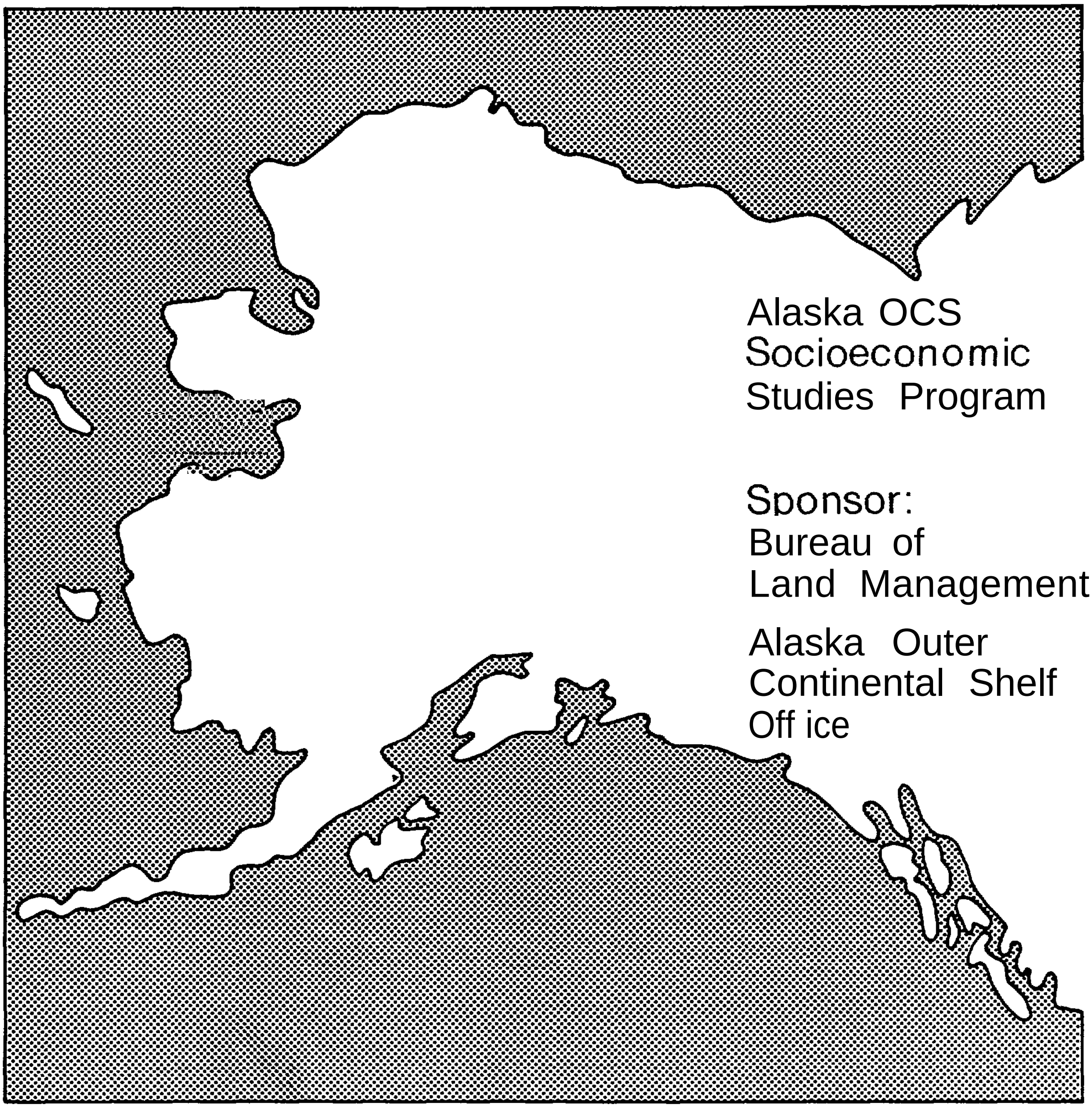
Technical Report Number 10



Alaska OCS
Socioeconomic
Studies Program

Sponsor:
Bureau of
Land Management
Alaska Outer
Continental Shelf
Off ice

Beaufort Sea Region
Natural Physical Environment

The United States Department of the Interior was designated by the Outer Continental Shelf (OCS) Lands Act of 1953 to carry out the majority of the Act's provisions for administering the mineral leasing and development of off-shore areas of the United States under federal jurisdiction. Within the Department, the Bureau of Land Management (BLM) has the responsibility to meet requirements of the National Environmental Policy Act of 1969 (NEPA) as well as other legislation and regulations dealing with the effects of off-shore development. In Alaska, unique cultural differences and climatic conditions create a need for developing additional socioeconomic and environmental information to improve OCS decision making at all governmental levels. In fulfillment of its federal responsibilities and with an awareness of these additional information needs, the BLM has initiated several investigative programs, one of which is the Alaska OCS Socioeconomic Studies Program.

The Alaska OCS Socioeconomic Studies Program is a multi-year research effort which attempts to predict and evaluate the effects of Alaska OCS Petroleum Development upon the physical, social, and economic environments within the state. The analysis addresses the differing effects among various geographic units: the State of Alaska as a whole, the several regions within which oil and gas development is likely to take place, and within these regions, the various communities.

The overall research method is multidisciplinary in nature and is based on the preparation of three research components. In the' first research component, the internal nature, structure, and essential processes of these various geographic units and interactions among them are documented. In the second research component, alternative sets of assumptions regarding the location, nature, and timing of future OCS petroleum development events and related activities are prepared. In the third research component, future oil and gas development events are translated into quantities and forces acting on the various geographic units. The predicted consequences of these events are evaluated in relation to present goals, values, and expectations.

In general, program products are sequentially arranged in accordance with BLM's proposed OCS lease sale schedule, so that information is timely to decision making. In addition to making reports available through the National Technical Information Service, the BLM is providing an information service through the Alaska OCS Office. Inquiries for information should be directed to: Program Director (COAR), Socioeconomic Studies Program, Alaska OCS Office, P. O. Box 1159, Anchorage, Alaska 99510.

TECHNICAL REPORT #10

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ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM
BEAUFORT SEA REGION NATURAL PHYSICAL AND BIOTIC BASELINE

FINAL REPORT

Prepared for

BUREAU OF LAND MANAGEMENT

ALASKA OUTER CONTINENTAL SHELF OFFICE

Prepared by

DAMES & MOORE

May 1978

Job No. 8699-014-20

<u>NOTICES</u> ‘

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2. This is a final report designed to provide preliminary petroleum development data to groups working on the Alaska OCS Socioeconomic Studies Program.

3. The units presented in this report are metric with American equivalents.

ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM
Beaufort Sea Region” Natural Physical and Biotic Baseline,
Final Report

Prepared by

DAMES & MOORE

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15. Supplementary Notes

16. Abstract

This report provides critical natural physical information in mapped and narrative form for the Beaufort Sea Region. It involves the identification of interrelated or interdependent components of the environment and cultural infrastructure. These components' include fish and wildlife distributions, water resources, gravel and sand resources, and terrain conditions. These components are evaluated and displayed on figures showing critical areas.

