-21.3	7.3-18.5	6.2-13.4	5.5-10.4	5.1-9.5	2.0-5.1
Total unemployment[2]	99	113	102	97	115	114	174
Total employment	794	709	765	877	1,299	1,299	4,627
Total	893	822	867	974	1,414	1,413	4,801
Nonagricultural wage and salary employment by place of work (annual average):							
Mining (petroleum-related)	280	119	117	103	290	2,611	1,271
Contract construction	137	104	70	119	380	3,738	—
Manufacturing	([3])	0	0	0	0	([3])	([3])
Transportation, communications, public utilities	86	80	95	168	145	185	316
Trade	([3])	([3])	([3])	([3])	([3])	129	([3])
Finance, insurance, real estate	([3])	([3])	([3])	([3])	([3])	56	([3])
Service	142	150	175	187	96	196	445
Miscellaneous	0	0	0	0	0	([3])	0
Government:							
Federal	128	168	173	171	283	265	239
State	37	114	161	224	358	525	652
Total	977	848	913	1,052	1,450	1,997	6,932

[1]Coextensive with the 1970 Barrow census division. Prior to 1976, the Barrow labor area did not include the Prudhoe/Deadhorse area.
[2]Does not include those who are unemployed for many reasons, including physical handicaps, those whose unemployment benefits have been exhausted, or those who were never covered by unemployment benefits.
[3]Withheld to comply with disclosure regulations.

From Alaska Department of Labor (1975; unpublished data for 1976).

family incomes for 1973 and 1975 for the traditional villages are shown in table A-10.

The cost of living in the North Slope region is the highest in Alaska (National Petroleum Reserve in Alaska Task Force, 1978c). Most commercial goods are freighted in by air or on a once-a-year barge. Some families require public assistance to supplement wage income. However, the total amount of public assistance dispensed has decreased. The Bureau of Indian Affairs paid out more than $61,000 to 109 recipients in 1970 but less than $23,000 to only 58 recipients in 1976.

i. Market Goods and Services

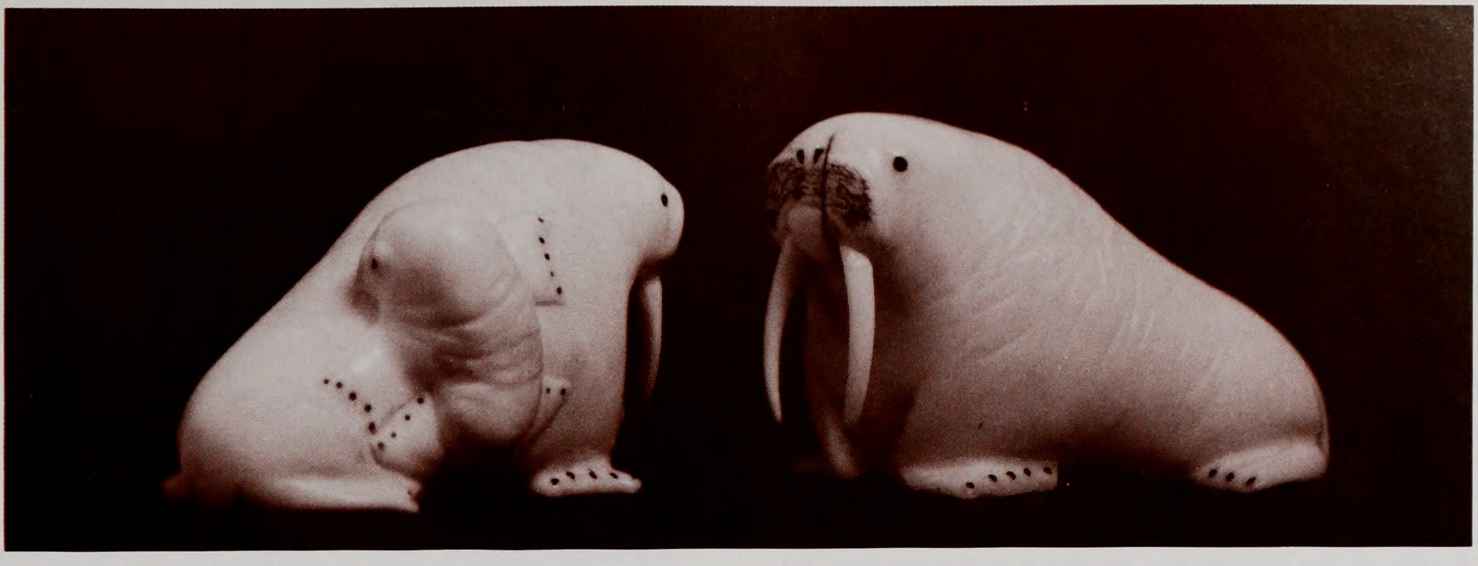
Barrow provides the greatest diversity in goods and services, including groceries, clothing, and hardware for hunting. The Top of the World Hotel, owned by the regional corporation, offers hotel and restaurant services. Wien Air Alaska and three small air taxi services have bases in Barrow. Point Hope, Wainwright, Nuiqsut, and Kaktovik have general stores.

Villagers probably do most of their consumer purchasing by mail order if they can wait for delivery. In emergencies, items are shipped by air. Shipping of large items or quantity supplies is done by barge once a year. Villagers sometimes defer purchases until visiting Barrow or another city where consumer goods are widely available at lower prices.

ii. Small Business Opportunities

Small business in villages throughout the borough earn relatively small amounts of money and employ few persons. However, they are important to the participants and to the communities. Native arts and crafts cottage industries began in the late 1880's and are continuing. Native clothing, ivory and bone carving, baleen basketry, and, recently, mask making are examples of locally made products for Natives, tourists, and collectors. An increasing value of furs in recent years has increased trapping and sale of pelts. Income from trapping can be significant to a family. A small commercial fishery for whitefish is located at the mouth of the Colville River and periodically along the Meade River and its drainages. Fish are sold or bartered.

A number of small businesses have recently opened in Barrow — taxis, shops, and restaurants. Opportunities to establish small businesses in Barrow and in other traditional villages will probably increase as the number of residents and tourists in the area increases.



Cottage industries began in the late 1880's and continue today. Ivory carvings, as shown above, are made locally and sold to tourists and collectors. (O. E. Cote, AEIDC)

e. Social Well-Being

Quality of life or well-being is difficult to assess because it depends on an individual's point of view. Past explorers and visitors to the Arctic region have emphasized hostile and extreme conditions — the cold, snow and ice, and desolation — to be endured. Present-day industrialists approach the North Slope as a frontier area requiring similar feats of endurance. Native inhabitants of the region represent a contrasting point of view. The North Slope is their homeland, and their livelihood is based on the land. Inupiat quality of life is measured against conservative values tied to a land-based tradition.

Unprecedented changes are taking place in northern Alaska. In order to fully realize the promise of the Prudhoe oil discovery, a settlement of interests among industry, government, Natives, and other public sectors was necessary. The North Slope is presently apportioned among these interests. ANCSA added another dimension to Inupiat life: each individual is a landowner and corporate shareholder. Each sector has a means for control and political action.

Responses to change or perceived impacts are closely related to point of view. Inupiat responses are mixed and reflect the complexity of rapid change in a unique setting. Negative responses are evident in the rise of social problems, such as alcohol abuse, mental illness, and crime. Positive responses are evident in the wide participation and experienced success of group endeavors — such as borough projects and corporate policy making. Throughout past and recent events, the conservative, land-based tradition has been the mainstay amid change. The question is whether continuing rapid change can take place in an orderly and fair way.

Following is a report on social conditions largely drawn from a regional socioeconomic profile pre-

Table A-10. Median Family Income in North Slope Borough

Traditional Community	Median Family Income 1973	Median Family Income 1975
Anaktuvuk Pass	$3,591	$10,062
Barrow	8,560	22,676
Kaktovik	16,500	15,289
Nuiqsut	3,800	11,899
Point Hope	6,770	11,992
Point Lay	6,250	7,832
Wainwright	5,833	8,906

Sources: Dupere and Associates (1973); North Slope Borough School District, written communication (1975).

pared by the Arctic Environmental Information and Data Center for the NPRA 105(c) Task Force (1978c).

i. Health and Crime

Alcohol abuse is a serious problem throughout Alaska; it is particularly prevalent in northern Alaska (Worl and Associates, 1978). Drinking bouts consume valuable time and cash and severely disrupt normal social and family patterns. Marijuana, LSD, and cocaine are readily obtainable and widely used, particularly by the young (Worl and Associates, 1978). Simultaneous use of more than one of these agents, particularly marijuana with alcohol, is quite common. Alcohol abuse ranked as the fourth leading cause of hospitalization at the Barrow Hospital from 1974 through 1976 (Worl, 1976); more than one-fourth of the injuries and accidents and more than 80 percent of all purposely inflicted injuries treated at the hospital were related to alcohol. During 1976 there was not a single unnatural death in the North Slope Borough that could not be directly attributed to alcohol (Worl, 1976). In 1977, 12 of the 17 unnatural deaths were alcohol-related.

Barrow Hospital records indicate that in 1973 a total of seven suicide attempts was reported (Worl, 1976). In 1975 this jumped to 23 attempts. These statistics reflect only those cases seen at the Barrow Hospital because they required medical attention; three Barrow residents committed suicide elsewhere during that year. A number of other less serious attempts are known to have occurred but are difficult to document. Again, the vast majority of recorded cases was alcohol-related.

The number of persons hospitalized for mental illness from the Barrow Census District during FY 1975 was one of the highest in the State. The average number of North Slope Borough residents housed at the Alaska Psychiatric Institute in Anchorage for mental illness problems has exceeded 30 in recent years (Worl, 1976). Many of these cases are also related to alcohol and drug abuse.

Crime is another serious problem in parts of northern Alaska. In 1977 Barrow reported a total of 130 juvenile arrests and 204 adult arrests. In a community of less than 3,000 persons, this is considered high. The crimes ranged from malicious mischief and joy-riding to burglary, rape, and homicide. Many of these crimes were drug- and alcohol-related.

ii. Social Participation

Formal and informal participation — in local government and corporate affairs, as well as at social occasions — perpetuates group solidarity.

Borough employment opportunities provide wages and associated responsibilities and status. Native residents are serving their commmunities as teacher's aides, hospital aides, policemen, firemen,

Christianity has replaced traditional religion in the last 100 years. This is a Sunday school group at Barrow in 1921. (Anchorage Historical and Fine Arts Museum)

and in a variety of elected positions. The regional corporation has also created numerous opportunities for participation. All Native residents of the area are stockholders in the corporation, and the board of directors and officers of the corporation and its subsidiaries are mostly Native as well. In addition, participation in a number of advisory councils and boards for the borough, regional and village corporations, and various Federal and State governmental agencies adds to local involvement on a broad base of interest areas.

Social occasions in villages are a mix of traditional and introduced holidays. The most important ceremonial event in coastal villages is the whaling feast or Nalukatak. This festival celebrates a successful whaling season and includes a feast, blanket toss, dancing, and distribution of muktuk and other whale products. In the larger villages several Nalukataks are conducted, each sponsored by groups of successful whaling captains. Point Hope holds a traditional festival at the time of the first appearance of sea ice each fall.

Community celebrations are also held on conventional Western holidays. On the Fourth of July an outdoor celebration is held in many villages. Children, women, and men compete in races, many of which have a traditional basis. During Halloween, parties are often given. Thanksgiving is an important holiday, a time of visiting, feasting, and sharing Eskimo food. Next to Nalukatak, Christmas is the most important festival in many villages. The celebration — feasts, dancing, traditional games — usually extends through New Year's Day. In Barrow, the festival usually ends with a religious service at midnight on January 1, followed by a 24-hour period of game playing.

iii. Religion

Generally, Christianity has replaced the traditional religions of the Inupiat in the last 100 years. However, it is widely felt that many aspects of traditional religions are still practiced. The first church in the region was established in 1899 by the Presbyterians. This congregation is one of the largest in northern Alaska. Barrow also has an Assembly of God group and a small Catholic congregation. Wainwright and Nuiqsut each have Presbyterian and Assemby of God groups, and Point Hope has two Assembly of God congregations and an Episcopalian group. Both Anaktuvuk Pass and Kaktovik have Presbyterian churches. There are Native ministers in Barrow, Wainwright, and Kaktovik.

iv. Education

Recent changes have placed Native residents in positions of responsibility requiring new skills. Adult education has become important to many individuals. Courses offered by the University of Alaska Extension Service and the Inupiat University of the North are geared to specific needs of the community. Courses for teacher's aides and health aides and instruction in business management, resource management, and government are regularly offered in Barrow. Both the borough and the regional corporation have sent individuals to universities outside the area to receive formal training. In addition, the State of Alaska, various labor unions, and the borough offer training programs to prepare residents for jobs associated with the trans-Alaska pipeline and the Prudhoe Bay oil field (Strong, 1977).

v. Science

Science in northern Alaska has been dominated by NARL. In addition to the main facility north of Barrow, field facilities are located in several of the region's villages. The typical pattern in the past has been for scientists to come into the area, conduct their research, and leave. Native Alaskans have occasionally served as guides and assistants but rarely as technicians. In recent years, interest expressed by residents has resulted in more available information on current research.

vi. Art

The demand for Native art objects, including ivory, stone and bone carving, baleen baskets, and etchings, has risen over the years. However, the amount of time required to produce these articles makes their sale unprofitable except as an income supplement. Native art objects are made primarily by a few old people in each village, and it is feared that the traditional art forms will die with them.

vii. Perceived Impact

Of all perceived impacts on the human environment, impacts on values tied to the people and their land are the most important. Like the whale-sharing ethic, these values are passed hand to hand as part of the Inupiat tradition. In times of change, values and traditions are subject to disruption. The most direct way to assess the effects of change is to question the people affected. In 1977 the Institute of Social and Economic Research (ISER), University of Alaska, conducted an extensive socioeconomic survey of the Native residents of the North Slope Borough (University of Alaska, ISER, 1977). This survey gave an idea of how the Native community viewed the changes that have taken place in their region. One basic question was, "Have conditions gotten better or worse since 1907?" The majority of respondents indicated that jobs, air transportation, facilities, size of houses, and, to a limited extent, schools and health care have improved. At the same time they reported that prices, drug and alcohol problems, fish and game conditions, sharing, housing costs, and racial problems had all worsened in that same period. The quality of drinking water and shopping were perceived as having remained unchanged in the eyes of most respondents.

6. Wilderness, Scenery, and Recreation Values

a. Wilderness

Wilderness is recognized by the Wilderness Act as an area where the land and its community of life

Wilderness values have been recognized by legislation. The Gates of the Arctic, located southeast of NPRA, has been proposed as a national park. (M. W. Williams)

are untrammeled by man and where man himself is a visitor. It is described further as undeveloped Federal land retaining primeval character and influence, without permanent improvements or human habitation, and managed so as to preserve its natural conditions. It is further defined as generally appearing to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable, and to offer outstanding opportunity for solitude or primitive and unconfined types of recreation. Wilderness may contain ecological and geological features of scientific, educational, scenic, or historical value. Designated areas under the Wilderness Act must be at least 5,000 acres (2,024 hectares) in size.

Practically all of the National Petroleum Reserve in Alaska (NPRA) is in a primitive state. Although there are places of regular seasonal habitation outside of the villages, these sites do not have substantial impact on the pristine character of the area. Little of the area shows signs of modern man's influence and presence. The Reserve contains many small and large areas of scientific, educational, scenic, and historical value.

Five attributes are considered in evaluating wilderness quality: 1) absence of nonconforming uses or activities which eliminate or tend to threaten the integrity of a wilderness resource; 2) the availability of high-quality primitive recreational opportunities; 3) the presence of abundant and varied wildlife, particularly those species which the public has identified as "wilderness-associated" and/or the existence of critical, untrammeled wildlife habitat; 4) an environment offering outstanding opportunities for adventure, excitement, and challenge, as well as solitude or serenity; and 5) opportunities for nature study or informal outdoor education and formal scientific study.

There are few potentially nonconforming uses or activities in NPRA. Four Native villages (Barrow, Wainwright, Atkasook and Nuiqsut) and airstrips and associated developments at Umiat and at Pitt Point (Lonely) are the major such uses now. Oil and gas exploration has been underway in the area for a number of years, and past operations have left scars. Present petroleum-related activities are being carried out under stipulations that should largely prevent long-term impacts on wilderness characteristics.

Wilderness conditions are essential for maintaining certain types of wildlife, particularly species that require large territories unaffected by man's activities. Opportunities to observe wildlife enhance the wilderness experience for visitors, and such opportunities are very good in NPRA. Wildlife in NPRA commonly associated with wilderness include grizzly bear, polar bear, wolf, wolverine, caribou, moose, Dall sheep, loon, gyrfalcon, peregrine falcon, golden eagle, and ptarmigan. Several areas of NPRA have high wildlife values (fig. A-20). Among these is the 4-million-acre (1.6-million hectare) Utukok River uplands; this is the primary calving ground for the Western Arctic Caribou Herd and the region of highest grizzly bear density in the Reserve. The Colville River valley is important habitat and a concentration area for cliff-dwelling raptors. In summer the coastal plain north of latitude 70° supports a large number of waterfowl, with the two areas of heaviest concentration being along the Chukchi Sea coast near Icy Cape and the area between the north end of Skull Cliff on the Chukchi Sea and the Colville River Delta. Two other areas notable for wildlife viewing possibilities are the De Long Mountains along the southern boundary of NPRA, where Dall sheep, wolves, wolverines, caribou, and grizzly bears, as well as migrating birds, may be seen, and capes like Barrow, Franklin and Icy, from which marine mammals may be observed in migration.

Recreational users of wilderness usually expect outstanding opportunities for adventure, as well as solitude and self-reliance. Virtually all of NPRA offers these.

The Reserve also has unique value for scientific study and has played an important part in Arctic research, particularly since the establishment of NARL at Barrow in 1947. The Reserve has many features typical of the environmental gradient between the Arctic coast and the Brooks Range. Scientists have stressed the importance of formal research in tundra ecosystems like those in NPRA.

Although almost all of NPRA qualifies for the National Wilderness Preservation System, not all is equally suitable. Following is a description of those areas believed to be the more outstanding choices for Wilderness status.

The De Long Mountains along the entire southern edge of NPRA provides many primitive recreational opportunities and has the greatest scenic variety of any part of NPRA. The area is habitat for caribou, wolf, and grizzly bear and includes important migration routes.

The Utukok River uplands encompasses the primary calving grounds of the Western Arctic Caribou Herd. The uplands, important to caribou survival in spring, are also habitat for grizzly bear and wolf. The Utukok River offers excellent opportunities for floating, hiking, and wildlife viewing. It has known archeological and cultural resources and is proposed for addition to the National Wild and Scenic Rivers System.

The Teshekpuk Lake area is used by large concentrations of waterfowl, particularly swans and geese that are susceptible to disturbance when nesting and/or molting. This area also contains unique biologic and geomorphic features.

The Colville River has excellent potential for recreational use. Parts of the river have been proposed for inclusion in the National Wild and Scenic Rivers System.

Although current recreational activities in NPRA are limited by access, backpacking and hiking opportunities in the foothills are excellent. (Atlantic Richfield Company)

The Colville River valley from the Nuka River to Ocean Point is believed to contain most of the prime nesting habitat in NPRA for cliff-nesting raptors, including rough-legged hawk, gyrfalcon and the endangered peregrine falcon. It also contains most of the winter habitat for moose in NPRA. Primitive recreational opportunities are excellent along this segment of the river which has been proposed for addition to the National Wild and Scenic Rivers System.

Kasegaluk Lagoon on the Chukchi Sea coast between Wainwright and Icy Cape contains some of the best examples of the Arctic's barrier islands-lagoon environments. Offering outstanding opportunities for scientific study, boating, and sightseeing along the protected lagoon, the area is habitat for large numbers of waterfowl and parallels sea mammal migration routes.

The Ikpikpuk River corridor is noted for its polygonal ground, pingos, oriented and oxbow lakes, meander scrolls, beaded streams, and dunes. Also present are examples of lake basin development, waterfowl nesting habitat, wet sedge tundra, riparian willow groves, and many lichen types. There are several significant paleontological and archeological sites.

b. Scenery

In recent years environmental awareness has grown to include the scenic resource, which is defined as the land, water, vegetation, animals, and structures visible on the land. Land managers and the public recognize that landscapes have different scenic qualities and that some alteration of the natural landscape has occurred and will continue to occur. The key factors in evaluation of scenery are landform, vegetation, water, color, distinctiveness, and cultural modifications. Overall value of a scene to an individual is determined by sometimes intangible feelings, such as well-being or spiritual awareness, evoked in part, perhaps, by the key factors. However, other factors such as smells, sounds, stillness, familiarity, mystique, or perceived changes in the surroundings may be equally important in experiencing a scene. Recognizing that these feelings, rather than the key factors, are the basis for placing value on scenery, and that these feelings are personal and culture subjective, the following critique is valid to the extent that a scenic appraisal can be made of a picture. Not considered is a host of time-dimension changes, such as atmospheric changes over a short period, daytime-nighttime changes, and seasonal changes.

The scenic evaluation of NPRA is based upon the premise that all landscapes have scenic value, but those with the most variety and contrast have the greatest potential for having high scenic value. There are some areas where the scenery has a high degree of visual variety, contrast, and harmony. Other areas exist which have a moderate degree of these qualities; and some have little visual variety or contrast.

About two-thirds of NPRA consists of flat to rolling topography with little visual variety or contrast in vegetation, water, and color. Nevertheless, these areas are distinctive because they are relatively flat, have polygonal ground patterns caused by ice wedges, and are dotted with thousands of lakes. About one-fourth of NPRA has moderate visual variety and contrast in landform, vegetation, water, and color or has some other distinctive characteristics. Examples are the oriented lakes south of Barrow and Skull Cliff, islands and spits, and sea and shore ice of the coastline. The middle segment of the Colville River, the De Long Mountains, and Liberator Ridge have the highest visual variety and contrast in landform, vegetation, water, and color found in NPRA. In these areas there are only two sites where man has altered the natural landscapes.

Vehicle trails, scattered oil drums, and buildings or materials at about 63 sites mar the landscape in the Reserve. Landscapes are being changed by oil and gas exploration, development of the Barrow gas field, installation of communications equipment, and creation of vehicle trails and landing strips. However, regulations governing current operations are reducing the amount of disturbance.

c. Recreation

The resources of the Reserve have relatively limited appeal to the visiting recreationist in comparison to many other areas of Alaska. In addition to the long distance from State population centers, costly aircraft access, lack of general public knowledge about the area, and the limited facilities and public services, the limitations are primarily physical and related to the relative lack of recreation opportunities. The winters, including the period of twilight/darkness, are considerably longer than in southern Alaska. Most of the terrain is upland tussock tundra or wet sedge meadow, which is very difficult to traverse in the summer. Most of the few navigable rivers contain enough water for floating only a few weeks each year. Wildlife populations, with the exception of caribou and migratory birds, are usually widely scattered, and little is known about sport fishing potential. The greatest assets are the expansive, untrammeled nature of most of the Reserve and the opportunity to view wildlife, such as caribou, grizzly bears, wolverines, wolves, and many species of birds.

Although there are numerous individuals of any species, their density is relatively low, as in much of Alaska. However, the locally abundant populations of some species combined with the relatively flat, treeless terrain makes the wildlife viewing opportunities in NPRA better than in much of Alaska.

Most of the present recreation-oriented visits to NPRA are associated with organized tours to Barrow, which contains virtually all of the area's tourist activities and facilities. Tourism is expected to account for the greatest increase in total number of visitors to the Reserve in the future. The increase, however, is dependent upon the development of additional visitor-oriented facilities and activities, such as a Native culture center, guided trips to archeological sites and other points of interest, scenic overflights, and guided dog team or snow machine trips.

The rivers are important as the only practical routes of cross-country travel through this arctic environment during the nonwinter months. Float trips on the Nigu-Etivluk, Colville, and Utukok are attractive to recreationists. Unlike the rest of NPRA, much of the De Long Mountains area is free of tussock tundra or wet, boglike terrain and, therefore, is more easily traversed by travelers on foot. This area also offers the most varied scenery in the Reserve. Hiking and backpacking opportunities are also good in river valleys and foothills where the terrain is suitable. Kasegaluk Lagoon offers unique opportunities to observe marine mammals and waterbirds during the summer, as well as boating opportunities.

Current recreational use of Federal lands in NPRA involves primarily backpacking in the De Long Mountains area along the southern edge of NPRA, floatboating on major rivers including the Colville, Utukok, and Nigu-Etivluk, sport hunting primarily for big game in the De Long Mountains and along the major river valleys, and winter activities, such as cross-country skiing. The De Long Mountains area, the major rivers, Kasegaluk Lagoon, and the land area immediately around Barrow are areas currently receiving the major recreational use and/or will experience expected future use.

II. Corridors and Terminals in Alaska

For this study, the transportation of oil or gas begins where the oil or gas from a production field is gathered at one point for transport to a major terminal site. The gathering lines necessary to deliver oil or gas from individual well sites to a central gathering station are considered part of the infrastructure associated with development and production phases.

Transportation is considered in two steps: first, the transport of oil or gas from the Reserve to either a terminal on the existing Trans-Alaska Pipeline System (TAPS) or to a marine terminal in the Arctic, and second, the transport from such terminal to a destination in the conterminous United States. With this approach, impacts of new construction can be evaluated within a regional context, separately from the overall impacts along major routes from the Alaska terminals.

Three very general corridors from NPRA to terminals are here considered: 1) from northeastern NPRA to TAPS at Prudhoe Bay, 2) from eastern NPRA to TAPS north of the Brooks Range, and 3) from western NPRA to the Bering Sea coast. A marine terminal at Barrow is also considered briefly.

