ATTACHMENT A
ENVIRONMENTAL IMPACT ANALYSIS

LIBERTY DEVELOPMENT PROJECT

Environmental Impact Analysis

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SUBMITTED TO:
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FOREWORD

This document provides the environmental impact analysis (EIA) for BP Exploration (Alaska) Inc.'s (BPXA's) proposed Liberty Development Project. This EIA is designed to provide the necessary information to support agency decision making for permits required for the project. Alternatives to the proposed action that were considered are analyzed in Section 1 as a basis for the alternatives evaluation required by the:

- National Environmental Policy Act (NEPA) (40 CFR 1502.14),
- Regulations of the MMS (30 CFR 250.261),
- Regulations of the U.S. Army Corps of Engineers (33 CFR 325 Appendix B), and
- U.S. Environmental Protection Agency 404(b)(1) Guidelines (40 CFR 230).

This EIA contains the following major components:

- Summary of the project as proposed in *Liberty Development Project Development and Production Plan* (DPP) and alternatives considered;
- Description of the affected environment, including physical, biological, and socio-cultural components;
- Assessment of the environmental consequences of the proposed project and alternatives;
- Mitigative measures incorporated into the proposed project, including compliance with lease sale stipulations; and
- Summary list of consultation and coordination with agencies and the public.

LIST OF ACRONYMS

AAQS	Ambient Air Quality Standards
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEWC	Alaska Eskimo Whaling Commission
AHRS	Alaska Heritage Resources Survey
Al	Aluminum
ANCSA	Alaska Native Claims Settlement Act
ANIMIDA	Arctic Nearshore Impact Monitoring in the Development Area
ANS	Alaska North Slope
ANWR	Arctic National Wildlife Refuge
AOGCC	Alaska Oil and Gas Conservation Commission
API	American Petroleum Institute
As	Arsenic
ASDP	Alpine Satellite Development Plan
ASOS	Automatic Surface Observing System
ASRC	Arctic Slope Regional Corporation
Ba	Barium
BACT	Best available control technology
BAT	Best available technology
bbl	Barrel
Be	Beryllium
BLM	Bureau of Land Management
BMP	Best management practice
BOP	Blowout preventer
bpd	Barrels per day
BPXA	BP Exploration (Alaska) Inc.
CAA	Conflict Avoidance Agreement
$CaCO_3$	Calcium carbonate
cANIMIDA	Continuation of Arctic Nearshore Impact Monitoring in the Development Area
CCP	Central Compression Plant
Cd	Cadmium
CDOM	Colored dissolved organic matter
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cm	Centimeter

Co	Cobalt
CO	Carbon monoxide
CO_2	Carbon dioxide
Cr	Chromium
Cu	Copper
dB	Decibel
DOC	Dissolved organic carbon
DOT	U.S. Department of Transportation
DPP	Development and Production Plan
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIA	Energy Information Administration
EIS	Environmental impact statement
EOR	Enhanced oil recovery
EPA	U.S. Environmental Protection Agency
ERD	Extended reach drilling
ERL	Effects Range-Low
ERM	Effects Range-Median
ESA	Endangered Species Act
Fe	Iron
FEIS	Final environmental impact statement
FG	Fracture gradient
FTE	Full-time equivalent
g	Gram
gal	Gallon
GNOME	General NOAA Operational Modeling Environment
GPB	Greater Prudhoe Bay
gpd	Gallons per day
GPS	Global Positioning System
H_2S	Hydrogen sulfide
HAZWOPER	Hazardous waste operations
Hg	Mercury
hr	Hour
H_{sat}	Saturating irradiance
HSE	Health, safety, and environmental
Hz	Hertz
IOPs	Inherent optical properties
IRA	Indian Reorganization Act
ISER	Institute of Social & Economic Research
kg	Kilogram
KIC	Kaktovik Iñupiat Corporation
km	Kilometer
km^2	Square kilometer
kt	Knot
KSOPI	Kuukpikmiut Subsistence Oversight Panel, Inc.
l	Liter

LoSal™	A trademark of BP p.l.c., associated with a BP process to produce low-salinity water for enhanced oil recovery
m	Meter
m^3	Cubic meter
mb	Millibar
mg	Milligram
MHHW	Mean higher high water
MLLW	Mean lower low water
MMbbl	Million barrels
MMS	Minerals Management Service
Mn	Manganese
MOU	Memorandum of understanding
MPI	Main Production Island
MPFM	Multi phase flow meter
MSA	Magnuson-Stevens Fishery Conservation and Management Act of 1996
MSDS	Material safety data sheet
MSL	Mean sea level
MWD	Measurement while drilling
NACE	National Association of Corrosion Engineers
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NGLs	Natural gas liquids
NMFS	National Marine Fisheries Service
Ni	Nickel
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPDES	National Pollutant Discharge Elimination System
NPRA	National Petroleum Reserve-Alaska
NRC	National Research Council
NSB	North Slope Borough
NSBSAC	North Slope Borough Science Advisory Committee
NSPS	New Source Performance Standards
NTU	Nephelometric turbidity units
O_3	Ozone
OCS	Outer continental shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OHA	Office of History and Archaeology (Alaska Department of Natural Resources)
OR&R	Office of Response and Restoration
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear aromatic hydrocarbons
PAR	Photosynthetically active radiation
Pb	Lead
PFFR	Photon flux fluence rate
PHC	Petroleum hydrocarbons

$PM_{2.5}$	Very fine particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per thousand
PSD	Prevention of Significant Deterioration
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
RS/FO	Regional Supervisor, Field Operation
RTE	Radiative transfer equation
Sb	Antimony
scf/stb	Standard cubic feet per stock tank barrel
scfd	Standard cubic feet per day
SD	Standard deviation
SDI	Satellite Drilling Island
sec	Second
SO_2	Sulfur dioxide
sp.	Species (singular)
spp.	Species (plural)
S/T	Steranes and triterpanes
STP	Seawater treatment plant
T	Transmissivity
TAPS	Trans Alaska Pipeline System
TDS	Total dissolved solids
Tl	Thallium
TLUI	Traditional Land Use Inventory
TOC	Total organic carbon
TPHC	Total petroleum hydrocarbons
TSS	Total suspended solids
TVP	True vapor pressure
uERD	Ultra extended reach drilling
µg	Microgram
µPa	MicroPascal
UIC	Ukpeagvik Iñupiat Corporation
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USCOE	U.S. Army Corps of Engineers
USDOI	U.S Department of Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
V	Vanadium
yr	Year
Zn	Zinc

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1. PROJECT SUMMARY

1.1 PURPOSE

The purpose of this document is to present an environmental impact analysis for BP Exploration (Alaska) Inc. (BPXA) proposed Liberty Development Project in the Alaskan Beaufort Sea. The Liberty Project is subject to the Federal, State, and local approvals, as identified in Section 1.3 of the *Liberty Development and Production Plan* (DPP), which provides a comprehensive description of the proposed project, including all the information required under 30 CFR 250.241-262. This environmental impact analysis document is submitted as an attachment to the DPP as required by 30 CFR 250.227. The oil spill response plan required by 30 CFR 250.250 is submitted under separate cover.

