Chapter Two: Property Description and Petroleum Potential

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A. Property Description

The sale area consists of uplands located just south of the Beaufort Sea coast, between the National Petroleum Reserve-Alaska (NPRA) and the Arctic National Wildlife Refuge (ANWR), with the Umiat baseline as its southern boundary (see Figure 1.1 and Chapter One). The entire sale area is onshore.

The sale area includes the Arctic coastal plain, between the Staines and Canning Rivers on the east and the Colville River on the west. This region is slightly smaller than the state of Massachusetts, encompassing more than 5 million acres of coastal lowlands, north-flowing braided rivers, and streams, lakes, and gently rolling hills and valleys. The southern boundary forms the east-west Umiat baseline located at about 69 degrees, 23 minutes north latitude where ground elevation varies between 500 and 1,200 feet above sea level. Elevation throughout the sale area is a key factor in the distribution of plants and animals as described in Chapter Three (AEIDC, 1975).

Prominent geographic features include the White Hills and Franklin Bluffs. Following the Sagavanirktok River to the south, the first 60 miles of the trans-Alaska oil pipeline bisects the sale area. The area also includes portions of numerous rivers, including the Colville, Miluveach, Kachemach, Itkillik, Anaktuvuk, Chandler, Ugnuravik, Sakonowyak, Kuparuk, Toolik, Putuligayuk, Sagavanirktok, Kadleroshilik, Ivishak, Shaviovik, Kavik, Staines, and Canning.

The entire sale area is within the North Slope Borough. This home rule borough, incorporated in 1972, extends from the Chukchi Sea to the Canadian border. The borough has the powers of taxation, land management and zoning, and is responsible for providing borough communities with public works, utilities, education, health, and other public services. The sale area includes lands in the vicinity of Nuiqsut on the Nechelik Channel of the Colville River, and the industrial community of Deadhorse at Prudhoe Bay. Nuiqsut residents rely heavily on the sale area for subsistence resources. Other borough residents from Kaktovik, Barrow, and Anaktuvuk Pass may travel to the sale area for subsistence (see Chapter Four).

B. Surface and Subsurface Ownership

The state of Alaska owns the surface of most of the sale area. Other surface estate owners within the general sale area boundary include Arctic Slope Regional Corporation (ASRC), the City of Nuiqsut, the North Slope Borough, the federal government, and many Native allottees. The state of Alaska owns most of the subsurface estate beneath the sale area; ASRC and the Kuukpik Village Corporation (Nuiqsut Village) also hold some mineral interests in the area.

The Alaska Statehood Act allowed the state of Alaska to select from the federal public domain 102.5 million acres of land as an economic base for the new state. The act also granted to Alaska the right to all minerals underlying these selections and specifically required the state to retain this mineral interest when conveying interests in the surface estate. The Alaska Native Claims Settlement Act (ANCSA), passed by Congress in 1971, allowed newly created regional Native corporations to select and obtain from the federal domain lands including the surface and subsurface estates within Native corporation boundaries as an economic base. It also allowed for Native village corporations and individual Native Alaskans to receive surface estate interests in land for their economic benefit.

1. Surface Estate

The surface estate of the uplands in the sale area fall into one of three ownership categories: land owned by the state of Alaska, land owned by ASRC or the Kuukpik Village Corporation (Nuiqsut), and land owned by Native allottees. With the exception of the bed of the Colville River, which is owned by the state, the surface estate of the uplands within the Colville River delta portion of the sale area falls into one of two ownership categories: land owned by the Kuukpik Village Corporation (Nuiqsut), and land owned by Native allottees. Kuukpik village land includes lands within and outside of NPRA.

Village-Owned Lands Outside of NPRA: ANCSA allowed the Village of Nuiqsut (Kuukpik Corporation) to select and acquire lands in the Colville River delta. Of Kuukpik's total entitlement of 115,000 acres (five townships), approximately 70,000 acres (three townships) could be selected outside of NPRA on lands that had been tentatively approved for conveyance to the state of Alaska. Under provisions of ANSCA, ASRC was allowed to acquire the subsurface estate beneath these lands. The 1974 agreement between Kuukpik, ASRC, and the state of Alaska, and the 1992 settlement agreement between ASRC and Kuukpik provided for the right of access to Kuukpik's surface. ASRC and the state of Alaska, their successors, assigns, and lessees were allowed to conduct oil and gas activities on Kuukpik's lands east of NPRA under the provisions of the 1992 settlement agreement, the lease, and, to the extent applicable, the requirements of AS 38.05.130.

Village-Owned Lands Inside of NPRA: In order to fully satisfy its land entitlement under ANCSA, Congress allowed Kuukpik to select certain lands within NPRA. Section 1431(o) of Alaska National Interest Lands Conservation Act (ANILCA) allowed ASRC an option to acquire the subsurface estate beneath these village lands, provided that the village corporation concurred. In 1987, Kuukpik conditionally concurred to ASRC's acquisition of these subsurface interests. ASRC subsequently conveyed an undivided ownership interest to certain sections of these lands, located along the Nechelik Channel of the Colville River, to the state of Alaska under the 1991 settlement agreement between the state of Alaska and ASRC (see above). In January 1996, ASRC initiated a lawsuit in federal court seeking a declaratory judgment that Kuukpik's consent rights under Section 1431(o) of ANILCA, the 1987 consent agreement and Section 14(f) of ANCSA do not constitute an absolute veto over exploration and development of ASRC's subsurface in NPRA, and that Kuukpik's consent may not be unreasonably withheld. The federal court ruled that the lawsuit lacked federal jurisdiction and dismissed the case. No other litigation has been initiated and the dispute remains unsettled.

Should these jointly-owned lands within NPRA be offered and leased, the lessee may not exercise its access rights to the Kuukpik-owned surface until the lessee makes provisions to compensate the landowner for all damages sustained by reason of entering upon the land as required by the lease and, to the extent applicable, the requirements of AS 38.05.130 as required in the terms of the lease.

