Chapter Three: Description of the Lease Sale Area

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Chapter Three: Description of the Lease Sale Area

A. Property Description

The lease sale area contains approximately 7.6 million acres in 1,347 tracts ranging in size from 1,280 to 5,760 acres. The lease area lies between NPR-A on the west, ANWR on the east, south of the Umiat Baseline and north of the Gates of the Arctic National Park and Preserve. The gross acreage of the entire lease sale area is in excess of 7.6 million acres. However, approximately 3.2 million of these acres are either Native-owned or Native-selected, and will not be included in the lease sale (Map 1.1 and Map 1.2).

The sale area is within the NSB and encompasses an area of about 88,817.1 mi^2 of land and 5,945.5 mi^2 of water or approximately 15% of the state (NSB 2005). It extends from the Chukchi Sea on the west to the Canadian border on the east, and 225 miles from Point Barrow on the north to the foothills of the Brooks Range on the south. 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 anadromous waters in the lease sale area are the Colville, Sagavanirktok, Ivishak, Nanushuk, Echooka, Saviukviayak, Itkillik, Anaktuvuk, Kanayut, Lupine, Ribdon and Canning rivers, portions of the Chandler River, and Accomplishment, Upper Section, Lower Section, Flood, Cobblestone, May creeks (Johnson and Klein 2009).

Portions of the lease sale area are located within the coastal zone where activities are subject to the Alaska Coastal Management Program. The boundary of the coastal zone extends inland along river corridors of the anadromous rivers listed above, including the Colville, Chandler,

USGS 2003

Upstream view of the Colville River at Umiat.

Itkillik, Anaktuvuk, Nanushuk, Sagavanirktok, Ivishak, Echooka, Lupine, Ribdon, Saviukviakak,and Canning rivers, and the May, Cobblestone, Accomplishment, Upper Section, Lower Section, and Flood creeks (Map 1.3). Lakes are infrequent, but many swift rivers originating in the Brooks Range cross through the foothills, occasionally braiding across gravel flats. Some streams freeze solid each winter, creating large aufeis deposits that last well into summer (ADF&G 2006).

The Brooks Range is directly south of the lease sale area. This mountain range is a west-to-east trending range, which creates the watershed divide for several large river systems. The range varies in elevation from 4,000 to 10,000 feet, and reduces in relief toward the north across the Arctic foothills to the coastal plain (Hall 1984).

1. Land and Mineral Ownership

The Alaska Statehood Act granted to the State of Alaska the right to select from the federal public domain 102.5 million acres of land to serve 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 its interests in the land (AS 38.05.125). Therefore, when state land is conveyed to an individual citizen, local government, or other entity, state law requires that the deed reserve the mineral rights for the state. Furthermore, state law reserves to the state the right to reasonable access to the surface for purposes of exploring for, developing and producing the reserved mineral. Surface owners are entitled to damages under AS 38.05.130, but may not deny reasonable access. Mineral closing orders, which are commonly associated with surface land disposals, do not apply to oil and gas leasing.

ANCSA, passed by Congress in 1971, also granted newly created regional Native corporations the right to select and obtain from the federal domain lands the land and mineral estates within the regional Native corporation boundaries. It also allowed Native village corporations and individual Alaskan Natives to receive land estate interests. However, overlapping selections created conflicts and delays in conveying the land from the federal government, and some selected lands have yet to be conveyed.

USGS 2005

North front of the Brooks Range along the southern margin of the central North Slope.

In Anaktuvuk Pass, the Arctic Slope Regional Corporation has ownership of the subsurface mineral estate for the village lands, and has also selected lands in the general Anaktuvuk Pass area for conveyance from the federal government. The federal government is the land manager for the nearby Gates of the Arctic National Park and Preserve (NPS 2009).

There are several parcels of which the surface estate was conveyed from the state through the federal government to Native allottees. The NSB also owns land as a result of the state's municipal entitlement program. Additional municipal conveyances are pending within the lease sale area. For the most part, the state, as the owner of the retained mineral estate, may lease these lands for oil and gas development.

Therefore, the North Slope Foothills Areawide lease sale contains tracts in which the state owns both the land estate and the mineral estate. Only those free and unencumbered state-owned oil and gas mineral estates within the tracts will be included in any lease issued.

B. Historical Background

Evidence of human habitation and hunting along the upper Colville River has been dated to about 5,670 B.C. by researchers. In addition, evidence of habitation was found at Anaktuvuk Pass, dating from about 4,560 B.C. Researchers have noted that the tracking of movement of coastal inhabitants inland toward the Brooks Range and the movement of inland hunters to the coastal areas has been complex (Anderson 1984). Movement of inhabitants from the Noatak/Kobuk river region after 1,400 A.D. resulted in occupation of the Brooks Range and Colville Basin (Hall 1984, citing to Hall 1976).

Anchorage Museum (AMRC-wws-3421-52)

Man gutting caribou near Anaktuvuk Pass, 1962.

The inhabitants of the Brooks Range were known as Nunamiut, formed from the Inupaiq for nuna 'land' and miut 'people of'. Social organization was founded upon maximizing hunting capabilities, mutual aid and building trading relationships. At various times during the nineteenth century migration was caused by changing economic conditions, which brought different societies together. For inhabitants of the mountains, the caribou was the primary component of their lifestyle, constituting more than 90% of the diet, clothing and shelter (Hall 1984). In the first half of the twentieth century, disease, starvation due to declining caribou herds in 1926-1927, and opportunities along the coast drew the mountain inhabitants to the coast. A few families returned to the area along the Killik River and Chandler Lake in about 1938, and a permanent community was established at Anaktuvuk Pass in the early 1950s (ADCRA 2009a; Hall 1984).

The incorporation of the NSB in 1972 provided residents with local government powers and a mechanism to assess and tax oil and gas infrastructure. Incorporation also created responsibilities of planning, zoning, education and utilities. Petroleum revenues and other funding have provided the borough with resources to pay for schools, fire stations, medical clinics, health care services, utilities, public safety facilities, family assistance programs, workforce development programs, community centers, public housing, administrative facilities, and jobs for borough residents.

C. Communities

1. North Slope Borough

Anchorage Museum (AMRC-wws-3421-116)

Post office at Anaktuvuk Pass, 1962.