In February 1998, BPXA submitted a DPP to the Minerals Management Service (MMS) for the Liberty Project, as required under 30 CFR 250.204. The DPP proposed to develop the Liberty oil field from a gravel island constructed on the Outer Continental Shelf. The proposed project included a manmade offshore gravel island, processing facilities located on the island, an offshore buried pipeline and an onshore elevated pipeline that would connect the island facilities to the Badami Pipeline, an onshore gravel mine, and onshore and offshore ice roads.

In accordance with the National Environmental Policy Act (NEPA), MMS prepared the 2002 *Liberty Development and Production Plan Final Environmental Impact Statement* (USDOI, MMS, 2002). The FEIS analyzed the environmental impact, as well as the impacts associated with modifying five project components (island location and pipeline route, pipeline design, upper slope protection system, gravel mine site, and pipeline burial depth). The proposed project was compared to three alternatives consisting of combined project components. In addition, the FEIS evaluated the effectiveness of potential mitigating measures and cumulative impacts resulting from the BPXA proposal and the alternatives.

The Liberty Development Project design and scope have since evolved from an offshore stand-alone development in the Outer Continental Shelf (production/drilling island and subsea pipeline) — as described in the 2002 FEIS — to use of existing infrastructure involving an expansion of the Endicott Satellite Drilling Island (SDI). This project evolution reflects a number of factors including environmental mitigation, advances in ultra-extended-reach drilling (uERD) technology, use of depth-migrated three-dimensional (3D) seismic data, and advances in reservoir modeling among others.

This environmental impact analysis describes the new Liberty Project, discusses the affected environment, and evaluates the potential direct, indirect, and cumulative impacts that result from significant project changes and alternatives.

1.2 NEED

The Outer Continental Shelf Lands Act identifies the Outer Continental Shelf as a vital natural resource reserve that should be made available for expeditious and orderly development. Consistent with the Act, the purpose of the Liberty Project is to recover oil from the Liberty oil field for production and transport of sales-quality oil to the Trans-Alaskan Pipeline System.

U.S. oil production is expected to decline over the next two decades. As a result, the United States will increasingly depend on oil imports from foreign producers. To reverse this trend, the U.S. Energy Policy encourages and facilitates domestic oil production. The Liberty field contains significant energy reserves with potential recoverable reserves of up to 105 million barrels of oil and up to 78.5 billion cubic feet of natural gas (including NGLs but excluding carbon dioxide). Production from the Liberty field will therefore help achieve U.S. energy goals by satisfying demand for domestic oil and by decreasing U.S. dependence on foreign oil.

The Liberty Project will also provide economic benefits to the Federal Government, the State of Alaska, and the North Slope Borough. Alaska will benefit directly from the infusion of new capital into the economy and the creation of jobs. Over the life of the project, additional benefits will accrue to the State through the State's share of the Federal royalty, the State corporate income tax, and ad valorem tax, some of which will also accrue to the North Slope Borough. This benefit will occur at a time when State revenue, heavily dependent on production from the large North Slope oil fields, is declining. The Liberty Project will help mitigate the severity of the decline to the State of Alaska and to the United States.

1.3 SUMMARY PROJECT DESCRIPTION

A detailed description of the proposed Liberty Project may be found in the Liberty DPP, and this environmental impact analysis is an attachment to the DPP. Following is a summary of the project.

The Liberty prospect is located about 5.5 mi offshore in about 20 ft of water and approximately 5 to 8 mi east of the existing Endicott SDI (Figure 1-1). To take advantage of the infrastructure at Endicott, BPXA has elected to drill the uERD wells from the SDI by expanding the island by approximately 20 acres to support Liberty drilling. Liberty is one of the largest undeveloped light-oil reservoirs near North Slope infrastructure. BPXA estimates the Liberty Project could recover approximately 105 million barrels of hydrocarbons by waterflooding and using the ***LoSal*™** enhanced oil recovery (EOR) process (***LoSal*™** is a trademark of BP p.l.c.).

The development drilling program will include one to four producing wells and one or two water injection wells. No well test flaring is planned for this drilling program. Production from the Liberty uERD project will be sent by the existing Endicott production flowline system from the SDI to the Endicott Main Production Island (MPI) for processing. The oil would then be transported to the Trans Alaska Pipeline System via the existing Endicott sales oil pipeline. Produced gas will be used for fuel gas and artificial lift for Liberty, with the balance being re-injected into the Endicott reservoir for enhanced oil recovery. Water for waterflooding will be provided via the existing produced-water injection system available at the SDI. This supply will be augmented by treated seawater if needed from the Endicott Seawater Treatment Plant. The ***LoSal*™** EOR process will be employed during a portion of the flood and will be supplied by a ***LoSal*™** facility constructed on the MPI.

Associated onshore facilities to support this project will include upgrade of the existing West Sagavanirktok River Bridge or construction of a new bridge, ice road construction, and development of a new permitted mine site adjacent to the Endicott Road to provide gravel for expanding the SDI. Existing North Slope infrastructure will also be used to support the project.

All wells for this project will be outside current industry performance for this depth. As a result, the state-of-the-art of uERD must be advanced. BPXA first plans to drill a single well in order to assure that such drilling is feasible. If that well is successful and the technology is proven, then BPXA will proceed with drilling additional wells and installing new facilities to complete the project as described in this document

1.4 DEVELOPMENT ALTERNATIVES

For purposes of this environmental impact analysis, BPXA examined the impacts of three development alternatives in addition to the SDI extension:

- The offshore, stand-alone drilling island proposed in the 2002 FEIS;
- A drilling pad at Point Brower, with processing at Endicott; and
- A drilling pad near the Kadleroshilik River with processing at Badami.

Figure 1-2 shows these alternatives, which are discussed briefly below. Table 1-1 presents of a comparison of the proposed SDI expansion with these three alternatives in terms of major project components. A brief description of each alternative is provided below.

1.4.1 Offshore Island Project (EIS)

BPXA's originally proposed Liberty Project involved a self-contained offshore drilling operation with processing facilities on an artificial gravel island with a buried sales oil pipeline to shore to connect with the Badami sales oil pipeline for shipment to the Trans-Alaska Pipeline System. The island would have been located in Foggy Island Bay in 22 ft of water about 6 mi offshore and 1.5 mi west of the abandoned Tern Island.