Native Allotments: The surface estates to certain lands within the sale area are owned by Native allottees. Should these jointly-owned lands be offered and leased, rights to exploration and development of the oil and gas resources may not be exercised until the lessees make provisions to compensate the landowner for all damages sustained by reason of entering upon the land as required by the lease, and, to the extent applicable, the requirements of AS 38.05.130.

2. Subsurface Estate

a. Agreement between State of Alaska and Arctic Slope Regional Corporation

The subsurface estate within the portion of sale area located within the Colville River delta is jointly owned by the state and ASRC. The joint ownership is the result of an agreement between the state and ASRC that was signed December 17, 1991, approved by the legislature and became effective on May 27, 1992. The agreement settled a long-running legal dispute concerning North Slope mineral ownership near Nuiqsut and Point Lay resulting from a 1974 agreement in which ASRC and the state agreed to exchange lands near Nuiqsut and Point Lay. Under the 1991 settlement, the state and ASRC agree to jointly own undivided interests in certain minerals (including oil and gas) in the mineral estate of disputed lands. The settlement also grants the state the executive right to hold oil and gas lease sales jointly for itself and ASRC.

If and when such lands are leased, the state and ASRC separately administer the lease with respect to its own undivided interest in the subsurface (the lessee must obtain a permit or approval from both the state and ASRC). The two parties have what is essentially an identical but separate relationship with the lessee with respect to the same mineral estate. Although such mineral cotenancies (possession of a unit of property by two or more persons) are unusual in Alaska, this is a frequent occurrence in other states, like Texas, where land ownership is more complicated. The agreement involves only the mineral estate; it does not change the surface ownership. The surface of the uplands within the agreement area near Nuiqsut is owned by the Kuukpik Corporation and by individual Native allotment holders. The subsurface estate beneath the tide and submerged lands, and bed of the Colville River within the sale area, are also jointly owned by the state and ASRC.

Under the settlement agreement, the state does not give up any of its duties to the public imposed by law. The state still must determine whether a sale would be in the best interests of the state, and must follow relevant substantive and procedural requirements for leasing and for permitting subsequent exploration, development and production. The state retains all rights under state law to ensure that development activity on leased tracts complies with laws governing natural resource management and protection.

b. Agreement between Arctic Slope Regional Corporation Agreement and the Kuukpik Corporation

Portions of the sale area are located within NPRA, and may also be subject to a 1987 land selection consent agreement between ASRC and the Kuukpik Corporation (Nuiqsut village). In that agreement these parties consented and agreed as follows:

(1) Kuukpik hereby gives its concurrence for ASRC to exercise its option under 1431(o) of ANILCA to acquire the ASRC Subsurface, but Kuukpik expressly conditions its concurrence in such acquisition of the ASRC Subsurface by reserving the right to consent to any Exploration and Development Activities that ASRC, its successors and assigns, may engage in from time to time with respect to the ASRC Subsurface.

(2) ASRC agrees that it will not engage in any Exploration and Development Activities with respect to the ASRC Subsurface without first obtaining the consent referred to in paragraph 1 of this agreement.

ASRC received title to these lands subject to this agreement. The state of Alaska received its undivided interest to the subsurface estate beneath these lands from ASRC in 1992, 1993, and 1994. The state’s title and leases issued on these lands are, therefore, also subject to the 1987 ASRC-Kuukpik Agreement.

Copies of the 1974 agreement, the 1991 settlement agreement between the state of Alaska and ASRC (which includes the 1987 ASRC-Kuukpik Agreement), and the 1992 settlement agreement between Kuukpik and ASRC will accompany the lease for any of the tracts to which the agreement applies. Copies of all agreements are available for review in the ADNR’s Public Information Center and are also available from DO&G on request.

C. Physical Characteristics

1. Geology

Northern Alaska is made up of three distinct geologic regions: the Brooks Range, the Arctic Foothills, and the Arctic coastal plain (Moore, et al., 1994). The sale area is located in the center of the Arctic coastal plain, and rock sequences with known petroleum potential underlie the entire region. The rocks under the sale area are exposed at the surface in the Brooks Range. Rock sequences are formed by geologic events and are often described in terms of the time period during which they were formed (see Table 2.2).

Table 2.1 Geologic Time and Formations

Eras	Periods	Epochs	Began Approximate Number of Years Ago
Cenozoic	Quaternary	Holocene (Recent) Pleistocene (Glacial)	10,000 1 million
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	7 million 25 million 40 million 60 million 68-70 million
Mesozoic	Cretaceous Jurassic Triassic	Upper and Lower	135 million 180 million 225 million
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian		270 million 325 million 350 million 400 million 440 million 500 million 600 million

Source: Webster's Ninth New Collegiate Dictionary, 1991:512; AEIDC, 1975:37

The Brooks Range consists of east-west trending mountain groups that reach heights in excess of 6,000 feet. Rocks of pre-Mississippian age (350 million-plus years) to Tertiary age (7 million-plus years) are exposed due to extensive uplift, folding, and faulting. There is little to no oil and gas potential in the Brooks Range because of this extensive deformation and uplift, however these pre-Mississippian to Tertiary-age rocks are studied by petroleum geologists, because they do contain petroleum where they occur beneath the sale area.

The Arctic Foothills is a narrow province between the Brooks Range and the Arctic coastal plain, consisting of a series of rolling hills, mesas, and east-trending ridges that descend from 1,500- to 900-foot elevations. The rocks in this area are less deformed and younger than those to the south.

The Arctic coastal plain contains surface sediments which were formed by fluvial (moving water) and deltaic deposition. These sediments are relatively uniform sandy silts (Craig, et al., 1985). The coastal plain is underlain by the Colville basin; a large east-west trending foreland basin of Cretaceous (135 million-plus years) to Tertiary age (7 million-plus years). The subsurface geology of this area and the history of previous petroleum production and exploration make it the most prospective area for hydrocarbons in northern Alaska.