These corridors represent only generalized transportation routes from NPRA. No map locations are inferred. The discussions that follow illustrate representative physical, biological, and human environments that might be encountered in developing any corridors. As such, they provide a point of reference for environmental impact identification.

A. From NPRA to Prudhoe Bay

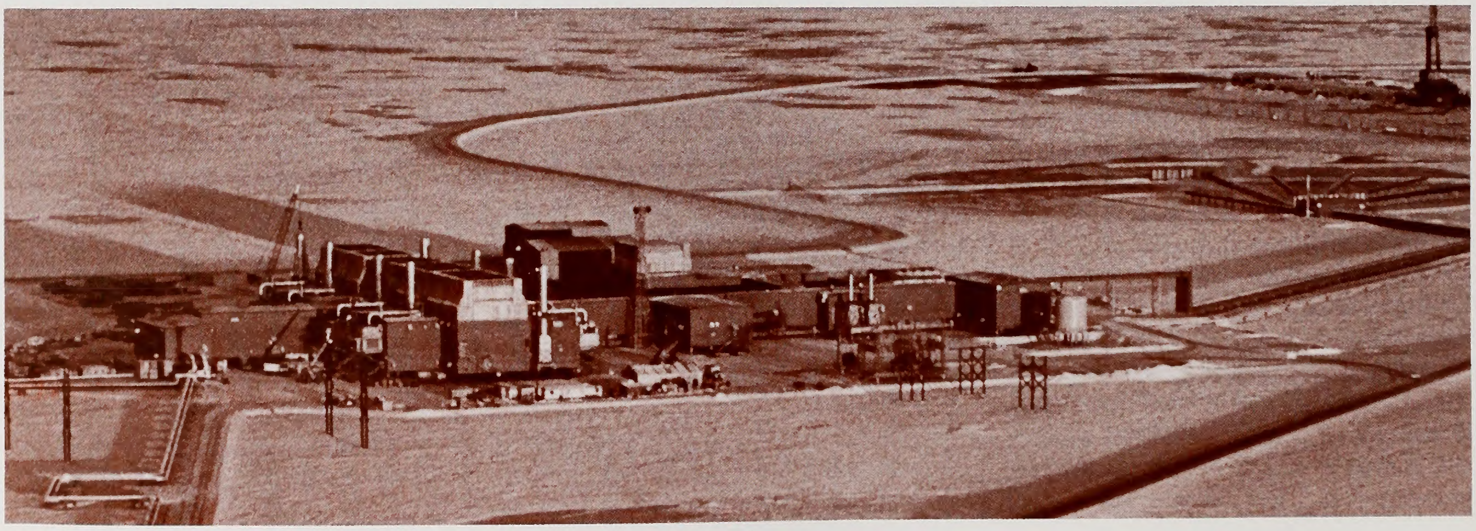
A general route for this corridor would extend from northeastern NPRA to the Trans-Alaska Pipeline System at Prudhoe Bay.

1. Physical Environment

A corridor along this general route would lie entirely within the Arctic Coastal Plain province. The terrain is flat and treeless, water is conspicuous, and numerous thaw lakes and scattered meandering streams afford the primary relief features. Because of the very low gradient of the terrain, drainage patterns are undefined, and the corridor is extremely wet and marshy during the summer. Ice-wedge polygons mark the land surface of virtually the whole area, while pingos and other thermokarst features provide additional relief. Altitudes along the corridor are less than 100 feet (30 meters).

The flat, marshy terrain of the coastal plain does not impose serious constraints to pipeline construction other than its wetness and ice-rich permafrost.

The central gas compressor plant at Prudhoe Bay provides natural gas for facilities and pump stations. However, most of the natural gas is reinjected into the ground. (Atlantic Richfield Company)



Both red and arctic fox occur in NPRA, arctic fox on the coastal plain and red fox in river valleys and foothills. (E. Klinkhart, Alaska Department of Fish and Game)

To protect the permafrost, an oil pipeline within the corridor would have to be entirely elevated; a gas pipeline could be either elevated or chilled and buried.

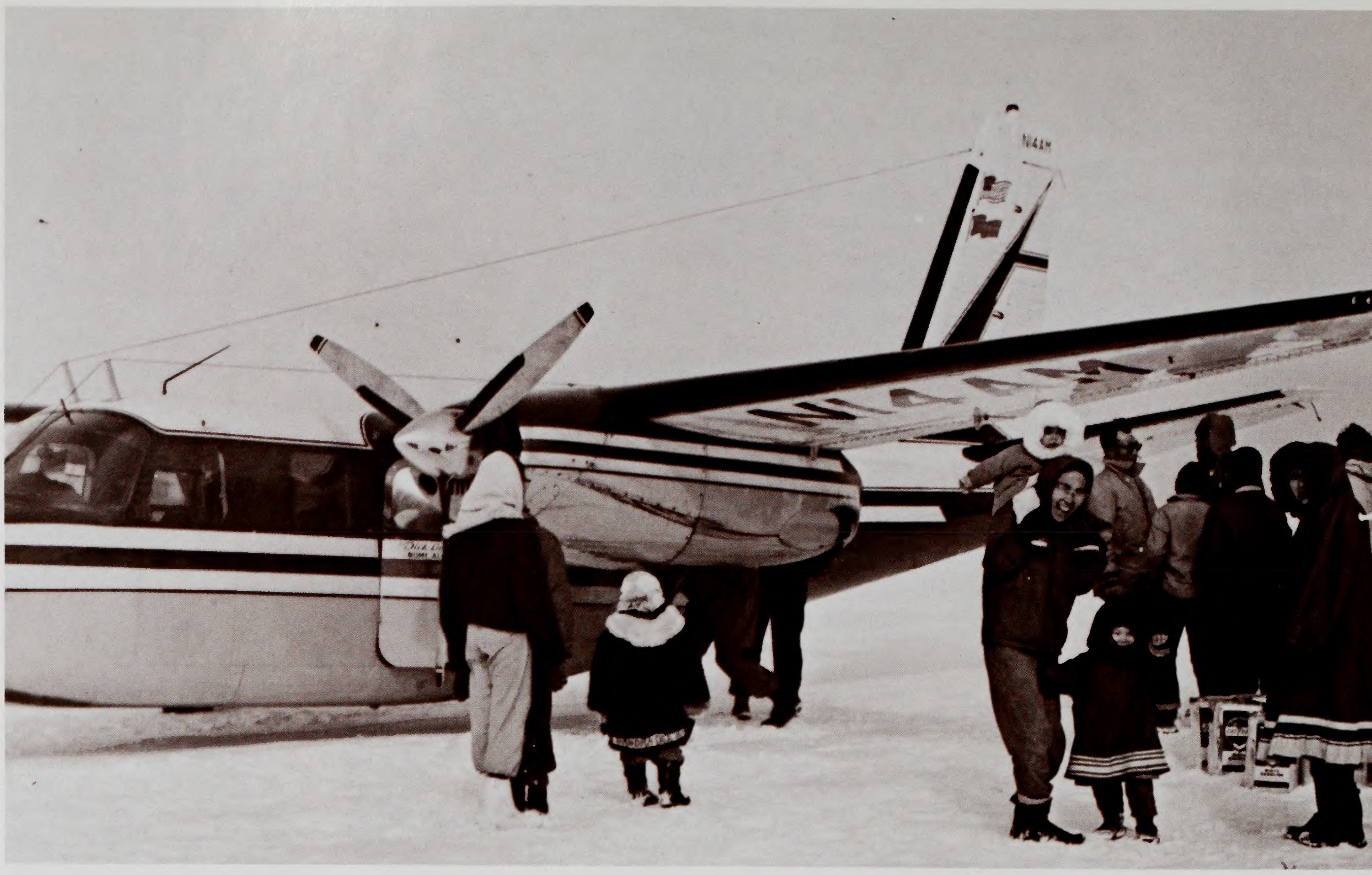
The corridor crosses one major river, the Colville.

Sand and gravel are found within the corridor. Deposits of sand and gravel are concentrated primarily along the Colville, Kuparuk, and Sagavanirktok Rivers. Although additional gravel resources are found in some lakes, gravel deposits along smaller streams in the large interbasin areas of the corridor are limited or not present. Sand deposits from along the coast could be used for construction if a suitable means of winter access could be devised between the coast and the corridor. Generally consisting of ice-rich silt, fine sand, and gravel, and overlain by a thick peaty surface layer, the soils are universally poorly drained. The polygonal ground in wet-tundra soils usually does not thaw to more than about 12 inches (30 centimeters) during the summer. Continuous permafrost, extending to depths of almost 2,000 feet (610 meters), underlies the entire corridor.

2. Biotic Environment

Vegetation, fish, and wildlife are typical of the Arctic coastal plain environment. Vegetation is a mixture of moist and wet tundra. Fish and wildlife are diverse, and the area contains particularly important waterfowl breeding, feeding, and molting habitats. In the summer, both the Western Arctic and the Central Arctic Caribou Herds occupy the general area; tundra vegetation provides forage, and the breezes of the coast provide relief from insects.

The Colville River is a major anadromous fish migration stream and forms a pathway for fish that extends to the Brooks Range. Most of the other streams and ponds in the general area support aquatic



Bush communities depend on small aircraft for passenger transport and delivery of vital supplies. (U.S. Army)

life (including some fish) and are extremely important to waterfowl and shorebirds as summer feeding habitat.

The corridor's most important wildlife area is the Colville River Delta. It contains spawning and overwintering habitat for fish. The extensive well-drained sites in the delta provide habitat for large numbers of burrowing mammals, notably arctic ground squirrel and arctic fox. A relatively high concentration of polar bear denning sites has also been reported. Numerous bird species use the area, notably the whistling swan. Seals are reported to enter the delta and lower reaches of the Colville River.

3. Human Environment

The only community in the general area is Nuiqsut, a reestablished Native community. The surrounding lands are undeveloped and are used for subsistence hunting by the Inupiat. Subsistence is the focal point for the social and cultural activities, as well as the health and well-being of the Native residents. The Colville River Delta is especially important for fishing and caribou hunting.

The potential for archeological finds is high, particularly along the lower reach of the Colville River.

B. From NPRA to TAPS

A general route for this corridor would extend southeastward from NPRA to the Trans-Alaska Pipeline System north of the Brooks Range.

1. Physical Environment

This general route crosses broad ridges of the Arctic Foothills province. The area's gently rolling slopes are interrupted by smooth buttes, knobs, mesas, and tundra plateaus. Altitudes range from 1,200 to 3,000 feet (370 to 910 meters), although local relief may reach 4,000 feet (1,220 meters). Numerous small drainages, scattered lakes, and ice-wedge polygons afford distinctive secondary relief features.

Except for permafrost conditions and the gravel resources required for development, right-of-way routing would not be constrained. Permafrost conditions would require elevated oil and chilled gas pipelines, except where thaw-stable stream bottoms are traversed.

Soils in this general area are for the most part poorly drained and are comprised of loam or silty clay loam with an overlying layer of peat. However, near streams, the soils may be well drained and contain more gravel and sand. The entire general area is underlain by continuous permafrost which extends to depths of between 700 and 1,000 feet (210 to 300 meters).

2. Biotic Environment

Vegetation consists of moist tundra plants and riparian high brush. The general area is used seasonally by the caribou from both the Western and Central Arctic Herds for grazing and migration. The high brush vegetation along major drainages provides prime habitat for moose. Unlike areas south of the North Slope, moose here tend to concentrate year-round in the major river valleys; only a small number disperse in summer to forage in the uplands. The endangered peregrine falcon nests along the Colville, Chandler and Anaktuvuk Rivers and may be present at other sites in the general area. Most of the major rivers in this area, especially the Colville, Anaktuvuk and Chandler Rivers, support anadromous fish runs and may offer overwintering habitat for resident fish.

3. Human Environment

There are no Native communities in the general area. The only permanent settlement nearby is the service area at Umiat, administered by the State of Alaska. All of the land is undeveloped and is used primarily for Native subsistence activities. Hunting of caribou is particularly important. The potential for archeological finds is high, especially near rivers.

Land in the Northwest Region is used by Native residents for reindeer herding as well as subsistence purposes. (Bureau of Land Management)

C. From NPRA to the Chukchi or Bering Seas

A general route for this corridor would extend from the southwest corner of NPRA to either the Chukchi Sea or the Bering Sea. A location on the Bering Sea would probably require a submerged pipeline across Kotzebue Sound because of route restrictions by land withdrawals. Pipelines would be predominantly above ground. Buried heated pipelines would be possible if thaw-stable conditions are found in thin soil over weathered bedrock.

A terminal in either area would consist of onshore storage tanks, a power generating station, transfer pumps, a control system, office and living quarters, an airstrip and heliport, and connecting roadway. A temporary wharf and barge at the shore would provide unloading facilities for use during construction of the terminal. Mooring dolphins with loading facilities would be located offshore in about 15 fathoms (27 meters) of water. Submarine pipelines would link the terminal to the mooring dolphins, with mooring dolphins having the capacity to load four tankers simultaneously, in 12 hours. Because of water depth at the mooring site, loaded draft would be limited to less than 90 feet (27 meters). Therefore, tankers would be limited in size to 280,000 dead-weight tons.

A liquified natural gas (LNG) terminal, if warranted, would be physically separated from any oil terminal, for safety purposes. The LNG processing facility would likely be fabricated in modules in the conterminous States and assembled on barges, then permanently affixed to the shore at the gas processing barges. Mooring dolphins would be located offshore in 10 fathoms (18 meters) of water because LNG carriers have a loaded draft of about 38 feet (12

In September of 1969 the "Manhattan," an ice-breaking tanker, became the first commercial vessel to transit the Northwest Passage. (Exxon)

meters). LNG would be transferred from the storage tanks to loading dolphins by insulated, submarine pipeline.

1. Physical Environment

This general route passes through the Arctic foothills. Topography consists of moderately rolling plateaus, river valleys, buttes, knobs, and mesas trending parallel to the north face of the De Long Mountains.

Gravel resources within the area are limited; even the river bottoms of the large rivers do not contain large gravel resources.

Continuous permafrost underlies the general area. The soil in general is dominantly silt, with varying amounts of gravel, overlain by peat. Erosion potential ranges from moderate to high.

Most of the coastline along the Chukchi Sea is shallow, and offshore mooring or extensive dredging would be required for tanker operations. Exposed bedrock of places along the coast would provide suitable foundations for onshore facilities. The rocks along the coast are moderately resistant to shoreline erosion and could be easily excavated.

Long severe winters characterize the climate of the area. Summers are cool, windy, and often wet along the coast. August is the only month when a primary storm track passes south-north along the Bering Sea. These storms can cause widespread coastal flooding from the wind-driven tides.

The shallow waters of the Chukchi Sea are ice covered for 7 to 8 months of the year. The average sea freezeup date at Point Hope is October 25 to 29; breakup is usually between June 10 and 16. Drifting ice comes primarily from the Arctic Ocean. Lasting until May, pack ice may be as much as 6 feet (2 meters) thick and contain pressure ridges up to 30 feet (9 meters) high.

Coastal currents off the terminal area flow northwest, parallel to the coast. Waters from the warmer Bering Sea flow northward at about 1 mile (1.6 kilometers) per hour. In the summer, water

Sea ice usually covers the northern Bering and Chukchi Seas from late autumn through early spring. (J. C. LaBelle, AEIDC)

residence time in the south Chukchi Sea is approximately 10 to 15 days. Tidal amplitudes along the coast average approximately 1 foot (30 centimeters) with a 5-foot (1.5-meter) maximum.

The 60-foot-depth (18-meter-depth) contour is approximately 0.8 mile (1.3 kilometers) offshore in the area from Cape Thompson to Kivalina. Sediments immediately offshore to the 60-foot (18-meter) contour are predominantly gravel with some clean sands.

Beaches, spits, and barrier islands usually contain gravel mixed with sand and silt. These are potential sources of construction materials. However, removal of materials can accelerate coastline retreat which, in turn, may threaten structures. Beach materials along these coasts are not quickly replaced by longshore transport.

2. Biotic Environment

This general route lies entirely within the northern tundra area of Alaska. Vegetation consists of alpine and moist tundra with some patches of high brush vegetation along the NPRA boundary and along rivers. This general route would begin in the western portion of the Utukok uplands. These are the main calving grounds of the Western Arctic Caribou Herd and have the highest grizzly bear density of the North Slope (NPRA Task Force, 1978b). It would likely intersect a major caribou migration pathway from overwintering areas to the south to summer ranges on NPRA. Reintroduced muskoxen are present on moist tundra in the general area.

Cliffs along parts of the coastline are used by various species of birds, including the pelagic cormorant, glaucous gull, black-legged kittiwake, common murre, thick-billed murre, black guillemot, pigeon guillemot, horned puffin, and tufted puffin. Cape Thompson supports a seabird nesting colony of 400,000 birds. Raptors, such as gyrfalcons and golden eagles, may also be present at suitable sites in the general area and peregrine falcons at inland or sea cliffs. Marine mammals, including walrus, seals, whales, and polar bear, are present along the coasts and in the nearshore waters during at least part of each year.

Reintroduced muskoxen are present near Cape Thompson. (Jo Keller, U.S. Fish and Wildlife Service)

King Island has been abandoned as a permanent village since the early 1960's, when residents moved to Nome.

Numerous species of terrestrial mammals occur in the general area, including moose and caribou and a high density of grizzly bears in spring. A few caribou remain in the area through the winter.

Phytoplankton growth in the coastal waters provides food for the invertebrate and vertebrate species in the food chain. Marine grass beds also provide food to marine animals. As a result, fish and mammals are abundant in many of the coastal waters. However, even though the critical dependence of marine animals upon the marine plant resource is clear, this delicate balance is not well understood. Fish species include all five species of Pacific salmon, sole, cod, flounder, sculpin, Pacific herring, and others. Smaller fish species provide a main food resource for the large coastal seabird colonies.

3. Human Environment

This general area was historically occupied by both northern and southern Eskimos. Residents of Diomede and King Islands have depended on whaling and residents of St. Lawrence depended mainly on walrus. Seals, migratory birds, fish, seaweeds, roots, greens, and berries supplemented their diets.

Archeological investigations near the Bering Strait commenced in the late 1920's and are continuing (Holmes, 1974). Gambell, Savoonga, and Northeast Cape on St. Lawrence Island and the Punuk Islands have yielded significant historic and prehistoric material. Probable locations of submerged archeological sites on the Bering Sea floor have recently been identified by members of the University of Alaska Museum staff. Evidence shows that St. Lawrence Island has been continuously occupied for at least 2,000 years.

In 1975 Native community populations in the general area were: Little Diomede, 141; Gambell, 367; and Savoonga, 410. Non-Natives comprised from 1 to 5 percent of the population, depending on location. The region's relatively large population is due to its strategic location near the migration routes of both walrus and whale.

Inhabitants continue to depend on subsistence harvest for economic survival, as well as for social and cultural well-being. Walrus, bearded seals, ringed seals, and fish remain mainstays of the subsistence economy; waterfowl are an important supplement. Outboard motors, snow machines, gas, guns, and other items have become an integral part of subsistence techniques, generating a need for cash income.

Few opportunities for earning cash are available. Income for most households is derived from a combination of seasonal wages, self-employment, and, in some cases, Government assistance. Government is the largest single employer within the region, operating schools, post offices, and public health clinics. Non-Eskimos comprise a small percentage of the population and generally fill positions as missionaries, teachers, and merchants. The sale of arts and crafts, particularly ivory, baleen, and bone carvings, has become an important source of income for many residents. Employment opportunities with Native corporations and other commercial enterprises in Nome and Kotzebue draw a significant number of wage earners out of the corridor. Commercial fishing and trapping offer important seasonal occupations on the mainland.

D. Barrow

As envisioned by the Arctic Institute of North America in a contract study for the U.S. Department of Commerce, Maritime Administration, a submarine oil port facility at Barrow would be the link between the production of oil and its transport by submarine or submersible tanker to the east coast of the conterminous United States. The facility would include an onshore tank farm and a buried pipeline to a loading and docking facility about 12 miles (19 kilometers) offshore. Neither its technical feasibility nor its need have been demonstrated at this time, and it is only briefly considered here.

1. Physical Environment

Barrow lies in the northern extremity of NPRA. Average temperatures range from -20°F to 60°F (-29°C to 25°C), with extremes of -55°F and 75°F (-48°C to 23°C). Average precipitation is less than 5 inches (12 centimeters), occuring mostly as snow. Winds at Barrow are predominately from the east and east-northeast and average about 10 knots (18 kilometers per hour) but occasionally exceed 50 knots (90 kilometers per hour); fog occurs about 65 days each year.

The sea ice in the Beaufort and Chukchi Seas is never completely solid. Open-water leads as much as 20 miles (32 kilometers) wide occur off Point Barrow. The Chukchi Sea is largely ice-free in summer; it has a longer open-water season than the Beaufort Sea, where the polar ice pack remains closer to shore. Tides along the Arctic coast are small, averaging 1 foot (0.3 meter) or less, but wind-generated waves of 5 to 6 feet (about 2 meters) occur, especially in late summer or early fall.

2. Biotic Environment

The biota associated with the Barrow area is that associated with the wet sedge meadow and marine and coastal environments. Polar bears are present, both on the ice pack and onshore, particularly in winter when pregnant females are denning. Waterbirds seasonally use barrier islands and wet tundra near Barrow.

Ten species of whales and six species of seals inhabit the marine environment. Only the walrus, ringed seal, bearded seal, and beluga could be considered common in the NPRA marine environment; they are most numerous during their spring and fall migration periods. Seals use nearby barrier islands as resting areas, and ringed seal females have pups in snow lairs on the ice in nearshore areas during winter and spring.

Of major significance to a terminal in the Barrow area is the migratory path of the bowhead whale, which is both an endangered species and a major subsistence item of the Native population.

3. Human Environment

More than half of the resident population of the North Slope Borough lives in Barrow. A description of the socioeconomic conditions in the Barrow area is contained in another section of this appendix.

III. Transportation Routes from Alaska to the Conterminous United States

The future development of oil and natural gas resources within NPRA will necessitate using either existing or proposed oil and gas pipeline and marine transportation systems from Alaska to the distribution systems of the conterminous United States. To date, the only existing oil transportation system is the 789-mile (1,262-kilometer) Trans-Alaska Pipeline System constructed from Prudhoe Bay to Valdez and its domestic shipping routes from Valdez to ports along the west, gulf, and east coasts. Unless significant oil discoveries are made west of Prudhoe Bay, this will probably be the only system available for overland transport southward. Existing and proposed oil transportation routes from Alaska to the conterminous United States are shown in figure A-20.

A route for transporting natural gas from Alaska to the conterminous United States has recently been decided by an agreement between Canada and the United States. The gas will pass overland by the proposed Alcan Northwest Pipeline route in Alaska and by the proposed Foothills Pipeline system through Canada to Caroline Junction in Alberta. From Alberta the gas would flow through existing and proposed distribution systems to areas in the West and Central United States. All proposed gas routes from Alaska to the conterminous United States are shown in figure A-21. However, inasmuch as the Alaska Alcan Gas Transmission System is the only system with current governmental approval, it is the only system considered herein.

The trans-Alaska pipeline spans 800 miles and crosses three major mountain ranges. (Alyeska Pipeline Service Company)

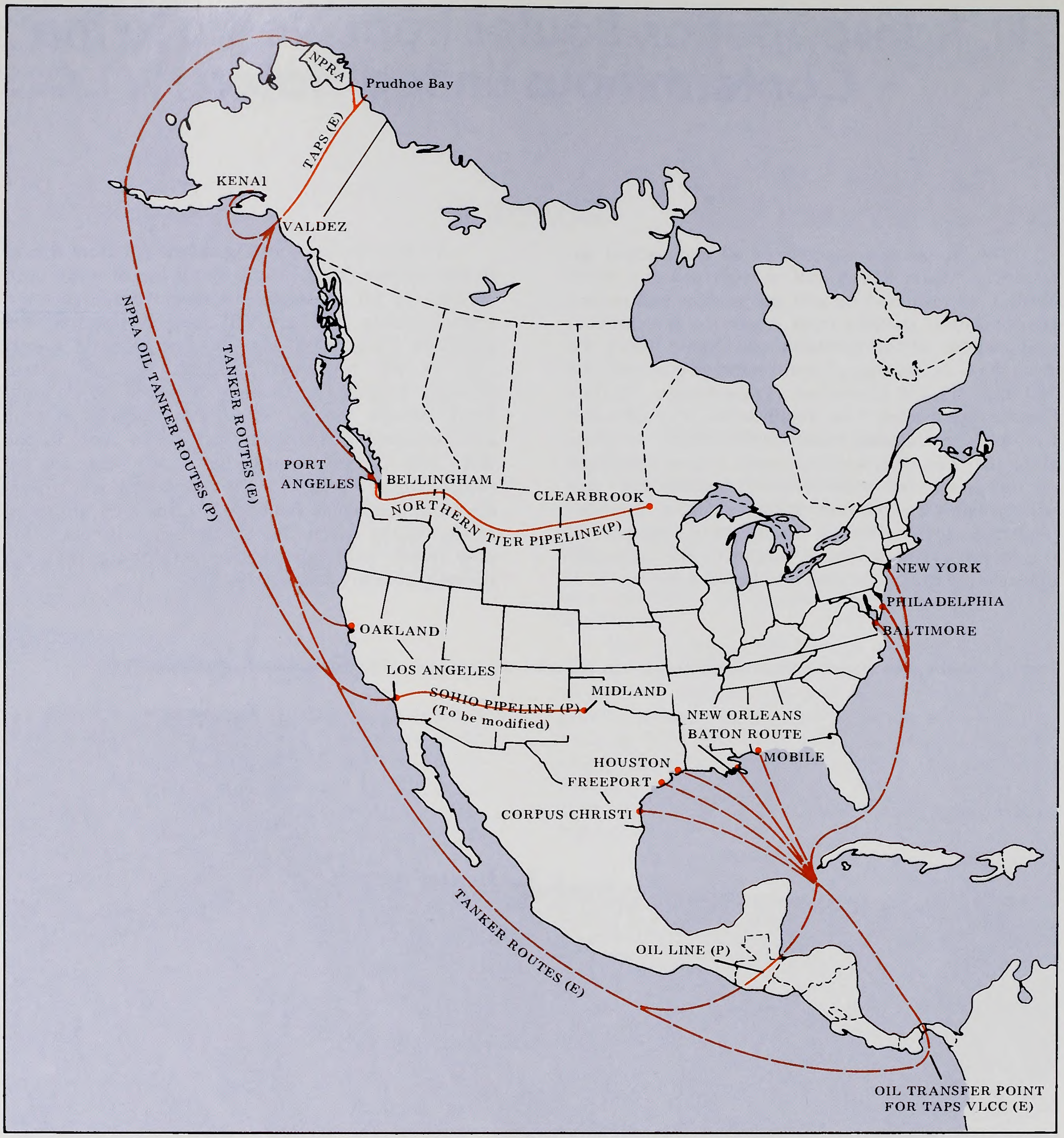


Figure A-20. Existing (E) and Proposed (P) Oil Transportation Systems from Alaska to the Conterminous United States.