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I. INTRODUCTION

The purpose of this study is to provide critical natural physical information in mapped and narrative form for the Beaufort Sea Region. The information will be used to form the basis for the projection of natural physical environmental impacts and resource conflicts. To assess the socioeconomic impacts of Beaufort Sea OCS petroleum development, an environmental baseline has to be established. Included in such a baseline are those aspects of the natural physical and biotic environment that may be related indirectly or directly to the economic and cultural infrastructure of the resident population.

The first step in establishing such a baseline is the identification of the significant interrelated or interdependent components of the environmental and cultural infrastructure. This was accomplished at a series of multi-disciplinary meetings using delphi techniques. (The delphi technique involves the identification, ranking and weighing of issues of concern or environmental 'factors through aggregation of opinions of a multi-disciplinary group in a series of discussion sessions. Several iterations are required to resolve conflicts and arrive at a group consensus of opinion on key issues and ranking/weighing of factors.)
The principal environmental components such as wildlife and fish distribution identified were related to subsistence activities. Water resources were considered critical due to the scarcity of the resources and because they could be affected significantly by petroleum development. Likewise, gravel and sand resources were judged economically important because they are scarce in some areas of the North Slope. The extraction of sand and gravel, in turn, may have potential for significant impact on water resources and fish distributions. Terrain conditions were a necessary consideration in the identification of surface water potential. Although it is recognized that many complex linkages exist in the natural physical and biotic environments, environmental components such as rare and endangered species were not considered for evaluation unless they are a subsistence food resource. Environmental components such as

tundra, which could be affected by petroleum activities, were not considered when linkages to the socioeconomic infrastructure were found to be unclear or unimportant. If, however, disturbance of terrain from petroleum development was envisaged to have the potential to result in significant loss of habitat, then that component was considered in the analysis.

Baseline environmental factors are most appropriately evaluated and presented on a series of figures; the components need to be Vocationally compared with existing communities, industrial infrastructure, Native activities, political jurisdictions and future offshore petroleum development. A scale of 1:350,000 reflects the study area requirements including representation of the North Slope and nearshore waters of the Beaufort and Chukchi Seas, Native villages, and the detail of the available data and presentation requirements. The base figures comprise two modules (east and west halves of the North Slope/Beaufort Sea) and were taken from U.S.G.S. 1:250,000 quadrangle topographic sheets.

The figures are source data figures for subsequent impact analysis; they are compiled from existing literature and professional experience in the study area. Due to variations in input data reliability and detail, some of the figures have been generalized to accommodate these variations.

The compilation, data content and use of the five source data figures are described in the following narrative. The narrative is designed to supplement and explain the data presented in the figures and is not intended to be a definitive statement on each environmental component.

II. SOURCE DATA MAPS

Water Resources

FIGURE COMPILATION AND PURPOSE

The water resources of the North Slope display wide annual variations in quantity and quality, particularly during the eight-month long winter when most of the water is locked up as ice or snow. The water resource figures document the locations of most water bodies on the North Slope. These figures were compiled using U.S. Geological Survey maps and existing literature and Dames & Moore knowledge of the area.

A major concern during the mapping process was to locate all known water bodies having winter water depths of at least eight feet water commonly freezes to depths of six to seven feet during winter. Therefore, water greater than eight feet deep is considered to have potential for winter water withdrawal. Moreover, groundwater availability in winter is in part dependent upon the surrounding soil remaining unfrozen. Therefore, areas beneath unfrozen surface water provide conditions favorable for groundwater withdrawal.

The water resource figures may be used to identify water availability and sensitivity of water withdrawal in addition to predicting the impact of petroleum development on the water resources. By first superimposing information about sand and gravel locations and permafrost the potentially available surface and groundwater resources having high domestic use quality can be located. Then, by superimposing information on fish distribution over this, the sensitivity of each water body with respect to water withdrawal can be predicted.

If petroleum development occurs, fresh water will have to be obtained for domestic and various industrial uses (e.g. drilling, river crossing over thickened ice, and secondary petroleum recovery by injection). The potential impact of these uses can be estimated by using the water resource figures and following the process described above to delineate water withdrawal sensitivity. It should be kept in mind that unfrozen sands and gravels (used for various construction purposes) are almost exclusively found in river floodplain alluvium. Hence, their extraction will have a direct impact on water quality by increasing suspended solids and turbidity. Additionally, consideration has to be given to overwintering fish distribution since regulatory agencies do not allow water withdrawal at known overwintering sites.

REGIONAL WATER AVAILABILITY, QUALITY, AND USE

The Arctic slope, bounded on the north by the Beaufort Sea, is dominated by thousands of shallow 'ponds, small coastal meandering streams, and a number of wide braided rivers that originate in the mountains to the south .

Lakes and ponds constitute major features of the coastal plain and generally range from two to twenty feet in depth. They act as catchments during spring breakup and often flood beyond their normal shorelines but water levels normally decrease during the summer. Water levels may drop below the outlet elevation and many lakes and ponds become stagnant by the end of summer.

Water is abundant during spring and summer. Breakup usually begins in early to mid-May and continues through June. The magnitude of spring flow depends to a large extent on the amount and timing of snow melt. Water commonly covers as much as 80 percent of the coastal plain during spring breakup. Flows decline throughout the summer but fluctuate somewhat in response to infrequent rainstorms. Springs are found in the foothills to the south of the coastal plain. These contribute year-round flow to many rivers, but discharge from the springs varies widely.

Groundwater is present on the Arctic slope, but because of permafrost it is difficult to predict groundwater location, quantity, and quality; however, groundwater commonly exists in alluvium beneath the major rivers and in soils beneath the larger lakes. Groundwater may be found above, below, and within permafrost. In the latter two cases, groundwater is normally brackish to saline. Groundwater found above permafrost usually freezes during the winter making it invariable for use eight or nine months of the year.

Fresh water temperatures range from a low of zero degrees C (32 degrees F) during winter to as high as or 18 degrees C (64 degrees F). Shallow tundra lakes may reach 15 degrees C (59 degrees F), and ponds may reach 18 degrees C (64 degrees F), but most deep lakes will only warm to six degrees to eight degrees C (43 to 46 degrees F). The rivers will usually warm to 15 degrees C (59 degrees F) and may warm slightly above this temperature.

Freeze-up begins no later than September and by mid-winter ice and snow have frozen almost all the water on the Arctic slope. The only free water will be found in deep water areas (greater than six to seven feet deep) in streams and lakes and in the spring areas.

In general, the water quality of the streams, lakes, and ponds on the Arctic slope is high. Principal characteristics of water quality include temperature, pH, dissolved oxygen, nutrients, suspended solids, turbidity, and color. These are discussed below.

In ponds, lakes, and streams, pH generally ranges from slightly below neutral to about 8.0. This range is sufficient to support a diverse flora and fauna.