The lease sale area is within the NSB. The borough has a population of 6,615 (U.S. Census Bureau Population Division. 2008) and is a home rule borough that was incorporated in 1972. The borough is Alaska's largest borough, and encompasses an area of about 88,817 mi^2 of land and 5,946 mi^2 of water, or approximately 15% of the state (NSB 2005). It extends from the Chukchi Sea on the west to the Canadian border on the east, and 225 mi from Point Barrow on the north to the foothills of the Brooks Range on the south (Map 1.1 and Map 3.1).

Approximately 74% of borough residents are Alaska Native or part Native. The majority of permanent residents are Inupiat Eskimos. Communities located within the borough include: Anaktuvuk Pass, Atqasuk, Barrow, Deadhorse/Prudhoe Bay, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright (ADCRA 2009d). 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 median household income in 2000 for the borough was $63,173, with $20,540 per capita income. The total work force population was 4,875, with 2,993 reported as employed in these fields: 34% professional, 18% service, 22% sales and office, 15% construction and maintenance, 10% production and transportation, and less than 1% fishing, forestry and farming. The government of the NSB is funded by oil and gas revenues, and the economy is heavily dependent upon oil and gas development and the services needed for this industry. Oil operations provide employment for about 5,000 non-residents throughout the borough (ADCRA 2009d).

Most communities rely on air travel to provide year-round access, while land transportation provides seasonal access. The Dalton Highway provides road access to Deadhorse/Prudhoe Bay, though it is restricted during winter months. "Cat-trains" are sometimes used to transport freight overland from Barrow and the Trans-Alaska pipeline to North Slope communities during the winter (ADCRA 2009d).

2. Anaktuvuk Pass

Anaktuvuk Pass is a village with a population of 284, located at about 2,200 ft elevation in the Endicott Mountains of the Brooks Range, on the divide between the Anaktuvuk and John Rivers (Map 3.1) (ADCRA 2009a). It is about 250 mi northwest of Fairbanks, and about the same distance from Barrow. Anaktuvuk Pass was traversed and hunted regularly by the Nunamiut bands who lived in a nomadic lifestyle. It is the only remaining settlement of the Nunamiut people. The present day location was established in about 1938 when families living on the coast returned to the mountains at Killik River and Chandler Lake (ADCRA 2009a). In 1949 several families moved to the vicinity

DCRA 2008

Anaktuvuk Pass.

of the current village location. The majority of the population is Alaska Native (88.3%), who practice a traditional subsistence lifestyle (ADCRA 2009a).

The settlement encompasses 4.8 mi^2. Contact Creek runs through the town center. A gravel airstrip provides year-round access. There is no road to the village, but cargo is transported from the Trans-Alaska pipeline haul road during winter months (ADCRA 2009a).

The utilities in the village are provided by the NSB. This includes electricity and water from two central wells. Most households have water delivered to water holding tanks, with 80% of them using running water in the kitchen (ADCRA 2009a).

The median household income in 2000 was $52,500, with the per capita income reported as $15,283 (ADCRA 2009a). The total potential workforce in 2000 was 205 people. There are 100 people reported as employed as 20% professional, 19% service, 21% sales and office, 21% construction and maintenance and 19% production or transportation (ADCRA 2009a).

Activities supported by the NSB provide government services and capital improvement projects, which have also led to service and temporary construction jobs for residents. The Nunamiut Corporation is active in the non-government business sector (ADCRA 2009a).

3. Nuiqsut

Nuiqsut, population 424 (ADCRA 2009e) is located approximately 35 mi from the Beaufort Sea on the west bank of the Nechelik Channel of the Colville River delta (Map 3.1). It encompasses 9.2 mi^2 of land. The Colville Delta has traditionally been a gathering and trading place for the Inupiat and offers good hunting and fishing. The old Village of Nuiqsut was abandoned in the late 1940s. In 1973, the village was resettled by 27 families from Barrow. In 1973 and 1974, a school, housing, and other facilities were constructed by federal agencies. The City of Nuiqsut was incorporated in 1975 (ADCRA 2009e). In 2000, 89% of the population was Inupiat Alaskan Native.

DCRA

Nuiqsut.

The median household income in 2000 was $48,036, and the per capita income was $14,876. The total potential work force was 264 people, with 176 people employed as 17% professional, 22% service, 15% sales and office, 30% construction and maintenance, and 15% production and transportation, and less than 1% fishing, forestry or farming (ADCRA 2009e).

The NSB provides utilities to Nuiqsut. Water is derived from a lake, treated and delivered to individual resident's water tanks. Most homes have running water to the kitchen. The Alpine oil field will soon provide piped natural gas to Nuiqsut, which will lower the cost of running diesel electric generators for heating homes and other facilities (ADCRA 2009e).

The NSB owns and operates a gravel airstrip and year-round access is provided by air travel. Marine and land transportation also provide local seasonal access and snowmachines are used for local transportation in winter months (ADCRA 2009e).

4. Barrow

Barrow has a population of 4,054 (ADCRA 2009b), and is located 10 mi south of Point Barrow on the Chukchi Sea coast (Map 3.1). The area encompasses 18.4 mi^2 of land and 2.9 mi^2 of water. Barrow was incorporated in 1958. Formation of the NSB in 1972, the Arctic Slope Regional Corporation, and construction of the Prudhoe Bay oil fields and the Trans-Alaska Pipeline have contributed to Barrow's development.

In 2000, 64% of the population was Inupiat, 22% was white, and 9% was of Asian descent. The NSB is Barrow's primary employer; however employment is also provided by state and federal agencies and numerous other businesses that provide support services to oil and gas field operations (ADCRA 2009b).

The median household income in 2000 was $67,097, with the per capita income of $22,902 (ADCRA 2009b). The total potential work force is 3,069, with 1,986 reported as employed as 39% professional, 15% service, 24% sales and office, 13% construction and maintenance, 8% production and transportation, and less than 1% fishing, forestry and farming (ADCRA 2009b).

DCRA

Barrow.

The NSB provides utilities to Barrow. Water is derived from a dam on Isatkoak Lagoon and is stored in a holding tank. The Barrow Utilities & Electric Cooperative operates the water and sewage treatment plants, generates and distributes electric power, and distributes piped natural gas for home heating. The local power plant is fueled by natural gas (ADCRA 2009b).

Year-round access is provided by air travel. The state owns the Wiley Post-Will Rogers Memorial Airport, which serves as the regional transportation center for the borough. The airport has a 6,500-foot-long asphalt runway. Marine and land transportation also provide seasonal access (ADCRA 2009b).