The history of rocks beneath the sale area is marked by periods of continental rifting, mountain building, and sedimentary deposition. This history is marked by four distinct geologic sequences of rocks with each having a unique sediment source area, depositional environment, and structural character. As these major rock sequences were being formed, relatively smaller-scale events, such as changes in sea level, altered the depositional environment and created additional internal complexities. The four major rock sequences from oldest to youngest (the oldest rocks are the deepest) are: the Franklinian, Ellesmerian, Rift, and the Brookian. The order of events in the evolution of the area geology was (see Figure 2.3):

1. A stable early Arctic Continental Platform before Devonian time,
2. onset of continental rifting with uplift to the north of this stable Arctic platform and deposition of sediments southward; and
3. continued rifting, uplift, and termination of deposition from the north, along with uplift of the Brooks Range and deposition of sediments from the south onto the Arctic coastal plain.

The oldest rock sequence, the Franklinian, may have once been a stable Arctic continental platform before middle Devonian time (about 400 million years ago). This sequence is also referred to as the pre-Mississippian sequence, because of a lack of continuous geologic information. The Franklinian sequence contains a wide range of rock types that include volcanics, granites, carbonates, and metamorphosed argillites. Due to its geology and tectonic history, the Franklinian sequence is considered to have low petroleum potential (Richter, 1997).

During middle to late Devonian time, a mountain-building and rifting event uplifted the Franklinian sequence, deforming and metamorphosing the rocks in the process. Sediments from the uplifted Franklinian sequence spread southward into the large arctic basin (epicontinental shelf). This process continued through to late Cretaceous time. These northerly-sourced sediments formed the Ellesmerian sequence (Moore, et al., 1994).

The Ellesmerian sequence is the most important geologically in terms of petroleum production. Formations within the Ellesmerian sequence form the primary petroleum reservoirs at Prudhoe Bay and Endicott. The Ellesmerian sequence contains marine carbonates and quartz- and chert-rich clastic rocks, representing about 150 million years of deposition (Mississippian through Triassic). From the center of the Colville basin, the Ellesmerian thins to the south due to depositional distance from its source and thins to the north due to subsequent uplift and erosion (Moore, et al., 1994).

Rifting of the continental mass dominated the geology by the end of the late Jurassic to late Cretaceous periods. The northern continental source for the Ellesmerian sediments supplied less and less sediment to the Arctic basin as time passed. Uplift and faulting of the Franklinian and Ellesmerian sequence formed fault blocks and grabens (low areas between fault blocks). These grabens were filled by sediments from the locally uplifted or upfaulted Ellesmerian and Franklinian sequences, forming the Rift sequence (Craig, et al., 1985). It is also at this time that the Barrow Arch formed along the present-day Beaufort coast. Sedimentation from the north eventually ended sometime in the Late Cretaceous and the following period of non-deposition along with continued uplift along the Barrow Arch created a regional Lower Cretaceous Unconformity (LCU) which becomes angular approaching the Barrow Arch from the south. To the north of the Barrow Arch the Ellesmerian sequence is absent. The LCU is an important migration and accumulation element for most of the oil fields on the North Slope, including Prudhoe Bay (Jamison, et al., 1980).

To the south, compressional forces in the Jurassic to early Cretaceous caused thrust faulting in what is now the Brooks Range. Sediments from the thrust faulted blocks in the Brooks Range poured into the Colville basin, progressively filling it from the south, forming the Brookian sequence. Brookian sediments filled the Colville basin and spread out over the Barrow Arch and onto Alaska’s continental margin during the upper Late Cretaceous through Tertiary time. Petroleum accumulations in the Brookian sequence are found throughout the North Slope basin, including at West Sak, Schrader Bluff, Flaxman Island, and the Outer Continental Shelf (OCS) accumulation at Hammerhead (Shell Oil’s current Sivulliq prospect) (Weimer, 1987).

Onshore present day geology of the sale area is, in general, comprised of a thick section of unconsolidated Quaternary sediments (Brown and Kreig, 1983), deposited within the last 1 million years. These sediments are probably of the Gubik Formation which unconformably overlies the weakly cemented sediments of the upper Brookian sequence. Most Quaternary deposits are unconsolidated sand and gravel composed of reworked Brookian sediments, along with materials from the present-day Brooks Range. Overlying these deposits are ice-rich silts and sandy silts (1.5 meters to 2.5 meters thick at Prudhoe Bay) that include variable amounts of organic matter, which are deposited by the numerous rivers on the North Slope. In addition to these fluvial deposits are local areas of eolian deposits (sand dunes) derived from river silts (Brown and Kreig, 1983).

1. Climate

The entire sale area is within the Arctic climate zone of Alaska. Surface conditions in the Arctic vary dramatically from year to year and day to day. In summer, the climate is generally mild. The three-month ice-free season is critical to biological productivity. In contrast, winters are severe, forcing many species to migrate south.