Arctic coastal lakes, ponds, and streams are normally near complete saturation of dissolved oxygen during the open water season and at freeze-up in the fall. Low levels of biological activity and atmospheric reaeration maintain the relatively high levels of dissolved oxygen. During late winter, however, severe deoxygenation may take place under ice, particularly in lakes and ponds, so that some water will become anaerobic.

Nutrients are present in low concentrations in waters of the Arctic coast. Phosphate levels are low in ponds, lakes, and streams, whereas nitrate levels are usually low in lakes but high in ponds and streams. The levels of nutrients in these Arctic waters are similar to levels found in uncontaminated surface waters of temperate regions.

Shallow lakes and ponds are usually turbid owing to wind mixing which keeps the particulate material in suspension. Streams are turbid during spring breakup when high suspended solids loads are carried. Non-glacial streams will clear after breakup. Some streams in the eastern portion of the North Slope have a glacial influence and remain turbid due to the presence of silt and clay-sized rock flour.

Tundra ponds are normally high in color, which results from the leaching of organic material. This leaching process is enhanced by poor drainage in the coastal plain.″ Lakes are usually slightly less colored than ponds, and the major rivers show little color influence.

As stated above, water quality in streams, lakes, and ponds of the North Slope is generally good. Coastal lakes and ponds, however, may exhibit relatively high salinity values for fresh water. Additionally, streams run temporarily high and turbid during spring runoff and after summer s terms. Deep lakes that do not freeze to the bottom during winter normally display their lowest oxygen content prior to spring breakup. Salty coastal waters become diluted by fresh water during the spring thaw, but by midsummer low fresh water runoff and tidal fluctuations cause salinity to increase in the estuaries.′

The quality of groundwater in the Arctic coast is probably best in alluvium beneath rivers. Shallow groundwater in these areas is of the calcium bicarbonate type and contains relatively low concentrations of dissolved solids. Dissolved solids likely become more concentrated with depth and the sodium chloride type predominates.

Prior to the discovery of oil and gas at Prudhoe Bay, water usage and waste disposal along the Arctic coast were limited to scattered villages and small scientific and geological exploratory teams. Lakes and streams during summer and snow and ice during winter were relied upon for water, and wastes were discarded on the surface. These practices continue in the villages of Barrow, Kaktovik, and Nuiqsut.

It should be noted that some houses in Barrow and Kaktovik have piped water systems and flush toilets. Even in these houses, however, water has to be hauled to fill the central storage tanks and wastes" are collected in plastic bags or 55 gallon drums and transported to a community dump. Winter water supplies in Barrow are in the form of lake ice, cut into blocks, and melted in the storage area. A water distribution and sewerage system is currently under construction.

The village of Wainwright has a community facility that houses a water treatment plant and storage tank, sewage treatment plant, laundry, and incinerator for solid waste. The petroleum companies at Prudhoe Bay have constructed piped water systems and use package plants for water and sewage treatment to meet their needs.

As would be expected, water use on the North Slope correlates with the ease with which water is obtained. On a per capita basis, water usage ranges between 2.0 and 10 gallons per day in the villages and approximately 70 gallons per day at Prudhoe Bay.

SUMMARY OF CURRENT USE PROBLEMS

Water resources are currently being used in the villages of Barrow, Kaktovik, Wainwright, and Nuiqsut and at the Prudhoe Bay complex. Water use problems in the villages are primarily related to sanitary concerns, That is, water used" for washing, cleaning, and cooking is dumped on the ground outside the housing unit. Human wastes are normally collected in "honey buckets" and transported to community dumps, which may or may not be covered. Barrow and Wainwright, however, have incinerator facilities for disposing of human wastes. The overriding concern is that surface waters and snow near the villages becomes contaminated and promotes various illnesses. Consequently, most village residents haul water or ice from nearby lakes. Because villagers haul their own water, consumption remains rather low. Estimates of water use vary from 2.0 to 10 gallons per capita per day in most of the villages and may be as high as 35 gallons per capita per day for some Barrow residents. Current water use in the villages does not significantly conflict with other water requirements such as fish and wildlife.

Water use at Prudhoe Bay has increased throughout the years as living facilities improve. Water use was estimated at 35 to 50 gallons per capita per day in 1972, and in 1977 it had increased to 70 gallons per capita per day. Additional water use is required for industrial purposes.

Purported winter water use conflicts arose in the spring of 1974 at Prudhoe Bay. It has been postulated that water withdrawal from the Sagavanirktok River was dewatering fish overwintering holes and killing fish. Consequently, state and federal agencies have increased their surveillance of the situation in the past few years and petroleum companies have improved their water storage facilities to meet current winter demand. A significant increase in water requirements, such as the building and maintenance of ice roads, and meeting new drilling demands or flooding for secondary recovery could easily stress winter water resource.

Gravel and Sand Resources

FIGURE COMPILATION AND PURPOSE

Gravel and coarse sand are one of the Arctic's most valuable resources because these scarce aggregates are required to construct roads, airstrips, work pads, foundations, causeways and, in the event of offshore drilling, artificial soil islands. Gravel is required to provide a stable and trafficable working surface and to provide insulation to the underlying permafrost. On the North Slope minimum gravel thickness for these purposes is about 1.5 meters (5 feet) where no artificial insulation is used.

The cost of gravel, specifically its haulage, is an important economic consideration of North Slope construction. The extraction of gravel is also a significant environmental concern. Thus the location and availability of gravel can be compared to the location and magnitude (demand for the resource) of petroleum development. Such a comparison will identify possible borrow sites which, in turn, can be evaluated for environmental sensitivity.

Since many of the available sand and gravel resources are alluvial deposits in floodplains and river terraces, the resource location often coincides with water and fish resources. Offshore sand and gravel resources also may occur in sensitive locations such as the summer habitats or migration routes of bowhead and belukha whales. Beach and barrier island resources occur where coastal erosion and sediment transport processes are often in delicate balance.

A map of North Slope and Beaufort Sea gravel and sand resources is an important tool in the assessment of impacts from offshore petroleum development. The gravel and sand resource figure was compiled from existing literature and data. The figure should be compared with those showing water resources, wildlife and fish, and petroleum development scenarios to identify areas of potential resource use conflict and environmental impact.

REGIONAL AVAILABILITY AND USE

Quantitative and qualitative data on North Slope and Beaufort Sea gravel and sand resources are limited. In National Petroleum Reserve - Alaska (NPR-A), gravel and sand resources have been mapped and estimated by Labelle (1973, 1974, 1976). More recently, surficial deposits, including sand and gravel, have been mapped by Williams and others in the reserve. Elsewhere on the North Slope, gravel and sand resources have not been mapped or evaluated specifically; they generally have been mapped along with other geologic units. In the central-eastern North Slope such maps have been compiled by Ferrians (1971) for the trans-Alaska pipeline corridor, by Yeend (1973) in part of the Beechy Point and Sagavanirktok quadrangles, and by Reiser et al. (1974) in the Demarcation Point quadrangle.