A. Trans-Alaska Pipeline System

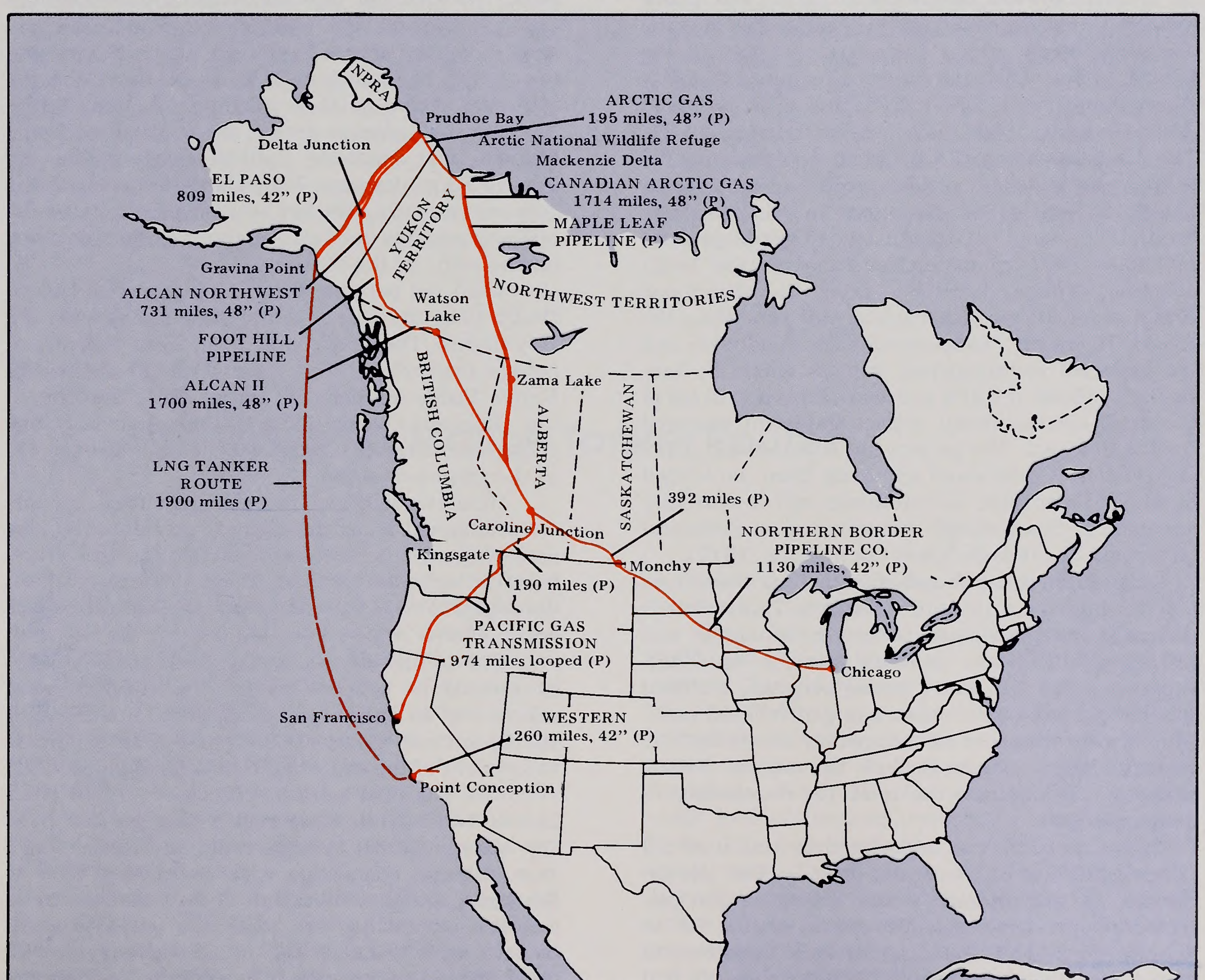
The history of the Trans-Alaska Pipeline System (TAPS) indicates the environmental constraints and problems generated by major pipeline construction projects in the Arctic and subarctic. Initially conceived as a buried heated oil pipeline to be built at a cost of close to $1 billion, the project was finally completed 10 years later with half its length above ground and at a cost of about $10 billion. The TAPS experience also illustrates the magnitude of the problems encountered in logistical support, as well as the resulting environmental and socioeconomic impacts in this remote area.

The 48-inch heated oil pipeline crosses three major mountain ranges, three rolling upland areas, and three relatively flat physiographic provinces. When fully developed, its capacity of 2 million barrels per day will utilize 12 pump stations spaced approximately 65 miles (104 kilometers) apart. The northernmost four stations are fueled by natural gas from Prudhoe Bay, the remaining eight by Arctic grade kerosene. Additional facilities required for and during construction were 380 miles (608 kilometers) of secondary standard road from the Yukon River to Prudhoe Bay, 17 construction camps housing 500 to 1,200 persons each, and approximately 280 access roads, 250 material sites, and 100 disposal sites. Of the 789 miles (1,262 kilometers) of right-of-way, 545 miles (872 kilometers) were constructed on Federal lands disturbing approximately 26,600 acres, (8,080 hectares), or about 49 acres (20 hectares) per mile (1.6 kilometers) of pipeline. The need for additional work areas for the remote arctic conditions increased the land disturbance area by a factor of three over conventional pipeline construction in the conterminous United States.

The pipeline was designed on a foot-by-foot basis to accommodate permafrost soil conditions, pipe mechanical properties, pipeline hydraulics, and seismic loading. At river crossings, scour depths, flood elevations, and burial depths were also considered in the design.

Due to unexpected difficulties in working with permafrost conditions, the pipeline was redesigned so as to move the oil above ground to protect the permafrost from melting and the pipeline from consequent structural failure. The aboveground thermopile mode is the first pipeline experience of its kind with the United States. To date, the aboveground system has performed as designed and has experienced very little thermopile failure. The buried sections have experienced heavy isolated trench slumping around the pipe, requiring remedial refilling and reworking. The buried 8-inch-diameter chilled gas pipeline from Prudhoe Bay to Pump Station 4 has also undergone heavy slumping in isolated areas and has interrupted surface and shallow ground-water flow patterns in places.

FigureA-21. Proposed (P) Gas Transportation Systems from Alaska to the Conterminous United States.



The Port of Valdez was selected as the southern terminus because of its deep water, favorable port characteristics, ice-free shipping season, and suitable navigation access. The terminal will be capable of loading four tankers simultaneously and will accommodate over 20 vessels per week. Currently the terminal oil storage capacitiy is 9.2 million barrels, to be increased to 16.3 million barrels in the future. The terminal has an air flotation facility to treat discharged ballast water.

B. Alaskan Alcan Gas Transmission System

The Alcan Pipeline Natural Gas Pipeline System II proposes to transport Prudhoe Bay gas through Alaska and Canada to users in the Central and Western United States. The system consists of an Alaskan segment to be constructed by Alaska Northwest Pipeline Company and a Canadian segment to be constructed by Foothills Pipelines, Ltd. The entire system would run from Prudhoe Bay, Alaska, to Caroline Junction, Alberta (U.S. Department of the Interior, 1976). At Caroline Junction the gas would be divided between the proposed Pacific Gas Transmission Company supplying the west coast and the Northern Border Pipeline Company supplying the Central States (Federal Power Commission (FPC), Alcan Supplement, 1976). Elements of the Alaskan Alcan gas transmission system are listed in table A-11. The Alaskan portion of this system would parallel the trans-Alaska pipeline corridor southward for approximately 539 miles (862 kilometers) to Delta Junction. From Delta Junction, the alignment would proceed 192 miles (307 kilometers) eastward to the Teslin Junction, Yukon Territory, along the abandoned Army products pipeline right-of-way paralleling the Alaska Highway. The environmental conditions and the expected environmental impacts would be very similar to those of TAPS and are discussed in detail in the draft environmental impact statement prepared for the proposal. The project has received the necessary Federal Government approvals from the United States and Canadian Governments and is currently undergoing closer design scrutiny and geotechnical investigations (Federal Power Commission, 1977).

The present design calls for a chilled 48-inch gas pipeline buried for the entire distance. This system is currently being evaluated to insure the safety and feasibility of design. As demonstrated by TAPS experience and the Alcan testing program, a chilled gas line poses pipeline stress and geotechnical problems which may not be adequately controlled by current design standards and techniques. Future analyses may indicate the need for remodeling or design changes.

The Alcan II line is designed to transport 2.2 billion cubic feet of gas per day initially. The Alaskan portion of the pipeline would utilize natural gas-fueled compressors located at approximately 60- to 70-mile (96- to 112-kilometer) intervals. Construction would disturb approximately 12,000 acres (4,800 hectares) (16 acres or about 6 hectares per mile) and would require 11.3 million cubic yards (8.6 million cubic meters) of borrow material. Existing TAPS pads and roads and pipeline rights-of-way would be used to the maximum extent. The construction is projected to begin in 1980-81 and to be completed in 4 years.

From Delta Junction eastward through Alaska the route is at altitudes of less than 2,000 feet (610 meters) and is underlain by discontinuous permafrost soils. The principal vegetative communities traversed are the bottomland spruce hardwood, lowland spruces, upland spruce hardwood, alpine tundra, and low brush bog muskeg. Wildlife species along the route are similar to those encountered along TAPS. The proposed pipeline crosses the range of the Delta, Chisana, and Mentasta Caribou Herds within the Tanana River drainage. The wildlife resources of the area are currently affected by their proximity to the highway and the moderate amount of homesteading immediately off the highway.

Land use patterns along the highway and specifically along the abandoned pipeline right-of-way are very diverse. The land is in Federal, State, Native, and private ownerships. Under the terms of the Alaska Native Claims Settlement Act of 1971, the Doyon, Ltd., Regional Corporation and numerous local Native village corporations have selected lands in the vicinity of the proposed route.

Homesteading and limited agricultural pursuits are established along the highway corridor. The area east of Tanana is considered suitable for agriculture; however, only the area near Delta Junction has been developed to date. Forestry potentials along the route are moderate.

Due to highway access, the local economy is not as subsistence oriented as it is in Alaska's more remote areas. Although subsistence hunting and fishing are still prevalent, cash flow is an important component of the white and Native family lifestyles.

The Canadian portion consists of 1,346 miles (2,153 kilometers) of 48-inch chilled gas line from the Alaskan border southeastward to Caroline Junction, Alberta, connecting with distribution lines at Kingsgate and Monchy as part of the Canadian Arctic Gas Proposal. Along the route the proposed alignment roughly parallels the Alcan Highway for 951 miles (1,521 kilometers) in Yukon and British

Table A-11. Elements of Alaskan Alcan Gas Transmission System

Alcan Proposal	Alaskan Segment	Canadian/Oceanic Segments Canadian Alcan II Proposal
Proposed length, in miles	731	2,022
Diameter, in inches	48	36, 42, 48
Number of compressor stations	10	20 (approximately)
CFD,[1] in billions	2.4	2.2
Acres of land required	12,000	—

[1] Cubic feet per day.

Columbia and parallels an existing pipeline for 397 miles (635 kilometers) in Alberta (Federal Power Commission, 1977).

One of the major determinants for selecting the Canadian Alcan proposal was the current socio-economic conditions along the Alcan Highway (Federal Power Commission, 1977; Berger, 1977). Land use along the northern segment of the proposed corridor is predominantly development- and recreation-oriented because of its proximity to Alcan Highway. Settlements along the corridor are generally small and of rural character. Except for a few mining operations, the land along this segment of the corridor is essentially unaltered by man. Along the southern portion of the corridor, land use revolves around agricultural and range activities; there is some oil and gas production and development.

Economic activities in Yukon Territory and in British Columbia focus primarily on natural resources. Important industries are tourism, commercial fishing, logging, and mineral exploration and development. Agriculture is an important source of income in Alberta and southern and central British Columbia. Manufacturing, construction, and commerce are economically important in Alberta. While depending on trapping and fur trading to provide a limited cash income, most of the Native population continues subsistence hunting and fishing.

C. Marine Tanker Routes

The marine tanker transportation routes for oil and LNG products from Alaska to the west, gulf, and east coasts are shown in figures A-20 and A-21. These routes cross the open ocean areas off the west coast and the Continental Shelf and slopes off the gulf and east coasts. Transportation to the gulf and east coasts entails passage through Panama Canal by medium-sized tankers up to 68,500 dead-weight tons, or around Cape Horn by tankers in excess of 250,000 dead-weight tons. Transport around Cape Horn would require transshipment to smaller tankers for delivery to United States ports.

A Central American pipeline has been proposed. This 42-inch, 227-mile (363-kilometer) pipeline would originate at a Pacific Ocean port east of Las Lisas, Guatemala, and terminate near San Francisco del Mar on the Guatemalan side of the Gulf of Omoa in the Carribean.

The only new tanker routes required from the Alaskan west coast terminals would be through the southern Chukchi Sea and Bering Sea.

The Bering Sea is one of the most biologically productive marine environments in the world, primarily because of its large share of the northern Continental Shelf. The Continental Shelf, covering nearly half of the area contributes more than two-thirds of the primary production. Ice is an important factor, especially in the winter. For example, the microalgal communities associated with the undersurface of the ice are highly productive and account for a substantial portion of the total primary production in that season. For marine mammals, ice may

NPRA development could require a new tanker route. The *ARCO Juneau*, pictured above, has a carrying capacity of 825,000 barrels. (Atlantic Richfield Company)

provide either an important habitat or a rigid barrier to air breathers.

Phytoplankton production follows the typical pattern of strong spring and fall blooms, but production is minimal in winter. Zooplankton forms are more heavily concentrated in offshore water than inshore waters, but biomass decreases from north of the Alaska Peninsula to south of St. Lawrence Island. In shallow waters, up to depths of 495 feet (150 meters), as much as 80 percent of the biomass is concentrated in the upper 260 feet (80 meters) or less.

IV. Distribution Within the Conterminous United States

The existing gas and oil distribution systems in the conterminous United States routinely move the oil needed by the Nation and should be capable of moving the reserves anticipated in NPRA. Gas and oil production from NPRA will likely be a limited increment to the United States distribution system in the next decade, with several alternatives available for delivery and distribution.

Results of current exploration in NPRA suggests that economically recoverable quantities of oil or gas may exist (not necessarily together), or that development of these may occur at different times. Hence, it may become desirable to provide transportation facilities for only one product (which one is not now known), or for both products at widely different times.

Some oil/gas markets can be conveniently and/or economically served only by one of these resources; for example, automotive fuel from petroleum, and ammonia production from natural gas. Yet there are other markets in which substitution of fuels is both possible and practical — for example, the generation of electric power by using steam from the combustion of either natural gas or oil. Distribution will be influenced by demand.

The intrinsic differences in the natural characteristics of the two resources also influence the practical modes of transportation and the preferred destinations. The major values obtainable from crude petroleum are realized only after the oil has been processed through refineries into useful products. Thus, the preferable domestic destinations for crude oil are the refining centers. On the other hand, natural gas requires only minimal treatment as it comes from the well; this can best be carried out near the producing fields. Hence, existing areas of demand and existing transmission pipelines would be important economic considerations in determining where gas from NPRA would be delivered.

A. Oil

The amount of oil imported has grown steadily in the United States in response to increasing demand and declining domestic production. In 1977 the average daily crude oil input to refineries was about 14.6 million barrels, of which 6.7 million barrels (46 percent) was imported; in 1972, 2.2 million barrels per day (19 percent) was imported.

The major areas of crude oil use and their demand as a percentage of crude oil processed in the United States are as follows: the gulf coast (Texas and Louisiana), 39 percent; California, 13 percent; Pennsylvania and New Jersey together, 9.5 percent; and the total of the northern tier States (Washington, Oregon, Idaho, Montana, Wyoming, Minnesota, and the Dakotas), about 6.5 percent. These four geographical areas process about 68 percent of all crude oil processed in the United States.

The importance of these facts in the selection of destinations for the crude oil originating in NPRA becomes evident when the specific locations of the refineries and their present crude oil sources are examined:

- Most of the gulf coast refineries are clustered in three areas: Houston-Beaumont-Port Arthur, Corpus Christi, and New Orleans-Baton Rouge. These areas have access for receipt of crude oil from oceangoing tankers. Inland refineries receive waterborne crude oil through pipelines from gulf coast ports.

- Although many of the central Great Lakes refineries are on or near inland waters, much of their crude oil supplies is received from pipelines from oil fields of east and west Texas and Oklahoma. These pipelines are also used to transport imported crude oil landed on the gulf coast.

- The refineries in California (the Los Angeles and San Francisco Bay areas) have deepwater access for receipt of crude oil by tankers, as does Seattle, Washington.

- Most of the refineries in the Middle Atlantic region are located on or near three major waterways: New York Bay, Delaware Bay, and Chesapeake Bay. All of these receive their crude oil by tankers.

Thus, more than two-thirds of the Nation's present crude-oil processing facilities can be accessed by oceangoing tankers docking in four narrowly

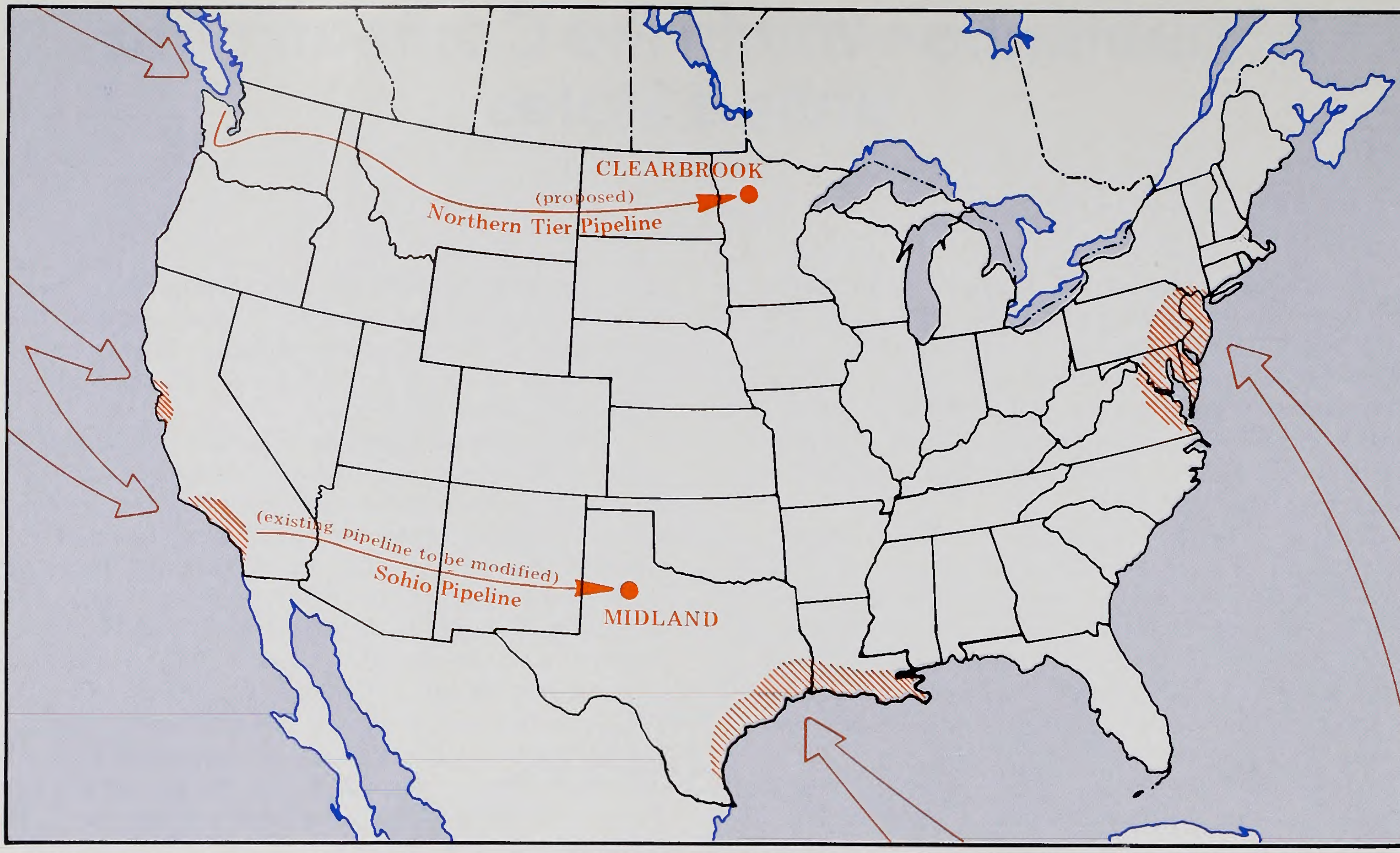


Figure A-22. Crude Oil Importation Points and Distribution.

definable areas: 350 miles (560 kilometers) of California coastline from San Francisco Bay to Long Beach; the Seattle, Washington, area; 500 miles (800 kilometers) of Gulf of Mexico coastline from Corpus Christi to the mouth of the Mississippi River; and 250 miles (400 kilometers) of Atlantic coastline from New York to Chesapeake Bay. These areas are shown in figure A-22.

Since TAPS began operations in July 1977, a glut of oil on the west coast has developed. In consequence, supplements to the conterminous United States oil distribution system have been proposed. Most notable are the SOHIO and Northern Tier Pipelines, also shown in figure A-22.

The Standard Oil Company (SOHIO) acting through SOHIO Transportation Company has made plans to build a terminal at Long Beach, California, and a 42-inch-diameter to transport Alaska crude eastward. The new port facility in Long Beach Harbor would be capable of off-loading three tankers simultaneously and providing transient storage for 5 million barrels of oil. The pipeline system would be a combination of new construction and conversion of existing facilities. A new 42-inch-diameter pipeline would be built eastward for 125 miles (200 kilometers) from Long Beach to Beaumont, California, where it will join an existing natural gas pipeline. That line is the 830-mile (1,320-kilometer) pipeline which previously transported gas westward from Jal, New Mexico; it would be converted to carry oil and flow in the opposite direction. From Jal, a new 42-inch-diameter pipeline would be built 72 miles (115 kilometers) eastward to Midland, Texas. At Midland, the crude oil would be pumped into the existing cross-country pipeline distribution systems. SOHIO, however, stated in June 1979 that it has abandoned its plans for those facilities.

A Northern Tier Pipeline System proposal involves construction and operation of a crude oil terminal and pipeline to transport oil from Port Angeles, Washington, to Clearbrook, Minnesota. The proposed action includes four components: a marine terminal with a 6-million-barrel storage capacity, a 1,541-mile (2,465-kilometer) petroleum pipeline system, delivery facilities, and support facilities.

The marine terminal is proposed for Port Angeles, Washington Harbor, or the vicinity of Green Point, east of Port Angeles. The pipeline will originate at the onshore storage facilities near Port Angeles, traverse the northern tier States of Washington, Idaho, Montana, and North Dakota, and terminate in Minnesota. The system will be capable of transporting 709,000 barrels of crude oil per day initially and 933,000 barrels per day ultimately to its terminal at the Clearbrook, Minnesota, delivery facilities. At Clearbrook, provisions will be made to deliver oil to existing systems. An environmental impact statement is currently being prepared for this system.

On December 17, 1976, the U.S. Department of Transportation issued a license to LOOP, Inc., for construction of a deepwater port in the Gulf of Mexico off the Louisiana coast (U.S. Department of

Transportation, 1976). The port facilities will consist of a terminal complex of offshore platforms and single-point moorings located in water approximately 110 feet deep, 18 miles south of Grande Isle, Louisiana; a large diameter (48-inch) buried pipeline from the offshore terminal complex to the storage facility approximately 25 miles inland near Galliano, Louisiana, with a booster station approximately 3 miles inland from the point at which the pipeline crosses the shoreline; an underground crude oil storage formed by leaching cavities out of a naturally occurring salt dome and related facilities, including a small boat harbor and an operations center. A vessel calling at the port would be moored to one of the moorings and would lift a floating hose which is then connected to the vessel's onboard manifold. The floating hose is connected by submarine pipeline to the offshore platform complex. After connection, the vessel pumps the crude oil cargo through the hose and pipeline to the offshore platform where large capacity pumps provide the power to move the oil through the buried pipeline to the booster station, which assists in moving the oil into storage.