5. Kaktovik

Kaktovik has a population of 272 (ADCRA 2009c), and is located on the north shore of Barter Island, between the Okpilak and Jago rivers (Map 3.1). The village encompasses 0.8 mi^2 of land and 0.2 mi^2 of water and lies within the Arctic National Wildlife Refuge (ANWR). The village was incorporated in 1971. The island served as a major trade center for the Inupiat, particularly as a bartering place for Alaska Inupiat and Canadian Inuit (ADCRA 2009c).

The median household income in 2000 was $55,625, with the per capita income of $22,031. The NSB, city services and school provide most of the year-round employment. The total potential work force is 190 people, with 117 reported as employed as 21% professional, 30% service, 24% sales and office, 10% construction and maintenance, and 15% production and transportation (ADCRA 2009c).

The NSB provides utilities to Kaktovik. Water is derived from a surface source, treated and stored in a 680,000-gallon water tank, and delivered by truck to home holding tanks. Approximately 80% of homes have running water in the kitchen. Homes that are not connected to the water and sewer system utilize holding tanks that are pumped and hauled on a regular basis (ADCRA 2009c).

Year-round access is provided by air travel. The Barter Island Airport is owned by the U.S. Air Force and operated by the borough. Marine and land transportation also provide seasonal access (ADCRA 2009c).

DCRA 2004

Kaktovik.

D. Cultural Resources

The ADNR Office of History and Archaeology has records of historic and archaeological sites throughout north Alaska. They maintain the Alaska Heritage Resource Survey (AHRS). There are documented reports of known concentrations of site localities and scattered historical resources throughout the lease sale area (Dale 2009, personal communication).

Cultural and historic resources are those sites and artifacts having significance to the culture of Arctic people. Historic and cultural sites are those identified by the National Register of Historic Sites, and include those identified in the NSB Traditional Land Use Inventory (TLUI), by the Commission on Inupiat History, Language and Culture, and sites identified in other published studies. Many places, such as ancient village locations along the tributaries of the Colville River, which contain archaeologically important relics, continue to be used today.

The AHRS and the TLUI are comprised of "restricted access documents" and specific site location data should not appear in final reports or be distributed to others.

E. Temperature and Precipitation

Surface conditions in the Arctic vary dramatically. 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.

At Anaktuvuk Pass, the average temperature in January is -14°F. Average summer temperature is 50°F. Precipitation averages 11 inches and snowfall averages 63 inches per year (ADCRA 2009a).

At Nuiqsut, temperatures range from -56 to 78°F. The daily minimum temperature is below freezing 297 days each year, on average. Precipitation averages 5 inches with the annual snowfall of 20 inches (ADCRA 2009e).

At Kaktovik, temperatures range from -56 to 78°F. Precipitation averages 5 inches with the annual snowfall of 20 inches (ADCRA 2009c).

At Barrow, temperatures range from -56 to 78°F. Precipitation averages 5 inches with the annual snowfall of 20 inches (ADCRA 2009b). The average summer temperature is about 40 °F. The daily minimum temperature is below freezing 324 days of the year. The sun does not set between May 10 and August 2 each year, and does not rise between November 18 and January 24 each winter (ADCRA 2009b).

F. Climate

The climate of the NSB and its villages is an Arctic climate. A study conducted of mean temperatures from 1951 to 2001 in Barrow showed a cooling trend of -0.28°C per decade from 1951 to 1975, and a warming trend of +0.52°C per decade since 1977 (Hartmann and Wendler 2005).

Temperature and precipitation records from 1949 to 1998 throughout Alaska show annual and seasonal mean temperature increases throughout the entire state. Barrow showed decreases in annual and winter precipitation (Stafford 2000).

Global surface temperatures have increased about 0.9°F since the late 19th century. The increase per decade was 0.05°C for the past century, and was about 0.16°C per decade during the past 30 years (NCDC 2008).

Temperature increase in Alaska over the last 59 years averages 3.1°F, although the temperature changes vary greatly across the state. Most of the change has occurred in winter and spring months (ACRC 2009).

At northern latitudes potential effects of climate changes include rising temperatures, melting glaciers, reduction in seasonal sea ice cover resulting in increased storm effects and higher coastal erosion rates, increased permafrost melting, shifting vegetation zones, increased fires, insect outbreaks, changing animal migration paths, and changing subsistence patterns. Climate changes and associated geologic hazards may threaten and negatively impact Alaskans and other users of the Arctic (DGGS 2010).

In 2006, the Alaska Climate Impact Assessment Commission was formed to assess the effects of climate change on citizens, resources, economy, and assets of the State of Alaska (ACIAC 2008). In September 14, 2007, Administrative Order 238 was signed, creating the Climate Sub-Cabinet to develop an Alaska Climate Change Strategy. The strategy serves as a guide for responding to climate change and will identify immediate priorities as well as long-term strategies, including recommendations for saving energy and reducing greenhouse gas emissions (Alaska Climate Sub-Cabinet 2009). On April 17, 2008, the Governor's subcabinet released its report of recommended actions including emergency planning and training, erosion control, and village relocation planning (IAW 2008).

The State of Alaska Climate Change Sub-cabinet combines representation from the ADEC, ADF&G, Alaska Department of Transportation and Public Facilities (ADOT), ADNR, Department Commerce, Community and Economic Development, University of Alaska, and the Office of the Governor. It is tasked with providing assessments and recommendations for adaptation, mitigation and for defining research needs to assist Alaskans with the impacts of climate change. In 2009, the ACIAC released a report that addressed mitigation, presented a range of potential mitigation measures, and stated that more analysis is needed for effective mitigation (ACIAC 2009). Barrow is named as one of the 31 Alaskan villages imminently threatened by coastline impacts (Alaska Climate Sub-Cabinet 2009).

G. Geologic Hazard Assessment

When assessing the kinds of geologic hazards and their potential impact it is critical to have an understanding of the types of geologic materials and processes present, their properties and distribution. The primary geologic hazards in or near the North Slope Foothills lease sale area

include faults and earthquakes, permafrost and frozen-ground phenomena, mass movements, river erosion, flooding and slope movements. These geologic hazards could impose constraints to exploration, production, and transportation activities associated with possible petroleum development, and should be considered in the siting design, construction, and operation of facilities.