Few data are available on offshore sea floor and subsurface gravel and sand deposits. Data on these resources have generally been collected incidentally as part of investigations on such problems as coastal processes, subsea permafrost and sediment transport rather than as specific resource evaluations. Such investigations include studies on coastal processes by Wiseman et al. (1973) and Cannon (1977), on coastal and permafrost erosion by Lewellen (1970, 1977), on subsea permafrost by Osterkamp and Harrison (1976), Sellmann (1977) and Hopkins et al. (1977a), and on offshore stratiography by Reimnitz, Wolf and Rodeick (1972). Some of these studies have involved shallow soil borings (Osterkamp and Harrison, 1976; Sellmann, 1977) and shallow seismic surveys (Reimnitz, Wolf and Rodeick, 1972; Rogers et al., 1975).

The classification of sand and gravel resources shown on Figure No. 2 has been kept general because of the highly variable data base. In NPR-A, for example, Labelle (1973, 1974, 1976) has mapped sand and gravel resources at a scale of 1:63,360 and has used classifications according to morphology and origin (alluvial, eolian, beach, etc.). The limited areas investigated in detail south and east of Prudhoe Bay have been mapped at a scale of 1:125,000 and 1:200,000; the unconsolidated surficial geologic units have been classified according to age, morphology and origin. Elsewhere on the North Slope and offshore the available data is at a most general reconnaissance level or totally lacking.

Onshore Deposits

North and west of the Colville River, and within NPR-A, gravel and coarse sand deposits are limited, primarily because the Colville River intercepts much of the north-flowing drainage and coarse detritus originating in the western Brooks Range. Streams from the Utukok River east to the Colville contain predominately fine sand and silt, and gravel beaches are rare along the coast between the Colville River delta and Point Barrow. Inland, the lakes of the coastal plain are devoid of gravel deposits with the exception of the northwestern shore of Teshekpuk Lake, which an estimated reserve of 688,000 cubic meters (900,000 cubic yards) (Labelle, 1974).

Within 40 kilometers (25 miles) of Barrow, gravel and coarse sand resources are estimated to be 79 (103 million cubic yards) million cubic meters of which 2.0 to 3.0 million cubic meters (3.0 to 4.0 million cubic yards) are regarded as exploitable (Labelle, 1973). The Beaufort Sea shores of NPR-A, which are actively eroding by thaw action, have some sand and gravel resources, notably in the spit and barrier island complex that commences at Eluitak Spit and runs nearly as far east as Cape Simpson. Labelle (1976) estimates that this complex contains nearly 3.0 million cubic meters (4.0 million cubic yards) of fill material. Cooper Island, for example, located about 40 kilometers (25 miles) east of Barrow, contains over 1.5 million cubic meters (2.0 million cubic yards) of coarse material, while the remainder of the Plover Island chain contains only 530,000 cubic meters (700,000 cubic yards) of sandy gravel and gravelly sand.

Only small sporadic accumulations of coarse materials are found on the mainland shore. East of the spit/barrier island complex, between Cape Halkett and Drew Point, 1.2 million cubic meters (1.6 million cubic yards) of gravel and coarse sand exist along coastal beaches. In Smith Bay, the beaches are composed-only of fine sand and mud, as are the few beaches in Harrison Bay. The Colville delta consists only of fine sand and mud.

The principal source of coastal sand and gravel is believed to be the Pleistocene Gubik formation, which is a mixed marine and alluvial deposit comprised of silt, sand" and gravel that underlies most of the coastal plain. Coastal erosion and bluff collapse provide the sediment which is winnowed by currents and wave action, leaving behind the coarser sand and gravel fractions as lag deposits. These in turn are transported along the coast by longshore drift forming beaches, spits, bars and barrier islands. Shoreline deposition by ice-push and ice-melt contribute minor amounts of the sediments deposited above sea level.

Extensive areas of fine to medium sand occur in stabilized and active dunes from the Colville River west to the Meade River and south to the foothills of the Brooks Range. The Colville River, as far north as the delta, is estimated to contain 27 million cubic meters (35 million cubic yards) of gravel, but the delta is composed of silt and fine sand (Labelle, 1974).

The above estimates of gravel and sand resources of NPR-A should be treated with caution since they are based upon aerial or surface observations and not depth/volume measurements obtained from borehole data. Less is known about the gravel resources east of the Colville River. Most of the major streams that head in the Brooks Range contain sand and gravel. Coastal resources east of the Colville are available in beaches, spits and barrier islands. Significant gravel deposits occur in a series of coalesced alluvial fans along the flanks of the Brooks Range east of the Canning River. The major rivers east of the Colville are generally braided gravel streams which have their headwaters in the Brooks Range.

In the Beechy Point and Sagavanirktok quadrangles south and southeast of Prudhoe the most suitable borrow materials are floodplain gravels, low terrace gravels and outwash gravels (Ferrians, 1971; Yeend, 1973). Extensive floodplain and terrace gravels occur in the major rivers such as the Sagavanirktok, ShavioviK and Kavik Rivers. In the foothills of the Brooks Range outwash gravels occur in high terraces bordering the main river valleys such as the Kavik and Canning. These were deposited during the Pleistocene when glaciation was extensive in the Brooks Range. As the Brooks Range approaches the Beaufort Sea coast east of Prudhoe Bay gravel and sand deposits of alluvial (floodplains, terraces, fans) and glacial-fluvial (outwash plains, terraces and fans) become more extensive. North of the Brooks Range in the Demarcation quadrangle, for example, the major surficial unit is alluvial fans composed predominately of coarse sand and gravel.

A recent geologic investigation of the Beaufort Sea coast and barrier islands has provided new data on coastal gravel resources (Hopkins, 1977b). This investigation revealed that the barrier islands originated from multiple sediment sources and derive mainly from hillocks of Pleistocene sediments that have been partially drowned and left as tundra-covered islands. The source hillocks have been completely removed by erosion, and the present, residual islands are gradually migrating westward and landward from the original source areas. Hopkins (1977b) concludes that if the islands were quarried for gravel, they would not be replaced by natural processes.

There are, however, areas along the mainland coast where gravel is accumulating in spits and accretionary bars from which borrow could be removed with minimum adverse effects. From the Kuparuk River to the Canning River on the Beaufort Sea coastal plain, subsurface gravel deposits are ubiquitous at depths of 10 meters (33 feet) or less. Development of upland borrow sites in these deposits or by deepening thermokarst lakes may be an alternative to extraction from river bars and channels. Additional information on coastal gravel and sand deposits has been gathered in recent coastal geomorphology studies (Cannon, 1977; Lewellen, 1977).

Offshore Deposits

Few data are available on offshore sea floor and subsurface gravel and sand deposits. These possible deposits are particularly important with respect to potential demand for offshore aggregate for artificial island construction. On a regional scale, from the shoreline to the 20-meter (66-foot) isobath, east of the Colville River delta, the bottom sediments consist mainly of sands and gravels. West of the delta, sediments are silts and clays (National Oceanographic and Atmospheric Administration, 1977).