In August 1979 the U.S. Department of Transportation issued a license to the Texas Deepwater Port Authority for construction of a deepwater port in the Gulf of Mexico about 26 miles off the Texas coast near Freeport, Texas (U.S. Department of Transportation, 1979). The port would consist of four mooring buoys, each connected by pipeline to a pumping platform. A vessel calling at the port would be moored to one of the buoys and would then discharge its cargo into the pipeline leading to the pumping platform. From the platform, the oil would be pumped to a storage terminal on shore. The facility would be designed to transmit up to 2.5 million barrels of oil per day. It would be located in water deep enough to accommodate very large crude-carriers of up to 500,000 dead-weight tons.

B. Gas

During the period 1972-77 annual domestic gas consumption ranged from 22.1 trillion cubic feet (TCF) to less than 20 TCF, of which only about 1 TCF was imported. In 1975, about 20.4 TCF of natural gas was consumed in the conterminous United States in the following regional pattern: New England and the Middle Atlantic States, 8.5 percent; East North Central States, 18.6 percent; West North Central States, 9.2 percent; South Atlantic and East South Central States, 11 percent; and the West South Central States (Texas, Louisiana, Oklahoma, and Arkansas), 36 percent. Texas alone accounted for 21.5 percent and Louisiana, for 9.7 percent of the total consumption. About 77 percent of the Nation's natural gas is consumed in 10 states: Texas-Louisiana-Oklahoma, which together consume nearly 35 percent; California, which alone uses 9.1 percent; and Illinois-Ohio-Michigan-Pennsylvania-New York, which together use 20.5 percent. Pennsylvania and New York, however, are much smaller consumers than the other three States.

The per capita consumption of natural gas in the largest consuming area in the Southwest is four to five times that in the other two high-consumption areas, suggesting a very high industrial use. Conversely, per capita gas consumption in Pennsylvania and New York is the lowest of the 10 high-use States, indicating high domestic consumption.

Most of the natural gas consumed in the Central, Northeastern, Southeastern, and West-Southwestern States originates in the West-Southwestern States. Consequently, two major transmission pipeline corridors have been developed, one from west Texas to the Central States, and one from east Texas-Louisiana through the Southeastern States to the Northeastern States. The decline in domestic gas production has resulted in available capacity in these gas transmission systems. Consequently, several LNG terminals on the gulf and Atlantic coasts have been proposed. California also anticipates a small decline in gas supply, and three LNG terminals are proposed there.

LNG represents a major new source of importable energy. Based on LNG importation contracts, it is estimated that as much as 2.5 TCF per year, or the energy equivalent of about 1.15 million barrels of oil per day, may be imported to the conterminous United States in 1985 from sources in Algeria, Indonesia, Iran, and Nigeria. As a result of these contracts, LNG terminals would likely be located on the gulf coast of Texas, Louisiana, and Mississippi; at Elba Island, Georgia; in the Chesapeake Bay–Delaware River–New York City–Boston area; and along the southern California coast, as shown in figure A-23.

The Alcan system to be constructed in the 1980's will transport Prudhoe Bay gas to the conterminous United States. According to the amended Alcan proposal as reported in the August 1977 Environmental Assessment issued by the Federal Power Commission, the Alcan Pipeline Company proposes to construct a high-pressure 48-inch-diameter natural gas pipeline from Prudhoe Bay, across Alaska and parts of Canada to a point of bifurcation near Caroline, Alberta. From this point, a 36-inch-diameter branch will proceed southwestward to the United States border near Kingsgate, British Columbia, to provide gas supplies for the Western United States. A second 42-inch-diameter pipeline will continue from Caroline to Monchy, Saskatchewan, to deliver gas to the proposed Northern Border Pipeline System, which will supply the East Central and Eastern United States. Initial design capacity of the system is 2.4 billion cubic feet per day (Bcfd), to be increased later to 3.2 Bcfd by the addition of compressor stations.

The Northern Border Pipeline Company is a consortium of six United States companies created to transport the Prudhoe Bay gas from the Canada-United States border near Monchy across six North Central States to an eastern terminus near Dwight, Illinois. The proposed pipeline will be 1,117 miles (1,787 kilometers) long. The initial design capacity could be expanded to 2.12 Bcfd by the addition of 11 compressor stations if additional flow is required. As many as five intermediate delivery points may be provided along the pipeline to supply gas to companies serving States east of the Rocky Mountains. These delivery points may be in South Dakota, Minnesota, Iowa, and Illinois. Gas flowing to the terminus at Dwight can be used indirectly to supply States in the East and Northeast by displacement of existing supplies through existing systems.

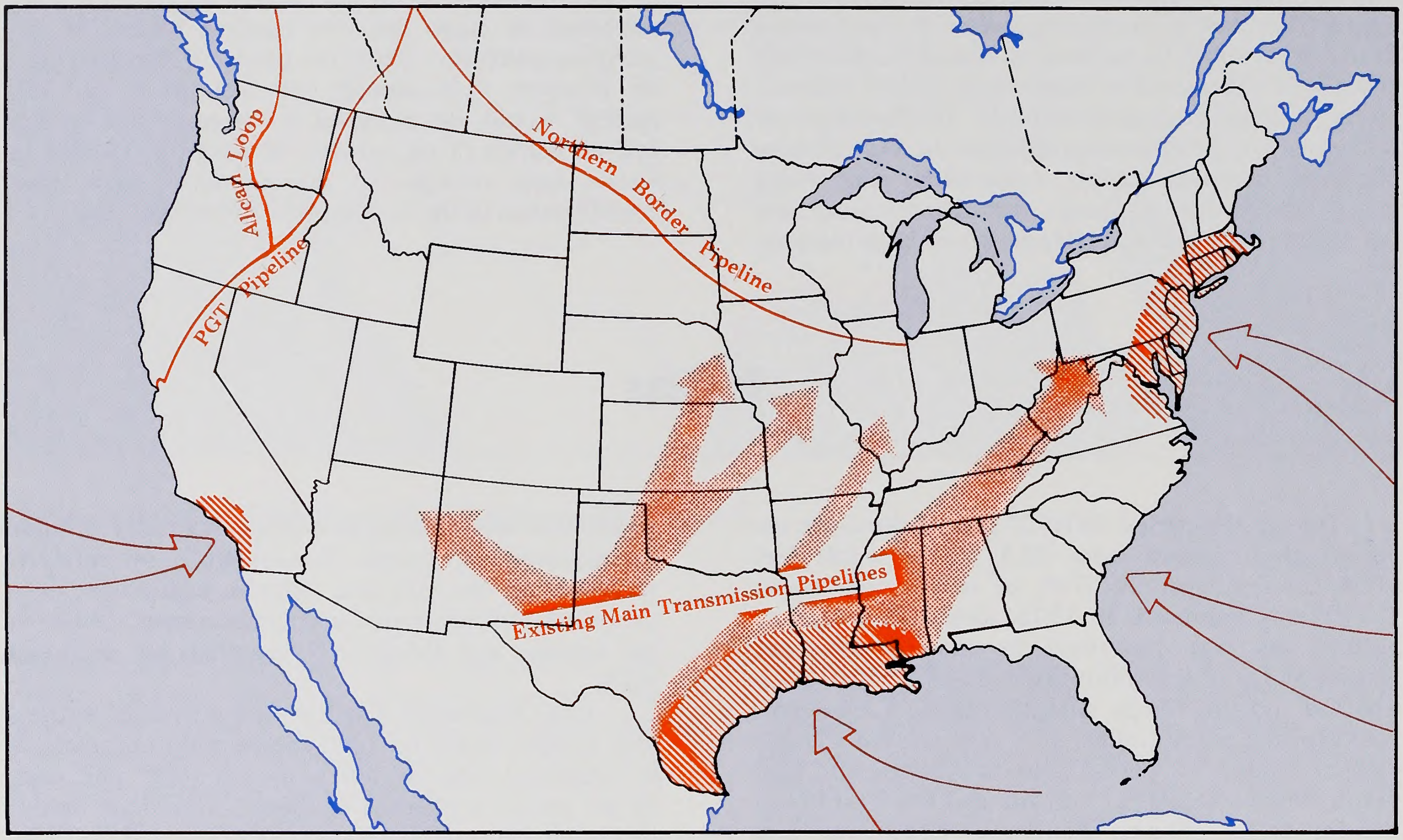


Figure A-23. New Gas Importation Points and Distribution.

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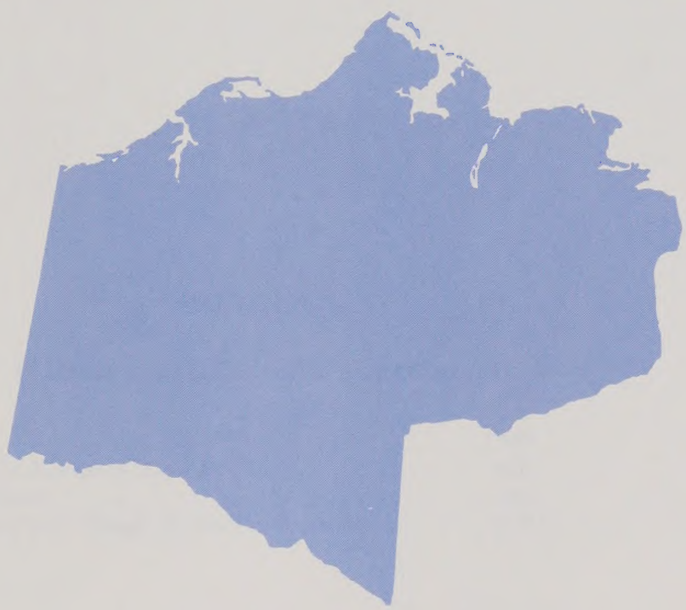
Appendix B

Planning and Environmental Controls



Contents

Illustrations

(*Insert map follows designated page)

Tables

I. Land Status

Laws prescribing land status and ownership rights and laws providing for the protection of environmental values constitute the planning controls described in this appendix. These controls may be general or highly prescriptive; they may be checks and indirect curbs on certain practices; and they may be in the form of guidelines or direction based on experience. An example of a highly prescriptive, though general, control is the Endangered Species Act of 1973, which makes it unlawful even to harass such wildlife or damage their habitat and requires "all necessary methods" of control. Examples of indirect curbing of certain practices are air- and water-quality standards. Certain of these practices may be strictly controlled by legally enforceable codes and stipulations.

Coordinated controls on planning, land use, and natural resource policy comprise a framework for an environmental overview and any subsequent decisions. Additional considerations are the interactions — not necessarily complementary — of local (borough), State, and Federal controls through legislation and policy. The following description will require updating in future decisionmaking processes. Controls dictated by policy may change in response to energy demands and national policy; other controls are less mutable and are required by law.

The Federal Government is the largest of the three major landowners in the Arctic region. NPRA and the Arctic National Wildlife Refuge together make up one-half of the regions's 50 million acres (20 million hectares). The State owns approximately 3.5 million acres (1.4 million hectares) between the Colville and Canning Rivers, centered on oil development in the vicinity of Prudhoe Bay. An additional 3.5 million acres (1.4 million hectares) is owned by eight Native village corporations — Barrow, Kaktovik, Nuiqsut, Wainwright, Atkasook, Point Lay, Point Hope, and Anaktuvuk Pass — and the Arctic Slope Regional Corporation. Approximately 1.4 million acres (0.5 million hectares) in the region is part of the Trans-Alaska Pipeline System (TAPS) corridor. Approximately 0.5 million acres (0.2 million hectares) of these corridor lands has been patented to the State. The State has a 200-foot (61-meter) right-of-way through the remaining corridor for the haul road. The rest of the corridor is owned by the Federal Government. Present federally recognized land ownership within NPRA is summarized in table B-1 and shown in figure 6 of the Environmental Analysis of this report.

A 1923 Executive Order established the 23.6-million-acre (9.5-million-hectare) Naval Petroleum Reserve No. 4 (U.S. Department of the Navy, 1977). A series of Navy claims to areas included in the Reserve has been contested by the State and the Native corporations. The boundary of the Reserve along parts of the Colville River and the coast are in dispute. Additonally, the Navy claimed jurisdiction to a 2-mile (3-kilometer) buffer zone around the Reserve, as well as ownership of tidelands in Smith Bay, Harrison Bay, Peard Bay, and Kasegaluk Lagoon in 1974. Although the State received title to tidelands 3 miles (5 kilometers) from the highwater mark of the coastline under the Submerged Lands Act of 1953, the Navy redefined the mark, thereby assimilating shallow, potentially oil-rich submerged tidelands from the State. To date, the State has made no formal response to the Navy's action.

In June 1977, Congress placed the Reserve under control of the Department of the Interior (DOI) and renamed it the National Petroleum Reserve in Alaska. How this jurisdictional transfer from the Navy to DOI will affect resolution of the boundary disputes remains a question.

A. Alaska Native Claims Settlement Act (ANCSA)

Under the provisions of the Alaska Native Claims Settlement Act (ANCSA) Public Law (P.L.) 92-203 of December 18, 1971, all Alaskan lands not previously designated for some specific purpose were withdrawn for Native selection, or were withdrawn under Section 17(d)(2) for possible inclusion in National Parks, Forests, Wildlife Refuges, or Wild and Scenic River Systems, or were withdrawn under Section 17(d)(1) for further determination. Table B-2 shows the distribution of about 43.7 million acres (17.6 million hectares) to Native Alaskans under ANCSA.

The passage of ANCSA superseded the Alaska Native Allotment Act of May 17, 1906, which authorized the Secretary of the Interior to grant as much as 160 acres (64 hectares) to each applying Alaskan Indian, Aleut, and Eskimo. However, applications filed before passage of ANCSA were to be processed and honored if the applicant so desired. About 250 parcels totaling 37,500 acres (15,150 hectares) were applied for in the Arctic region (University of Alaska, Arctic Environmental Information and Data Center, 1975). Most are along the coast from Kaktovik west to Cape Lisburne, and along

Table B-1. Land Ownership, National Petroleum Reserve in Alaska

	Acres
State of Alaska:	
Airport and Naval Arctic Research Laboratory facilities at Umiat	1,450
Total (State of Alaska)	1,450
Native village corporations:	
Atkasook	68,652
Barrow	201,235
Nuiqsut*	50,657
Wainwright	154,026
Total (Native village corporations)	474,570
Federal:	
Naval Arctic Research Laboratory	4,541
Bureau of Land Management**	23,119,439
Total (Federal)	23,123,980
Total NPRA	23,600,000

*Nuiqsut — That part of entitlement that lies within NPRA estimated to be approximately 75,000 acres (30,300 hectares), depending on the outcome of the boundary dispute description.

**Assuming 23.6 million acres (9,550,000 hectares) in NPRA. An acre is equal to 0.404 hectare.

Source: National Petroleum Reserve in Alaska Task Force, Study Report 2, Section 10 (1978)

Representatives from all North Slope villages participated in regional corporation land selection.

Table B-2. Distribution of 43.7 Million Acres of Land to Natives under the Alaska Native Claims Settlement Act

22 million acres:[1]
The village corporations were to own only the surface estate to lands they selected; the subsurface estate generally belongs to regional corporations, except in Naval Petroleum Reserve No. 4 and National Wildlife refuges.

16 million acres:
These lands were to be selected by regional corporations on the basis of land area within their regions. Under a complicated land-loss formula, these lands were chosen by 11 regional corporations excepting the regional corporation for Southeast Alaska. Only six regions share in this 16 million acres: Ahtna, Arctic Slope, Chugach, Cook Inlet, Doyon, and Northwest Alaska Native Association.

2 million acres:
The remaining 2 million acres was set aside for grants of title of lands to special Native corporations organized in the non-Native cities of Sitka, Kenai, Kodiak, and Juneau (which had been historic Native places); for Native allotments which were claimed before the passage of the act; and for cemeteries and historic sites.

40 million acres:
Total entitlement for all categories, except for village corporations electing to retain their former Indian Reservation status.

Approximately 3.7 million acres:
Where villages on revoked reserves voted to acquire title to their former reserves, they obtain fee simple title not only to its surface but also to its minerals. They forego, however, other benefits under the act.

Total lands to be conveyed to Alaska Natives:
Approximately 43.7 million acres.

[1]Acres x 0.404 = hectare.

inland rivers. These allotment lands were to be part of the 2 million acres (0.8 million hectares) shown in table B-2.

Section 17(d)(2) of ANCSA directed the Secretary of the Interior to set aside as much as 80 million acres (32.3 million hectares) of Alaska's land for possible addition to the National Wildlife Refuge, Forest, Park, and the Wild and Scenic Rivers Systems. Congressional hearings were held throughout Alaska on various "d-2" proposals. The Secretary of the Interior, in September 1977, proposed that the Colville River (from the headwaters to Umiat) and the Utukok River (from the headwaters to T. 5 N., R. 36 W.) be added to the National Wild and Scenic Rivers System. The U.S. House of Representatives passed H.R. 39 (May 1977), which would have designated NPRA as a National Wildlife Refuge and the Colville, Etivluk-Nigu, Ikpikpuk and Utukok Rivers for study as potential additions to the National Wild and Scenic Rivers System.

On December 18, 1978, Section 17(d)(2) ceased to be in effect, as prescribed by ANCSA. Lands previously withdrawn under that section were to revert to Section 17(d)(1) status. However, on November 16, 1978, the Secretary of the Interior withdrew most of the "d-2" lands under Section 204(e) of the Federal Land Policy and Management Act (FLPMA). Further, on December 1, 1978, President Carter, using the Antiquities Act of 1906, established by proclamation many of the "d-2" areas as National Monuments. These new National Monuments included only lands already withdrawn by Section 204(e) of FLPMA.

Neither NPRA nor the four rivers previously proposed for study or designation as National Wild and Scenic Rivers was included in either action.

New National Monuments and FLPMA withdrawn lands lying within the area of concern are as follows:

National Monuments

Bering Land Bridge, 2.6 million acres
Cape Krusenstern, 560,000 acres
Gates of the Arctic, 8.2 million acres
Kobuk Valley, 1.7 million acres
Noatak, 5.8 million acres

FLPMA Withdrawals

Arctic	Gates of the Arctic
Kanuti	Kobuk Valley
Koyukuk	Noatak
Selawik	Killik River
Bering Land Bridge	Koyuk River
Cape Krusenstern	

B. Federal, State, and Local Government Ownership and Withdrawals

1. Federal Ownership and Military Reserves

All Federal lands in Alaska have either been withdrawn as reserves for particular purposes, for Native selection, and for classification, or have been selected by the State. Until 1959, when Alaska became the 49th State, about 99 percent of Alaska was federally owned.

Several areas in the Arctic are under Federal jurisdiction as military reserves. Among these are 7 active and 10 inactive Distant Early Warning (DEW-Line) stations along the Alaskan Arctic coast (fig. B-1). Facilities at these sites typically consist of several buildings, fuel storage tanks, a landing strip, and short, local roads.

The Office of Naval Research established the Naval Arctic Research Laboratory (NARL) on the Arctic coast approximately 4 miles (6 kilometers) northeast of Barrow. NARL began in 1947 as a small adjunct to the original petroleum exploration base camp. Since that time, NARL has been expanded to include the entire camp. The laboratory facilities now occupy 4,541 acres (1,834 hectares).

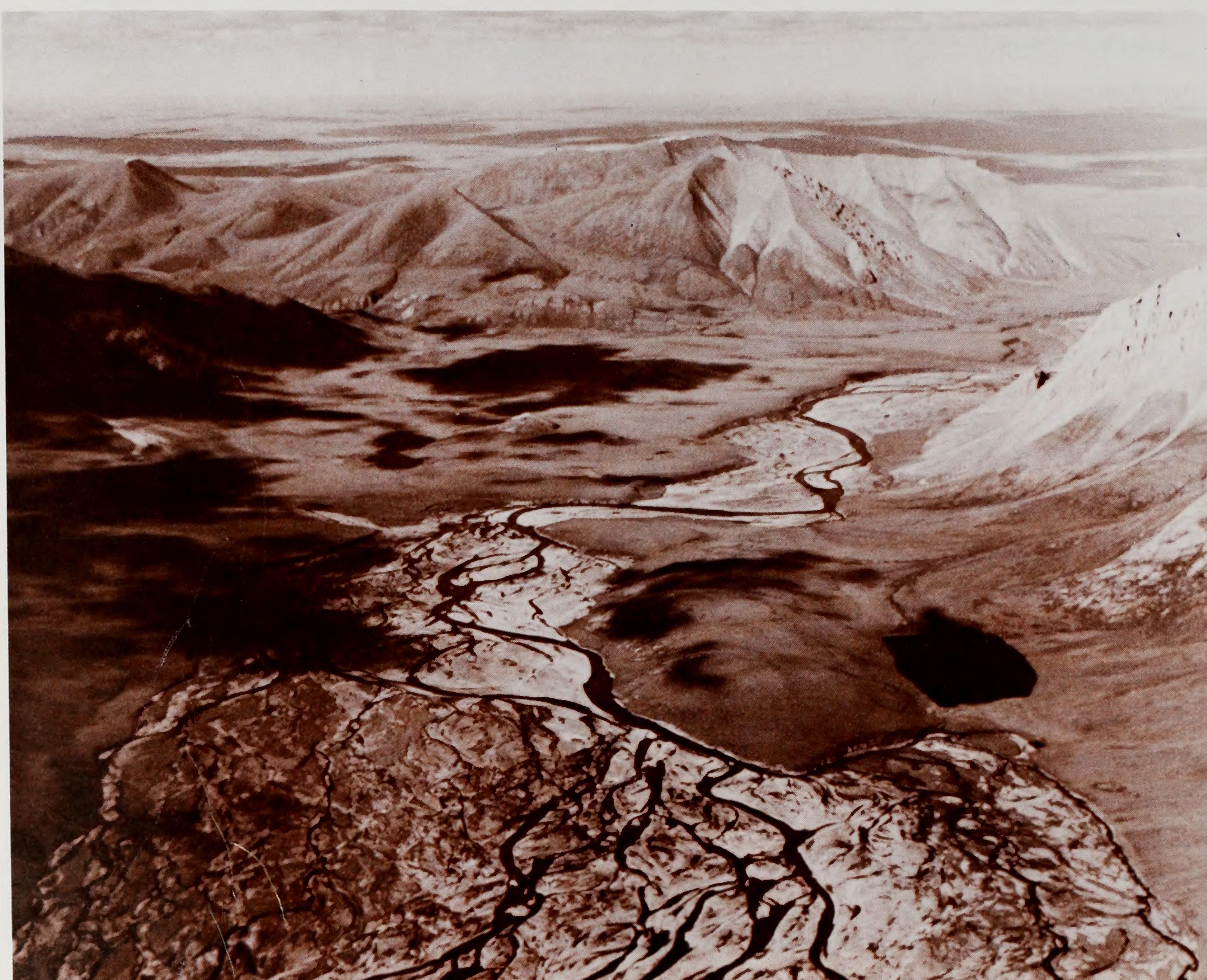
Other Government agencies maintaining facilities in and near Barrow include the National Aeronautic and Space Administration (NASA), the U.S. Coast Guard, the Federal Aviation Administration (FAA), the Bureau of Indian Affairs (BIA), the U.S. Public Health Service (USPHS), and the National Weather Service.

2. State Ownership, State Selections, Statehood Act

The State owns about 3.4 million acres (1.4 million hectares) in the Arctic region and an additional 1 million acres (0.4 million hectares) pending or tentatively approved along the eastern bank of the Colville River and in the vicinity of Point Lay, Point Hope, and other Native villages. Additional selections are expected with boundary resolution or under ANCSA (d)(1) and (d)(2) withdrawals.