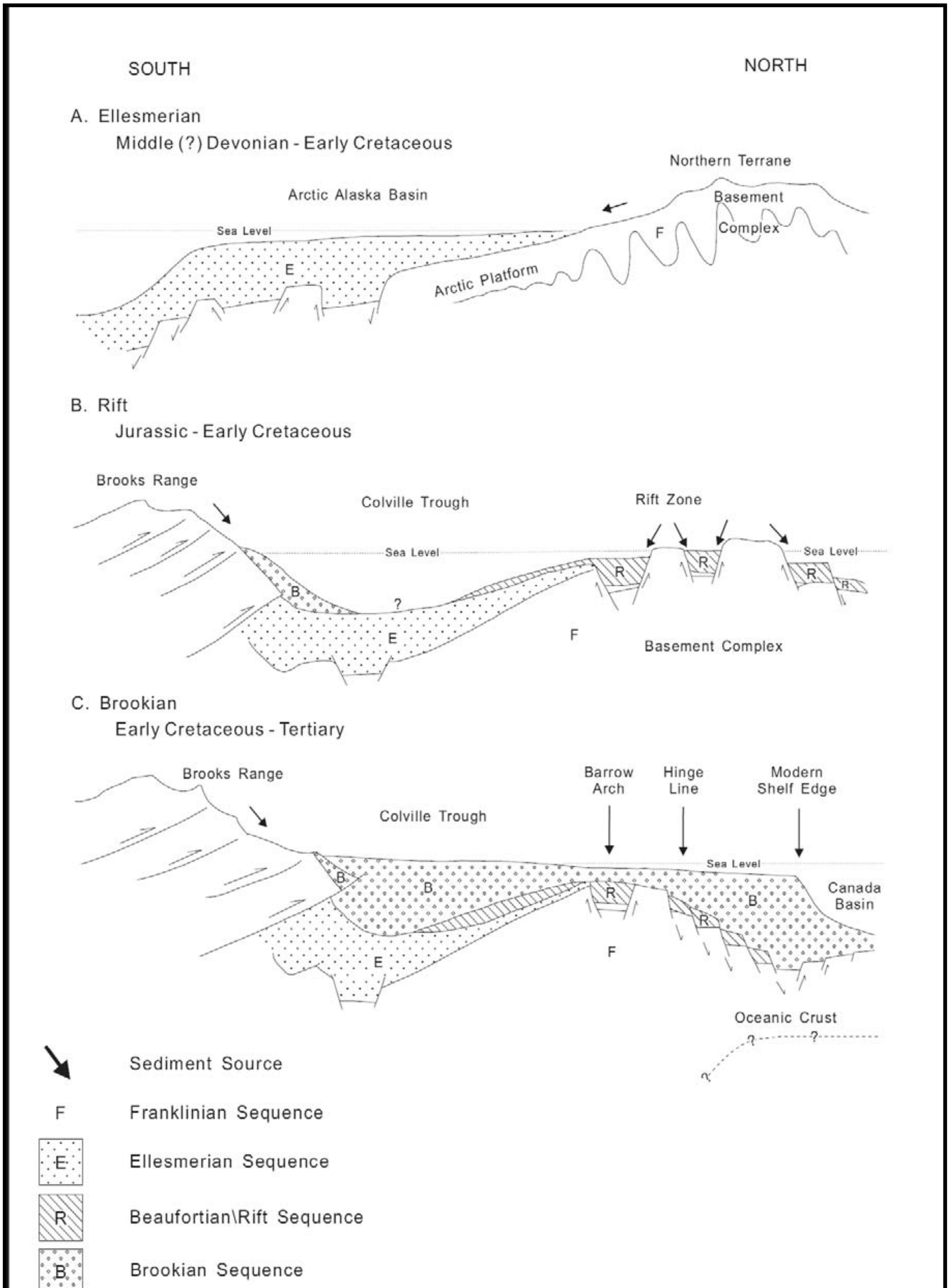
a. Precipitation

Precipitation throughout the sale area varies with location. Heaviest rain and snow falls occur in higher elevations. Along the Beaufort Sea coast, the amount of precipitation is low. Air temperature controls how much moisture the air holds as a vapor. Extremely cold air can contain only very small amounts of water vapor, resulting in low precipitation. Therefore, the frozen region is classified as a desert (AEIDC, 1975). The average annual precipitation ranges from 40 inches in the Brooks Range to 5-8 inches along the foothills and coast (NSSI, 2006). Umiat, at the southern boundary of the sale area receives an average of 5.49 inches of precipitation and 33.0 inches of snowfall each year (Alaska.com, 2006). In contrast, Barrow receives an average of 4.16 inches of precipitation and 29.1 inches of snowfall each year (ACRC, 2006). In the Nuiqsut-Prudhoe Bay area, precipitation averages 4.02 inches with an annual snowfall of 33.1 inches (*Ibid.*). Anaktuvuk Pass, located outside the sale area and deep in the Brook Range receives an average of 11 inches of precipitation and 63 inches of snowfall annually (ADCED, 2006).

a. Temperature

While winters are long, the North Slope is not a year-round icebox. Summer high temperatures range between 40 and 60 degrees Fahrenheit and the sun does not set between May 10 and August 2 (NSSI, 2006). Winter temperatures range between 0 and minus 40 degrees Fahrenheit and the sun does not rise above the horizon from November 18 to January 24 (*Ibid.*). The average annual high temperature for the sale area is around 18 degrees Fahrenheit, with July being the warmest month (Alaska.com, 2006; ACRC, 2006). February is the coldest month and the average annual low temperature is around 4.5 degrees Fahrenheit

Figure 2.1 Evolution of North Slope Geology



Source: Craig and others, 1985

(ACRC, 2006; Alaska.com, 2006). Anaktuvuk Pass is the only part of the sale area with a more continental climate. Average temperature in January, the coldest month, is minus 14 degrees Fahrenheit and the average summer temperature is 50 degrees Fahrenheit (ADCED, 2006).

b. Winds

A semi-permanent area of high pressure is centered approximately 600 miles north of the Alaska Arctic coast. Air continually flows south from this area of higher pressure as a north wind. By the time it reaches the Beaufort Sea coast, its direction is between northeast and east because of the rotation of the earth (AEIDC, 1975). Wind direction is predominately easterly (ACRC, 2006). Sea breezes (air moving inland in response to unequal heating across the coastline) control at least 25 percent of the summer surface wind direction and extend to at least 20 kilometer offshore (MMS, 1996a; Kozo, 1984).

Surface wind speeds along the coast are persistent and strong compared to those in the south. Coastal wind speeds up to 65 mph occur along the coast during winter months, while calm conditions are more common to the south (ACRC, 2006; AEIDC, 1975). Barrow and Barter Island experience calm winds only one percent of the time, while the winds are calm at Umiat about 17 percent (ACRC, 2006; AEIDC, 1975). The average annual wind speed is about 11 mph at Barrow and 13 mph at Barter Island (ACRC, 2006).