The stratigraphy and thickness of offshore sediments in the inner shelf of the Beaufort Sea between the Colville River and Tigvariak Island have been mapped by the U.S. Geological Survey (Reimnitz, Wolf and Rodeick, 1972), using shallow seismic techniques. Holocene marine deposits, consisting predominantly of muddy sand, range in thickness from 25 meters (83 feet) in the eastern part of the area to five meters (16 feet) or less near the Colville River delta. A series of borings in Prudhoe Bay extending from the North Prudhoe Bay State No. 1 well to Reindeer Island indicated that the subsea soils are sandy gravel with some silt overlain by a thin layer of silty sand (Osterkamp and Harrison, 1976). This layer increases in thickness from a few meters nearshore to about 14 meters (46 feet) at 3.4 kilometers (2.1 miles) offshore. Seaward of the barrier islands bordering Simpson Lagoon, the sediments are generally less than five meters (17 feet) thick. Four borings in the Prudhoe Bay area have provided additional data on the marine geology, stratigraphy and permafrost conditions. Three major groups of sediment were recognized (Hopkins et al. 1977): a) an upper sequence of Holocene marine mud, clay, sand, 5.0 to 10 meters (33 feet) thick, and beach sediments (well-rounded gravel and coarse sand) one to two meters 3 to 7 feet) thick; b) a middle sequence of angular sand and gravel 5.0 to 20 meters (16 to 66 feet) thick interpreted as glacial outwash deposited by the Sagavanirktok River during the last major glaciation in the Brooks Range; and c) an ancient alluvial deposit of the Sagavanirktok River consisting of pebbly sand, well-sorted sand, and gravel.

A summary of current knowledge of Beaufort Sea sediments is contained in Arctic Project Bulletin No. 15 (OCS Environmental Assessment Program, 1977). Sandy bottom sediments are generally confined to the shelf area east of Cape Halkett. Local areas of gravel, much of which is derived from erosion of coastal bluffs, occur with increasing abundance east of the Colville River delta. West of Cape Halkett clayey sediments predominate.

SUMMARY OF CURRENT USE PROBLEMS

The availability of gravel on the North Slope shows a regional pattern of scarcity west of the Colville River and increasing supplies east of the Colville River to the Canadian border. This pattern may be repeated offshore.

River gravel resources in the Arctic are further limited by problems associated with extraction. The Alaska Departments of Fish and Game and Environmental Conservation prohibit gravel removal from the Colville River delta and from other rivers, such as the Sagavanirktok and Kuparuk, without prior approval of a plan showing pit location and specific quantities of gravel required. Data on the total amounts of gravel which have been extracted to date from the Sagavanirktok River for construction of the Prudhoe Bay facilities and Alyeska pipeline are not available, but estimates for Prudhoe Bay indicate more than 76 million cubic meters (100 million cubic yards) had been used by 1974 (Arctic Institute of North America, 1974).

The El Paso trans-Alaska gas pipeline proposal indicated gravel requirements of 12.5 million cubic meters (16.4 million cubic yards) of gravel and sand (Woodward-Clyde, 1976). That portion of the Arctic Gas pipeline to be constructed in Alaska would have required an estimated 2.4 million cubic meters (3.1 million cubic yards) of gravel and sand. Offshore development, unlike onshore development, will require borrow materials from both onshore and offshore sources, thus impacting both the marine and terrestrial environment. Principal concerns relating to offshore and onshore borrow extraction are:

- Acceleration of coastal erosion (see MacCarthy, 1953, for a discussion of accelerated coastal erosion at Barrow resulting from borrowing beach material)

- Disturbance of marine sediment transport system affecting stability of barrier islands

- Increase in marine turbidity levels affecting plankton, benthic organisms and fish

- Disturbance to whales by marine traffic and dredging activities

- Floodplain excavation with impacts on hydrologic regime, water quality and aquatic biota, especially disturbance to fish spawning, fish overwintering, and entrapment of fish (Woodward-Clyde Consultants, 1976).

Although a map of sand and gravel resources of the North Slope and Beaufort Sea is a valuable tool in impact analysis, it is only a first step in such an evaluation. More site specific and project specific data are required to fully access the problem. In addition to potential environmental impacts and their mitigation, other considerations include:

- the identification and assessment of potential borrow sites;

- the geotechnical suitability of gravel and sand deposits with respect to their intended use;

- the geotechnical problems of gravel and sand extraction including groundwater conditions, permafrost conditions (especially ice content of frozen materials), slope stability and erosion, and site rehabilitation;

- the economics of gravel extraction and haulage;

- the facilities and equipment requirements of gravel extraction, processing and transportation.

Terrain Features

FIGURE COMPILATION AND PURPOSE

The figure showing terrain features of the North Slope was designed to provide physiographic information applicable to an assessment of water availability and quality. Terrain features generally correlate with available fresh water resources. The combination of maps showing terrain features and water resources results in the identification of surface water potential. An additional step in such an analysis is the assessment of water availability to identify sites where water can be withdrawn for any use. This involves consideration of surface water potential, permafrost conditions and the location of sand and gravel resources. The terrain units identified on Figure No. 3 are therefore classified primarily according to hydrologic and hydrographic parameters.

REGIONAL TERRAIN FEATURES

The Arctic coastal plain can be subdivided into two sections: the Teshekpuk section, which is a flat-lying lake-dotted plain, and the White Hills section, east of the Itkillik River, which is characterized by scattered groups of low hills. The coastal plain is at its narrowest (about 18 kilometers or 11 miles) near the Canadian border. It widens significantly to the west; at Point Barrow it is about 180 kilometers (110 miles) across. Most of the coastal plain is underlain by unconsolidated silts and sands, with some clays and gravels, which comprise the predominantly marine Gubik Formation of Quaternary Age (Black, 1964). These deposits, which are up to 45 meters (149 feet) thick, unconformably overlie Mesozoic sediments (shales, mudstones, and sandstones) west of the Colville River and Tertiary rocks east of the river.

The coastal plain is underlain by continuous permafrost up to 610 meters (2,001 feet) thick. This permafrost, coupled with the low relief, result in generally poor drainage and the development of patterned ground, 'thermokarst features, and ice-cored mounds such as pingos. One of the most unique features of the plain is the thousands of lakes which cover an area of approximately 435,000 square kilometers (168,000 square miles); many of these lakes are oriented with their long axes a few degrees west of north.