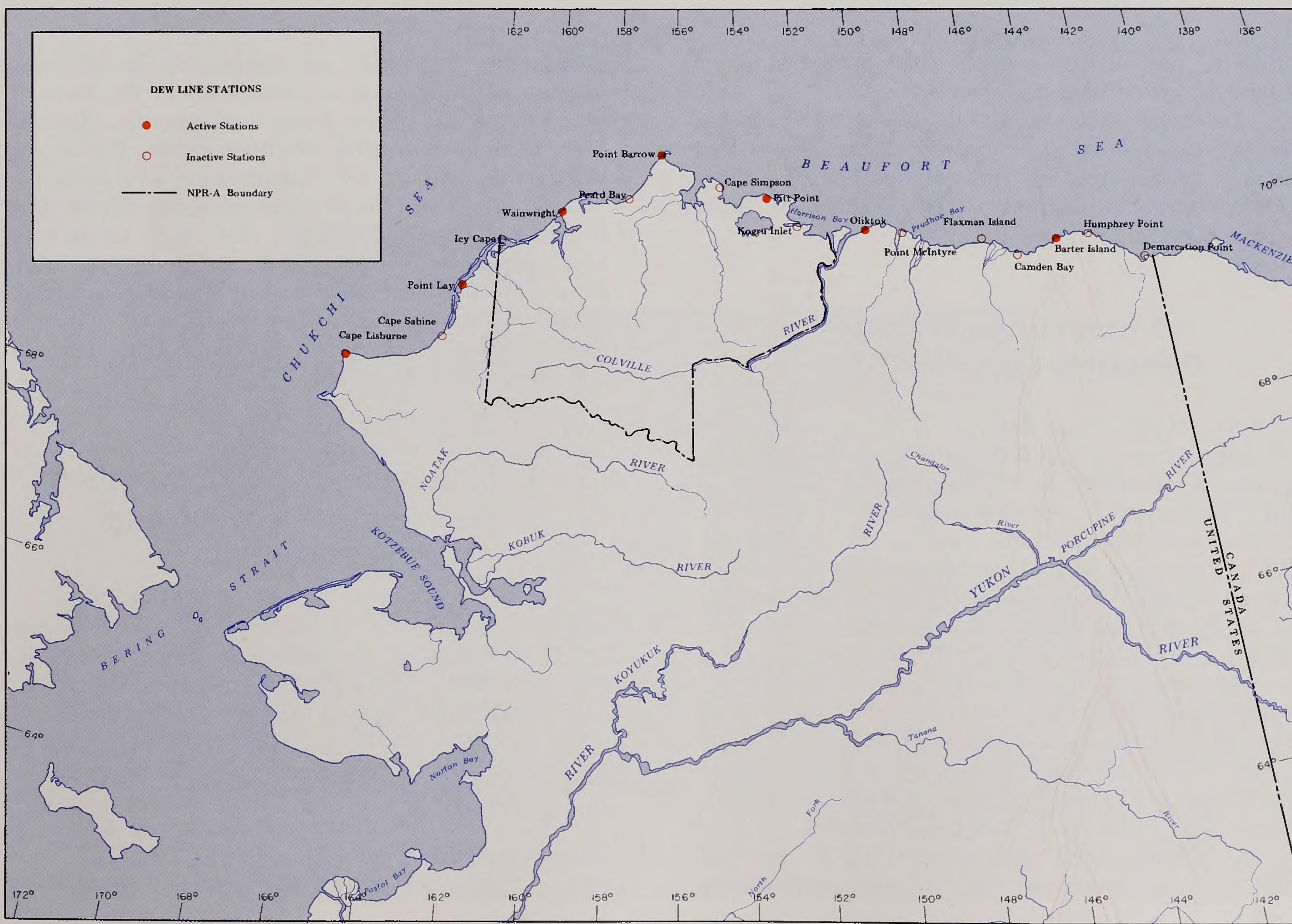
The 1958 Statehood Act provided that 102.5 million acres (41.4 million hectares) of general grant lands from the "vacant, unappropriated and unreserved" lands of Alaska could be selected by the new State within 25 years. Alaska was also entitled to University and Mental Health Lands granted before statehood, to 400,000 acres (161,000 hectares) from the public domain, and to another 400,000 acres (161,000 hectares) from the National Forests for community development and recreation. The State also gained title to submerged offshore lands to the

Land withdrawn by the Federal Government before 1971, such as the Arctic National Wildlife Range, is subject to village selection under ANCSA. (C. D. Evans, AEIDC)



The Naval Arctic Research Laboratory, near Barrow, was established to conduct scientific studies in the Arctic. (J. C. LaBelle, AEIDC)

Figure B-1. Location of Distant Early Warning (DEWLine) Sites in Northern Alaska.



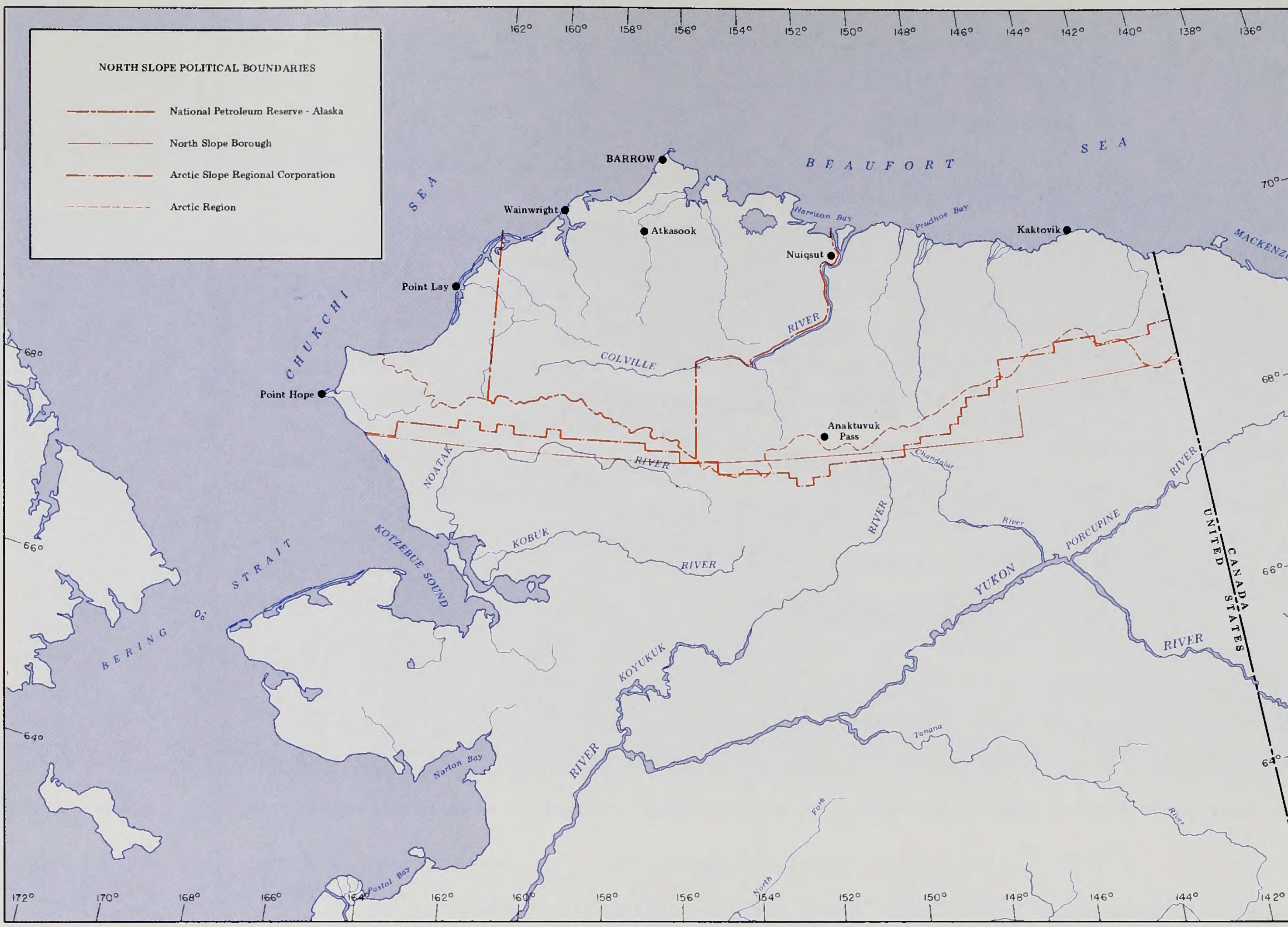


Figure B-2. North Slope Political Boundaries.

limits of the territorial sea and submerged lands of inland navigable lakes and streams.

Inasmuch as the remaining State entitlement was to be selected almost entirely from unreserved Federal public domain, the designation of ANCSA (d)(2) "national interest lands" diminished State selection opportunities.

3. North Slope Borough Ownership and Jurisdiction

The North Slope Borough (NSB) covers an area of approximately 88,000 square miles (140,800 square kilometers). Its boundaries contain all of the Arctic region and the northern parts of the Yukon and Northwestern regions of Alaska (fig. B-2). More than half of the North Slope Borough is owned by the Federal Government through previously mentioned administrative withdrawals, including NPRA and the Arctic National Wildlife Range.

In 1963 the State legislature authorized the creation of organized boroughs, permitting each borough to select within its boundaries 10 percent of the State's general grant lands conferred under the Statehood Act. The North Slope Borough has applied for nearly all of its 10 percent allotment of State patented land, or 33,324 acres (13,462 hectares). The State, however, has rejected these applications, maintaining that lands are unavailable for selection because of prior State commitments in the form of oil and gas and other leases and permits. Because there is no precedent for this State action, the issue is in litigation, and a lower court decision is on appeal.

Whatever additional lands the State selects after the boundaries of the (d)(1) and (d)(2) lands have been resolved, the NSB will be entitled to an additional 10 percent of the State's lands. Although Alaska is required to complete its land selection procedure by 1984, the NSB has no time limit on selection of its entitlement.

4. Arctic Slope Regional Corporation and Village Ownership and Conveyances

The boundaries of the Arctic Slope Regional Corporation (ASRC) generally encompasses the same land area as the North Slope Borough. However, the coastal ASRC boundary extends offshore about 6 miles (10 kilometers), and the southern boundary irregularly crosses the borough boundary in the Brooks Range.

Twelve regional corporations, set up as profit-making entities under ANCSA, and their 203 associated village corporations are receiving land and cash settlements under ANCSA. Those in northern Alaska are shown in figure B-3. Each of the villages, pending certification, is eligible for entitlements of 69,120 acres (27,920 hectares); each village is also eligible for entitlements of 320 acres (129 hectares) per individual, up to a maximum of 7,680 acres (3,100 hectares) per village. Land entitlements will encompass about 22 million acres (8.8 million hectares).

Individual Natives benefit as shareholders in the Native corporations but cannot sell their shares of stock until 1991 (20 years after passage of ANCSA), and they enjoy certain tax advantages, paying no taxes on their stock until 1991. The regional corporations, similarly, are not taxed on their lands unless they sell or develop the resources before 1991; however, corporate profits are not exempt from taxation. All Native corporations are free to sell all or any part of their lands at any time. Leasing is the preferred option of the Native corporations at this time.

Most land selections were made by December 18, 1974, and were 99 percent completed by December 18, 1975 (4 years after ANCSA's passage). On June 3, 1977, the Arctic Slope Regional Corporation received its last conveyance from the Bureau of Land Management, bringing its total of surface and subsurface lands to 2.9 million acres (1.1 million hectares) with an additional 221,575 acres (89,520 hectares) near Anaktuvuk Pass pending. Although the lands will not be fully conveyed until they are surveyed, the corporation now has all the privileges and rights of ownership. The subsurface rights to all Native lands are owned by the Native regional corporations except within NPRA. In the case of individual Native allotments, the subsurface is retained by the United States. Village corporations that retained their former Indian Reservation status will also own the subsurface.

The Arctic Slope region is considered to have the greatest potential for oil, natural gas, and coal development of any of the Native regions. Although the ASRC is prohibited by terms of ANCSA from obtaining title to the mineral estate of NPRA, provisions were made whereby the regional corporation could make selections of subsurface estate outside NPRA "in lieu" of lands not available within NPRA. Where the Native village corporations own the surface estate and the Native regional corporations own the subsurface estate, some of the ownership problems are being resolved in Federal courts — for example, whether gravel is a surface or subsurface material and what constitutes the village boundaries relative to the village "veto power" on development.

Lands yet to be conveyed under ANCSA to the corporation include both "in lieu" and "dual withdrawal" lands. As previously explained, the in-lieu lands consist of subsurface rights to replace those that normally would have been acquired in conjunction with village-selected surface lands at Barrow, Wainwright, Nuiqsut, and NPRA and the Arctic National Wildlife Range. The dual withdrawal lands include areas selected by ASRC but which are also identified

The Arctic Slope Regional Corporation, whose offices are shown here under construction, was the first Native corporation in the State to receive interim conveyance of settlement lands.

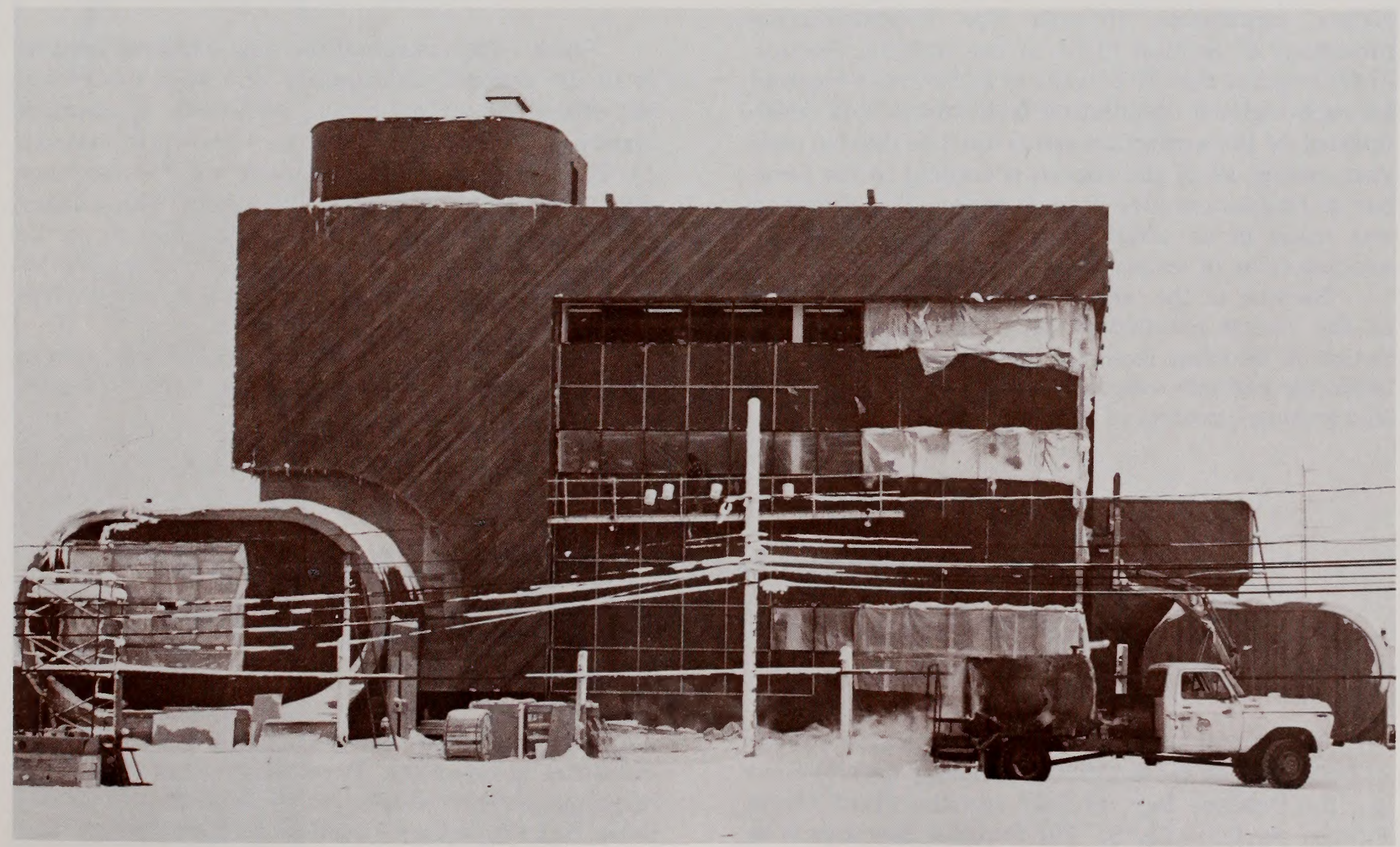


Table B-3. Native Village Conveyances under the Alaska Native Claims Settlement Act [Section 12(a)] as of August 22, 1979

	Entitlement (acres[1])	Acreage Received[1] (approximately)	Acreage Pending
Atkasook (Atkasook Corporation)	69,120	68,652	468
Barrow (Ukpeagvik Inupiat Corporation)	161,280	153,105	8,175
Point Hope (Tigara Corporation)	138,240	134,143	4,097
Point Lay (Cully Corporation)	69,120	67,385	1,735
Nuiqsut (Kuukpik Corporation)	115,200	[2]42,741	[2]72,459
Wainwright (Olgoonik Corporation)	115,200	109,401	5,799
Anaktuvuk Pass (Nunamiut Corporation)	92,160	89,646	2,514

[1]Acres x 0.404 = hectare.
[2]Some of the acreage Nuiqsut has received is in litigation.

Source: Carlene Welfelt, ANCSA Operations, Bureau of Land Management, oral commun., Aug. 22, 1979.

for inclusion in the proposed (d)(2) lands. In general, the village corporations selected lands which were traditional sites of village subsistence hunting, fishing, and gathering. Regional corporations able to select lands on their own behalf, however, tended to select on the basis of natural resource potential (Alaska Division of Energy and Power Development, 1977).

Several Native corporations have exercised selection rights on lands which may contain oil or on other lands where the presence of timber and metallic and industrial minerals is known or suspected. In the event of a major oil discovery, not only would the owner corporation be benefited, but monies derived would also be distributed among the State's entire Native population through the revenue-sharing provisions of Section (7)(i) of the ANCSA. Section (7)(i) requires that 70 percent of all revenues received by each regional corporation from timber and development of the subsurface estate must be divided each year among all of the regions according to the number of Natives enrolled in each region. This provision was made in an effort to level the effects of the unequal value of resources between regions.

Because of the large size of their regions relative to the Native population, only six regions had the option of selecting lands for their resource value. The following regional corporations share 16 million acres (6.4 million hectares) of fee simple land:

- Ahtna, Incorporated
- Chugach Natives, Inc.
- Doyon, Ltd.
- Northwest Alaska Native Association (NANA) Regional Corporation
- Arctic Slope Regional Corporation
- Cook Inlet Region, Inc.

ANCSA provides,

> that the right to explore, develop, or remove minerals from the *subsurface estate* in the lands within the boundaries of the Native village shall be subject to the consent of the village corporation [Section (14)(f)].

Some village corporations may withhold approval to the regional corporations who want to develop the village subsurface estate. Resistance to development near villages is expected for a variety of reasons: 1) Development could conflict with subsistence lifestyles; 2) development could conflict with villages' surface development plans; and 3) the impacts on the villages caused by development may not be considered worth the revenues returned to the village corporations under Section (7)(i).

Villages in the region have obtained interim conveyance for lands totaling more than 700,000 acres (282,000 hectares) (table B-3).

C. Outside NPRA – Prudhoe Bay, Trans-Alaska Pipeline System (TAPS) Right-of-Way

Two major features of the Arctic region outside of NPRA which are significant to energy development are the Prudhoe Bay oil field and the Trans-Alaska Pipeline System (TAPS). The Prudhoe Bay area is an industrial enclave in a region that is otherwise nonindustrial in character. Development and land use is dispersed because of the size of the field (400 square miles, or 1,035 square kilometers). The leases are held

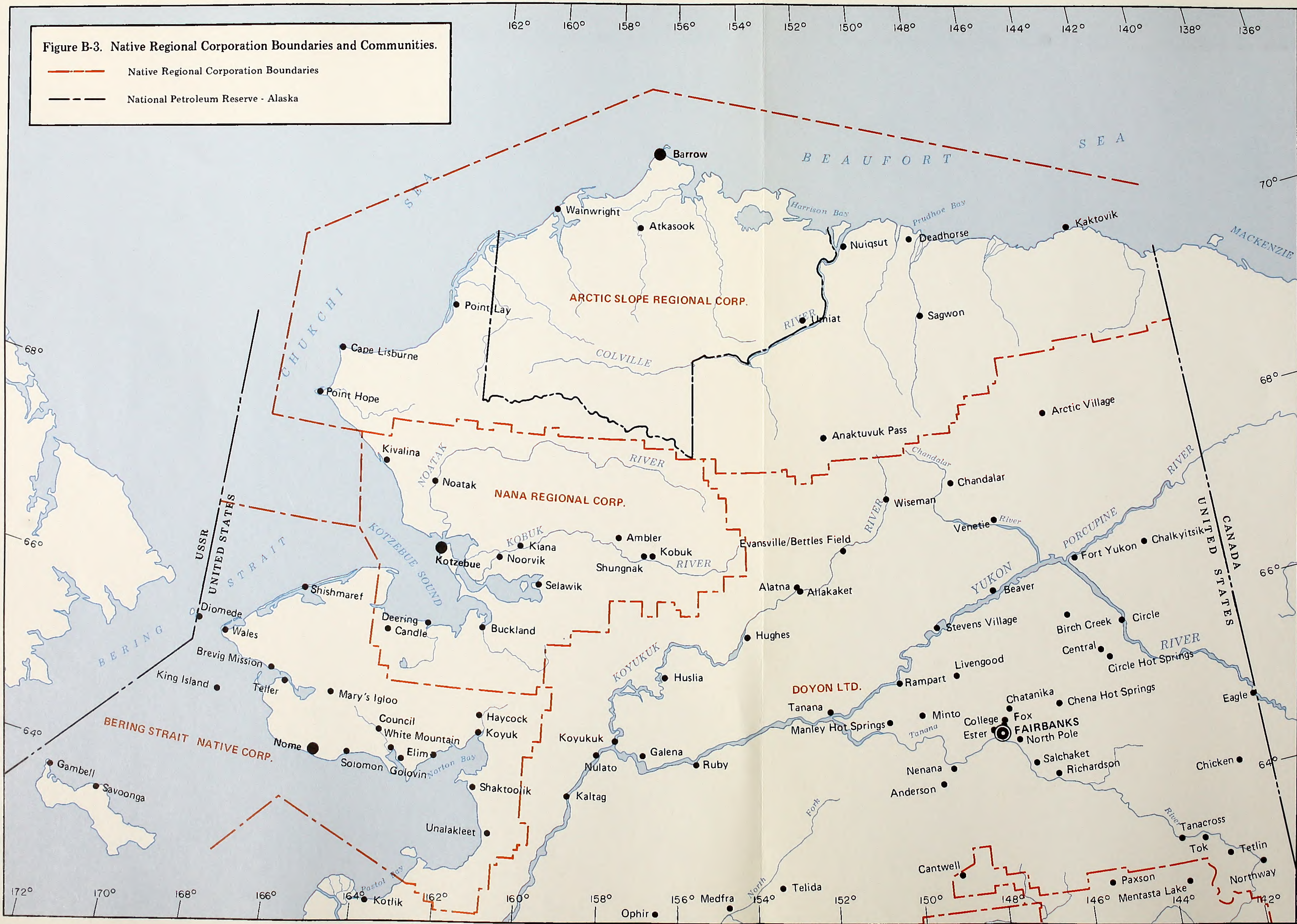


Figure B-3. Native Regional Corporation Boundaries and Communities.

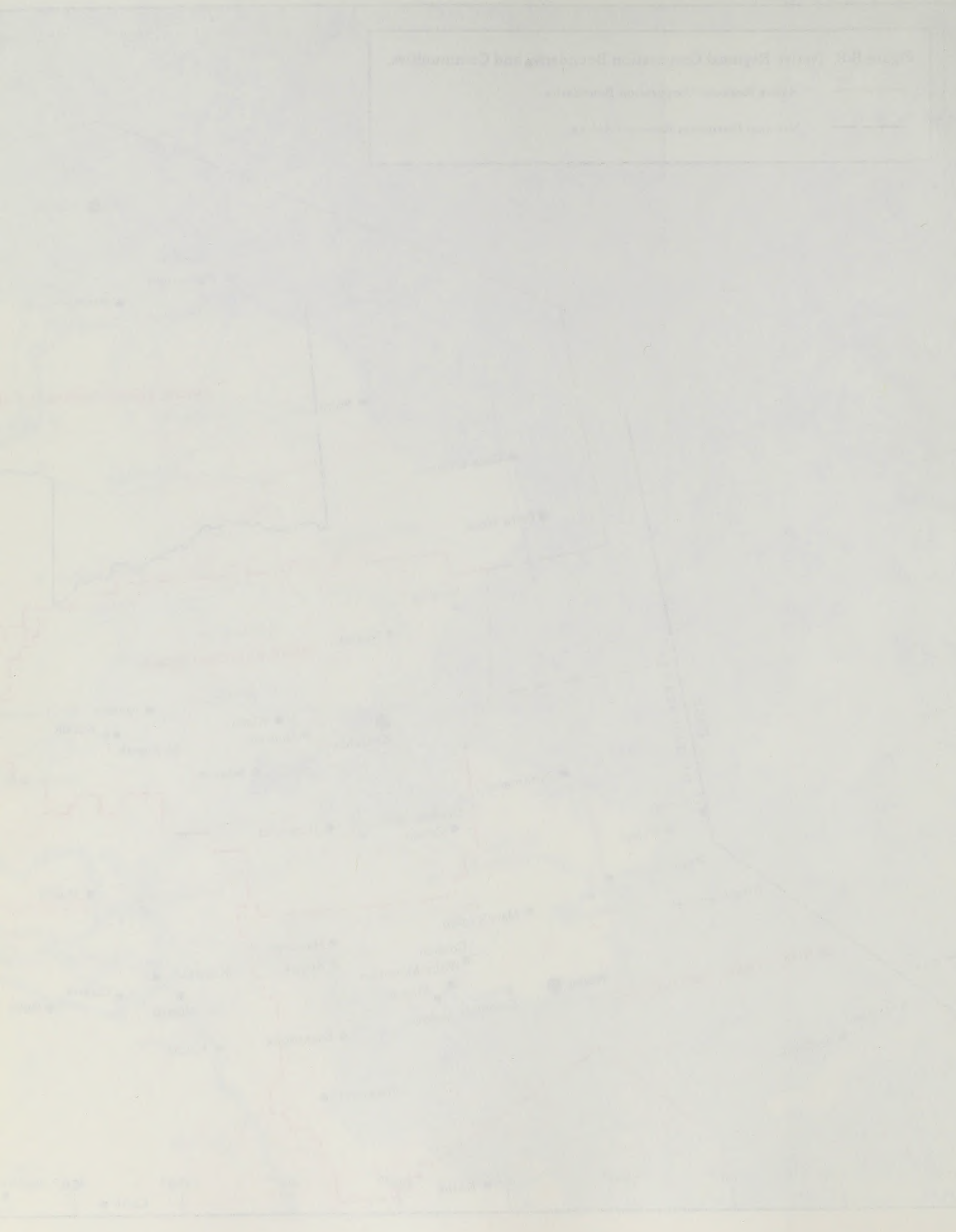


Figure B.8. [illegible] Regional Cooperation Boundaries and Communities.

by 16 oil companies. The Deadhorse Airport lands belong to the State and are managed by the Division of Aviation. Operation of the Prudhoe oil fields is divided between the Atlantic Richfield Company (ARCO) and SOHIO-British Petroleum Alaska; the former is responsible for the eastern half of the field, and the latter for the western half.