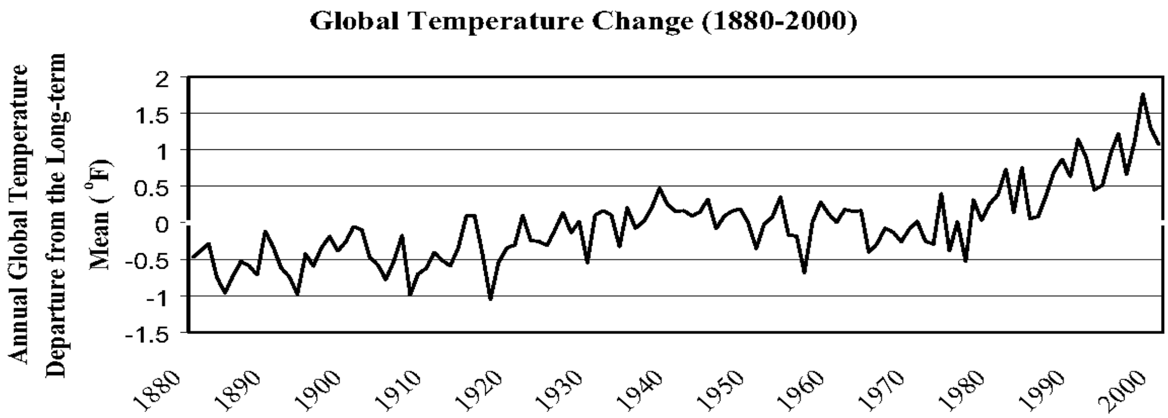
Surface wind conditions affect nearshore currents, the movement of ice floes and oil spills, and the formation and break-up of sea ice. Winds also influence the timing of migratory activity in animals, including arctic fishes, and the relative safety of subsistence harvesting and oil and gas activities in the Arctic (Kozo, 1984). Strong winds produce extensive coastal erosion, and can cause structural damage to buildings. Arctic winds also blow snow and cause whiteout conditions, making surface navigation across the flat, horizon-less coastal plain nearly impossible. Finally, strong winds can severely restrict aircraft travel in the sale area (AEIDC, 1975).

c. Climate Change on the North Slope

Since the late 19th century, average global temperatures have increased 0.5 to 1.0 degree Fahrenheit (BLM, 2005). Temperature increase in Alaska over the last 50 years averages 3.5 degrees Fahrenheit, although the temperature changes vary greatly across the state and more variance has occurred in winter and spring months (ACRC, 2006). A study of oil exploration wells along the Arctic coastal plain and foothills measuring the temperature of permafrost to depths of more than 600 feet estimates that temperatures along the North Slope have increased 4 to 8 degrees Fahrenheit over the last century (BLM, 2005). A general increase in permafrost temperatures in Alaska has also occurred over the last several decades; however the rate of increased slowed in the 1990’s, compared to prior decades (Richter-Menge, et al., 2006). Temperatures in Alaska and throughout the Arctic appear to have fluctuated over the last few centuries. Regional climatic change is difficult to quantify and much less reliable than global estimations (BLM, 2005; ACRC, 2006).

According to the Bureau of Land Management (BLM), global warming would negatively affect the Arctic environment, including tundra, sea ice, and changes in the permafrost depth. Reduction in sea ice as a result of global warming would affect marine mammals (particularly polar bears), fish, and birds, with related implications for Native subsistence harvests. Vegetation is expected to move northward, with forests replacing tundra, and tundra vegetation moving into previously barren areas. Early thawing of rivers may impact caribou migrations to calving grounds. However, some Arctic fisheries may become more productive due to global warming. Global warming would also contribute to a rise in sea level, impacting estuaries and coastal wetlands, and alter regional temperature and rainfall patterns, with major implications to agricultural and coastal communities. In addition, this sea level rise and thawing of tundra could have negative effects on oil and gas-related infrastructure (BLM, 2007). These effects must be considered in determining facility siting, design, construction, and operation and in determining the optimum oil and gas transportation mode. Structural failure can be avoided by proper facility setbacks from coasts and river banks. See Chapter 6, Section A Geophysical Hazards.

Figure 2.2 Global Temperature Change



Source: BLM, 2005, citing USDOC, NOAA, National Climatic Data Center, 2001

2. Hydrology and Soils

The southern half of the sale area lies in the northern foothills of the Brooks Range. These foothills are characterized by irregular buttes, knobs, mesas, east-trending ridges, and intervening, rolling tundra plains. Most streams east of the Colville River are braided with large gravel flats. The Arctic coastal plain west of the Colville River is flat with occasional pingos and a section of active and stabilized sand dunes which rise as high as 40 feet above the plain. East of the Colville River, the White Hills and Franklin Bluffs provide some topographic relief above the plain. The combination of extensive flat terrain, and a continuous layer of permafrost beneath a shallow active permafrost layer result in poorly drained soils and marshes throughout the northern portion of the sale area (AEIDC, 1975).

a. Hydrology

The summer season on the Arctic coastal plain is initiated by extensive spring flooding along the coastal margin. The heaviness of this flooding varies from year to year and depends on factors such as amount of upland snow accumulation and the timing of river ice and sea ice breakup. The speed, direction, and persistence of summer winds determine whether freshwater river runoff accumulates or dissipates in the nearshore waters of the Beaufort Sea. This brief, but heavy, seasonal flood breathes life into all habitats of the sale area after a long dormant winter. River deltas are made up of major and minor channels, and numerous oxbows and lakes. These river deltas, especially the Colville, provide important migrating, spawning, feeding and overwintering habitat for Arctic fish (see Chapter Three). The river systems of the sale area also provide important habitat for many species of birds, like peregrine falcon, and migratory and feeding habitat for caribou, bear, wolves, and foxes. Additionally, subsistence harvesting is heavily dependent on the productivity and species diversity of the rivers, streams, and lakes of the North Slope.

Numerous lakes in the sale area are formed by thermokarst (freeze and thaw) processes. Thermokarst topography consists of mounds, sink holes, tunnels, caverns, short ravines, lake basins, and circular lowlands. Melting of the underlying permafrost creates settling of the soil, resulting in depressional features, such as thaw lakes. On the Arctic coastal plain, thaw lakes are elongated and oriented on a north-northeast axis by prevailing wind patterns. Thaw lakes cover more than half of the total surface area of the plain. In the southern portion of the sale area, lakes are less oriented and are fewer in quantity.