Infrastructure and facilities necessary to drill wells and process and export 65,000 barrels of oil per day to shore would be installed on the island. The project involved 14 producing wells, six water injection wells, two gas injection wells (one of which would be pre-produced), and one disposal well (23 total) at a wellhead spacing of 9 ft. Space for up to 40 well slots would be provided. Produced gas would be used for fuel gas and artificial lift with the balance being either re-injected or exported for use in an EOR program at the nearby Badami Unit. Seawater would be treated and used to waterflood the Liberty reservoir. Produced water would be commingled with treated seawater and injected as waterflood. A 12-inch sales oil pipeline would be built to transport crude oil to the Badami sales oil pipeline, and a 6-inch products pipeline would import fuel gas for drilling and start-up activities to Liberty from the Badami products pipeline prior to first Liberty production, and would then export product to the Badami pipeline after start-up. The offshore portion of the pipelines would be approximately 6.1 mi long, with the overland portions will be approximately 1.5 mi long to a tie-in point with the Badami pipeline system.

Associated onshore facilities to support this project would include use of existing permitted water sources, ice roads and ice pad construction, and development of a gravel mine site in the Kadleroshilik River floodplain. In addition, existing North Slope infrastructure would be used in support of this project.

1.4.2 Point Brower Drilling Pad

This alternative would involve building a new gravel pad onshore at Point Brower to access the Liberty reservoir by means of uERD. A 15.2-mi-long pipeline would be built from the pad to the Endicott facilities on the MPI, where the oil would be processed for shipment in the Endicott sales oil line. The project would also involve construction of a 7.3-mi-long gravel road to connect the pad to the existing Endicott Road in order to provide the necessary logistical support for the uERD wells.

1.4.3 Kadleroshilik Pad

This alternative would involve a new gravel pad onshore near the mouth of the Kadleroshilik River to access the Liberty reservoir by means of uERD. An 11.5-mi-long pipeline would be built from the pad to the existing Badami facilities, where the three-phase fluid would be processed to ship oil through the Badami sales oil pipeline. A gravel road 15.2 mi long would be constructed from the pad to the Endicott Road to provide for necessary logistical support.

2. AFFECTED ENVIRONMENT

This section discusses the affected environment in the vicinity of the proposed Liberty Project and alternatives. The discussion covers the physical, biological, cultural, and socioeconomic environments.

2.1 AIR ENVIRONMENT

2.1.1 Climate and Meteorology

The North Slope of Alaska is bounded to the south by the Brooks Range and by the Arctic Ocean to the north. The mountains provide a natural barrier separating this region climatically from the rest of Alaska (Figure 2.1-1). This region is the coldest and driest of Alaska with a Köppen climatological classification of ET (polar tundra) and frequent high winds. The winters are cold and the summers are cool and short, with only 3 to 4 months with mean temperatures above freezing.

The following sections provide climatological data based on five locations (Barrow, Prudhoe Bay, Deadhorse, Kuparuk, and Barter Island) in Arctic Alaska (National Climatic Data Center, NCDC). The climate stations are shown in Figure 2.1-1, while the characteristics are given in Table 2.1-1. No climate stations with long-term records are located in the immediate vicinity of the Liberty Project area. However, the data at the five stations indicated above provide a reasonable depiction of the conditions anticipated at the Liberty site.

2.1.1.1 Air Temperature

Table 2.1-2 presents the air temperatures for Barrow, the station with the longest record of climatological data on the North Slope. These data are presented graphically in Figure 2.1-2. The data shown are for the period 1975-2004, as climatological normals are usually based on a 30-year period. July is on average the warmest month, with a mean temperature of 4.6°C, while February is the coldest month with a mean of -26.0°C. For most of Alaska, January is the coldest month, and this delay of 1 month in the Arctic is typical for a maritime climate. Only 3 months (June, July, August) have a mean temperature above the freezing point, and the average daily maxima are below 10°C for all months. The record high, 26°C, was measured on 13 July 1993. The lowest temperature recorded in Barrow during the last 30 years was -47°C, and this occurred on 3 January 1975. This is a relatively benign value compared to the statewide absolute minimum of -62°C, measured at Prospect Creek south of the Brooks Range in northern Interior Alaska. The relatively strong winds experienced year-round in Arctic Alaska are a primary reason why temperatures do not go as low as in the Interior.

Table 2.1-3 presents climatological data for other stations on the North Slope. It should be noted, however, that the observational period is not identical for the different stations and slight differences in the climatological statistics might occur due to this fact.

In general, the two stations located directly at the Beaufort Sea coastline (Barrow and Barter Island) are somewhat cooler in the summer than the three other stations, which are located a distance inland. The period with mean temperatures above freezing also is extended at the inland stations. Alternatively, the winter temperatures at the coastal stations were somewhat warmer, a sign of the maritime influence of the Beaufort Sea.

2.1.1.2 Precipitation

Precipitation is light on the North Slope. The annual precipitation (water equivalent) for four of the stations is summarized in Table 2.1-4. Because the precipitation record for Deadhorse is incomplete, these data were not included. The mean annual precipitation ranges from 10.1 cm at Kuparuk to 15.7 cm at Barter Island. The precipitation maximum occurs in August for all stations, while during the winter months (November through April) the precipitation is very light.

The annual snowfall for the four stations is presented in Table 2.1-5. The mean annual snowfall ranges from 78.2 cm at Kuparuk to 106.2 cm at Barter Island. The maximum snowfall, 211.7 cm, was recorded at Barter Island. A permanent snow cover is normally established in September. The increase in snow depth (Figure 2.1-3) is fairly rapid from the middle of September through the end of October, at which time about half of the seasonal maximum snow cover is reached. The snow depth increases slowly from November through March, with the maximum snow cover of about 30 to 40 cm reached in April. Thereafter, melting commences, and the snow depth declines quickly. By mid- to late June the seasonal snowpack has disappeared.

The depth of snow on the ground is influenced primarily by snowfall during the winter. However, due to blowing and drifting, the snow cover can be redistributed. Furthermore, densification of freshly fallen snow occurs. Both processes can result in a decrease in snow depth at a time when the temperature is far below the freezing point and no melt is possible. Figure 2.1-3 does not show such processes, as it is the average of many years of observations.

2.1.1.3 Wind

The winds are fairly strong on the North Slope, with monthly mean values around 10 knots (1 kt = 0.51 m/sec). There is no strong annual course in wind speed, but there is a slight indication of a maximum in the fall when the adjoining Beaufort Sea is still ice-free and the land has already substantially cooled. This strong thermal contrast in the surface temperature of the ocean and land might at times enhance the wind speed. The mean monthly and annual wind-speeds for Barrow, Deadhorse and Barter Island are presented in Table 2.1-6.

Winds are normally from an easterly direction, with westerly winds occurring more infrequently. The mean annual wind rose for Barrow (Figure 2.1-4) clearly shows the bi-modal wind direction distribution. Calms are very seldom, with annual values of less than 2%.