The TAPS haul road, built to transport men and material to construct the pipeline, is the only road into the Alaskan Arctic. Current proposals call for limited public use.

A major gas pipeline (Alcan) has been proposed for the area. In the Arctic region the gas line would follow generally the route of the oil pipeline.

Effective use of Federal lands in Alaska in the grant of right-of-way for TAPS is the Interior Department's concern. "Effective" is rooted in several sources: the Mineral Leasing Act of 1920 (30 USC 185, as amended) providing for rights-of-way for pipeline purposes; the Department of the Interior's Final Environmental Impact Statement on TAPS of March 20, 1972; the Trans-Alaska Pipeline Authorization Act of 1973 (87 Stat. 584 et seq.), directing the Secretary of the Interior and other Federal officers to facilitate prompt construction of TAPS; and an Agreement and Grant of Right-of-Way dated January 23, 1974, with conditions and stipulations from the Secretary of the Interior to the seven owner companies of TAPS.

The Department of the Interior's (DOI) stipulations connected with the TAPS right-of-way are "general," "environmental," or "technical" in nature. General stipulations deal with such matters as organization and authority of the DOI Monitoring Office, public access to the project, hunting and fishing provisions, health and safety, and surveillance and maintenance. Environmental stipulations deal with erosion and pollution control, fish and wildlife protection, restoration, oil discharge, and contingency plans. Technical stipulations deal with such considerations as pipeline system standards, construction mode requirements, earthquakes, stream and flood-plain crossings, glacier surges, and pipeline corrosion.

Some questions remain about the eventual disposition of the two pipeline corridor withdrawals. The main Prudhoe-to-Valdez corridor could remain withdrawn until all pipelines are no longer needed, or withdrawn but limited to the narrowest width possible to contain the pipeline(s). The proposed Alcan Gas Pipeline project will use this corridor through the Arctic region. The presently unused corridor that follows the western and southern boundaries of the Arctic National Wildlife Range into Canada may remain, could be eliminated during the "d-2" resolution process, or may be eliminated at a later date.

Opening of the trans-Alaska pipeline haul road to public traffic has become a subject of controversy. (Atlantic Richfield Company)

II. Environmental Legislation and Regulations

A. Federal Requirements

In addition to the controls of land ownership, there also exists a significant body of environmental legislation which will affect development of the petroleum resources of NPRA. Several key items of legislation will directly affect all aspects of development, production, transportation, and distribution of petroleum resources from NPRA. Their effects will range from adoption of specific controls on operational procedures to outright prohibitions of activities in certain areas.

1. Resource Recovery

The key legislation regarding resource recovery is the National Environmental Policy Act (NEPA) of 1969 (P.L. 91-120, 42 USC 4321-4347, January 1, 1970, as amended by P.L. 94-52, July 3, 1975, and P.L. 94-83, August 9, 1975). Section 102(2)(c) of the act requires that:

> All agencies of the Federal Government shall * * * include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on * * * the environmental impact of the proposed action.

Environmental statements will be required at such time as programs may be developed in the future.

Regulations implementing NEPA are in Title 30, Code of Federal Regulations, Part 1500. These regulations became binding on all Federal agencies on July 30, 1979. The regulations have three primary purposes:

1. To reduce paperwork,

2. To reduce delays, and

3. To produce better decisions which further the national policy to protect and enhance the of the human environment.

Title 30, Code of Federal Regulations, Part 221 (30 CFR 221) — Oil and Gas Operation Regulations, states that the regulations in this part shall be administered under the Director of the Geological Survey (30 CFR 221.1). The Area Oil and Gas Supervisor, Conservation Division, Geological Survey, is

> authorized and empowered to supervise and direct oil and gas operations and to perform other duties prescribed in the regulations of this part, or any subordinate acting under his direction [30 CFR 221.2(c)].

> The [Area Oil and Gas] Supervisor is hereby authorized to require compliance with lease terms, with the regulations in this part, and all other applicable regulations, and with applicable law to the end that all operations shall conform to the best practice and shall be conducted in such manner as to protect the deposits of the leased lands and result in the maximum ultimate recovery of oil, gas, or other products with minimum waste. Inasmuch as conditions in one area may vary widely from conditions in another area, the regulations in this part are general, and detailed procedure hereunder in any particular area is subject to the judgment and discretion of the Supervisor, and to any real plan of development that may be adopted pursuant to law. The Supervisor may require satisfactory evidence that a lease is in good standing, that the lessee or operator is authorized to conduct operations, and that an acceptable bond has been filed before permitting operations on the leased land [30 CFR 221.4].

To this end, the Alaska Area Oil and Gas Supervisor has issued Notices to Lessees and Operators of Federal and Indian oil and gas leases (NTL's). Two such notices, NTL-2B and NTL-6, are of environmental consequence.

NTL-2B addresses the disposal of produced water. It states, in part:

> All produced water from [onshore Federal and Indian Oil and Gas] leases must be disposed of by (1) injection into the subsurfaces; (2) lined pits; or, (3) by other acceptable methods. All such disposal methods must be approved in writing by the [Area Oil and Gas] Supervisor regardless of the physical location of the disposal facility.

NTL-6 addresses the approval of operations. It states:

> In order that the environmental impact of proposed operations may be properly evaluated, all applications to conduct leasehold operations or construction activities must be accompanied by an appropriate surface use plan. As a minimum, such applications and surface use plans must provide a detailed description of the technical aspects of the proposed operation or activity, the

magnitude of surface disturbance involved, and the procedures to be followed in rehabilitating the surface once the operation or construction activity has been completed.

2. Air and Water Quality

Public Law 95-95, Clean Air Act and amendments, establishes ambient air quality standards. Activities associated with potential development of petroleum resources of NPRA will be required to conform to these standards.

Under the Clean Air Act, as amended (P.L. 95-95), the Environmental Protection Agency (EPA) is authorized to prescribe regulations for the attainment and maintenance of national ambient air quality standards for any air pollutant determined to have an adverse effect on public health and welfare and to prevent significant air quality deterioration. Air quality must be assured within an entire geographic area comprising each State. Under the act, States have the primary responsibility for attaining and maintaining the Nation's ambient air quality standards by adopting a State Implementation Plan (U.S. Department of the Interior, 1979). Permit application for a major emitting facility would be transmitted by the State to the EPA. The EPA in consultation with the Bureau of Land Management (BLM) would authorize or deny the permit based on the operator's demonstration that emission from the facility would have no adverse impact on the air quality-related values of the land (including visibility). The State may then issue the permit.

Public Law 92-500, Federal Water Pollution Control Act (FWPCA) and amendments, establishes water quality standards for surface water. Components of the act relating to NPRA are those requiring permits for discharge of polluted waters into lakes and streams under the National Pollution Discharge Elimination System (NPDES) and prohibiting degradation in high-quality waters constituting an outstanding national resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational and ecological significance.

Provisions of the Clean Water Act (91 Stat. 1566, 1977), which amended the FWPCA, apply to both onshore facilities and related Outer Continental Shelf activities. Section 311 requires that oil spills be reported and that costs of cleanup and restoration of natural resources be covered by the spiller. It provides for a liability up to $50 million for actual costs of oil removal and cleanup (except where operator or owner is not at fault), as well as replacement or restoration costs of natural resources damaged or

Each Native village in the borough, such as Point Hope, is authorized to select village lands under ANCSA. (J. C. LaBelle, AEIDC)

destroyed by a spill (U.S. Department of the Interior, 1979).

Under FWPCA Amendments of 1972 (86 Stat. 816), the NPDES was created to control discharges into the territorial seas, waters of the contiguous zone, and the oceans. The NPDES applies to fixed platforms, and any discharges from these sources require a permit issued by the EPA. NPDES permits, however, do not apply to discharge of pollutants from any vessels or floating craft, or subsurface injection wells for production purposes. Subsurface injection is subject to U.S. Geological Survey regulations and operating orders (U.S. Department of the Interior, 1979).

The EPA is also primarily responsible for facilities not related to transportation, such as terminal and storage facilities, and permits for any discharges would be issued by the EPA or designated States according to established effluent guidelines.

3. Fish and Wildlife

The Fish and Wildlife Coordination Act (P.L. 73-12; 48 Stat. 401, as amended by P.L. 73-624; 72 Stat. 563; 16 USC 661-666e) provides that wildlife conservation shall receive equal consideration and be coordinated with other features of water resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. The Secretary of the Interior is authorized to make surveys and investigations of the wildlife of the public domain. The act further states that whenever the waters of any stream or other body of water are proposed or authorized to be controlled or modified for any purpose whatever, by any department or agency of the Federal Government or by any public or private agency under Federal permit or license, such department or agency first must consult with the U.S. Fish and Wildlife Service (USFWS) and the Department of the Interior with a view to the conservation of wildlife resources by preventing loss of and damage to such resources.

The Endangered Species Act of 1973 (P.L. 93-205; 87 Stat. 884; 7 USC 136; 16 USC 460e-g, 460k-l, 668dd, 714i, 715s, 1362, 1402, 1531-1543) requires that Federal actions do not jeopardize the continued existence of plant and animal species classed as threatened or endangered, nor destroy or modify habitat of such species determined by the Secretary of the Interior to be critical for the species.

During the preparation of the Bureau of Land Management's (BLM) environmental impact statement for oil and gas leasing in the Beaufort Sea, the BLM formally consulted with the USFWS regarding the peregrine falcon, an endangered species which inhabits northern Alaska. USFWS responded with the following:

> Transportation through, or construction activities in, peregrine nesting areas could disrupt nesting activity. Therefore, *any activity or program authorized, funded or carried out by a Federal agency that occurs within a 15-mile radius of an active or historical peregrine falcon eyrie will require Section 7 consultation.* These actions by a Federal agency related to the exploration, production, and development of the subject lease areas could include: (1) the operation of service, crew, and barge vessels, (2) the construction and operation of pipelines and associated facilites, (3) the construction and operation of support bases, (4) the construction and operation of onshore development facilities, (5) the related operation of fixed-wing aircraft and helicopters, and (6) transportation and storage of materials [U.S. Fish and Wildlife Service, 1978].

Public Law 92-522, Marine Mammal Protection Act, prohibits the harassment, capture, or kill of any marine mammal. Activities related to petroleum development which would result in harassment or killing of such marine mammals is prohibited. However, the act does not interfere with subsistence harvest of marine mammals.

Under the Marine Protection, Research, and Sanctuary Act of 1972 (16 USC 1431-1434), the Secretary of Commerce is empowered to designate areas as marine sanctuaries "as necessary for the purpose of preserving or restoring such areas for their conservation, recreation, ecological, or esthetic values," following consultation with the Secretaries of State, Defense, Interior, and Transportation, and with the Administrator of the EPA. Once an area is designated a marine sanctuary, National Oceanic and Atmospheric Administration's (NOAA) Office of Ocean Management is required to issue "necessary and reasonable regulations" for control of activities permitted within the marine sanctuary. Multiple uses (including oil and gas development) may be permitted within a marine sanctuary, providing they comply with the regulations governing the sanctuary.

4. Cultural Resources

Legislation related to archeologic and historic values, wilderness, and wild and scenic rivers will have a significant impact on petroleum development. Beginning with the Antiquities Act of 1906, several major Federal laws have been passed that control and limit destruction. or alteration of historic or prehistoric landmarks, structures, and objects.

The Antiquities Act of 1906 (P.L. 59-209; 34 Stat. 225; 16 USC 431-433) protects historic, paleontologic, and archeologic resources. Executive Order 11593, related to these two acts, requires archeologic clearance prior to Federal action, and cessation of activities if unforeseen resources are uncovered, until determination is made for protection, salvage, or abandonment. Public Law 93-291, Archeologic and Historic Preservation Act of 1974, permits halting construction if archeological data are in danger of destruction and enables Government agencies to fund or bill the lessee or licensee for archeological survey and excavation.

Any oil and gas operations performed under 30 CFR 221 regulations will be contingent upon a cultural resources clearance granted with the approval of the authorized land management agency.

The National Historic Preservation Act of 1966 (P.L. 89-665; 80 Stat. 915; 16 USC 470-470n) provides authority for the Secretary of the Interior to maintain a register of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, and culture, which is referred to as the National Register. The act also establishes the Advisory Council on Historic Preservation. Federal agencies having direct or indirect jurisdiction over a project or having authority to license any project must take into account the effect of its undertaking on any site, building, structure, or object that is included in the National Register. The head of the Federal agency shall afford the Advisory Council on Historic Preservation the opportunity to comment with regard to such undertaking.

Executive Order 11593, Protection and Enhancement of Historical and Cultural Properties, directs Federal agencies to 1) administer the cultural properties under their control in a spirit of stewardship and trusteeship for future generations; 2) initiate measures necessary to direct their policies, plans, and programs in such a way that federally owned sites, structures, and objects of historical, architectural, or archeological significance are preserved, restored, and maintained for inspiration and benefit of the people; and 3) in consultation with the Advisory Council on Historic Preservation [16 USC 470(i)], institute procedures to assure that Federal plans and programs contribute to the preservation and enhancement of nonfederally owned sites, structures, and objects of historical, architectural, or archeological significance.

The order also directs that heads of Federal agencies initiate measures to assure that where, as a result of Federal action or assistance, a property listed on the National Register of Historic Places is to be substantially altered or demolished, timely steps be taken to make or have made records, including measured drawings, photographs, and maps, of the property, and that a copy of such records then be deposited in the Library of Congress as part of the Historic American Buildings Survey or Historic American Engineering Record for future use and reference.

5. Land Management

The Coastal Zone Management Act of 1972 (P.L. 92-583; 86 Stat. 1280; as amended by P.L. 94-370, July 26, 1976; 16 USC 1451-1464) encourages the States to exercise their full authority over the lands and waters in the coastal zone by assisting the States in developing land and water use programs for the coastal zone. Each Federal agency conducting or supporting activities directly affecting the coastal zone shall conduct these activities in a

The Marine Mammal Protection Act prohibits the harvest of seals except for subsistence purposes. (John F. Schindler, Husky Oil Company)

manner which is, to the maximum extent possible, consistent with approved State management programs. After approval by the Secretary of Commerce of a State's management program, any applicant for a required Federal license or permit to conduct activities affecting land or water uses in the coastal zone of that State shall provide in the application to the licensing or permitting agency a certification that the proposed activity complies with the State's approved program and will be conducted in manner consistent with the program. The applicant concurrently shall furnish to the State or its designated agency a copy of the certification with all necessary information and data. At the earliest practicable time, the State or its designated agency shall notify the concerned Federal agency that the State concurs with or objects to the applicant's certification. If the State or its designated agency fails to furnish the required information within 6 months after receipt of its copy of the applicant's certification, the State's concurrence with the certification shall be conclusively presumed. No license or permit shall be granted by the Federal agency until the State or its designated agency has concurred with the applicant's certification or such certification is conclusively presumed.

After the management program of any coastal State has been approved, any person who submits to the Secretary of the Interior any plan for the exploration or development of or production from any leased Outer Continental Shelf area shall attach to such plan certification that each activity in such plan complies with such State's approved management program and will be carried out in a manner consistent with such program. No Federal official or agency shall grant such person any license or permit for any activity described in such plan until such State or its designated agency receives a copy of such certification and plan, concurs with such person's certification, and notifies the Secretary of the Interior of such concurrence. A license or permit can also be granted if State concurrence is presumed or the Secretary finds that each activity in such plan is consistent with the objectives of this act or is otherwise necessary in the interest of national security.

Section 304 (1) of the act states "excluded from the coastal zone are lands the use of which is by law subject solely to the discretion of or which is held in trust by the Federal Government, its officers or agents." NPRA falls under this category; however, development of oil and gas may have spill-over effects on Alaska's coastal zone.

Subpart C of Section 307(c)(1) and (2) refers to direct Federal activities including development projects. A Federal agency proposing an action which directly affects the coastal zone must notify the proper State agency. The Federal agency makes a determination as to whether the proposed action is consistent with the approved State coastal zone management plan. The responsible State agency then has 90 days to review the proposed plan and consistency determination; however, the State cannot deny approval of the proposed action. If there is a disagreement on consistency, subpart G of this section states that the Secretary of Commerce will mediate.

Section 307(c)(3)(A) of the act refers to federally licensed and permitted activities which significantly affect the coastal zone. In this case, the applicant determines if his proposal is consistent with the State's approved coastal zone management program. The final consistency determination is made by the State, and the State has up to 6 months to concur. The Federal agency which grants the license or permit may not do so if the State does not concur with the applicant's consistency determination. If the State issues a negative consistency concurrence, the applicant may appeal to the Secretary of Commerce.

Whether subparts (1) and (2), or subpart (3) of section 307(c) will apply to NPRA will be determined by which management option is implemented. It should be noted that, to date, the State of Alaska has not received approval of its coastal zone management plan from the Secretary of Commerce. The relationship of petroleum development in NPRA to coastal zone management can only be determined after specific programs for the North Slope coastal area are developed and approved.

The Wilderness Act (P.L. 88-577; 78 Stat. 890; 16 USC 1131-1136) provides for establishment of Wilderness Areas within the Federal land system. Although mineral development can occur in Wilderness Areas, it is "subject, however, to such reasonable regulations governing ingress and egress * * *." This act is administered by the Secretary of Agriculture. It basically adds the force of law to administrative protection for 54 areas within the National Forests. It also permits the Secretary of the Interior to add land parcels within National Parks to these "Wilderness Areas." One of the act's special provisions controls exploitation/extraction of any minerals contained in Wilderness Areas. It designates that provisions must be made for "the protection of the wilderness character of the land consistent with the use of the land for the purposes for which they are leased" [16 USC 1131 et seq. 4(d)]. These lands will not be available for leasing or any appropriation under present mining laws after November 1, 1984.

Both the Gates of the Arctic and the Noatak National Monuments have been proclaimed as areas with outstanding wilderness characteristics. As units of the National Park System the areas will be administered under the National Park Service Organic Act of August 25, 1916,

> which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

The Wilderness Act of 1964 allows the National Park Service to administer designated wilderness for use and enjoyment as wilderness. The act also states that "Wilderness Areas shall be devoted to this public purpose of recreational, scenic, scientific, educational, conservation, and historical use."

The Bureau of Land Management has developed a wilderness protection lease stipulation. This stipulation states:

> By accepting this lease, the lessee acknowledges that the lands contained in this lease are being inventoried or evaluated for this wilderness potential by the Bureau of Land Management (BLM) under Section 603 of the Federal Land Policy and Management Act of 1976 [90 Stat. 2743, 2785; 43 USC 1782].

Until the BLM determines that the lands covered by the lease do not meet the criteria for a Wilderness Study Area as set forth in Section 603, or until Congress decides against the designation of such lands "wilderness," the following conditions apply:

1. Any oil or gas activity conducted on the leasehold for which a surface use plan is not required under NTL-6 (for example, geophysical and seismic operations) may be conducted only after the lessee first secures the consent of the BLM. Such consent shall be given if the BLM determines that the impacts caused by the activity will not impair the area's wilderness suitability.

2. Any oil and gas exploratory or development activity conducted on the leasehold which is included within a surface use plan under NTL-6 is subject to regulation (which may include no occupancy of the surface) or, if necessary, disapproval until the final determination is made by Congress either to designate the area as wilderness or remove the Section 603 restrictions.

If all or any part of the area included within the leasehold estate is formally designated by Congress as wilderness, oil and gas exploration and development operations taking place or to take place on that part of the lease shall become subject to: 1) those provisions of the Wilderness Act of 1964 which apply to National Forest Wilderness Areas (16 USC 1131 et seq., as amended); 2) the act of Congress designating the land as wilderness; and 3) Department of the Interior regulations and policies pertaining thereto.

The Wild and Scenic Rivers Act of 1968 (P.L. 90-542; 82 Stat. 906; 16 USC 1271-1287) authorized designation of "wild," "scenic," and "recreational" rivers. Depending upon the class of designation, development activities on or along the river are prohibited or restricted.

The purpose of this act is to implement a policy of preserving selected rivers or portions thereof in their free-flowing condition to protect their water quality and to fulfill other national conservation purposes. The act institutes a National Wild and Scenic Rivers System, designates the initial components of the system, and prescribes the methods and standards according to which additional components might be added to the system.

Section 9 of the act specifically defines the relationship of this law to Federal mining and leasing laws. Nothing in the act affects the applicability of the mining and leasing laws except:

1. All mining activities on lands that are part of the Wild and Scenic Rivers System are subject to such regulations as the Secretary of the Interior or, in the case of National Forest lands, the Secretary of Agriculture may prescribe to effectuate the purpose of the act.

2. Rights of such lands are limited to the mineral deposits and to the use of the surface and surface resources as are reasonably required to carry on prospecting or mining operations.

3. The minerals constituting the bed or banks of the river and those situated within one-fourth mile of the bank of any river designated as a wild river are withdrawn from all forms of appropriation under the leasing and mining laws.

The Secretary of the Interior (or, in the case of National Forest System lands, the Secretary of Agriculture) shall effect regulations to provide, among other things, safeguards against pollution of the river involved and unnecessary impairment of the scenery within the component in question. To date, no wild or scenic rivers have been designated in NPRA.

Executive Order 11988, "Flood-plain Management," seeks to avoid to the extent possible the long- and short-term adverse impacts associated with occupancy and modification of flood plains and to avoid direct or indirect Federal support of flood-plain development whenever there is a practicable alternative. Under the order, agencies shall take action to preserve the natural and beneficial values of flood plains in carrying out their responsibilities for conducting Federal activities and programs affecting land use. Each agency shall determine whether a proposed action will occur in a flood plain. For major Federal actions significantly affecting the quality of the human environment, this evaluation will be included in environmental statements prepared under the National Environmental Protection Act (NEPA). Agencies shall consider alternatives to projects that have adverse effects or involve incompatible development of flood plains. If it is found that the only practicable alternative requires siting in a flood plain, the agency shall design the action to minimize potential harm to the flood plain.

The agency must notify the State and areawide clearing houses for the geographic areas affected. The notice shall include: 1) the reasons why the action proposed is to be located in a flood plain, 2) a statement indicating whether or not the action conforms to applicable State and local flood-plain standards, and 3) a list of the alternatives considered. Agencies shall also encourage and provide appropriate guidance to applicants to evaluate the effects of their proposals in flood plains prior to submitting application for Federal licenses or permits.

Executive Order 11990, "Protection of Wetlands," provides a comprehensive policy for wetlands protection for the entire Federal Executive Branch. Previously, protection was provided only by section 404 of the Federal Water Pollution Control Act, which required a permit from the Corps of Engineers for the disposition of materials in water of the United States.

The President, in furtherance of NEPA, has ordered that: 1) each Federal agency shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out activities and programs affecting wetlands, including but not limited to water and related land resources, planning, regulating, and licensing activities, and 2) each agency, to the extent permitted by law, shall avoid undertaking or providing assistance for new construction located in wetlands unless the head of the agency finds a) that there is no practicable alternative to such construction, and b) that the proposed action includes all practicable measures to minimize harm to wetlands which may result from such use. In making this finding, the head of the agency may take into account economic, environmental, and other pertinent factors.

Each agency shall also provide opportunity for early public review of any plans or proposals for new construction in wetlands, in accordance with Section 2(b) of Executive Order 11512, as amended, including the development of procedures to accomplish this objective for Federal actions whose impact is not significant enough to require the preparation of an environmental impact statement.

When federally owned wetlands or portions of wetlands are proposed for lease, easement, right-of-way, or disposal to non-Federal public or private parties, the Federal agency shall 1) reference in the conveyance those uses that are restricted under identified Federal, State, or local wetlands regulations; and 2) attach other appropriate restrictions to the uses of properties by the grantee or purchaser and any successor, except where prohibited by law; or 3) withold such properties from disposal.

In carrying out this order, each agency shall consider factors relevant to a proposal's effect on the survival and quality of the wetlands. Among these factors are:

1. Public health, safety, and welfare, including water supply, quality, recharge and discharge; pollution; flood and storm hazards; and sediment and erosion;

2. Maintenance of natural systems, including conservation and long-term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, wildlife, timber, and food and fiber resources; and

3. Other uses of wetlands in the public interest, including recreational, scientfic, and cultural uses.

The term "wetlands" includes those areas that are inundated by surface or ground water with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar areas, such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds.

B. State Requirements

Alaska Statutes Title 46, Water, Air, and Environmental Conservation, provides authority for many Department of Environmental Conservation standards and regulations. These standards and regulations include water-quality control, air-quality control, wastewater control, solid waste management, and oil and hazardous substances pollution control. State requirements do not preclude the adoption of more stringent regulations by local agencies. Alaska Statutes Title 16 provides authority for protecting fish and game, for regulating subsistence hunting, and for control over State game refuges and sanctuaries. The State may also designate and protect endangered species. The Alaska Department of Fish and Game may exercise some control over the use, lease, or other disposal of land under both private ownership or State jurisdiction within critical habitat areas.

The most significant State legislation aimed at preserving cultural values is the Alaska Historic Preservation Act of 1971. The act protects sites of historic interest against destruction from any State funded or licensed project. It also reserves for the State title to all historic, prehistoric, and archeological resources on State-owned land.

In general, Alaska's State-owned lands are subject to local planning and zoning controls. Alaska statutes require that "subdivisions of land made by the State * * * shall comply with ordinances and other local regulations [A.S. 40.15.200] * * *." Alaska Statute Section 35.10.020 requires that the University of Alaska and the Department of Public Works "shall comply with all local planning and zoning ordinances and the local regulations in the same manner and to the same extent as other landowners."

These two agencies have the general jurisdiction over all State construction of buildings, and thus the law for all practical purposes covers all State agencies. However, the Governor may waive this requirement if there is an overriding State interest.