Across the coastal plain, ground-surface depressions cause pooling of water in summer. This pooling causes the underlying permafrost to melt. Thaw continues along lake margins, extending the lake which may merge with other thaw lakes. Eventually, thaw extension of the lake continues until higher ground is breached and the lake is drained through an outlet channel. Some thaw lakes are connected to river channels while others are not. Drained lakes leave behind a marshy depression surrounded by a ridge of surface material (residual), formerly the lake margin. The initial surface residuals rise 10 to 15 feet above the adjacent drained basins and cover about 25 percent of the land surface on the coastal plain (AEIDC, 1975).

b. Soils

Major river corridors of the Colville, Kuparuk, Sagavanirktok, Shaviovik, and Canning are underlain by unconsolidated alluvial (stream laid) deposits. These deposits are: coarse-grained; generally well-drained; not frost-susceptible; provide good foundation material; and are relatively easy to excavate. The uplands between these rivers are overlain by coastal plain deposits. These deposits include both course and fine-grained material, and have generally high silt content, especially near the surface. Coastal plain deposits generally are poorly drained, high in ice content, difficult to excavate, and are frost-susceptible, making them less suitable for foundation material. In the southern portion of the sale area, Tertiary-age bedrock is exposed in the White Hills, Franklin Bluffs, and in the rolling hills to the west of the Canning River. Organic surface material, called peat, is distributed throughout the sale area and provides the bedding to support the tundra mat above. Peat is poorly drained, contains a high content of ice or water, and is commonly removed or filled over prior to construction (AEIDC, 1975). Windblown silts may form thin layers mixed with or underlying the peat layer (AEIDC, 1975).

Permafrost consists of any soil or other superficial deposit, including bedrock, that has been colder that 0 degrees Celsius (C) for two or more years. Permafrost soils may be nearly ice free in coarse, unsaturated materials and may contain more than 50 percent water in finer grain saturated soils. Alaska has two types of permafrost classified as continuous or discontinuous. Continuous permafrost implies that the ground is frozen over nearly all the landscape and is colder than -5 degrees C at the depth below annual seasonal temperature changes (depth varies based on rock type and water content, but is about 15 meters). Discontinuous permafrost is ground that is between 0 degrees C and -5 degrees C and as the term suggests, is not continuous. In discontinuous zones of permafrost, ground on south-facing slopes and under large bodies of water are usually not frozen. Generally the permafrost is continuous north of Atigun Pass (crest of the Brooks Range) (Brown and Kreig, 1983). Heading offshore the permafrost becomes progressively more discontinuous (MMS, 1996).

Near Prudhoe Bay, permafrost extends to a depth of about 600 m, which is also the probable case for most all of the onshore portions of the sale area (Brown and Kreig, 1983; Combellick, 1994, citing to Collett and others 1989). The depth of the active layer, or the layer of seasonal thaw is generally less than 0.9meters and 1.8meters beneath active stream channels. Ice content varies from minor segregated ice to massive ice in the form of ice wedges and pingos. Permafrost, like coastal winds, shallow gas deposits, and earthquakes, is a geophysical phenomenon which may pose hazards to oil and gas operations (see Chapter Six).

D. Exploration History

Oil seeps have long been known to the Inupiat people of the North Slope, who excavated tar-saturated tundra for use as fuel within historic time. Following reports of oil seeps along the coast by early traders, the first geologic and topographic studies were conducted in 1901 and the first formal descriptions were recorded by the U.S. Geological Survey (USGS) in 1919. By 1921, prospecting permits were filed and in 1923, President Harding established the Naval Petroleum Reserve No. 4 (NPR-4) by executive order. The USGS conducted reconnaissance mapping from 1923 through 1926 and published the results in 1930 (Jamison et al, 1980; AEIDC, 1975).

The first exploration phase of NPR-4 ended in 1953. Between 1923 and 1953, the United States Navy drilled 37 test wells and found three oil accumulations and six gas accumulations within and adjacent to the reserve. Only two of these discoveries were considered sizable, namely Umiat, with an estimated 70 million barrels of recoverable oil, and Gubik (partly outside the reserve), with an estimated 600 billion cubic-feet of recoverable gas (Molenaar, 1982; Kumar, et. al., 2002). Gas from another of the discoveries, the small South Barrow gas field, is being produced today for local consumption at Barrow.

BLM opened North Slope lands for competitive bidding in 1958 when 16,000 acres were offered in the area of the Gubik gas field. That same year BLM opened four million acres in an area south and southeast of NPR-4 for simultaneous filing and subsequent drawing. From 1962-1964 industry exploration programs expanded rapidly. During this period, Sinclair and British Petroleum drilled a total of seven unsuccessful wildcat wells in the Arctic foothills (Jamison et al, 1980).

In 1964, under the Statehood Act, the state of Alaska selected some 80 townships across the northern tier of lands between the Colville and Canning Rivers and received tentative approvals on the 1.6 million acres from the federal government in October of the same year. In December 1964, the state held the 13th State Competitive Sale (the first on the North Slope) of leases covering 625,000 acres in the area east of the Colville River delta. In July 1965, the state held the 14th State Competitive Sale, which included the onshore area in the vicinity of Prudhoe Bay. In the 18th State Competitive Sale, held in January 1967, the offshore Prudhoe Bay tracts were offered and leased (Jamison et al, 1980).

Following the succession of dry holes in the Arctic foothills, exploration shifted northward to the central coastal area. In 1965, the first holes drilled in the area immediately surrounding the Prudhoe Bay structure came up dry. In January 1967, in what was essentially a last-ditch effort, a rig was moved to the Prudhoe Bay State No. 1 location near the mouth of the Sagavanirktok River. Twelve months later the discovery of the Prudhoe Bay oil field was announced (Jamison et al, 1980; AEIDC, 1975). Prudhoe Bay field began production in 1977 and, with its satellite fields, is currently estimated to have originally contained in excess of 15 billion barrels of economically recoverable oil (Figure 2.1), making it the largest oil field ever discovered in North America.