Five years of wind speed and direction measurements at Endicott are available as part of the MMS Beaufort Sea Meteorological Monitoring and Data Synthesis Project (USDOI, MMS, 2007). The average hourly mean wind speed measured between January 2001 and September 2006 was 5.3 m/sec, while the maximum hourly mean wind speed was 23.7 m/sec. The maximum instantaneous wind speed at the Endicott site during this period was 30.6 m/sec. Wind directions were bimodal, typically prevailing from an east northeasterly direction (approximately 45% of the time) or from a west northwesterly direction (approximately 25% of the time (USDOI, MMS, 2006c). It should be noted that the wind measurements at Endicott are known to be biased low during winter months due to icing problems (USDOI, MMS, 2006c)

2.1.1.4 Storminess

Storms are of special interest for many reasons, such as coastal erosion, visibility restrictions due to blowing snow, operational restrictions, and possible extremely low wind chill factors. Figure 2.1-5 presents the number of days during which the wind speed at Barrow exceeded 30 knots (15.4 m/sec) for at least 1 hour. On average, there are about 10 cases of such high wind events each year, with significant annual variability. There is an indication that the frequency has increased, but the change is not statistically significant. Further, such strong storms are least likely to occur in summer, but most likely to occur in the fall (Table 2.1-7).

2.1.1.5 Cloudiness

The mean cloudiness on the North Slope is high, especially in late summer/early fall, when Arctic stratus clouds are observed for most of the days. At Barrow, the long-term mean cloudiness value for September is 93%. The minimum in cloudiness is observed in winter with values around 50%.

2.1.1.6 Atmospheric Pressure

The atmospheric pressure reduced to sea level is nearly identical for both Barrow and Barter Island. The station pressure approximates the sea level pressure for these stations, as they are both less than 12 m above sea level. The lowest mean pressure (1012.2 millibars, mb) is observed in late summer, which also is the time with the highest amount of cloud cover and the greatest amount of precipitation. The highest mean atmospheric pressure (1020.7 mb) is observed in March and is accompanied by a low amount of cloudiness and little precipitation.

2.1.1.7 Visibility

Visibility is measured continuously at the Deadhorse airport as part of the Automatic Surface Observing System (ASOS). The most restrictive category (visibility less than 1 mi) occurs on average about 10% over the year, with a minimum in summer and a maximum in winter. This distribution is likely caused by blowing snow, which can strongly impair visibility when severe. In the absence of snow cover (summer), such events cannot occur. In contrast, conditions of blowing or drifting snow take place nearly 25% of the time during the winter. Further, fog is more likely to occur in the summer, when it is formed over the cold ocean and drifts into the coastal area. In the winter, freezing fog may occur, especially in the presence of a temperature inversion.

2.1.1.8 Climate Change

Temperature Trends

Temperature trends from 1948 to 2004 are plotted in Figure 2.1-6 for the five climatological stations on the North Slope. The record extends to 1948 for only two stations (Barrow and Barter Island). In general, the time series of mean annual temperatures for the different stations are very similar. This finding is expected due to the fairly uniform surface conditions (tundra) found at each station.

While large variations in the annual temperatures occur from year to year, a general warming trend is apparent. The best-fit linear trend for the Barrow data indicates a temperature increase from -13°C to -11°C over the 56-year period. This increase of 2°C over 56 years is substantial when compared to the global average of about 0.6°C per century (IPCC, 2001), and is an often-observed enhancement of warming in polar regions. Furthermore, the warming trend is in general agreement with Stafford, Wendler, and Curtis (2000) and Shulski, Hartmann, and Wendler (2003), who analyzed the temperature trends of Alaska for slightly earlier time periods. It also is noteworthy that the temperature in Arctic Alaska has continued to rise in the last 25 years, a time during which the mean annual temperature of the rest of Alaska has remained constant or decreased somewhat (Hartmann and Wendler, 2005).

When seasonal temperature trends are considered, substantial warming is evident during winter, while the warming trend is less pronounced in spring and summer. The temperature trend for fall is quite flat, but recent years display above-normal temperatures. This finding is consistent with the observed decrease in sea ice concentrations in coastal regions during this time period (Wendler et al., 2003). Figure 2.1-7 illustrates the decrease in Beaufort Sea ice concentrations between 1970 and 2000.

In Figures 2.1-8 and 2.1-9 the number of days with temperatures below (-18°C and 34°C) and above (0°C and 10°C) certain thresholds are presented as a time series plot for Barrow from 1949 to 2004. The number of days with a minimum temperature below -18°C decreased from 170 to 160 days during the 55-year period. More pronounced is the decrease of days with extreme low temperatures (below -34°C). At the beginning of the time period, there were on average 40 days annually with the minimum temperature below -34°C. Currently, there are only 22 such days, a reduction close to 50%. This finding is in agreement with the general warming trend that has occurred during the last half century in northern Alaska.

As indicated in Figure 2.1-9, days with a high temperature above 0°C and 10°C have increased in frequency of occurrence between 1949 and 2004. Days when the maximum temperature was above freezing (0°C) increased from 102 to 121 during the 55-year period, while the increase for days with maxima above 10°C increased from 15 to 24 (an increase of about 50%). If this trend continues, vegetation changes may be expected for the North Slope, depending also on the precipitation regime.

Precipitation Trends

A decrease in precipitation of about one-third has been observed in the Arctic for the last half century (Stafford, Wendler, and Curtis, 2000). This decrease was not limited to Alaska, but also was found in most of the Western Arctic (Curtis et al., 1998). The change is especially pronounced in winter and spring, when the highest temperature increase has been observed. This finding is somewhat surprising, as normally an increase in temperature is associated with an increase in precipitation.

Snowmelt Trends

There has been a trend for earlier snowmelt in the Arctic, as first pointed out by Foster (1989), who analyzed the Barrow data going back to 1940. Dutton and Endres (1991) suggested that the trend was in part due to the rapid development in the village of Barrow, and that the effect was overestimated by Foster. Stone et al. (2002) confirmed Foster's finding when they showed that from 1940 to present the snowmelt occurs some 8 days earlier on average. This result is not unexpected given the climatological observations, which show a decreasing trend in winter snowfall and higher spring temperatures.

2.1.2 Air Quality

Good air quality exists in the Liberty Project area, which is located in the Northern Alaska Intrastate Air Quality Region. The Alaska Department of Environmental Conservation (ADEC) has designated the area as in attainment or unclassifiable for all criteria pollutants, including nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}), ozone (O_3), sulfur dioxide (SO_2), and lead. The closest existing nonattainment area to the Liberty Project is the Eagle River area of Anchorage, designated nonattainment for PM_{10} and located approximately 1,000 km south of the project area. A portion of the Fairbanks North Star Borough may be designated as nonattainment for very fine particulate matter ($PM_{2.5}$) sometime in 2007 or 2008. Fairbanks is located approximately 625 km south of the project area.

Measurement of ambient concentrations of NO_2, CO, and SO_2 was begun on the SDI on February 1, 2007. Recent ambient pollutant data are available from monitoring stations located on A Pad and the Central Compression Plant (CCP) pad at the nearby Greater Prudhoe Bay (GPB) facility. The data collected in 2005, which are summarized in Table 2.1-8, confirm that the air quality in the area is good and that measured pollutant concentrations are well below any applicable air quality standard.