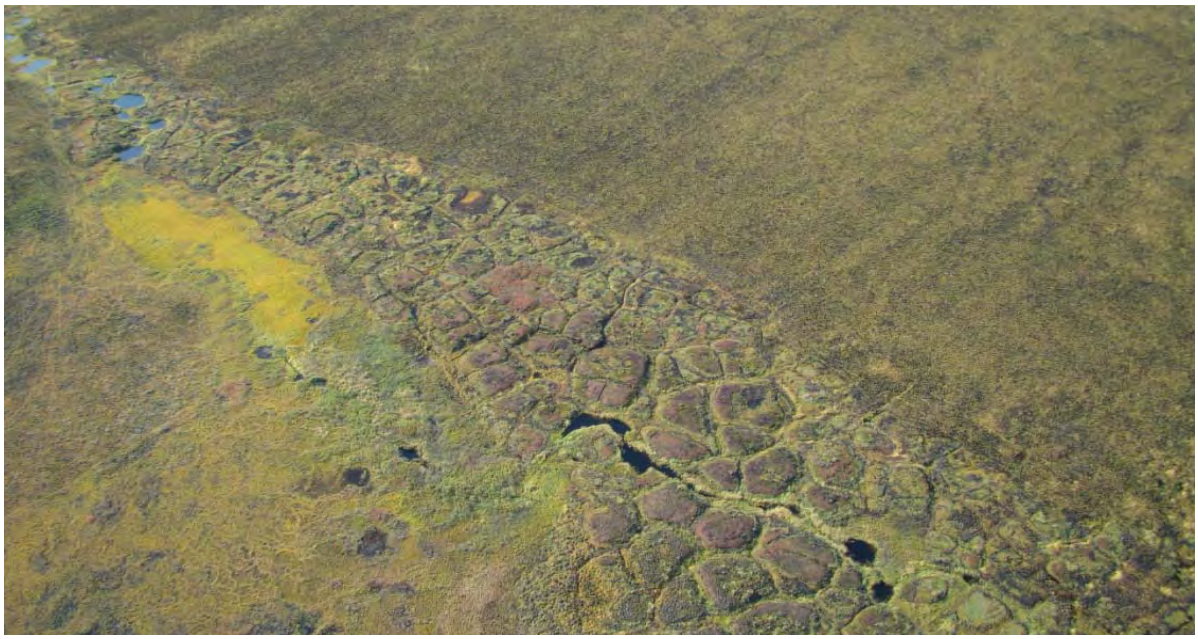
Long, linear ridges, buttes, and mesas composed of tightly folded sedimentary rocks divide narrow alluvial valleys and glacial moraines. Above a thick, continuous layer of permafrost are ice-related features, such as gelifluction lobes, pingos, and ice-wedge polygon networks. Because the permafrost impeded drainage, soils are usually saturated and have fairly thick organic horizons (ADF&G 2006).

1. Geologic Materials

Most surficial geologic mapping in the region has been done at a reconnaissance level and more detailed work should be completed prior to siting design and infrastructure development. Reconnaissance mapping of the Phillip Smith Mountains (Hamilton 1978), Chandler Lake (Hamilton 1979), and Killik River (Hamilton 1980) quadrangles was completed at a scale of 1:250,000 and engineering-geologic maps have been published for the Ikpikpuk River (Carter and Galloway 1988) and Umiat quadrangles (Carter and Galloway 1986). Other maps have been published documenting surface geologic materials and hazards along potential transportation corridors within the lease sale area (Stevens and Smith 2003a; Stevens and Smith 2003b; Stevens and Smith 2003c; Stevens and Smith 2003d; Stevens and Smith 2003e; Stevens and Smith 2003f).

Geologic materials may be composed of bedrock, unconsolidated materials, or a mixture of both. In general bedrock outcrops are more common at higher elevations and close to the Brooks Range, although exposures along streams and steeper slopes are not uncommon in northern areas. Valley bottoms, slopes and low hills are typically characterized by unconsolidated deposits.

Unconsolidated deposits in the lease sale area include alluvium, outwash, glacial drift, colluvium and low-lying silt and sand deposits. Alluvium and outwash are generally found along stream bottoms



P. Karczmarczyk, ADOTPF, 2009

Polygonal ground in the Anaktuvuk Pass area.

and former glacial drainage channels and include terrace and floodplain materials. These deposits typically range from poorly sorted to moderately well stratified subangular coarse gravel with cobbles and boulders near moraine fronts and at the heads of mountain valleys to well-sorted sandy gravel with subrounded pebbles and cobbles along some stream stretches (Hamilton 1978; Hamilton 1980).

Glacial drift consists of poorly sorted nonstratified material, ranging in composition from silty sandy boulder gravel to clayey stony silt, with local stratified ice-contact deposits consisting of moderately well sorted sand and gravel (Hamilton 1978; Hamilton 1980). These deposits are associated with Tertiary, Pleistocene and Holocene glacial advances northward from the Brooks Range and may form arcuate landforms (moraines) adjacent to stream valleys. Thin glacial drift locally mantles upland areas, especially in the northern foothills of the Brooks Range. Younger deposits tend to retain primary glacial morphology while older deposits have less relief and are more heavily modified by slope processes.

Colluvial deposits associated with downslope movement of material are common throughout the study area. Such deposits are found along and at the base of many slopes, and range from angular rock debris to poorly sorted, nonstratified mixtures of sand silt and clay (Hamilton 1980). These types of deposits may pose significant geologic hazards due to their potential instability.

Deposits in the low-lying areas beyond the limits of glaciation in the northern part of the study area generally consist of silt and sand, commonly in the form of loess and dunes. Loess deposits typically contain abundant ice in the form of lenses, wedges and interstitial grains (Hamilton 1980). Such deposits may be organic rich and are especially subject to hazards associated with permafrost. These deposits commonly display evidence of solifluction and slope movement on steeper surfaces (Hamilton 1980).

2. Faults and Earthquakes

Surface faults have been mapped throughout the central North Slope, including high-angle faults, basement-involved normal faults, listric growth faults, and north-dipping gravity faults. Locally, two or more types may occur in close proximity to each other.

North of the lease sale, high-angle faults exist along the Barrow Arch extending into Harrison Bay. Along the Barrow Arch they are related to the basement tectonics of the Arctic Platform, while in Harrison Bay they offset the Tertiary and older units. Displacement of Pleistocene or Holocene sediments has not been documented and there has been no recent seismicity associated with these faults. Thus, differential movement along these faults seems to have ended prior to the beginning of the Quaternary period (Craig and Thrasher 1982).

A number of shallow faults have been mapped north of the Arctic Platform. Included in these faults are the upper extensions of detached listric growth faults that exist deep in the Brookian section. These faults have been mapped in the greatest detail in the Camden Bay area where some of these faults may have been reactivated in the late Cenozoic and can have several tens of meters of offset. Shallow faults have also been mapped beneath the outer shelf, west of Cape Halkett and are reported to show from 3 to 10 m of Quaternary offset (Grantz et al. 1983). The Neotectonic map of Alaska shows these structures as active during the Holocene and late Pleistocene (Plafker et al. 1994).