Following the Prudhoe Bay discovery, exploration activity increased dramatically. Thirty-three exploration wells were completed in 1969, as industry prepared for the Lease Sale 23 in September of that year. The state offered 413,000 acres along the Arctic coast between the Canning and Colville Rivers and earned more than $900 million in bonus bids on 164 tracts (Weimer, 1987; Jamison et al, 1980). One significant find that came out of this increased activity was the discovery of the Kuparuk River field. In the spring of 1969, the Sinclair Ugnu No. 1 well tested oil from the Kuparuk Formation at a rate of 1,056 barrels of oil per day (Masterson, 1992). Subsequent delineation proved the field to contain over one billion barrels of recoverable oil. Production at Kuparuk began in December of 1981, and current estimates place the ultimate recovery of oil from the field at more than 2.6 billion barrels, including satellite accumulations (PN, 2007). The 1969 sale was the last lease sale on the North Slope until the joint federal-state sale in December 1979. After the discovery of the Prudhoe Bay field and before the 1979 joint sale, more than 100 exploratory wells were drilled on the North Slope, with 19 of those wells discovering oil or gas.

In 1974, spurred by the OPEC oil embargo of 1973, the federal government began a second large exploration program in NPR-4, which was re-designated the National Petroleum Reserve-Alaska (NPRA) in 1976. Between 1974 and 1981, the USGS drilled a total of 27 test wells within NPRA. Other than two additional gas fields that are currently being produced to supply Barrow, no commercial deposits were discovered by this program. The two currently producing fields are the Walakpa field, which contains an estimated 142 billion cubic feet of economically recoverable gas (Imm, per. comm., 1996), and the East Barrow field, which contains an estimated 13 billion cubic feet of economically recoverable gas (Kornbrath, 1995;12). In 1980, Congress authorized competitive leasing within NPRA. From 1982-1984, four lease sales were held. A total of more than 1.3 million acres were leased in the first three sales, generating over $84 million in total bonus bids. The final sale received no bids. Only one industry well was drilled on a lease acquired in these sales. This well, the ARCO Brontosaurus No. 1, was completed, plugged, and abandoned in 1985.

The 1994 discovery of the giant Alpine field in previously unknown Jurassic sandstones on the northeastern border of NPRA demonstrated that the area contained significant untapped potential for commercial oil and gas accumulations. The field began production in late 2000, and is currently estimated to contain 429 million barrels of economically recoverable oil (PNA, 2000). The discovery and subsequent development of the Alpine field has spurred renewed interest in the oil and gas potential of NPRA, as well as the exploration and potential development of similar places in the Colville delta area.

Since the 1979 joint sale, five federal lease sales have been held in the Beaufort Sea, and there have been 28 state lease sales offering both onshore and submerged Beaufort Sea acreage. To date, 31 exploratory wells have been drilled in the federal waters of the Beaufort Sea, resulting in five discoveries: Seal Island/Northstar, Kuvlum, Hammerhead, Sandpiper, and Tern Island/Liberty. Exploration wells drilled through 2006 on North Slope state leases have resulted in 26 discoveries.

It is not surprising that many of these accumulations were found in the vicinity of Prudhoe Bay and Kuparuk, where the density of wells and seismic control is the highest and the geologic conditions optimal. At least eight of these post-Prudhoe Bay discoveries are currently producing oil because of the Prudhoe Bay infrastructure and their relatively close location to the trans-Alaska oil pipeline. Six of these, Lisburne, Kuparuk, Milne Point, Endicott, Niakuk, and Point McIntyre are major fields (See Table 2.1). While initial production on the North Slope was from onshore areas, five fields, Endicott, Point McIntyre, Milne Point, Niakuk, and Northstar, produce at least some of their reserves from offshore areas.

The most recent development projects in the Kuparuk and Prudhoe fields have involved low-gravity oil sands (Shrader Bluff/West Sak, and Ugnu) that were primarily discovered in the Kuparuk River area in 1969. In the Kuparuk area, the West Sak sands alone contain an estimated 16 billion barrels of oil in-place and combined estimates for the West Sak and Ugnu area are as high as 40 billion barrels in-place (Werner, 1987). Start-up of production of the West Sak occurred in 1997, with estimates that the initial pilot area contains 300-500 million barrels of economically recoverable oil (ADN, 1996b). Low-gravity production from the correlative Schrader Bluff formation sands at the Milne Point field exceeded 20,000 barrels of oil per day on average by 2004 (AOGCC, 2007). The geographic area over which this West Sak/Schrader Bluff resource occurs is extensive, and includes portions of the Kuparuk, Milne Point and Prudhoe Bay units. Since the initial production at Kuparuk and Milne Point fields, the Prudhoe Bay field has begun its own Schrader Bluff oil projects in the western portion of the unit, called Orion and Polaris, and recent Schrader Bluff oil discoveries have been unitized to the northwest of Milne Point (Nikaitchuq) and southeast of Kuparuk (Rock Flour).

State lands east of Prudhoe Bay saw renewed exploration activity during the 1990s, yielding oil discoveries in Canning formation sandstones and the Sourdough and Yukon Gold prospects south of the Point Thomson field adjacent to ANWR. Current information indicates Sourdough could contain 100 million barrels of recoverable oil. The Sourdough project would require up to 35 miles of pipeline to link up with the Badami field (Peninsula Clarion, 1997).