ADEC has classified the Liberty Project area a Prevention of Significant Deterioration (PSD) Class II area. The nearest PSD Class I area is Denali National Park including the Denali Wilderness but excluding the Denali National Preserve. Denali National Park is located approximately 725 km south of the project area.

2.2 RESERVOIR GEOLOGY

Section 3.1 of the Liberty DPP contains a detailed discussion of reservoir geology.

2.3 GEOMORPHOLOGY

2.3.1 Marine Geology

The Liberty prospect is located at the northern extremity of the Arctic Coastal Plain province. Part of the North Slope physiographic unit, the Arctic Coastal Plain is characterized by a gently sloping tundra-covered plain extending from the foothills of the Brooks Range to the Beaufort Sea. The area is underlain by continuous permafrost, and consists of alluvial and glacial sediments overlying sedimentary bedrock (TAPS Owners, 2001).

Foggy Island Bay is situated between the Sagavanirktok and Shaviovik rivers, and is sheltered by the McClure Islands. The coast can be defined as a tectonically stable trailing-edge type (Inman, 2003). The shoreline is actively retreating, through both wave-induced and thermal erosion processes.

Surficial seafloor sediments found in Foggy Island Bay typically consist of a 2- to 3-m layer of Holocene deposits composed primarily of fine sands and silts (BPXA, 1998). Borings drilled in support of the Liberty Project during 1998 indicate that the Holocene sediments are generally lagoonal and deltaic deposits (Duane Miller and Associates, 1998). Coarser sand and gravel are found at higher-wave-energy environments near the shoreline and the barrier islands. Pleistocene deposits comprised of stiff plastic silt and clay are present under the Holocene layer, but also outcrop on the seafloor in some areas (Duane Miller and Associates, 1998). Permafrost was not encountered in the offshore areas during the 1998 soil-boring program. Frozen soils were prevalent, however, near the shoreline and onshore (Duane Miller and Associates, 1998).

A lag deposit of cobbles and boulders known as the “Boulder Patch” is found in Foggy Island Bay. The course material is derived from the Flaxman formation, and is widely believed to have originated from the bedrock of the Canadian Shield (Duane Miller and Associates, 1998). The Boulder Patch is a unique biological community.

2.3.2 Bathymetry

The Liberty prospect is located in Foggy Island Bay, approximately 10 km southeast of the SDI. Foggy Island Bay is sheltered by the McClure Islands. Water depths inside the barrier island chain typically are less than 30 ft. In general, the sea bottom is characterized by mild slopes and only minor local relief. Widely scattered strudel scours and ice gouges comprise the primary local relief.

The SDI, which will be expanded to accommodate the proposed Liberty drilling program, is situated in the Sagavanirktok River delta. Water depths on the east side of the SDI typically range from 2 to 3 m (F. Robert Bell and Associates, 2007). Shallower water prevails to the south and west.

Sedimentation rates in the Liberty area range from non-detectable (i.e., no recent sediment in the past 50 years) to 0.05 to 0.1 cm/yr (Trefry et al., 2003), and partially support the work by Reimnitz, Graves, and Barnes (1988) that describes the area as net erosional at present. Deposition of fine-grained sediments closer to the mouth of the Sagavanirktok River is expected, but no direct determinations of sedimentation rates have been made nearshore.

2.3.3 Coastal Sediment Processes

The nearshore waters of the Alaskan Beaufort Sea typically remain ice-covered for about 9 months of the year. As a result, the total wave energy impacting the coastline tends to be small compared to that which might occur in a more temperate climate. However, waves generated by northeast and northwest storms can produce erosion of the mainland coast, barrier islands, and coastal facilities.

Sediment sources to the region include coastal erosion and fluvial material derived from the Sagavanirktok, Kadleroshilik, and Shaviovik rivers. Arcuate-shaped deltas are present at the ocean outlet of each of these rivers. Waves and currents transport the deltaic sediments along the coast and offshore.

2.3.3.1 Coastal Erosion

Coastal retreat tends to occur at two different rates (Walker, 1983). Storm-induced erosion typically is rapid, and is most pronounced during westerly storms due to the rise in sea level that accompanies such events. More gradual retreat results from the seasonal cycle of thawing and periods of sustained high air temperatures, which induce thermal erosion of ice-rich sediments. These sediments are then removed by normal summer wave conditions.

At many arctic coastal locations, the coastal bluffs thaw during the summer months, creating mud flows which drain onto the beach below. If the thawing is extensive, as might occur during periods of abnormally high temperatures, large-scale slumping or "thermal erosion" can become the dominant cause of bluff recession (Leidersdorf, Gadd, and Vaudrey, 1996). Thermal erosion is most rapid along bluffs that contain monolithic ice lenses ("massive ice") or a high percentage of ice and fine-grained sediments. Such slumping of the thawed bluff material, particularly when gravel and sand are present, may deliver substantial volumes of beach sediment that temporarily protect the bluff face from wave-induced undercutting.

Prior investigators have reported a wide range of bluff retreat rates along the Alaskan Beaufort Sea coast. These findings indicate that erosion rates can vary substantially from location to location, and from year to year at a given location. Bluff retreat estimates along the Alaskan Beaufort Sea coast are summarized in Table 2.3-1, while bluff retreat rates specific to Foggy Island Bay are presented in Table 2.3-2.

Estimated long-term bluff retreat rates along the Alaskan Beaufort Sea coast (Table 2.3-1) range from a modest 0.3 m/yr to over 9 m/yr. Short-term erosion rates can exceed the long-term rates, particularly during periods of frequent coastal storms or sustained high air temperatures. At the Heald Point location, for example, the short-term bluff retreat rate during the 1980s (2.4 to 3.1 m/yr) was found to be twice that of the long-term rate (Leidersdorf, Gadd, and Vaudrey, 1996). The Heald Point site included a section of bluff that contained a 2-m-thick lens of massive ice, further underscoring the importance of thermal erosion in ice-rich bluffs (Leidersdorf, Gadd, and Vaudrey, 1996). Despite witnessing large-scale bluff erosion at many arctic coastal locations, Leffingwell (1919) also emphasized that certain shore areas have remained stable for centuries.

Estimates of bluff erosion rates were developed for four locations in Foggy Island Bay in support of previously considered development strategies for Liberty (Coastal Frontiers, 1997a, 2006). Three of these sites were located on the mainland shoreline, while one was located at Point Brower in the Sagavanirktok River delta (Figure 2.3-1). Bluff recession rates at the three mainland sites were found to be moderate by arctic standards. The maximum short-term rates ranged from 1.6 to 2.7 m/yr, while the long-term recession rates ranged from 0.6 to 1.1 m/yr. The east side of the Pt. Brower site exhibited considerably higher erosion rates than those observed at the mainland sites. The average long-term erosion rate along the east side of the Pt. Brower Site was 2.0 m/yr, while the maximum short-term bluff recession rate was 9.6 m/yr. In contrast, the west side of the Pt. Brower site was relatively stable with an average long-term bluff recession rate of 0.2 m/yr, and a maximum short-term rate of 2.0 m/yr.