On the outer Beaufort shelf and upper slope, seaward of the 50-65 m isobaths, are gravity faults that are related to large rotational slump blocks (Grantz and Dinter 1980; Grantz et al. 1982). South of these slumps, which bound the seaward edge of the Beaufort Ramp, these faults have surface offsets ranging from 15 m to as high as 70 m (Grantz et al. 1982). Grantz and others (1982) have inferred that these faults have been active in recent geologic time. Similar gravity fault features occur offshore and along the coast of the Gulf of Mexico and have been shown to move seismically and aseismically (creep).

Within the lease sale, many east-west trending structures have been mapped along the north side of the Brooks Range (Map 3.2). These structures offset Paleogene bedrock (older than ~24 million years) and are not known to have been active in the Quaternary.

Several active faults exist south of the lease sale area, including the Kobuk fault, Preacher fault, Medicine Lake lineament, Dall Mountain fault, Pivot fault, and the Kaltag fault (Map 3.2). Quaternary activity is inferred for all of these faults (Plafker et al. 1994), however, little is known about their rupture histories. The Kobuk fault extends roughly east west approximately 200 km south of the lease sale and is characterized by north side up motion. The Kaltag fault, Preacher fault, and Medicine Lake lineament are part of the Tintina fault system that extends across central Alaska in an arcuate bend roughly parallel to the Alaska Range and the Denali fault to the south. Motion along the Tintina system is right lateral strike-slip with a component of north-side-up displacement in some localities. Large magnitude earthquakes along these structures could generate strong ground motions; however, due to their distance from the lease sale, the effects of seismic shaking are expected to be minor.

Since 1968, 130 earthquakes of magnitude M=2 have been recorded in the region surrounding the lease sale, with only four events of magnitude M≥5.0 (Map 3.3). Although seismicity is diffuse in northern interior Alaska, several prominent NE- to NNE-striking seismic trends, including the Dall City, Rampart, Minto Flats, Fairbanks, and Salcha seismic zones, occur south of the lease sale area (Biswas and Gedney 1979; Rupert and Hansen 2008). At least 9 historic earthquakes of magnitude M≥6.0 have occurred within this belt of seismicity (Rupert and Hansen 2008). The Dall City and Rampart seismic zones have not been associated with particular surface faults; however this lack of surface-fault evidence is likely due to lack of investigation. To the northeast, these seismic zones extend across the eastern end of the lease sale area, but become more diffuse and less defined. Along strike of the zone, the Camden Bay area is seismically active with several faults mapped as historic and late Pleistocene (Plafker et al. 1994).

3. Permafrost, Frozen Ground and Thermokarst

Permafrost is defined as ground (soil and rock as well as included ice and organic matter) that remains at or below 0°C for at least 2 consecutive years and can be found in both unconsolidated sediment and in bedrock (Noetzli and Gruber 2009; Pullman et al. 2007; French 2007). In the sale area permafrost is considered continuous, occupying 90-100% of the land area with unfrozen areas generally present only below rivers or lakes (Brown et al. 1997). For the most part permafrost is overlain by an active layer of unconsolidated sediment. This active layer refers to a surface layer of ground or soil above permafrost that is alternately frozen each winter and completely thawed each summer (Gary et al. 1972).

Depth of permafrost is variable and depends on the amount of solar radiation, aspect, thickness and duration of snow cover, material properties, altitude and latitude (French 2007). Permafrost thickness has been measured from numerous wells north of the lease sale area where it generally thins from east to west. East of Oliktok Point, it has been measured to be 500 m thick, whereas west of the Colville River it has been measured to be 300 to 400 m thick (Osterkamp and Payne 1981). At Umiat the depth of permafrost has been measured to be 322 m (French 2007; Washburn 1979). Records from the northern Brooks Range and Foothills suggest the base of permafrost lies at a depth of 150-300 m in the Killik Quadrangle (Hamilton 1980) and 150-250 m in the Chandler Lake Quadrangle (Hamilton 1979). Ferrians (1965) and Williams (1970) provide additional information regarding permafrost depth in and near the sale area.

Many geologic hazards in permafrost regions are related to the changes in both the active layer and permafrost thickness related to seasonal and long term temperature fluctuations (Kane et al. 1991; French 2007), as well as to manmade ground disturbances and structures. Surface response to melting permafrost and seasonal ground ice is not uniform, and is related to the amount and type of

ground ice and the interactions of slope position, soil texture, and hydrology (including snow cover), as well as vegetation and the effects of fire over time (Jorgenson et al. 2008; French 2007). Ice content in the permafrost varies throughout the sale area from segregated ice to massive ice in the form of wedges and pingos, and is highest in fine-grained, organic-rich deposits and lowest in coarse granular deposits and bedrock (Collett et al. 1989). Lilly et al. (2008) suggest that changes in the distribution of ice in soil pore space can impact sediment strength on both seasonal and long term scales. Generally, soil strength is greater during the winter when soil water is frozen than during summer months when melting occurs.

DO&G Permitting Staff

Example of thermokarsting on the North Slope.

Natural (forest fires, floods and erosion) and manmade ground disturbances often lead to an increase in thawing of permafrost resulting in instability of the ground surface and ground settlement (Richter-Menge et al. 2006).

Such disturbances may make the surface unsuitable for many construction purposes (Carter and Galloway 1986). Ground settlement occurs whenever a heated structure is placed on ground underlain by shallow, ice-rich permafrost, and proper engineering measures are not taken to adequately support the structure and prevent the structure's heat from melting the ground ice. Degree of settlement is a function of the original thickness of the active layer, the increase in the active layer as it adjusts to the surface disturbance, and the thaw strain of the underlying permafrost (Pullman et al. 2007). In general the magnitude of settlement depends on the nature and abundance of ice and the severity of the disturbance. Arctic lowland areas are particularly at risk for thaw subsidence because of the high volume of ground ice at the top of the permafrost (Jorgenson et al. 2006). Pullman and others (2007) suggest potential for thaw settlement is least in areas of active river deposits and eolian sand and can be greater than 1 meter in areas of alluvial marine deposits.