Drainage on the coastal plain is predominantly north to the Arctic Ocean. The major rivers have headwaters in the Brooks Range. The Colville is the largest of these rivers; it is over 690 kilometers (430 miles) long and drains about 30 percent of the Arctic slope, intercepting much of the drainage and coarse sediments from the Brooks Range. East of the Colville many rivers also originate in the Brooks Range and transport coarse sediment. These rivers generally exhibit braided patterns and have numerous gravel and sand bars interspersed with continuously shifting channels. West of the Colville, the rivers on the coastal plain are generally shallow, poorly-integrated and have meandering channels. The most significant hydrologic characteristics of the coastal plain are the virtual cessation of flow during the winter, the concentration of most of the season's flow in a short period of time, and the inclusion of large amounts of ice in river flow, usually during peak discharge (Walker, 1973).

Several studies have provided physiographic or geomorphic classifications of the Arctic slope. Sellmann et al. (1975) have classified thaw lakes on the Arctic coastal plain according to basin morphology and distribution patterns. Lake classification parameters included size, development of elongate axis, orientation of elongate axis, and lake density (percentage water coverage).

The Beaufort Sea coastline is varied, including such features as beaches, barrier islands, barrier bars, spits, lagoons, dunes and river deltas

(Hartwell, 1973). Low but steep sea bluffs in many places are under active retreat as a result of a combination of thermal and wave erosion during the short summer open-water season.

The coastline of the Beaufort Sea and Chukchi Sea coasts has been classified on the basis of predominant coastal processes or genesis (land erosion, river deposition, wave erosion and marine deposition) and relief characteristics (low - less than two meters, moderate - two to five meters, high - five to eight meters, very high - more than eight meters) (Hartwell, 1973). Summaries of North Slope geomorphology and surficial processes are provided by Black (1969) and Walker (1973).

RELATIONSHIP TO WATER RESOURCES

The terrain features figure was designed to provide physiographic information applicable to an assessment of water availability and quality since terrain features generally correlate with available fresh water resources. The combination of figures showing terrain features and water resources results in the identification of surface water potential; the classification of lakes, streams and coastal areas given on Figure No. 1, Water Resources, will provide realistic information on surface water potential only if the physiographic setting of these water bodies is considered. For example, large deep lakes at the coast may have less water potential because of possible salt water intrusion than lakes further inland. Such an approach is further refined by comparing or combining a surface water potential figure with figures showing permafrost conditions and the location of sand and gravel resources. This results in a figure showing water availability by identifying sites where water can be withdrawn for any use.

Wildlife and Fish Distribution

The socioeconomic emphasis of this project suggests that the evaluation of components of the natural environment be directed to those most directly related to the needs of regional residents and visitors. Animals have been identified which are important for human subsistence, commercial or recreational value that could be influenced by outer continental shelf petroleum development.

The zone of greatest impact on fish and wildlife resources was assumed to lie between the edge of the pack ice and a line roughly 50 miles inland from the Beaufort Sea coast. This area not only includes the greatest biological diversity, but it also is the zone most heavily utilized by hunters, fishermen, and commercial operators.

WILDLIFE DISTRIBUTION

Terrestrial

The truly resident wildlife along the Arctic coast are few in number. Only the caribou, musk oxen, polar bear, Arctic fox, raven, snowy owl, Arctic hare, ground squirrel, vole, and lemming remain through the winter period. However, from May through September the coastal fringe is invaded by hundreds of thousands of migrating waterfowl, shorebirds and terrestrial birds, including more than 150 species. Figures 4 and 5 show the major fish and' wildlife patterns in the study area.

Birds from all four continental flyways nest on the shores of the Beaufort Sea. The most concentrated waterfowl use occurs in the rich estuarine waters, while shorebirds frequent gravel bars, ponds, and sedge-grass marshes. The sandpipers and phalaropes are the most abundant shorebirds (Bergman, 1974). Arctic loons, red-throated loons, oldsquaws, eiders, pintails, white-fronted geese, lesser Canada geese, and black brant are the most common waterfowl (Bergman, 1974; Gavin, 1974). There are also glaucous gulls, Ross gulls, Sabine's gulls, Thayers gulls, Arctic terns, and all three types of jaegers.

Raptors include snowy owls, rough-legged hawks, golden eagles, gyrfalcons and peregrine falcons. Willow ptarmigan are present through the summer. Lapland longspur and snow bunting are the most common passerine species between Point Barrow and the Canning River (Bailey, 1948).

Terrestrial mammals found near the beach include caribou, Arctic fox, musk oxen, wolves, Arctic ground squirrels and, occasional grizzly bears.

There are four caribou herds: the Arctic herd in the west, the Central Arctic herd near the Sagavanirktok River, the Porcupine herd in the east, and a small resident herd between Teshekpuk Lake and the Colville River (Alaska Department of Fish and Game, 1976a; Cameron and Whitten, 1976; 1977; Davis and Valkenburg, 1977; Hemming, 1971; White et al., 1975). At times each of these herds overlap in the vicinity of Prudhoe Bay.

Major caribou activity on the coast begins in May and June when the Porcupine, Central Arctic, and Teshekpuk herds move to traditional calving grounds near the beach. The Arctic herd calving area is well away from the coast at the headwaters of the Colville, Utukok and Ketik Rivers. The calving ground of the Central Arctic herd extends from Oliktok eastward to Bullen Point. The Alaska Department of Fish and Game has concluded that essentially all of the Prudhoe Bay oil field has been abandoned as a caribou calving area since about 1974 (Cameron and Whitten, 1976; 1977). The Porcupine herd also calves along the coast between the Katakturuk and Kongakut Rivers. In late summer, when biting insects increase in abundance, many caribou move onto river deltas where lower temperatures and nearly constant winds offer some relief from insect harassment.

Wolves are not common along the beach fringe, but they do follow caribou herds, particularly during the winter. Occasionally small numbers of caribou winter along the coast between the Colville and Sagavanirktok Rivers. Musk oxen range in the western portion of the Arctic National Wildlife Range from Barter Island on the east to the Canning River on the west.

The coastal inshore zone is an important denning area for Arctic foxes. Beach ridges; river deltas and pingos are good denning habitat. Once dens are established, they tend to be used again each year.

Polar bears are known to den between the Sagavanirktok and Canning Rivers, but nontraditional sites have been identified. The bears usually range beyond the shorefast ice.

Howe Island, at the mouth of the Sagavanirktok River, supports the only snow goose colony on the Arctic coast of Alaska. This small colony includes about 60 nesting pairs. In late summer the area of the coastal plain between Sadlerochit and Aichilik Rivers is used as a migration staging area for snow geese from Canada and Alaska.

The Plover Islands area is an extremely important shorebird staging area from mid-July to August. Red phalaropes are the most abundant species. From Pitt Point to Cape Halkett, shorebirds and molting oldsquaws form dense aggregations in mid-summer (Weller et al., 1977). Eiders, glaucous gulls, and Arctic terns make extensive use of Niakuk, Gull, Cross, and Stenup Islands.