2.3.3.2 Barrier Island Processes

The barrier islands that shelter Foggy Island Bay are highly dynamic sedimentary structures that fluctuate in location and shape in response to the environmental forces of waves, wind, currents, and ice. These islands are bounded by dynamic inlets and are subject to sporadic, rapid, and generally westward sediment transport driven by the persistent easterly winds of the region.

Barrier islands in the Beaufort Sea typically are oriented parallel to the mainland coast and are separated from the mainland by lagoons and bays. By virtue of their location, they receive the full impact of coastal storms while providing partial protection for the mainland coast. Arctic barrier islands typically experience significant changes in plan form due to phenomena that include elongation, truncation, coalescence, inlet formation, and inlet closure. Wiseman et al.

(1973) hypothesized that thermal erosion may play a particularly important role in the formation of some arctic barrier islands. They theorized that the lagoons backing barrier island chains originated through the erosion and coalescing of thaw lakes. This implies that the islands are actually residuals of the original shoreline. The fact that several offshore islands (such as Tigvariak Island, located immediately east of the Liberty site, and Flaxman Island, located farther to the east) have a tundra veneer lends some credence to this hypothesis.

Arctic barrier islands are commonly low in profile, slender in width and arcuate in shape. These characteristics, coupled with the storm surge induced by westerly winds, make them susceptible to wave overwash as well as high alongshore sediment transport rates. Their migratory nature has been well-documented in the past (Wiseman et al., 1973; Cannon and Rawlinson, 1978; Gadd et al., 1982; Miller and Gadd, 1983). Migration rates on the order of several meters per year are common, with the movement typically directed to the west in response to the prevailing easterly storms of the open-water season. However, island movement to the east also has been observed.

2.4 OCEANOGRAPHY

The Liberty prospect is located in Foggy Island Bay, which is part of Stefansson Sound. Foggy Island Bay is situated between the Sagavanirktok and Shaviovik rivers, and is sheltered by the McClure Islands. Three rivers discharge into Foggy Island Bay: the East Channel of the Sagavanirktok River, the Kadleroshilik River, and the Shaviovik River.

2.4.1 Seasonal Generalities

The nearshore waters of the Alaskan Beaufort Sea typically remain ice-covered for about 9 months of the year. Breakup in Foggy Island Bay occurs from mid-May to mid-June and is initiated by river breakup and the overflow of freshwater onto the landfast ice. Open-water typically occurs by mid- to late July. The initiation of freeze-up in the Liberty area ranges from late September to late October. All of Foggy Island Bay and most of Stefansson Sound become entirely ice-covered within 1 week after freeze-up begins. The transition from freeze-up to winter ice conditions in Foggy Island Bay usually occurs in early to mid-November when the ice thickness is at least 30.5 cm.

2.4.2 Circulation

Circulation in Foggy Island Bay is influenced by wind-driven currents, tidal motion, river discharge, ice characteristics, and bathymetry. Wind-driven circulation predominates during the open-water season. Major contributors to under-ice circulation during winter months include wind-induced coastal setup, tides, and sea-ice brine rejection.

Winds are predominately from an easterly direction, with westerly winds occurring more infrequently. During the open-water season, easterly winds generate currents to the west, while westerly winds move water to the east. Surface currents are greater than bottom currents (Aagaard, 1984). The mean current direction is to the west, owing to the prevalence of easterly winds.

Cross-shore circulation also occurs during both easterly and westerly wind events. This phenomena is known as Ekman transport. Coriolis forces deflect surface waters offshore during easterly wind events. Modest upwelling occurs as bottom water moves onshore in response to offshore movement of surface water. Conversely, westerly winds promote onshore movement of surface waters accompanied by a modest offshore movement of bottom water known as downwelling. In both cases, the transport of bottom water (upwelling or downwelling) only partially compensates for the surface water transport. The net result is decreased water levels during easterly wind events and increased water levels during westerly wind events.

Circulation under ice is generally westerly in direction, but is muted compared to open-water conditions (BPXA, 1998). Despite ice cover during the winter, meteorological-driven circulation can occur through wind-stress and coastal setup and setdown (EBASCO, 1990). Weingartner and Okkonen (2001) speculate that wind-forced currents dominate during the winter. Tidal motions also contribute to under-ice circulation (BPXA, 1998). In addition, density-driven currents resulting from brine rejection in sea ice occur during the winter (EBASCO, 1990).

During the spring freshet, the large and sudden discharge of fresh water from rivers can induce under-ice circulation. Weingartner et al. (2005) estimates that the freshwater plume associated with spring river discharge can extend up to 20 km offshore. During May and June 2004, Alkire and Trefry (2006) measured an under-ice plume from the Sagavanirktok River that extended approximately 17 km to the north and 15 km to the west. Following river breakup, flow rates at North Slope rivers are typically low and exert less influence on nearshore circulation during the open-water season.

2.4.3 Currents

As indicated above, wind-driven circulation predominates during the open-water season, with easterly winds generating currents to the west and westerly winds moving water to the east. Winds are predominately from an easterly direction, hence the mean current direction is to the west.

Weingartner et al. (2005) obtained year-round current measurements at four locations in the nearshore Alaskan Beaufort Sea for a period of 3 years between 1999 and 2002. One such station ("McClure") was located in Foggy Island Bay. The maximum current velocity measured at the McClure station during the open-water season was 68 cm/sec, and more than 50% of the current measurements exceeded 15 cm/sec. Current directions were found to be significantly correlated with winds. Current velocities for the open-water season presented in the Liberty Project FEIS (USDOI, MMS, 2002) are in general agreement with the findings of Weingartner et al. (2005).

Open-water current measurements were obtained as part of the Endicott Environmental Monitoring Program on several occasions during the 1980s (LGL Ecological Research Associates Inc. and Northern Technical Services, 1983; Hachmeister et al., 1987; Short et al., 1990; Short et al., 1991; Morehead et al., 1992a; Morehead et al., 1992b; Morehead, Dewey, and Horgan, 1993). During the summer of 1982 (prior to construction of the Endicott facilities), the mean current speeds at four sites in the Sagavanirktok River delta ranged from 12 to 15 cm/sec, with a maximum recorded current speed of 51 cm/sec. Following construction of the causeway, current speeds at sites near the SDI typically ranged from 5 to 15 cm/sec. The maximum recorded current velocities ranged from approximately 25 to 60 cm/sec. These findings are in general agreement with the more recent observations of Weingartner et al. (2005).

Increased current velocities have been documented in the vicinity of the Endicott Causeway breaches (Rummel et al., 1987; Johannessen and Hachmeister, 1987 and 1988; Morehead et al., 1992b; Morehead, Dewey, and Horgan, 1993). Current directions were found to be bi-modal, responding to changes in wind direction and largely perpendicular to the breach orientation. Mean daily current velocities were highly variable. During the summer of 1987, for example, mean daily current speeds for the near-surface waters at the breaches were found to range between 7 and 108 cm/sec. The maximum current speeds at the outer breach ranged from approximately 110 to 250 cm/sec. At the inner breach, the maximum current speeds were found to be slightly lower, ranging from approximately 90 to 150 cm/sec.