In addition to settlement, seasonal freeze-thaw processes will cause frost jacking of nonheated structures placed on any frost-susceptible soils unless the structures are firmly anchored into the frozen ground with pilings or supported by non-frost-susceptible fill (Combellick 1994). The depth of this layer of seasonal thaw is generally less than 1 m below the surface and 2 m beneath most active stream channels and is dependent on site-specific hydrological and geotechnical water crossing conditions. Borings along the Colville River, for example, show it remains thawed year-round (Collett et al. 1989). The frost susceptibility of the ground is highest in fine-grained alluvium, colluvium, thaw-lake and thermokarst deposits; moderate in alluvial-fan deposits and till; and lowest in coarse-grained flood-plain deposits, alluvial terrace deposits and gravelly bedrock (Carter et al. 1986; Ferrians 1971; Yeend 1973a; Yeend 1973b; Carter and Galloway 1986).

Thermokarst is caused by the elevation of ground temperatures, generally because of disturbance or removal of insulating vegetation that results in local melting of ground ice. This may cause uneven topography in the form of mounds and sink holes. Even small disturbances such as a vehicle driven across the tundra can create thermokarst features. In the past, off-road and seismic trail disturbances associated with oil development activities have led to the development of thermokarst (Pullman et al. 2007). This can be mitigated through seasonal and area restrictions on vehicles.

USGS

Discontinuous permafrost, Yukon Flats;
similar to permafrost of the North Slope Foothills area.

Many geologic processes in areas of permafrost and seasonally frozen ground are sensitive to seasonal and long term variability of climate; long-term records indicate that temperatures at the depth of zero seasonal temperature variations in permafrost are warming on the North Slope (Richter-Menge et al. 2006; Pavlov and Malkova 2008). Ground subsidence, increased erosion, change in the hydrologic regime, and the other potential impacts of permafrost degradation described above will negatively impact infrastructure if climate continues to warm unless new mitigation techniques are adopted (Alaska Regional Assessment Group 1999).

As a result, continued monitoring of permafrost stability, including water content and temperature variability of soils, and continued assessment of mitigation techniques are necessary. Frozen-ground problems can be successfully mitigated through proper siting, design, and construction, as demonstrated at Prudhoe Bay and elsewhere. Structures such as drill rigs and permanent processing facilities should be insulated to prevent heat loss into the substrate. Pipelines can be trenched, back-filled, and chilled (if buried) or elevated to prevent undesirable thawing of permafrost. In addition, ADNR regulates winter travel across the tundra and authorizes travel only after determining that the tundra is sufficiently frozen and protected by ample snow cover so that the travel will not have major environmental effects such as permafrost degradation (Bader and Guimond 2006).

4. Mass Movement

Mass movement is the downward and outward movement of slope-forming material under the influence of gravity (Goudie 2004). Melting ice and permafrost can facilitate movement due to the lubricating effect of water and reduction of effective stress in saturated materials. Mass-movement processes present a significant geologic hazard in the study area because they can lead to slope instability, which can impact infrastructure and development (Carter and Galloway 1986; Stevens and Smith 2003a; Stevens and Smith 2003b; Stevens and Smith 2003c; Stevens and Smith 2003d; Stevens and Smith 2003e; Stevens and Smith 2003f).

In the lease sale area, mass-movement processes commonly produce solifluction deposits, slides, flows, slumps, talus and rockfalls (Hamilton 1978; Hamilton 1979; Hamilton 1980; Nelson et al.

2001; Hobson 2006; ACIA 2004). Geologic hazards associated with mass movement are not restricted to unconsolidated materials. Depending on temperature, and material properties such as porosity, permeability and the presence or absence of discontinuities, ice can occur in bedrock (French 2007) and may influence its stability (Noetzli and Gruber 2009). Repeated expansion and contraction of ice can potentially enlarge discontinuities, leading to failure. Melting ice can also lead to mass movement by lubricating surfaces along discontinuities. Mass movement associated with bedrock failures is especially important in portions of the lease sale area where steep bedrock slopes exist (Hamilton 1978; Hamilton 1979; Hamilton 1980).

Mass movement of snow can also be a potential hazard in the lease sale area. Avalanches, which involve the downhill movement of snow, ice and rock debris, are possible, especially where snow accumulates on oversteepened slopes (French 2007). Slushflows, which are flowing, water-saturated snow masses, may develop on steep slopes if water content of snow increases (Tomasson and Hestnes 2000). Conditions are often favorable for slushflows during rapid snowmelt or after large rain events when snow cover is abundant. Both avalanches and slushflows have the potential to cause significant damage and destruction. In January 1983, slushflows damaged or destroyed 20 houses in Northwest Iceland (Tomasson and Hestnes 2000).

In addition to hazards associated with slope movement itself, increased erosion can occur as material is delivered to streams from mass movement processes (Hobson 2006).

5. River Erosion and Flooding

Stream sediment load, discharge, and amount and type of bank vegetation, as well as sediment cohesiveness, influenced by the degree and depth of seasonal frost, and permafrost, are all important factors in determining the effectiveness of stream erosion in the study area (Veldman and Ferrell 2002; Vandenberghe 1993). High erosion rates are documented along braided channels, which usually develop in areas composed of noncohesive sediment (Scott 1978). In a study along the Sagavanirktok River, aerial photographs showed a maximum erosion rate of 4.5 m per year during a 20-year period. In this area, most of the erosion appeared to occur in small increments during seasonal breakup flooding and was concentrated in specific areas where conditions were favorable for thermo-erosional niching (Combellick 1994).

Erosion rates and river-bank stability must be considered in facility siting, design, construction and operation. Vandenberghe (1993) suggests that past climatic changes have impacted stream erosional and depositional processes and, with recent studies indicating climatic warming (Richter-Menge et al. 2006; Pavlov and Malkova 2008), there is potential for increased rates of erosion, especially as permafrost melts along river banks, thus reducing sediment cohesiveness. Facility siting, design and construction must be considered in determining the optimum oil and gas transportation mode. Structural failure can be avoided by proper facility setbacks from river banks. Docks and road or pipeline crossings can be fortified with concrete armor, and by placing retainer blocks and concrete-filled bags in areas subject to high erosion rates.

Floods occur annually along most of the rivers and many of the adjacent low terraces in the lease sale area due to seasonal snowmelt and ice jams (Rawlinson 1993; Walker and Hudson 2003). Spring ice breakup on rivers in the region often occurs over the first few days of a three-week period of flooding in late May through early June. Up to 80% of the flow occurs during this period (Walker 1973). The geologic impact of flooding is in large part related to the magnitude and timing of seasonal ice breakup. The formation of ice jams is strongly linked with catastrophic flooding (Walker and Hudson 2003). Some of the most damaging floods are associated with an above-average snowpack that is rapidly melted by rainstorms and sudden warming.