Marine

The bowhead whale is an endangered species, numbering 1,500 to 3,000 animals. Each spring in April and May these large cetaceans migrate northward from the Bering Sea through the flaw zone to the Beaufort Sea and Amundsen Gulf (Fiscus, Marquette, and Braham, 1976; Alaska Department of Fish and Game, 1977). They pass very close to shore off Point Barrow. In September they return to their wintering grounds, passing near shore from Cape Simpson to Point Barrow (Braham, et al., 1977). These large mammals feed on marine invertebrates. Recent sampling indicates that euphausids are a primary food item in the vicinity of Point Barrow.

The belukha whale population off the Bering and Beaufort Seas is estimated to contain at least 5,000 individuals. They are gregarious mammals and occur in nearshore waters, including large rivers and areas above the tidal influence. Herds of 100 to 1,000 animals have been observed during migration, but small groups of 2 to 15 whales are most common. Timing of migration is dependent on ice conditions, but belukhas usually arrive in the Arctic during April. Some groups return to the same ice-free area each summer. Young are born from May through July. As ice begins to form in the fall, the whales migrate south where leads are abundant or the area is ice-free. Belukhas feed on fish and often concentrate in estuaries when species such as smelt or salmon smelt are abundant (Alaska Department of Fish and Game, 1977).

Three species of ice-inhabiting hair seals occur regularly in the Beaufort Sea. Within nearshore waters, the ringed seal is the most abundant, followed by the spotted seal and bearded seal. Only limited information exists about these populations due to inadequate census technology and minimal research emphasis in the past (Alaska Department of Fish and Game, 1977).

Species distribution commonly overlaps, but each seal species is usually found in distinct geographical areas. Adult ringed seals are found predominantly in areas of land fast ice in the winter and in broken floating ice during the summer. Spotted seals inhabit the outer edge of the pack ice in winter and remain near coastal areas or islands during the summer. Bearded seals prefer moving ice in the winter and broken floes of polar ice (over shallow water) in the summer.

Food requirements between seal species are quite different. Spotted seals are fish eaters favoring nearshore species. Ringed seals forage on zooplankton, shrimp, copepods, and other small marine organisms. Bearded seals are bottom feeders, relying" mostly on crabs, mollusks, and small bottom fish.

Polar bears occur throughout Arctic waters and onshore areas of the Beaufort Sea. Pregnant females excavate dens in river banks, or on the ice where there is sufficient snow accumulation. Dens may be used from December until April. Present information indicates that some of the most important denning habitat on the Alaskan coast extends from the Colville River east to the Canadian border. This zone is about 80 kilometers (50 miles) wide and includes a corridor of land extending about 40 kilometers (25 miles) from the coast and the strip of adjoining shorefast ice (Weller et al., 1977). Males and nonpregnant females remain active year round on moving pack ice.

North of Point Barrow polar bears move east toward Barter Island where ice is more stable. The southern edge of the ice pack varies in position during summer, depending upon the winds. It can be lodged against the shore or can be as far as 160 kilometers (100 miles) offshore. Polar bears generally stay with the moving ice during the summer and concentrate on its southern edge where seals are abundant.

Lagoons are nesting and molting sites for waterfowl, resting areas for migratory geese, nurseries for young waterfowl, and feeding grounds for many shorebirds. Estuaries formed at river deltas are low salinity environments which provide good habitat for waterfowl.

Aquatic

More than 30 species of fish have been recorded in nearshore habitats of the Beaufort Sea (Weller et al., 1977). Arctic char and Arctic cisco are the most abundant and widespread (Bendock, 1976). Adult whitefish have been found only within the river systems, but shallow bays and lagoons are important feeding and migration areas for immature whitefish. Arctic cod ("Tom cod") are seasonally abundant.

Among the nearshore fishes, species diversity is low. Anadromous species migrate and concentrate along shallow coastal estuaries. Freshwater fishes are found in the rivers and occasionally in the estuaries when salinities are low. Most of the coastal streams freeze up each winter leaving only occasional unfrozen pools under the ice. These nonfrozen pockets are critical habitat for overwintering anadromous and resident fishes such as Arctic char, Arctic cisco, least cisco, grayling and round whitefish.

Marine fish species such as the fourhorn sculpin, Arctic flounder and Arctic cod are found in brackish waters during the ice-free summer season, but apparently move farther offshore in winter (Weller et al., 1977). The waters surrounding nutrient-rich river deltas are critical habitat for larval and juvenile fish.

HUNTING AND FISHING

Residents of the Arctic coast harvest caribou, small game such as ptarmigan and owls, bird eggs, whales, seal and fish as part of their food resource. Spawning areas, overwintering fish sites, calving grounds, and nesting sites require special protection to assure long-term viability for food production. Figure 6 shows village subsistence hunting and fishing areas.

Fish and wildlife resources within a day's access of communities are used intensively. In the nearshore areas, spotted seals, ringed seals, and bowhead and belukha whales are taken. Ringed seals are the most common species taken by local village residents. Traditionally seals were used by coastal residents for food, oil, dog food, boat coverings, clothing and other practical items. Natives still depend on seals for some products, but a continuing shift to a cash economy has reduced this dependence.

In the 1960's, harvests of the four species of hair seals in all Alaskan waters averaged about 18,000 per year. Declines in utilization from cultural changes and control imposed by the Marine Mammal Protection Act have resulted in harvests of 7,000 to 9,000 animals per year since 1972 (Alaska Department of Fish and Game, 1977). Seals are usually hunted on foot, by boat, or a combination of both. Foot hunters usually walk to a suitable lead and wait for seals to surface, while boat hunters may pursue seals in open water or locate seals resting on ice or land. Although winter hunting has been popular, the majority of seals are presently killed in the spring during break-up or in the fall before freeze-up. Restrictions of the Marine Mammal Protection Act have totally eliminated sport hunting for marine mammals.

Harrison Bay is an important belukha whale hunting area. Although whales provide large amounts of meat and fat, seals are the staple of the Eskimo diet (Selkregg, 1975). A small commercial fishery has operated in the Colville River delta since 1950, harvesting cisco and whitefish. The largest subsistence fisheries in the Arctic are conducted at Point Barrow, Kaktovik and Point Hope, mainly taking whitefish, cisco and Arctic cod (Selkregg, 1975). In addition, residents at Point Hope and Kaktovik harvest char for personal use.

Caribou have always been an important food source in the Arctic. Today, caribou are still taken in large numbers, but the Alaska Department of Fish and Game has instituted a permit system which establishes seasonal limits. Most caribou hunting is done when the ground is frozen and snow machines can be used for transportation. Most of the migrating caribou herds leave the Arctic Coastal Plain by early fall, but some remain longer and can be hunted in the winter.

The constantly increasing demand for sport hunting and fishing throughout Alaska has resulted in increased use of the Arctic slope by guides and sportsmen. Because of limited supply points coastal villages are important staging areas for hunting and fishing operations. Moose, caribou, Dan sheep, grizzly bear, Arctic char, grayling, and lake trout are the most important recreational species.