Leased lands within the jurisdiction of an authorized zoning authority must comply with the applicable zoning regulations. Accordingly, the State's leases at Prudhoe Bay must now conform to land use planning, zoning, platting, and similar regulations of the North Slope Borough. The land has been zoned for industrial uses including petroleum production.

C. Local Requirements and Policy

The State Legislature authorized the creation of organized boroughs in 1963. In 1972 the North Slope Borough was incorporated, and in 1974 the North Slope Borough adopted a Home Rule charter. As a Home Rule borough, the North Slope Borough gains its authority to regulate land use development via Alaska Statutes Title 29 (Municipal Government), Title 40 (Lands), and its own charter. Local control of land use is provided by zoning and subdivision ordinances. State law provides for State compliance with local (Home Rule) planning and zoning.

Under the Federal supremacy clause of the United States Constitution, the Federal Government is exempt from compliance with local planning and zoning laws. Thus, most of NPRA lands are not legally subject to borough planning and zoning regulations. Because certain boundaries of NPRA on the Colville River and along the coast near Barrow are not yet defined, regulatory authority in these areas may be decided through litigation.

The North Slope Borough has adopted a subdivision ordinance and a zoning ordinance. The main purposes of the zoning ordinance are to keep additional new communities from developing in the borough and to provide separation of industrial operations from residential areas.

All of the village-selected lands around Anaktuvuk Pass, Atkasook, Barrow, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright are zoned "RD" (Rural Development). This zoning district permits all land use activities except uses

> that may be noxious, injurious or hazardous to surrounding property or persons by reason of the production or emission of dust, smoke, refuse matter, odor, gas fumes, noise, vibration, or similar substances or conditions; provided, however, that this section shall not be construed to prevent or unduly restrict the exploration, development, production, processing and marketing of oil, gas and associated substances, other minerals and materials and activities associated thereto so long as such operations are carried on in a manner consistent with applicable Federal and State standards with respect to environmental quality [B.C. 19.24.040].

Lands in the Prudhoe Bay development area are zoned "RI" (Resource Industrial District). This zoning classification prohibits the following uses:

> all single family or multifamily dwellings, mobile homes, trailers, and boarding houses, lodging or rooming houses, trailers, or other living quarters on a permanent or semipermanent basis except as accessory uses to the development of natural resources pursuant to the rights granted under the provisions of a Federal or State oil, gas, mineral or materials base [B.C. 19.24.040].

The North Slope Borough's Department of Conservation and Environmental Security is responsible for policy directed at protecting the land against any harmful results of Arctic energy and resource development. The following information is from a formal statement by the Director of the Department (Neakok, written communication, 1976):

> It is the policy of the North Slope Borough to recognize the inevitable development of Arctic energy and mineral reserves, and the threats to our environmental security posed by this development.

The NSB opposes permanent immigration to the Arctic and the creation of permanent oil field communities. Public use of the Fairbanks-Prudhoe oil pipeline haul road is also opposed.

The NSB's environmental protection policy is carried out through four points of management: 1) Arctic coastal zone management in cooperation with State, local, and Canadian governments; 2) surface disturbance management aimed at the protection of environment and conservation of traditional land use values; 3) game management to improve arctic game management through the use of modern technology and traditional hunting skills; and 4) arctic environmental research management to lead and organize a sustaining program of national and international scientific research and cooperation able to deal with the Arctic as a whole.

The NSB's Planning Department documents traditional/historical use of Beaufort coastal zone lands that might be affected by offshore and NPRA oil operations. The borough's intention is to designate industrial development and historic use zones. Historic sites identified by the borough may also be deemed eligible for nomination to the National Register.

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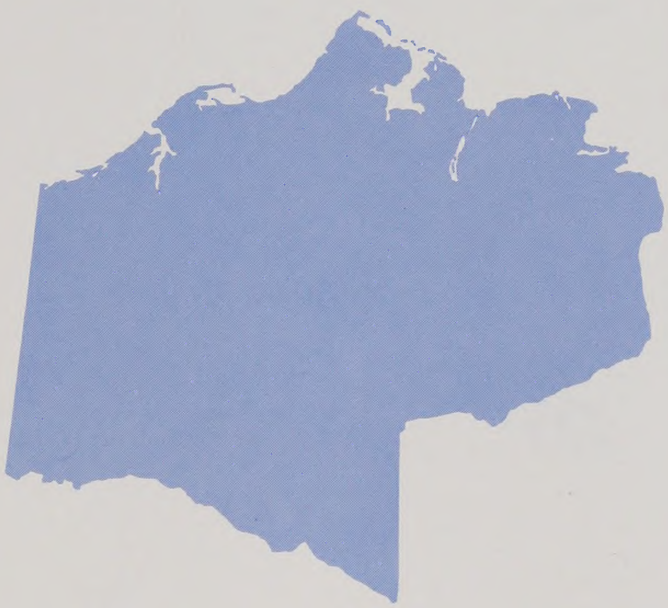
Appendix C

Current and Standard Practices



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I. Development and Production

Practices that have been developed in the Prudhoe Bay oil field and on the Trans-Alaska Pipeline System (TAPS) are well documented. Close observance and improvement in planning for the development, production, and transportation of oil and gas within NPRA and for transportation and distribution from NPRA to refineries and markets have been part of that project. Building on experience is especially important in the arctic environment, where, except for experiences of the Soviet Union in western Siberia, the experiences of Prudhoe Bay and TAPS make up the bulk of our knowledge and present-day technology.

Drill rigs and production facilities used in arctic oil field development are basically the same as those used in other environments. However, special protection for workers and, in some cases, heat to the machinery must be provided so that both people and machinery can function; drill rigs, production facilities, and oil and water pipes are commonly heated and insulated against the extreme cold. Table C-1 lists facilities common to all oil fields and their distinctive characteristics in Arctic regions.

Prudhoe Bay workers have adapted drilling and production techniques used in northern Canada and other northern climates to meet the special challenges of cold and permafrost. The possibility of failure of components and the difficulty and cost of immediate repairs dictated that safety factors and backup systems have higher standards than those for most temperate climates. After special techniques for drilling and cementing casing in permafrost were developed in the Prudhoe Bay field, the drilling of exploratory wells in the permafrost in NPRA became more routine.

The Prudhoe field wells each produce an average of 10,000 barrels of oil per day; the gas-oil ratio is 700 cubic feet per barrel, and the oil has a very low moisture content. The gas is injected into the gas cap to maintain reservoir pressure, and water is injected to enhance oil recovery.

A. Support Facilities

1. Buildings and Structures

Major camps at Prudhoe are self contained; they include water and sewage treatment plants, generator plants, auto repair shops, and vehicle storage buildings. The drilling rigs at the well sites are also self-contained camps with their own water and sewage treatment plants, but on a smaller scale to accommodate an average of 60 people. Buildings are typically insulated and elevated.

The buildings are of rigid-frame construction insulated with 2-inch-thick (5-centimeter-thick) urethane bonded to both the exterior and interior metal surfaces of the walls and roof. The buildings are also designed to resist wind pressures up to 40 pounds per square foot (195 kilograms per square meter) and earthquake forces as high as 5.5 on the Richter scale. The floors are of steel and elevated on steel pilings or of reinforced concrete elevated on wood pilings. The steel pilings are capped with concrete to retard the transfer of heat from the building to the permafrost. Both wood and steel piles are set in holes as deep as 50 feet (15 meters) and bonded in place with a gravel-water slurry that freezes and expands, stabilizing the pilings in the permafrost. The number of piles used is determined by the load to be supported.

Most buildings are elevated 5 feet (1.5 meters) above a 3- to 5-foot-thick (1- to 1.5-meter-thick) gravel pad. This provides air circulation under the buildings, which protects against heat transfer from building to the pad; it also allows snow to blow away rather than drift. Some of the housing units at Prudhoe have the lower 5 feet (1.5 meters) of the longer sides contoured at 45^{o} angles to create a venturi effect and assist the natural flow of the wind.

Modular building units fabricated in the conterminous United States and barged to the North Slope from the west coast have proved to be more durable and economical than buildings constructed at the site. The living facilities are similar to those of modern motel units, except that the walls are about 8 inches (20 centimeters) thick and the doors are air tight with electrically heated interface surfaces to prevent ice locking. All modular units are elevated and supported by sponsons, support elements of "legs" that require minimal connections to the foundation. They are an integral part of the structure, providing support to the unit during transportation and effectively distributing the weight of the unit on the ground.

The living units at the Prudhoe camp are of compact design to save energy and reduce construction costs. The Atlantic-Richfield (ARCO)/Exxon facility is a two-story complex constructed in two phases. The first phase consisted of three 40- by 125-foot (12- by 38-meter) wings that house 204 people in double occupancy. The second phase consisted of four 38- by 100-foot (11.5- by 30-meter) wings that house 224 people. The SOHIO-British Petroleum (BP) Alaska facility is a 137,400-square-foot (12,760-square-meter) three-story facility that accommodates 264 people. At Prudhoe Bay, both single and double occupancy living quarters are provided for 700 operations personnel and 2,750 construction workers.

2. Powerplant

Prudhoe Bay operations are served by one central powerplant of 159 megawatt (MW) capacity. This plant provides electricity for the two field operators, the ARCO and SOHIO-BP Alaska. Both the powerplant buildings and the generating units are modular to facilitate construction, provide flexibility, and reduce costs. The generators are driven by gas turbines which are compact, reliable, and easily maintained. The Prudhoe powerplant consists of two 16-MW units, five 24-MW units, and several auxiliary and standby units that total 7 MW. The units are housed in three 37- by 1,176-foot (11- by 358-meter) buildings and controlled from a separate 37- by 102-foot (11- by 31-meter) building. All buildings are connected by covered walkways, are elevated, and have an insulating pad beneath to protect the permafrost.

Table C-1. Facilities Common to Oil Fields and Comments on Their Distinctive Characteristics in Arctic Regions

Facility	Comments
Camps (self-contained)	Sewage treatment plant. Water treatment plant. Generator plant. Auto repair shop. Vehicle storage buildings.
Buildings (office, living, dining, medical, recreational, drilling rigs)	Modular. Insulate against 100-mile (60-kilometer) per hour winds. Insulate against low temperatures (-70°F or -57°C). Insulate to avoid melting permafrost (on pads, sponsons, pilings).
Electric power	159 megawatt at Prudhoe Bay.
Airfields:	
All weather	5,500 feet (1,677 meters) long. All-gravel pad, or insulating mat-gravel.
Winter use only	Frozen lakes.
Roads and trails:	
All weather	Large gravel requirements.
Winter trails	Compacted snow, 10-20 inches (25-50 centimeters). Ice. Problems of shortage of snow and water.
Storage areas	5-foot (1.5-meter) gravel base. 20 acres (8 hectares). Warehouse.
Drill sites	Gravel pads, 5 feet (1.5 meters) thick. Mud pits. Multiple wells from single site.
Compressor plants (natural gas)	Gravel pad.
Flow stations	Gravel pad. Elevated building, 70,000 square feet (6,500 square meters), set on piles.
Gathering lines	High-strength steel pipe (60,000 psi minimum yield strength). Withstand temperatures of -70°F to 90°F (-57°C to 32°C). Pipe insulated with 2-4 inches (5-10 centimeters) of polyurethane and covered with protective wrap. Pipe mounted on steel pilings 2-3 feet (0.7-1 meter) above ground surface.

The SOHIO-BP and Atlantic Richfield camp facilities at Prudhoe Bay represent the highest "state of the arts" in arctic construction. The only birch trees north of the Brooks range are housed in the SOHIO-BP base camp. (Mary Aho, AEIDC)

Power is generated at 13.8 kilovolts (kV), stepped up to 69 kV by transformers, and transmitted by pole-supported transmission lines to various parts of the development. The length of the transmission lines and the power requirements determine the transmission voltage.

One electrical construction problem in the cold environment is a loss of ductility in metal at low temperatures. This has been mitigated by the use of improved materials. "Frost jacking" (ejection) of the transmission line poles has been controlled by setting the poles well below the active (freezing and thawing) layer of the permafrost.

Transmission lines are designed to minimize equipment failures. "Grounding" of electrical equipment continues to be difficult because of the high resistivity (about 30,000 ohms) of the ice and permafrost. If a transmission line touches the ground, dangerously high voltage may build up on buildings and equipment because the high resistance of the ice and permafrost impedes discharge.

3. Airfield

The Prudhoe Bay airfield has one runway, oriented 40°–220°. The runway is 5,500 feet (1,676 meters) long and 50 feet (15 meters) wide and is underlain by a 5-foot-thick (1.5-meter-thick) gravel pad. The runway has medium intensity lighting. The north apron is large enough to accommodate five Boeing 727's, the south apron, two 727's. Both ARCO and SOHIO-BP operate hangars capable of accommodating aircraft as large as Twin Otters.

4. Roads and Trails

Permanent roads in the Prudhoe Bay field have a minimum 5-foot (1.5-meter) gravel base and a driving surface 24 to 30 feet (7 to 9 meters) wide. Experience will show if the 5-foot-thick (1.5-meter-thick) gravel base is thick enough to prevent thawing of the permafrost. Side slopes are constructed to have a horizontal-to-vertical ratio of 3:1. Roadway curves (excluding intersections) are 5° or less. The grades are held to 3° or less to ease the movement of heavy modular units.

Some of the first roads built at Prudhoe Bay had gravel bases of only 2 or 3 feet (about 1 meter). That thickness of gravel did not adequately protect the permafrost, and the roads subsided. These roads are being salvaged by increasing the base to a minimum of 5 feet (1.5 meters). The Kuparuk field, 45 miles

(72 kilometers) from the Prudhoe Bay field, was developed with roads having 3- and 3.5-foot (about 1-meter) bases. This minimal road base, which may not adequately protect the permafrost, is used to reduce initial costs because the field may not prove to be economical. The roads to the Kuparuk oil field are being upgraded to 5 feet (1.5 meters).

B. Operational Facilities

1. Well Site

Directional drilling from multiple well sites is the only accepted method for developing proven onshore Alaskan North Slope petroleum reserves. Both ARCO and SOHIO-BP Alaska drill multiple wells from a single well-site pad. This practice reduces rig moving cost, permits concentration of surface facilities in a small area, and minimizes environmental disturbance. The road network area and the number of pads are also reduced.

On a typical well-site pad as used by SOHIO-BP Alaska, seven wells can be drilled from a 488- by 960-foot (148- by 293-meter) pad. Individual wells are located in a line and spaced 110 feet (33 meters) apart. This configuration allows maximum utilization

The first arctic roads were built with insufficient insulation of the permafrost, resulting in severe slumping. (G. J. Ferrians, U.S. Geological Survey)

of the pad while providing ample separation for the drilling activities. If additional wells are required, the pad is extended sufficiently along the line of wells to maintain the 110-foot (33-meter) spacing.

SOHIO-BP Alaska has drilled as many as 17 wells from a single pad and may increase this number to 20. Economics and terrain determine the number of wells drilled from a pad. The Prudhoe field well-site pads are constructed with about a 5-foot (1.5-meter) gravel base to protect and maintain the permafrost. Ideally, the pads go unused for about 1 year after construction in order to allow permafrost to become reestablished and form a solid foundation for the drill rigs.

SOHIO-BP Alaska drill rigs are supported by timber mats laid over the gravel base. For exploratory drilling in NPRA Husky Oil has used pile supports in addition to the 5-foot (1.5-meter) gravel base. Normally, the wooden piles are set into the permafrost to a depth of 25 feet (7 meters). Where heavier, deep-hole rigs (20,000-foot or 6,100-meter capability) are located, a combination of steel and wooden piles is set to depths of as much as 45 feet (14 meters).

Prudhoe field wells are drilled vertically through the permafrost, which is about 2,000 feet (610 meters) thick at Prudhoe. After penetrating the permafrost, the wells are directionally drilled to the desired location. Drilled holes commonly terminate within 50 feet (15 meters) of the target even though the hole bottom may be as much as 12,000 feet (3,660 meters) from the drilling site. Individual wells drilled from a single pad may tap 640, 320, or 160 acres (about 260, 130, or 65 hectares) or, on close spacing, as few as 80 acres (32 hectares) of the oil reservoir. The actual well spacing is largely determined by the thickness of the oil-bearing formation and its porosity and permability. In general, thick, freely yielding formations require fewer wells for acceptable oil recovery and return on the drilling investment.

Actual drilling of the borehole requires circulation of a special drilling fluid, called drilling mud, from a mud storage area, into the hole through the drill stem, and return to the storage area. The drilling mud floats drill cuttings to the surface as it circulates upward through the annulus between drill stem and well casing to the mud storage area. It also lubricates and cools the drill bit, and it controls formation pressure.

Drilling fluid is essentially water mixed with a swelling clay. The drilling fluid may be treated with a wide variety of chemicals to affect its viscosity and gel characteristics. When drilling stops, mud circulation may or may not be stopped. Where circulation stops, the gel strength of the mud must be sufficient to hold the cuttings in place.

The drilling fluid may also be treated with weighted materials to increase the density of the mixture. Density of the drilling fluid must be sufficient to overbalance the pressure of naturally occurring fluids in the hole and thus reduce the possibility of cave-in in the hole or of blowouts. The geostatic gradient may vary greatly where a closed reservoir, formed at great depths, has been uplifted by faulting and folding. Knowledge of such geologic conditions is critical because control of the density of the drilling fluid is the primary method of controlling blowouts. Drilling muds are stored either in metal tanks or pits. SOHIO-BP Alaska has used both in the development drilling of the Prudhoe field. The tanks store mud used in actual drilling operations, and a reserve mud pit stores excess mud generated from drill cuttings. The SOHIO-BP Alaska pits are 5 feet (1.5 meters) deep by 300 feet (91 meters) wide, and the pits extend the length of the drill site pads. The bottom of the pit is the surface of the tundra, and a 5-foot (1.5-meter) gravel berm confines the mud. Until recently, no plastic or rubber liner was used in the pit.

In the past SOHIO-BP Alaska constructed some mud pits by excavating the permafrost. This is Husky Oil Company's practice today in its exploratory drilling of NPRA. Husky's reserve mud pits are approximately 200 feet by 350 feet by 10 feet deep (61 by 107 by 3 meters). Depth is obtained by excavating the permafrost to a depth of 5 feet (1.5 meters) and constructing a 5-foot (1.5-meter) gravel berm. If ice is present, a filter layer of gravel is placed on the side of the pit to protect the ice from the hot mud. After plugging and abandoning a dry exploratory well, part of the pad is bulldozed into the reserve pit as temporary cover; recontouring is done in the winter.

2. Flow Stations

Much like those used worldwide, the flow station in use at Prudhoe field consists of a fluid separation system, water-handling facilities and gas facilities in which the mixture of oil, water, and gas as pumped from several well sites is treated and separated.

At each Prudhoe flow station the equipment is protected from the elements by an insulated, elevated building set on piles. The building occupies about 70,000 square feet (0.6 hectare). A gravel pad beneath the building protects the permafrost.

The produced fluid enters the flow station manifold, where the separation process begins. This manifold consists of the following:

1. A high-pressure oil separator and gas scrubber;
2. A heat exchanger (for heating or cooling the crude oil) located between the high-pressure and intermediate-pressure separator;
3. An intermediate-pressure separator; and
4. An emulsion treater and flash drum.

All units are equipped with emergency low-level–high-pressure safety shutdown controls and alarms. In case of an emergency, the oil and gas is diverted to the flare.

The separators separate the oil from the gas and the free water. They are designed to withstand specified pressures and to handle a specified maximum flow of gas and liquids. The scrubber is similar to a separator, performs the same function, and limits the amount of liquid carry-over into the gas stream. A heat exchanger maintains the crude oil at the temperature for further separation and process control. On startup, for example, the oil may be cold and require heat to minimize foaming. As flow is established, and under high-flow conditions, the produced oil may require cooling. Free-produced water is drawn off from the intermediate separator to the drum. The flash drum is a third stage of separation at lower pressure. The oil and water emulsion from the flash drum is passed through a heater treater, where, as the name implies, heat and chemicals are added to break the emulsion into its two components. After separation from the gas and water, the crude oil is moved by electric or gas turbine-driven centrifugal pumps to the main pipeline terminal or shipping point.

Gas is gathered at the flow stations, cooled to remove the gas condensate, brought in contact with glycol to remove the water, and allowed to flow to the central compressor plant. There, except for

Blowouts are prevented by regulating the density of drilling fluids during drilling operations. (U.S. Geological Survey)

field fuel use (camp facilities, electric powerplant, flow stations and outside local customers), the gas is compressed to 4,500 pounds per square inch (psi) and pumped back into the reservoir. This is done to conserve the gas and also to maintain reservoir pressure, which results in a greater percentage of recovery of the oil in place.

Flow station gas processing and delivery to the central compressor plant is the same whether or not the gas is used in powering gas turbines, pump stations, and other field activities. At the compressor plant sale gas would likely be routed to the gas processing area for carbon dioxide (CO_2) removal and dewpoint control after passing through separators and coolers. Hydrocarbon liquids removed during the gas processing would be used for local fuel in the CO_2 process, and heavier hydrocarbons would be comingled with the produced crude oil and delivered to the transportation point. After processing the gas for CO_2 removal and dewpoint control, the gas could be either compressed to 1,200-1,600 psi and transmitted by pipeline or it could be liquefied. Facilities for the latter method are more expensive, and energy (gas) is used inefficiently in processing the gas. To compress the gas, centrifugal compressors driven by gas or electric turbines would be used. They form compact, reliable, easily maintained units that are well suited for remote locations.

The salty water produced by the separation process is treated to remove undesirable solids and chemicals, and then injected either into a shallow disposal sand or back into the oil-producing formation. Water lines from the flow station to the injection wells must be heated and insulated to prevent freezing. The water passing into the disposal sand has little effect on permafrost and can be cooled before injection. Also, the disposal wells must be equipped with a glycol-water circulating system to prevent freezing if the system is shut down. Wells for injecting the water into disposal sand are usually located near the flow station. Wells for injecting the water back into the formation are usually located in a specific centralized area which may or may not be near the flow stations. The exact location is determined by reservoir engineers. All injection wells are similar to producing wells in drilling and casing design. Injection wells commonly become clogged. Clearing a clogged well requires flushing (pumping and surging), chemical treatment, or a combination of both.

For the most part, very little water has been generated from Prudhoe production wells. Nevertheless, as a reservoir is depleted, the volume of produced water commonly increases, and the emulsion formed between the produced water and oil may be difficult to break down even with the assistance of heat and chemicals.

3. Compressor Stations

The gas from all the flow (gathering) stations in the Prudhoe field flows to the central gas compression plant where, with the exception of field fuel gas, it is compressed and injected back into the formation. The gas is separated from the oil in three stages at pressures ranging from atmospheric to 600 psi. The gas at pressures below 600 psi is boosted to 600 psi by a single 15,000-horsepower (hp) gas turbine-driven centrifugal compressor at each of the three ARCO flow stations (with a similar unit on standby at each station); and by two 4,000-hp and two 1,500-hp centrifugal compressors at the SOHIO-BP Alaska gathering stations. The gas is compressed in two stages from 600 psi to 4,500 psi. The first-stage compressor system consists of eight parallel compressor trains. Each train comprises a suction scrubber to remove any liquid water or hydrocarbons, a 22,500-hp compressor, and an interstage cooler. Gas is received at 600 psi and discharged at 2,150 psi. The second-stage compressor system consists of four parallel compressor trains. Each train comprises a suction scrubber, a 22,500-hp compressor, and an aftercooler. Gas is received at 2,150 psi and discharged at 4,500 psi at 140°F (60°C).

The injection gas flows from the second-stage compressors into a header and from there through 10-inch, 0.625-inch-wall pipe and 6-inch, 0.432-inch-wall pipe to the injection wells. The wells are completed with 7-inch tubing capable of transmitting as much as 100 million cubic feet per day. Two injection wells penetrate the gas cap so that gas can be withdrawn if required for startups. All wells are equipped with surface and subsurface safety valves, low-pressure alarm systems for the hydraulically operated safety valves, and a high-pressure alarm system in the casing annuli.

4. Pipelines

Pipelines are used to transfer crude oil produced at the well heads to the gathering (flow) stations and to transfer the separated oil, water, and gas from the gathering stations to their destinations. The rate of flow from individual SOHIO-BP Alaska Prudhoe field production wells, which are typical of Prudhoe field oil production, averages 10,000 barrels of oil per day (BOPD). Total daily production for SOHIO-BP Alaska wells is about 600,000 BOPD. The individual flowlines from the well-site well heads to the three SOHIO-BP Alaska gathering stations are 6 inches in diameter. After separation, the oil is transfered in a single pipeline from the gathering stations to TAPS Pump Station No. 1. The diameter of the oil pipeline increases from 24 to 34 inches where production from the gathering stations is introduced. The separated produced gas is likewise transmitted in a single line but at the central gas compression plant. The diameter of this line increases progressively from 24 to 34 to 38 inches, handling about 400 million cubic feet per day.

The Arctic's extremely low temperatures necessitate special strength pipes, valves, fittings, and other materials for the field pipeline system. The pipes are high-strength steel with 60,000 psi minimum-yield strength, modified to have a high impact strength at low temperatures while conforming to other standard specifications. In addition, the material must withstand temperatures ranging from -70° (-56°C) for startup to 190°F (87°C) while in operation. Expansion loops, which compensate for the expansion and contraction of the pipelines with changes in temperature, are designed into the system. All pipelines — oil, gas, or produced salt water — are insulated with 2 to 4 inches (5 to 10 centimeters) of polyurethane foam and covered with a protective wrap. The insulation maintains the oil in a high temperature — low viscosity condition, thus controlling condensation of gas and water. The saltwater line also contains a heating element throughout its length to prevent freezing. The pipelines are mounted on pipe supports designed to withstand vertical loads, lateral forces, and horizontal forces. At river crossings the supports are designed to withstand lateral ice forces. Earthquakes of magnitudes up to 5.5 on the Richter scale are also considered in the design of supports. To prevent heat transfer to the tundra and to reduce drifting of the blowing snow, the pipelines are elevated by the supports from 2 to 3 feet (about 1 meter) above the level terrain. However, even though the pipe is elevated where the pipeline access pad (road) lies parallel to the pipeline, snow can drift around the pipes.