During flooding, small changes in river flow can be caused by changes in sediment bars. Consequently, areas of significant bank erosion can be variable. The amount of erosion depends on

factors such as sediment character, amount of water and its level with respect to the river bank (Veldman and Ferrell 2002). Ice carried along by rivers can also produce significant erosion, especially if breakup occurs during lowering river stage, allowing the ice to erode stream banks (Walker and Hudson 2003).

In addition to seasonal flooding, many rivers in the lease sale area are subject to seasonal icing prior to spring thaw. This is due to overflow of the stream or groundwater under pressure, often where frozen or impermeable bed sections force the winter flow to the surface to freeze in a series of thin overflows, or where spring-fed tributaries overflow wide braided rivers (Veldman and Ferrell 2002). In areas of repeated overflow, residual ice sheets often become thick enough to extend beyond the flood-plain margin. These large overflows and residual ice sheets have been documented on many of the streams in the study area but warrant further study prior to infrastructure siting design and development (Stevens and Smith 2003a; Stevens and Smith 2003b; Stevens and Smith 2003c; Stevens and Smith 2003d; Stevens and Smith 2003e; Stevens and Smith 2003f; Dean 1984; Combellick 1994).

Seasonal flooding of lowlands and river channels is extensive along major rivers that drain into the sale area. Thus, measures must be taken prior to facility construction and field development to prevent losses and environmental damage. Pre-development planning should include hydrologic and hydraulic surveys of spring break-up activity as well as flood-frequency analyses. Data should be collected on water levels, ice floe direction and thickness, discharge volume and velocity, and suspended and bedload sediment. Also, historical flooding observations should be incorporated into a geologic hazard risk assessment. All inactive channels of a river must be analyzed for their potential for reflooding. Containment dikes and berms may be necessary to reduce the risk of flood waters that may undermine facility integrity.

H. Mitigation Measures

Several geologic hazards exist in the North Slope Foothills area that could pose potential risks to oil and gas installations. As discussed above, these potential hazards include earthquakes, permafrost and frozen-ground phenomena, river erosion, flooding, overpressured and unstable sediments, and shallow gas deposits and gas hydrates.

The risks from earthquake damage can be minimized by siting onshore facilities away from potentially active faults and unstable areas, and by designing them to meet or exceed national standards and International Building Code seismic specifications specific for Alaska. National industry standards help assure the safe design, construction, operation, maintenance, and repair of pipelines and other oil and gas facilities. Sometimes referred to as “technical standards” they establish standard practices, methods, or procedures that have been evaluated, tested, and proven by analysis and/or application. These standards are intended to assure the safe design, construction, operation, maintenance, and repair of infrastructure. National consensus standards, such as the American Petroleum Institute, American Society of Mechanical Engineers, National Fire Protection Association, and National Association of Corrosion Engineers, can carry the equivalent weight of law. In fact, many of them are codified by incorporation of all or parts of them into regulations by reference. They are constantly reviewed and upgraded by select committees of engineers and other technical experts (PHMSA 2008).

Design for arctic based development should consider all environmental events which influence the design of an arctic structure (API 2001). Design conditions are those environmental conditions to which the structure is designed. Additional precautions should be taken to identify and accommodate site-specific conditions or events that can act on a structure such as unstable ground, flooding, and other localized hazards. Proper siting and engineering will minimize the detrimental effects of these natural processes.

Safe design of oil and gas facilities are based upon design codes and recommended practices that assist the engineer by setting out procedures for achieving acceptable levels of safety. Recommended practices provide guidance for the design of arctic structures and pipelines considering the environment and permafrost. Once the design conditions have been established for each process, they become the basis for that system's design. The primary goal of codes is safety, which is accomplished by providing a minimum set of rules which must be incorporated into a sound engineering design concerning materials, fabrication, testing, and examination practices used in the construction of these systems. All of these are intended to achieve a set of engineering requirements deemed necessary for safe design and construction of these structures and their associated piping systems. Lessees are responsible for following design codes and recommended practices to ensure the safety and integrity of their facilities and operations.

Although geologic hazards could damage oil and gas infrastructure, measures in this final best interest finding, along with regulations imposed by state, federal, and local agencies, in addition to design and construction standards discussed above, are expected to avoid, minimize, or mitigate those hazards. Mitigation measures address siting of facilities, design and construction of pipelines, and oil discharge prevention, gas incident prevention and contingency plans. All lessees are encouraged to refer to the available investigations and associated findings relating to assessment of natural and geologic hazards and mapping of surficial geology within the North Slope Foothills prior to planning, siting, constructing, and maintaining of oil and gas facilities to reduce negative impacts. Additionally, a complete listing of mitigation measures is found in Chapter Nine.