Current velocities during the winter are more muted when compared to those observed during the open-water season. Under-ice currents are affected by tides and atmospheric pressure variation rather than by meteorological process (BPXA, 1998). The current direction is westerly/northwesterly 60 to 70% of the time on average (Ban et al., 1999). Under-ice current velocities were collected by Aagaard (1984) at two nearshore Beaufort Sea sites in March and April, 1976. Currents generally were found to be less than 5 cm/sec. More recently, Weingartner et al. (2005) documented a maximum under-ice current velocity in Foggy Island Bay (McClure station) of 14 cm/sec. Approximately 90% of the current measurements were less that 10 cm/sec. In contrast to the open-water season, under-ice currents were not well correlated with winds. These findings are in general agreement with the current velocities presented for winter conditions in Liberty Project FEIS (USDOI, MMS, 2002).

Under-ice currents were measured in Foggy Island Bay by Weingartner et al. (2005) at the time of the spring freshet. Cross-shore current velocities of approximately 10 cm/sec were observed with strong correlation to discharge rates and the associated under-ice plume of the Sagavanirktok River. These velocities were much greater than cross-shore directed flow rates observed under the ice during the winter months. During the 2004 spring freshet, Alkire and Trefry (2006) documented an average under-ice current of 7.2 cm/sec, with a mean northwesterly direction. Currents in excess of 10 cm/sec were typically found at plume fronts.

2.4.4 Water Levels

Tides in the Beaufort Sea are semidiurnal in nature, meaning that two high tides and two low tides occur each day. The National Ocean Service (NOS) reports a mean tide range of 16 cm and a diurnal range of 21 cm for the tide station located in Prudhoe Bay (NOS, 2006). The tidal characteristics for this station, which are directly applicable to the conditions at Foggy Island Bay, are shown in Table 2.4-1. Mean lower low water (MLLW) lies 10.3 cm below mean sea level (MSL), while mean higher high water (MHHW) lies 10.6 cm above MSL.

Given the relatively small tide range, water-level fluctuations in the vicinity of the Liberty Project are governed more by meteorological effects than by astronomical tides. As discussed in Section 2.4.2, Coriolis forces deflect surface waters offshore during easterly wind events and onshore during westerly wind events. As a result, westerly wind events produce positive storm surges, while easterly wind events produce negative surges. Since the Prudhoe Bay tide station was established in 1990, the lowest observed water level was 102 cm below MSL on October 9, 2006 (NOS, 2006). The greatest water level measured during the 16-year period of record was 116 cm above MSL on August 11, 2000 (NOS, 2006).

A site-specific hindcast of oceanographic conditions was conducted for the Liberty Project in 1997 (OCTI, 1997) using input data from a more generalized deep-water hindcast study of conditions in the Beaufort Sea performed in 1982 (Oceanweather, Inc., 1982). Extreme water levels for westerly storms were predicted for three locations: the original Liberty Island site and two candidate pipeline shore crossings (“East” and “West”). The predicted water levels included three components: storm surge, astronomical tides, and inverted barometer effect. The resulting predictions for each site are given in Table 2.4-2. The 100-year-return-period water level at the original island site is predicted to be 1.89 m above MSL, while for the two shore crossing sites, it is predicted to range between 1.89 and 2.04 m.

More recently, a joint industry project was begun to update the original deep-water hindcast study (Oceanweather, Inc., 1982) referenced above. The updated hindcast, known as “Beaufort Sea Ocean Response Extremes,” or “BORE,” incorporates more than two decades of additional storm events and the possible effects of climate change (Oceanweather, Inc., 2005). A site-specific hindcast of oceanographic conditions in the vicinity of Endicott was conducted using the BORE results (Resio and Coastal Frontiers, 2007). The resulting predictions are given in Table 2.4-2. The 100-year-return-period water level in the vicinity of the SDI is predicted to be 1.66 m above MSL.

2.4.5 Waves

The open-water season in Foggy Island Bay is brief, with sea ice covering the region for about 9 months of the year. During the open-water season, wave heights are limited by the shallow waters adjacent to the coast and the shelter provided by barrier islands. Moreover, the proximity of the arctic pack ice limits the fetch available for wave generation.

Beaufort Sea storms, and hence wave directions, can be classified as either easterly or westerly. Easterly storms typically are of longer duration than westerly storms (Oceanweather, Inc., 1982). As indicated in Section 2.4.4, westerly storms often are accompanied by elevated water levels, while easterly storm may produce lower than normal water levels. Westerly storms tend to be more severe, in part due to the associated storm surge.

Wave measurements were obtained in the vicinity of the Foggy Island Bay during the summers of 1980, 1981, 1982, and 1983 in support of the Endicott Development (LGL Ecological Research Associates Inc. and Northern Technical Services, 1983; OSI, 1984). In 1980 and 1981, wave heights were less than 0.6 m approximately 90% of the time, with an average wave period less than 4 seconds. The maximum wave height measured was 1.7 m. Small, short-period waves also persisted through most of the summer of 1982, with an average significant wave height of less than 0.2 m and an average wave period of less than 4 seconds. Wave heights exceeded 1.0 m on only three occasions, with each event associated with an easterly storm. The largest significant wave height measured was 1.3 m with an associated period of 3.5 seconds. During the summer of 1983, the sea surface was calm (wave heights were less than 0.1 m) approximately 50% of the time. The greatest significant wave height measured was 0.6 m on October 6.

Given the scarcity of wave measurements in the Beaufort Sea, extreme wave information must be generated using oceanographic hindcast models. A site-specific hindcast of oceanographic conditions was conducted for the Liberty Project in 1997 (OCTI, 1997) using input data from a more generalized deep-water hindcast study of conditions in the Beaufort Sea performed in 1982 (Oceanweather, Inc., 1982). Extreme wave conditions for easterly and westerly storms were predicted for three locations: the original Liberty Island site and two candidate pipeline shore crossings (“East” and “West”). The resulting predictions for westerly and easterly storms are given in Tables 2.4-3 and 2.4-4.

In all cases, the wave heights associated with westerly storms were found to be larger than those with easterly storms. The 100-year westerly wave height at the original island site (located in a water depth of 6.4 m, MSL) was predicted to be 3.7 m with a period of 11.4 seconds. At the East Shore Crossing site in a water depth of 0.6 m, the 100-year westerly wave height was predicted to be 1.0 m with a period of 11.4 seconds. Slightly smaller wave heights were predicted for the West Shore Crossing site in a water depth of 0.6 m, with a 100-year westerly wave height of 0.9 m and associated period of 11.4 seconds.