Other animals are sought primarily for their pelts to make clothing for residents and to sell on the open fur market. Wolves, polar bears, Arctic foxes and other fur-bearing animals are sought for their commercially-marketable fur. Marine mammals, with the exception of the polar bear and walrus (which occur only rarely in the area), may be used for subsistence or commercial handicrafts only by Natives, as stipulated by the Marine Mammal Protection Act of 1972.

CRITICAL AREAS

Based on species that are important for both sport and subsistence hunting and fishing near the Arctic coast, critical areas have been identified in Table 1.

TABLE 1

CRITICAL AREAS

SPECIES	LOCATION	REMARKS	USER GROUP
Bowhead and Belukha Whales	Point Barrow-Pitt Point	Seaward to about 15 miles	Barrow
Ringed Seals	Wainwright-Barrow	Landfast ice and grounded pack ice	Wainwright and Barrow
	Cape Simpson-Pitt Point	Landfast ice and grounded pack ice	Barrow
	Cross Island-McClure Island	Landfast ice and grounded pack ice	None
	Maguire Island-Camden Bay	Landfast ice and grounded pack ice	Kaktovik
Waterfowl and Shorebirds	Plover Islands	Staging and molting	Barrow
	Pitt Pt.-Cape Halkett-Teshekpuk Lake	Staging and molting	Barrow and Nuiqsut
	Colville River Delta	Nesting	Nuiqsut
	Jones Islands	Nesting	Nuiqsut
	Howe Island	Only snow goose nesting colony in Alaska	Nuiqsut
	Kaparuk River Delta	Nesting	Nuiqsut
	McClure Islands	Nesting	Nuiqsut
	Canning River Delta	Nesting	Kaktovik
	Sadlerochit River-Aichilik River	Snow goose staging area	Kaktovik
Musk Oxen	Canning River-Okpilak River	Resident	Tourists in Arctic Wildlife Range
Caribou	Teshekpuk Lake-Cape Halkett	Calving and resident caribou herd	Nuiqsut and Barrow
	Oliktok Point-Bullen Point	Calving and summer range	Tourists at Prudhoe Bay
	Katakturuk-Kongakut River	Calving	Kaktovik
Fish	Lower Meade River	Overwintering	Barrow-Atkasook
	Teshekpuk Lake	Overwintering	Barrow-Nuiqsut
	Lower Colville River	Overwintering	Nuiqsut
	Lower Kuparuk	Overwintering	Nuiqsut
	Lower Sagavanirktok River	Overwintering	Nuiqsut
	Lower Canning River	Overwintering	Kaktovik

References: Alaska Department of Fish and Game, 1977; Bergman, 1974; Burns et al., 1976; Cameron and Whitten, 1976, 1977; Craig and McCart, 1976; Davis and Valkenburg, 1977; Gavin, 1974, Hemming, 1971; Selkregg, 1975; Ward and Craig, 1974; Weller, 1977; Yoshihara, 1973.

III. CONCLUSIONS

The evaluation of baseline environmental conditions of the North Slope and Beaufort Sea has identified five important components related potential impacts or conflicts to the existing socioeconomic arid cultural infra-structure from offshore petroleum development. These are:

Water Resources (Figure No. 1)

Fresh water is a key resource for both domestic and industrial (petroleum) use. Water resources are important socioeconomically for three principal reasons. The possibility of use conflicts over water resources between domestic and industrial users may exist in future offshore petroleum activities. Petroleum development may also adversely affect water quality and availability through activities such as gravel extraction. Water extraction for industrial use and changes in water quality may in turn impact fish populations which are important subsistence food resources.

Gravel and Sand Resources (Figure No. 2)

Gravel and sand resources are important construction materials which will be required in large quantities for offshore petroleum development. They have been evaluated for three principal reasons: 1) as valuable, and locally scarce, resources, gravel and sand owned by Natives has important economic implications; 2) to a lesser degree, gravel and sand are important because conflicts in resource use could occur locally; and 3) environmental impacts of gravel extraction could affect water quality, water availability and fish populations.

Terrain Features (Figure No. 3)

Terrain features are an important input to the evaluation of water availability since there is a close correlation between the two.

Wildlife and Fish Distribution (Figure. Nos. 4 and 5)

In addition to a general environmental concern with species degradation, wildlife and fish populations were selected for analysis because they are important both socioeconomically and culturally as subsistence resource base. The mapping of species distribution and critical habitats for such subsistence food resources as the bowhead whale, ringed seal, Arctic char and caribou is essential in the analysis of potential impacts of offshore petroleum. development.

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V. GLOSSARY OF SCIENTIFIC TERMS

Accretionary bars - bars formed or increased by external addition or accumulation.

Alluvial fan - a mass of sediment deposited at a point along a river where there is a decrease in gradient.

Anadromous species - species which travel up rivers or streams from the sea for the purpose of breeding.

Barrier island - an island roughly parallel to a shore and separated by a lagoon type area.

Borrow, borrow sites - an excavated area where material has been dug for use as fill in another location.

Braided rivers - a river consisting of interwoven channels constantly shifting through islands of alluvium and sandbanks.

Cetaceans - an order of marine mammals including whales, dolphin, porpoises and related forms with barge heads, fishlike hairless bodies and paddle shaped forelimbs.

Delphi techniques - identification, ranking and weighing of issues of concern or environmental factors through aggregation of opinions of a multidisciplinary group in a series of discussion sessions.

Deoxygenation - to remove oxygen or air from water.

Detritus - loose material that results from disintegration or wearing away.

Eolian - deposited, produced, or eroded by the wind.

Euphausids - small luminescent crustaceans that resemble shrimp and form an important element in marine plankton.

Fauna - the animals or animal life of a region, period or special environment.

Flora - the plant life characteristics of a region, period, or special environment.

Glacial fluvial - glacial stream, relating to or produced by a glacial stream.

Groundwater - water in the part of the ground that is wholly saturated.

Hillocks - a small hill.

Leaching process - to dissolve out by the action of a percolating liquid.

Morphology - the external structure of rocks in relation to the development of erosional forms.

Passenine species - of or relating to the largest order of birds which includes more than half of all living birds and consists chiefly of altricial song birds of perching habits.

Permafrost - permanently frozen ground.

pi-l - a measure of the acidity or alkalinity of liquid on a scale of 0 - 14 with 7 representing neutrality. Numbers from O - 6 represent acidity and numbers from 8 - 14 represent alkalinity.

Phosphate level - the amount or level of phosphoric acid found in a substance.

Pingos - a low hill or mound forced up by hydrostatic pressure in an area underlain by permafrost.

Reaeration - resupplying or recharging water with oxygen or air.

Salinity - the amount of percentage of salt present in water.

Seismic surveys - study of sub-terranian structure using acoustic penetration techniques.

Surficial deposits - a deposit of or relating to the ground surface.

Thermokarst - unusual topography caused by percolating hot ground waters and underground streams.

Turbidity - a condition which sometimes occurs to water which is so stirred up or disturbed as to become opaque or obscurred.

Winnowed - to remove by a current of air, to treat by exposure to a current of air so that waste matter is eliminated.