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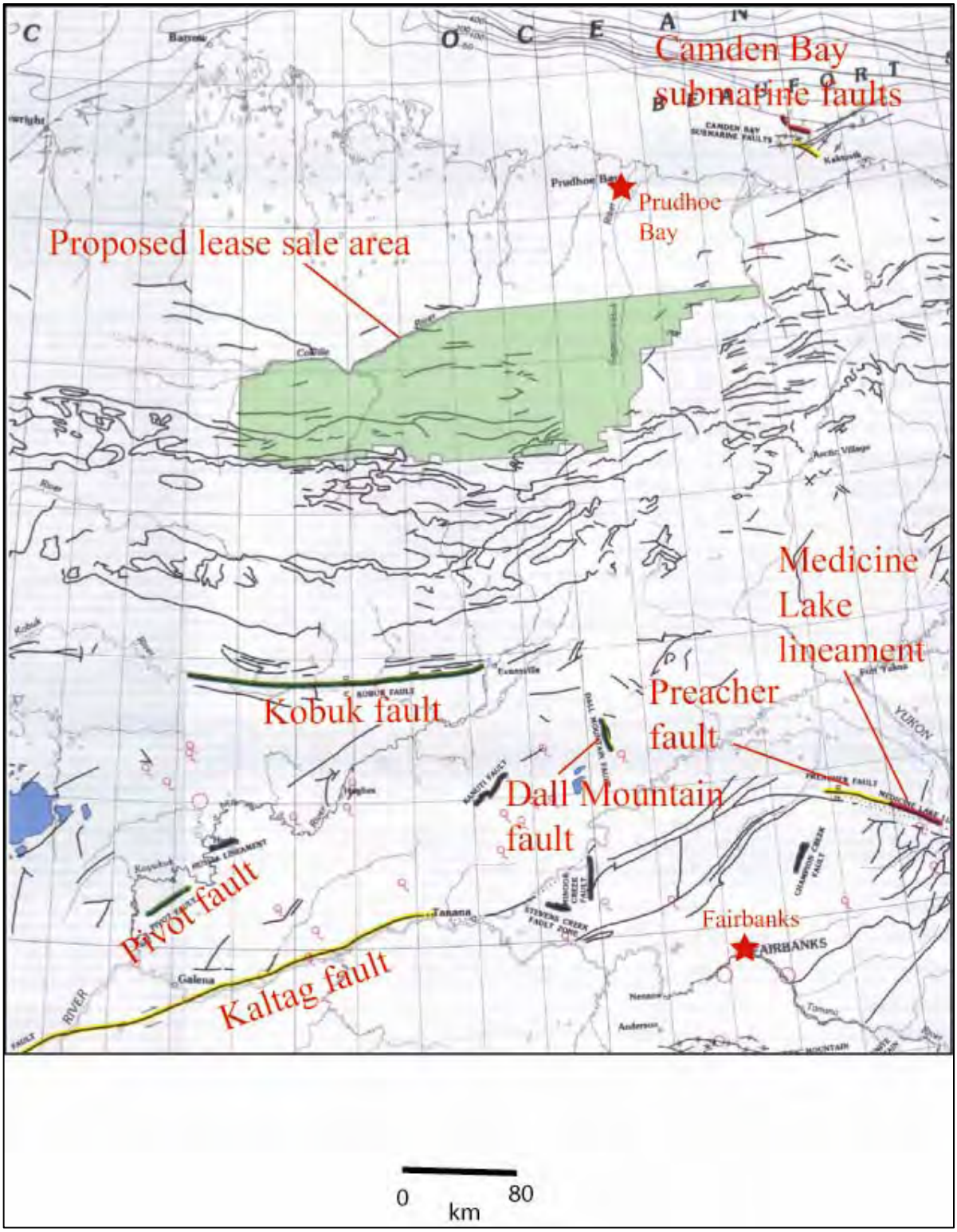
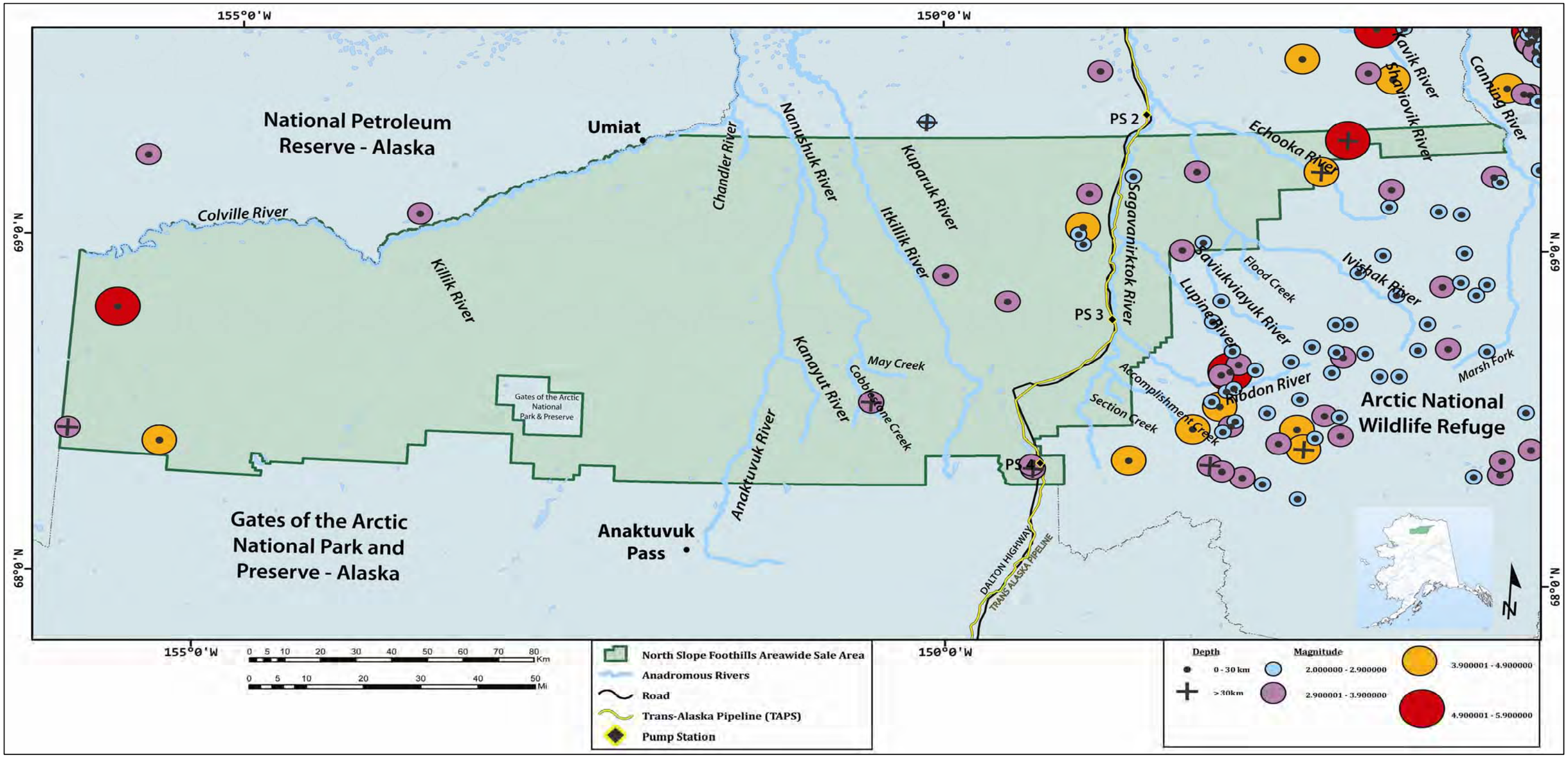
J. Maps

Map 3.1. **North Slope region of Alaska, including Barrow, Nuiqsut, Kaktovik, and the North Slope Foothills lease sale area.**



Source: Plafker et al. 1994.

Map 3.2. Locations of faults in and around the North Slope Foothills lease sale area.



Source: AEIC 2010.

Map 3.3. Locations of earthquakes in and around the North Slope Foothills lease sale area.