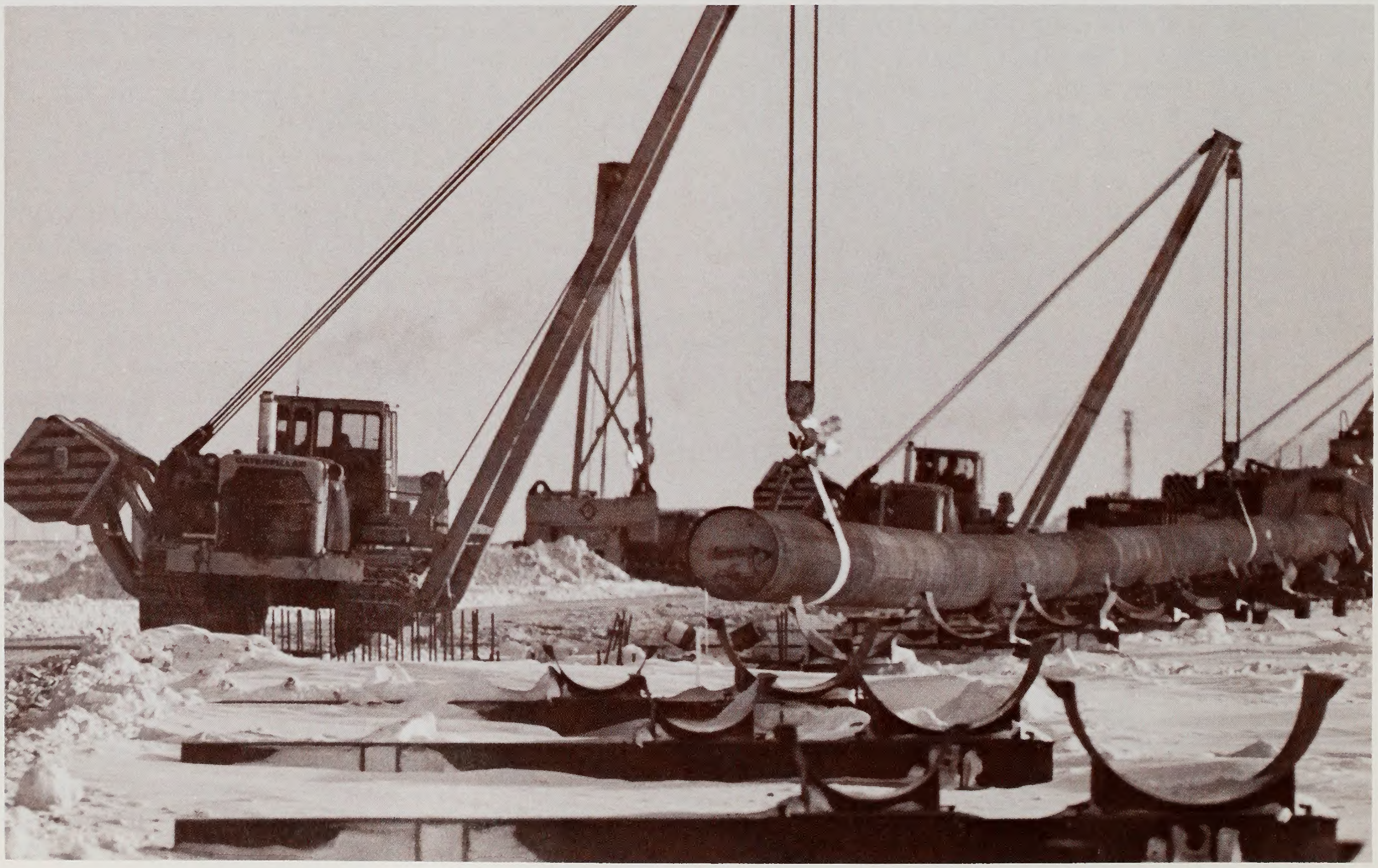
The pipeline supports consist of steel piling and structural steel crossbeams, with each support having at least one pile penetrating the frost to a depth of 16 feet (5 meters) below the ground surface.

Construction pads parallel all pipelines. These all-season limited-access pads (roads) are used to construct and maintain the pipeline. They have a 24-foot (about 7-meter) crown and at least a 4-foot (slightly more than 1-meter) gravel base. Where pipelines cross roads or at caribou ramps, the pipe passes through an open-ended casing for protection and for minimizing heat loss to the surrounding gravel and tundra. The protective casing rests on an insulating pad to maintain the permafrost in a frozen condition. Road crossings require a minimum of 3 feet (1 meter) of gravel over the casing and for heavy loads timbers have to be added to the gravel fill. Caribou crossings are gravel ramps that have gentle slopes (6:1 ratio, lateral to vertical distance) and guide deflector fences. Selected natural drainage patterns in the field area are maintained by appropriately placed culverts.

All pipelines, including the large-diameter oil and gas transmission lines, have flow control devices. Pressure-relief systems prevent pressure buildups in the lines, and block valves isolate line sections that are damaged or affected by a power failure. Check valves that automatically prevent a reverse flow are included at appropriate locations.

In the Prudhoe field construction, none of the pipelines were buried below ground level even for road and caribou crossings, nor were the pipelines elevated for caribou crossings. This differs from the Trans-Alaska Pipeline System, where the pipeline was buried where possible.

Due to the harsh environment, welding in the winter is done inside portable buildings through which the pipes are pulled. (Atlantic Richfield Company)



II. Transportation and Distribution

A. Pipelines

1. Stipulations

Pursuant to the Trans-Alaska Pipeline Act (P.L. 93-153), the Department of the Interior specified design and construction stipulations as part of the grant of right-of-way. The stipulations addressed the preservation and protection of the environment but not the sociocultural or economic concerns.

The stipulations included general statements on the following concerns: surface disturbance; clearing, site preparation, and timber appraisal; erosion and drainage control; restoration and revegetation; esthetics; archeology; river and flood-plain activities; fish and wildlife; solid waste disposal, sewage treatment; water quality and supply; air quality; fuel handling and spills; pesticides and chemicals; environmental briefings; snow pads; and safety. Several organizations helped maintain compliance with the stipulations.

The Alaska Pipeline Office (APO) administered activities on Federal lands; the State Pipeline Coordinator's Office (SPCO) administered those on State lands. Under both the APO and SPCO was the State-Federal Fish and Wildlife Advisory Team. The APO employed technical support contractors (TSC's), including one for arctic engineering, one for pipeline technology, and one for protection of the environment. The permittee, Alyeska Pipeline Service Company, submitted plans for its operations, including its plan to mitigate environmental impacts. The plans were reviewed by SPCO and APO, and changes, modifications, and restrictions were incorporated. Based upon the results of this "design review," the permittee provided the constructors with a series of procedural handbooks which were subsequently modified or supplemented in response to field realities. Field direction, compliance monitoring, and advice were provided by a multidisciplinary field group consisting of an SPCO representative on State land and others under the direction of the APO on Federal land. In a number of instances, special environmental studies were undertaken in response to unforeseen problems.

The TAPS experience provides a basis for future arctic projects; in some areas improvements can be made. In terms of the Presidential Study and NPRA, the TAPS problems suggest that new mitigative policies or better definition of existing policies may be developed. For example, problems and spills associated with the startup of TAPS indicate the need for a formal systems-safety evaluation of all future arctic transportation systems.

The environmental stipulations did not precisely define "compliance." Consequently, field monitoring personnel were required to judge whether or not a specific mitigative action would result in the achievement of the objectives stated in a stipulation, and interpretation of compliance was a subjective determination made by field surveillance personnel. Lack of firm definitions led to inconsistent application of the stipulations. Ambiguous wording such as "as soon as practical" and "in a timely manner" conveyed little direction to the contractors. For example, time limits could have been specific for fish and wildlife constraints, snow pad utilization, initiation of erosion control and revegetation, and corrective actions on noncompliances.

A full description of the stipulations applicable to the construction and operation of TAPS is given in "Agreement and Grant of Right-of-Way for Trans-Alaska Pipeline between the United States of America and Amerada Hess Corporation, ARCO Pipeline Company, Exxon Pipeline Company, Mobil Alaska Pipeline Company, Phillips Petroleum Company, Sohio Pipeline Company, and Union Alaska Pipeline Company" (Alyeska Pipeline Service Company, 1974) and are summarized in "Federal and State Stipulations Governing the Trans-Alaska Pipeline System," a small pocket-size booklet published by Alyeska, Bechtel, and Fluor Alaska, Inc. (1974).

2. General Construction Practices

Winter road or trail construction was to be permitted only after seasonal frost was 12 inches (30 centimeters) deep and average snow depth was 6 inches (15 centimeters), usually in late October in the Arctic. Such construction was to stop when snowmelt began in the daytime, usually in early May. In practice, most construction was carried on after late February and until November because of the rigorous conditions during December, January, and early February. Prolonged darkness, intense cold, and generally hostile weather made construction during this latter period impractical. However, the freighting of supplies by barge and tractor-train has been carried on for years in winter months. In NPRA all petroleum exploration has been conducted throughout the winter.

Snow roads were difficult to construct because the snow cover is both variable and ephemeral. Snow once gathered for a road must be immediately packed to keep it from blowing away. Snow fences have been

Empty oil barrels at abandoned sites were a scenic eyesore. During recent summers they were removed by clean-up crews using Rolligons. (Atlantic Richfield Company)

utilized to help trap snow for use as water supply and snow roads. At least once, snow blowers were effectively utilized to supply snow for roads on the TAPS project. Ice roads are currently in use in the petroleum exploration phase of NPRA.

Vehicles operating in summer on the tundra on tires or tracks were supposed to maintain less than 3.5 psi ground-bearing pressure, according to the Bureau of Land Management requirements.

Gravel pads without artificial insulation were required to be 5 to 6 feet (about 2 meters) thick. Pads with artificial insulation could be as little as 2 feet (0.6 meter) in total thickness. This base consisted of a thin basal layer of gravel to mask the irregularities in the tundra surface, 2 to 4 inches (5 to 10 centimeters) of styrofoam, and 15 inches (38 centimeters) of gravel on top. The efficiency of road fill designs, with or without insulation, has not yet been demonstrated over a long period of time. Where the thermal regime would not be affected, such as on rocky ridges or gravel bars, the gravel pad might not be required for insulation.

Frozen lakes have long been used as winter airstrips. A 4-foot (1.2-meter) thickness of ice is sufficient to land the largest of the planes currently used in freighting in the Arctic. Snow on the ice, which retards freezing of the lake water, may be scraped away to speed up the freezing time; this practice, however, may increase winterkill of aquatic organisms.

a. **Pipeline Specifications**

On the TAPS project, elevated pipelines were required where rock materials below the centerline of the pipe were frozen and contained more than 6 percent of silt- or clay-size material (50 percent or more of the material passes the 200-mesh sieve according to the Unified Soils Classification). On this basis, a requirement for an elevated mode on the coastal plain within NPRA for a hot oil pipeline is not a certainty, but the elevated mode would likely be extensively used. At the Colville River where the silt and clay content of the upper 50 feet (16 meters) would most likely be less than 6 percent, a buried pipeline might be permitted.

In the elevated mode, the pipe is supported on vertical support members (VSM's), and the pipe must be a minimum of 2 feet (about 0.6 meter) above the ground surface. Sagbend game crossings are allowed if it can be demonstrated that there would be less than 2 feet (about 0.6 meter) of ground settlement if the buried pipe were to melt the permafrost.

The pipe at these localities is still placed on VSM's, but the whole configuration is buried just below the ground surface. The sagbend game crossings are 60 to 70 feet (18 to 21 meters) wide. Game crossings are also provided by elevating the pipe 8 feet (about 2.4 meters) above the ground surface for 100 feet (30 meters). The elevated pipe is insulated.

In the buried mode within permafrost, a trench with a minimum depth of 8 feet (2.4 meters) is excavated both by blasting and with a backhoe or bucket-trencher. At some river crossings on the TAPS project, the pipe was buried 22 feet (7 meters) below ground surface to get beneath the potential depth of scour. The trench is backfilled with selected material around the pipe to lessen the chance of a large boulder or cobble damaging the protective coating on the pipe (and initiating consequent corrosion) or causing a dent that might reduce structural strength or prevent passage of the pipeline "pigs." A minimum of 4 feet (1.2 meters) of cover was placed over the pipe. The pipe in the buried mode was wrapped to guard against corrosion, and selected segments were insulated. Buried pipe was also protected from corrosion by sacrificial anodes placed at intervals along the pipe length.

Gas would be transported via pipeline at subfreezing temperatures, allowing for maximum gas flow for the energy expended in compressing and moving the gas. In permafrost regions in Russia, cold gas lines are buried only in areas of low ice content to avoid frost heaving.

Radiographic inspection was required for all welds on the 48-inch pipeline but not for all welds in the TAPS system. Shut-off valves were located with respect to hazardous areas.

b. Stream Crossings — Roads and Pipelines

Where pipelines were buried at stream crossings, allowance was made for river scour. At the point of maximum scour, the cover over the pipe was required to be at least 20 percent more than the computed scour but not less than 4 feet (about 1.2 meters). The TAPS pipeline was built to withstand the project design flood, which was in excess of a 100-year flood. Culverts and bridges were built to accommodate 50-year floods on the larger rivers. Stilling basins were constructed at the outflow end of culverts, and the pool sides were stabilized with riprap. Riverbanks and pipeline fill in flood plains were also stabilized with riprap.

Temporary access over streambanks was made through use of fill ramps rather than by cutting through streambanks.

c. Fish and Wildlife Protection

Any artificial structure or any stream channel change that would cause a blockage to fish movements was required to have a fish passage structure or other similar facility that met all Federal and State requirements. The stipulation also provided that if material sites were approved adjacent to or in certain lakes, rivers, or streams, the Authorized Officer could require permittees to construct levees, berms, or other suitable means to protect fish and fish passage and to prevent siltation of streams or lakes. Provision was also made for the protection of wildlife mobility and migration.

d. Water Supply

Attempts to locate good, potable sources of fresh water in Arctic regions were met with little success. At Prudhoe Bay, artificial deep lakes were excavated on an abandoned part of the flood plain of the Kuparuk River. These are currently being used for year-round water supply. They are refilled naturally during the summer by meltwater. Other reservoirs have subsequently been utilized in the Sagavanirktok River and Big Lake.

e. Sewage and Solid Waste Disposal

All wastes generated in construction, operation, and maintenance, and termination of the project were to be removed or otherwise disposed of in a manner acceptable to the Authorized Officer. In practice, package plants with flow control management reservoirs (sewage lagoons) were used. However, there has been leakage, with subsequent pollution of surface water and associated thermal erosion of permafrost. Solid wastes, including sewage sludge, were burned. The unburnable solids were placed in disposal sites, such as old material sites.

f. Material Sites

The permittee was required to obtain written approval before gravel could be extracted. Written approval for these material and disposal sites was required because such lands were not part of the grant of right-of-way.

Special Land Use Permits were given, and auctions for gravel used by Alyeska were held by the Bureau of Land Management.

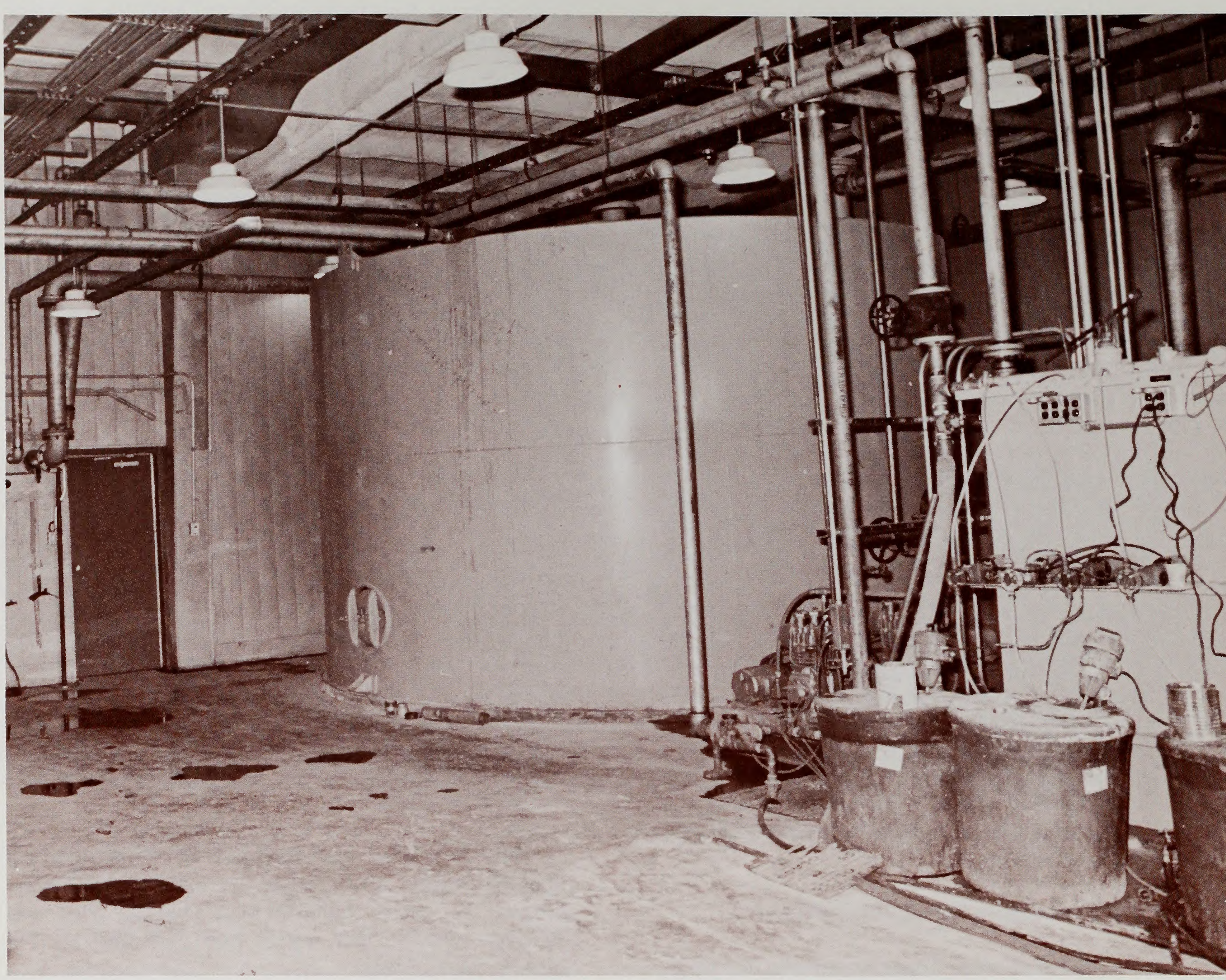
Thawed gravels were the most desirable material for construction; however, these were available in large quantities only in the flood plain of the Sagavanirktok River. Nevertheless, frozen gravels occur in numerous river and stream terraces. They were ripped and either allowed to thaw in progressive stages or utilized in the frozen condition.

For locations where there was overburden, the stipulations required that surface materials be stockpiled and utilized during restoration. Stabilization practices included seeding, planting, mulching, and placement of mat binders, soil binders, rock or gravel blankets or structures.

Sand confinement techniques are currently being studied as part of the exploration phase of NPRA. Sand could be an alternative aggregate source within NPRA.

g. Erosion Control

For the TAPS project the companies had drawn up plans and designs for control of erosion on almost every type of slope and drainage condition encountered in the Arctic. Each situation required a special solution involving cut or fill, culvert, bridge, low-



Deep artificial lakes have been created to insure a sufficient water supply. Pictured here are the water treatment facilities at Prudhoe Bay. (Grossman-Granger Productions)

water crossing, or the like. A full description of erosion control procedures was written for the Erosion Control Field Manual, Report No. Er-002.5A, published by Alyeska Pipeline Service Company (1975).

h. Slope Stability

Areas subject to earth movement phenomena, such as mudflows, landslides, avalanches, and rockfalls were to be avoided. Where avoidance was not practicable, the permittee was required to provide measures to prevent earth movement or protect the facility. Such mitigation included excavation and removal of unstable materials, monitoring potential slide areas, and using engineering techniques to stabilize slopes if they became hazardous.

i. Antiquities and Historical Sites

An archeologist was required to inspect construction sites for archeological significance. If paleontological, archeological, or historical sites were encountered, the archeologist was to be notified and protection measures were to be taken. The operations could be suspended if necessary to preserve evidence pending investigation of the site. However, during the operation of heavy equipment, such sites often were unnoticed and were destroyed.

j. Oil Spills

Containment dikes were required around all fuel handling and storage areas. The permittee was required to give immediate notice of an oil spill. The companies developed oil spill contingency plans to handle spills, including guidelines as to the most efficient means of handling the spills in various environments. A detailed description of the contingency plan is given in "Oil Spill Contingency Plan," by Alyeska Pipeline Service Company (1978).

k. Air and Water Quality

Permittees were required to perform all activities in accordance with applicable air- and water-quality

Although feeding wild animals is prohibited, people do not always comply. (Atlantic Richfield Company)

standards pursuant to the Clean Air Act and the Federal Water Pollution Control Act.

l. Other

Public access was restricted during construction. No hunting, fishing, or related activities were permitted within 5 miles (8 kilometers) of TAPS during construction. Restrictions also covered animal feeding and keeping of pets. No construction activity in connection with the project was conducted within 0.5 mile (0.8 kilometer) of any officially designated Federal, State, or municipal park, wildlife refuge, research or natural area, recreation area or site, or any registered National Historic Site or National Landmark.

The permittees were required to remove all improvements and equipment except as approved by the Authorized Officer, and revegetation was required on all disturbed sites unless it was biologically not feasible. However, the permittees were not required to "pick up and remove" gravel from workpads or access roads. Exceptions were made for the work pads in the flood plain, for reshaping a work pad to provide a year-round trafficable roadway to avoid interference with surface runoff and drainage, and for certain access roads, which were assessed as visual impacts, to be terminated and restored.

Complete channel restoration was required at all stream crossings; bridges were to be left as permanent structures. Where culverts were to be left as permanent structures, partial channel restoration was required above and below the installation.

B. Marine Tankers

The world's tanker fleet capacity has greatly expanded in recent years, principally through a major use of supertankers for oil shipments and the development of the liquefied natural gas (LNG) trade.

The United States tanker fleet is the seventh largest worldwide, numbering 218 ships. It has a total capacity of approximately 7.4 million dead-weight tons (DWT) and comprises less than 4 percent of world tanker tonnage (U.S. Department of Commerce, Maritime Administration, 1978). Domestic shipment of oil within the United States will grow substantially by 1980 principally because of the introduction of new production from Alaska, estimated to reach 2 million barrels per day by 1980. Since this trade will equal all of the present (1978) domestic coastwise trade by tanker, it will mean a significant increase in domestic tanker demand and use. If other oil is discovered in Alaska (in NPRA or offshore regions), even greater demands on domestic tanker trade will follow.

The movement of crude oil from Alaska to the conterminous States 'by mid-sized supertankers will continue. The amount of this traffic and the sizes of vessels could be a function of discoveries of offshore deposits and in NPRA. The movement of oil by large supertankers (200,000 DWT and above) is at present restricted by the following constraints (U.S. Department of Commerce, Maritime Administration, 1978).

1. It is not economical to haul crude oil in very large crude carrier (VLCC) tankers a short distance, i.e., 3,000 miles (4,800 kilometers) or less.

2. VLCC tankers cannot pass through the Panama Canal to the gulf or east coast; such traffic either has to travel south around Cape Horn or establish a lightering operation at the Panama Canal very similar to that presently used for the transport of North Slope crude from Alaska to the gulf or east coast port sites.

3. The depths of existing domestic ports, channels or harbors constrain the deadweight tonnage of American tankers operating in domestic trade. Most domestic ports are presently limited to vessels under 50,000 DWT; only a few ports are able to accommodate intermediate tankers in the 85,000-DWT range. The extreme northern and southern California ports are the only ones having enough depth to accommodate large vessels in the 150,000- to 250,000-DWT range.

Tankers have also been transporting LNG since 1964 to various shipping centers of the world. One such location is the Phillips-Marathon Kenai Terminal on Cook Inlet, Alaska, which has been in use since 1969. LNG tankers with capacities ranging from 75,000 to 135,000 cubic meters have been constructed or ordered. The world LNG tanker fleet, as of August 1977, consisted of 40 foreign and 2 domestic flagships in operation with an additional 23 and 20 ordered, respectively. The preferred size in the industry today is of the 130,000-cubic-meter class.

A typical 130,000-cubic-meter LNG tanker is 960 feet (293 meters) in overall length and 140 feet in beam and has a loaded draft of 36 feet (11 meters), a displacement of 110,000 long tons, and dead-weight tonnage of 65,000 long tons. The light ship is 45,000 long tons. In appearance, an LNG tanker differs from an oil tanker in that it has a much higher freeboard, owing to the difference in cargo density; LNG has about one-half the specific gravity of oil.

The relatively shallow draft of LNG tankers eliminates the draft problem confronting VLCC tankers in most domestic ports. However, the beam width of a current 130,000-cubic-meter LNG tanker is too great to allow passage through the Panama Canal.

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