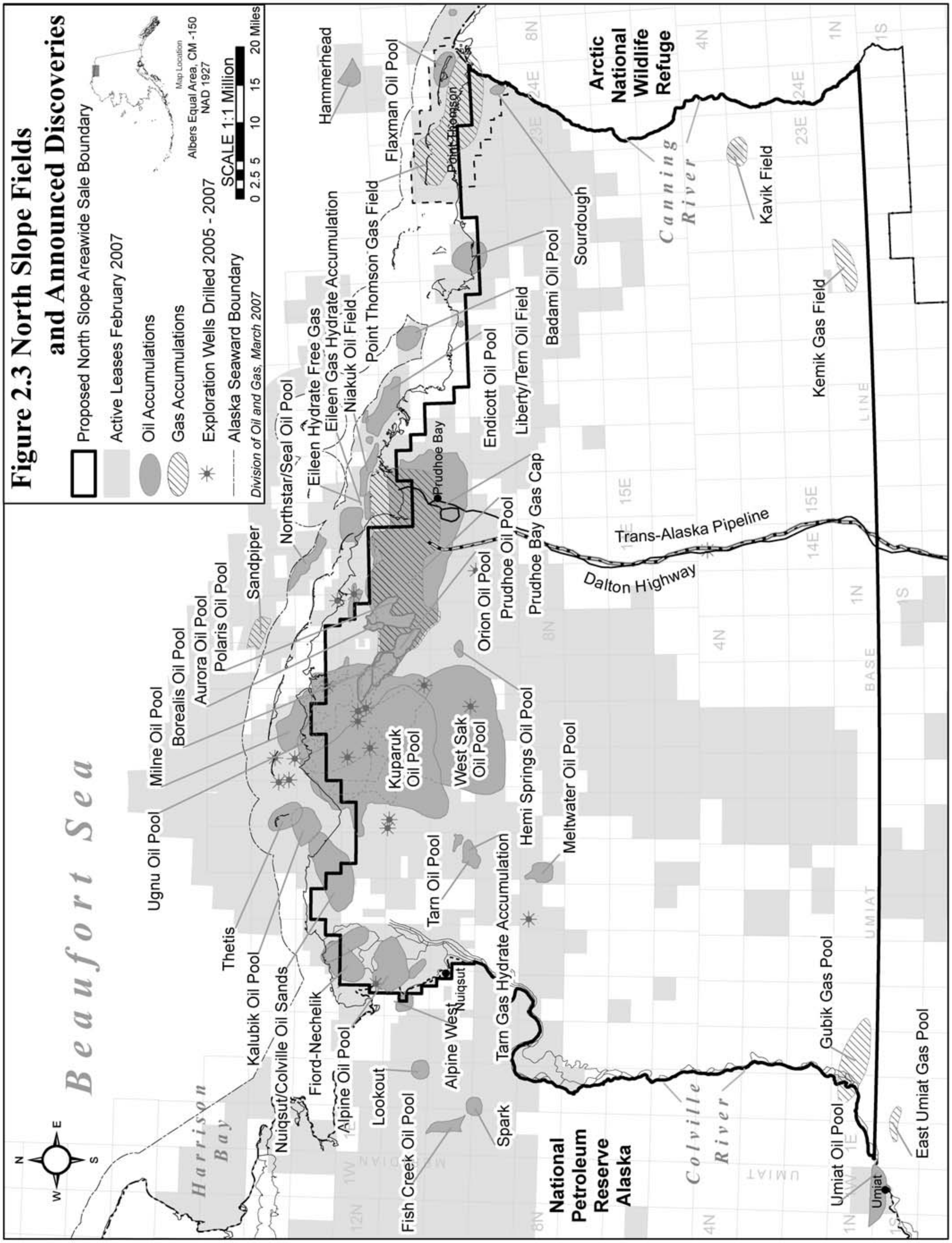


Figure 2.3 North Slope Fields and Announced Discoveries

Table 2.2 Major Producing Fields on the North Slope and in the Beaufort Sea

Field Name	Discovery Date	Production Began	Known Current Estimated Ultimate Recoverable Oil (MMBBL)*	Known Current Estimated Ultimate Recoverable Gas (BCF)
Prudhoe Bay	1967	1977	15,201	24,526
Kuparuk River	1969	1981	3,538	1,150
Colville River	1992	2000	675	400
Milne Point	1969	1985	633	14
Endicott	1978	1986	585	843
Northstar	1984	2001	205	450
Badami	1990	1998	6	

* Volumes include satellites

Source: Hartz, 2006

E. Petroleum Potential

The sale area encompasses a vast and diverse area, which makes it difficult to assign an overall petroleum potential. ADNR has determined the petroleum potential to be low to moderate, with the potential generally increasing from south to north. Determining the petroleum potential involves the evaluation of several elements including geology, geophysics, and exploration history of the area.

For an accumulation of hydrocarbons to be recoverable, the geology must be favorable. This may depend on the presence of source and reservoir rock; the depth and time of burial; the presence of migration routes and geologic traps or reservoirs, and the timing of fluid movements from source to trap. Source rocks are organic-rich sediments, generally marine shales, which have been buried for a sufficient time and with sufficient temperature and pressure to form hydrocarbons. As hydrocarbons are formed, they will naturally progress toward the surface if a migration route exists. An example of a migration route might be a permeable layer of rock in contact with the source layer, or fractures which penetrate organic-rich sediments. A hydrocarbon reservoir is permeable rock that has been geologically sealed at the correct time to form a “trap.” The presence of migration routes therefore affect the depth and location where oil or gas may pool and form an accumulation.

For a hydrocarbon accumulation to be economically producible, the reservoir rock must have sufficient thickness, good porosity (the number of pore spaces per volume), permeability (a rock’s capacity for transmitting a fluid), and hydrocarbon volume or fill. The North Slope has all these favorable geologic conditions and, considering the exploration history of the area, the chances of finding undiscovered petroleum reservoirs are very good. However, proximity to the collection, processing, and distribution network, directly affects the economic field size limit for an oil accumulation. Whereas accumulations in the order of a few tens of millions of barrels are considered economic to develop in the vicinity of the existing oil fields, accumulations need to be on the order of hundreds of millions of barrels to be considered economic in the more remote areas of the sale area. Proximity and the resultant economic field size limit generally skew the petroleum potential to be low in the more remote southern portions of the sale area. It is anticipated that the remaining undiscovered accumulations are expected to be near or below the economic size limit. In light of these factors, ADNR considers the petroleum potential of the sale area to generally increase from low in the southern portion to moderate in parts of the northern portion.

The process of evaluating the oil and gas potential for state lease sale areas such as the North Slope involves the use of data, including seismic and well information, which by law the division keeps confidential under AS 38.05.035(a)(8)(C). In order to protect these data, the division must generalize the assessment that is made public.