As indicated in Section 2.4.4, the BORE project was initiated in 2004 as an update to the original deep-water hindcast study (Oceanweather, Inc., 2005). A site-specific hindcast of oceanographic conditions in the vicinity of the SDI was conducted using the BORE results (Resio and Coastal Frontiers, 2007). Predictions of extreme wave conditions for easterly and westerly storms were derived for nine locations around the perimeter of the proposed SDI pad expansion (Figure 2.4-1). The predictions for easterly and westerly storms are given in Tables 2.4-5 and 2.4-6.

The predicted wave heights along the perimeter of the proposed pad expansion vary considerably due to sheltering from the Endicott Causeway and SDI, and the variation in water depths. On the northern side of the pad (Sites 7, 8, and 9), wave heights associated with westerly storms were found to be larger than those with easterly storms. The predicted 100-year westerly wave heights at this location ranged from 2.2 to 2.3 m, with wave periods of 11.8 to 11.9 seconds. The east and south sides of the pad expansion (Sites 1 through 6) are sheltered from westerly waves. The predicted 100-year easterly wave heights at these sites ranged from 0.4 to 1.6 m, with wave periods of 11.5 to 11.9 seconds.

2.4.6 River Discharge

The East Channel of the Sagavanirktok River, the Kadleroshilik River, and the Shaviovik River all discharge into Foggy Island Bay. The Sagavanirktok and Shaviovik rivers drain from the foothills of the Brooks Range, with drainage areas of approximately 11,000 and 4,400 km^2, respectively (USDOI, MMS, 2002). The Kadleroshilik River is confined to the coastal plain, draining an area of approximately 1,700 km^2 (USDOI, MMS, 2002).

The average annual flow rate is approximately 78 m^3/sec in the Sagavanirktok River, 23 m^3/sec in the Shaviovik River, and 9 m^3/sec in the Shaviovik River (BPXA, 1998). River flow during the winter months is minimal to nil (TAPS, 2001). The peak flow rates typically occur at the time of spring breakup or during the summer months in response to thunderstorms in the Brooks Range. The maximum mean monthly discharge for the Sagavanirktok River (164 m^3/sec) occurs in June (Figure 2.4-2). The average daily discharge measured in the Sagavanirktok River from 1983 to 2006 is shown in Figure 2.4-3. The maximum flow rate during the period of record, 935 m^3/sec, occurred in August 2002.

Rivers are the primary source of fresh water entering Foggy Island Bay. River water temperatures in the summer (10 to 17°C) are higher than the nearshore water temperature, and typically remain warmer until September (USDOI, MMS, 2002). At certain times of the year, river discharge can affect nearshore circulation.

In the spring, before the sea ice starts to deteriorate, melting snow swells the upland river channels. The bottomfast ice offshore of the river deltas forms a dam, which causes the flood waters to pour out over the top of the sea ice during late May or early June. As breakup progresses, river water also flows below the sea ice. The average date that the Sagavanirktok River begins to overflood the sea ice in Stefansson Sound and western Foggy Island Bay is May 20, with a standard deviation of 9.6 days, based on a 26-year period from 1973 through 1999, excluding 1991 (Coastal Frontiers, 1999b). During this period the Kadleroshilik and Shaviovik also flood the sea ice along the southern and southeastern shoreline of Foggy Island Bay. As breakup progresses, river water also flows below the sea ice.

The overflood water, which can exceed a depth of 1 m, can spread as far as 6 km offshore into Foggy Island Bay. Historical river overflood limits in Foggy Island Bay, shown in Figure 2.4-4, display significant inter-annual variability (D.F. Dickins and Associates, 1999; Coastal Frontiers, 2000, 2003a). In the floating landfast ice zone (typically in water depths greater than 2 m), the overflood waters drain through holes and discontinuities in the ice sheet caused by tidal cracks, thermal cracks, stress cracks, and seal breathing holes. Drainage in the bottomfast ice zone (typically in water depths less than 2 m) is limited until the ice sheet loosens and rises to the surface.

If the overflow rate is high, powerful strudel jets can develop at the drain sites and create large scour depressions in the seafloor. Drainage, and hence seafloor scouring, tends to be more severe in the floating landfast ice zone and less pronounced in the bottomfast ice zone. In both cases, however, strudel drainage can provide a pathway to transport an oil spill below the ice sheet.

The locations of individual drainage features in Foggy Island Bay were mapped on five occasions between 1997 and 2003 (Coastal Frontiers, 1998, 1999a, 2000, and 2003a). An attempt was made to record all drainage features off the East Channel of the Sagavanirktok River during each of the 5 years. The average number of drains found off the Sagavanirktok River was 51. The greatest number of drains observed was 141 (mapped in 1997), while the fewest number was 10 (mapped in 1998). Comprehensive mapping of drainage features attributable to the Kadleroshilik River overflood was performed only in 1997 and 1998. Nine features were found in 1997, while 64 drains were mapped in 1998. In 1997, 30 drains were mapped off the western portion of the Shaviovik River overflood.

River water also flows under the sea ice during the spring freshet. The freshwater plume associated with spring river discharge may extend up to 20 km offshore (Weingartner et al., 2005). During the 2004 spring freshet, the under-ice plume from the Sagavanirktok River was estimated to be 1.0 to 1.5 m thick and extend 17 km to the north and 15 km to the west (Alkire and Trefry, 2006).

2.4.7 Sea Ice

2.4.7.1 Ice Seasons

Sea ice covers the Foggy Island Bay region of Stefansson Sound for a little more than 9 months of each year. The average length of the ice season is 288 ± 10 days, with a median freeze-up date of October 4 and a median breakup date of July 4. First open-water usually occurs in the 6-m water depth range by July 19. The average length of the gross open-water season is 77 days. The dates are based on a combination of on-site observations from 1980 through 1996 (Vaudrey, 1981a-1986a; Vaudrey, 1988-1992; Coastal Frontiers, 1997b; satellite imagery from 1972 through 1996 (National Ice Center); and ice charts acquired from 1953 through 1975 (Cox, 1976).

Freeze-up

Freeze-up is defined as the first time in the fall when nilas or young ice (10 to 15 cm thick) covers 100% of the sea surface at a specific site or over a particular region. The initiation of freeze-up ranges from the third week in September to the last week in October with a median date of October 4. An undisturbed ice sheet can typically grow to 30 cm thick within the first 3 to 4 weeks after freeze-up occurs.

All of Foggy Island Bay and most of Stefansson Sound become entirely ice-covered within 1 week after freeze-up begins. However, the young first-year ice (10 to 30 cm thick) remains susceptible to movement and deformation by storm winds in October. These events are not unusual in the middle of Foggy Island Bay. A total of five ice pile-up events created by freeze-up ice movements affected Tern Island during the month of October from 1982 through 1984.

First-year ridging (60 to 90 cm high) and rafting may occur during these early freeze-up ice movement events. However, 80% of the time (i.e., 8 out of 10 years) the first-year sheet ice in Foggy Island Bay remains relatively flat (surface ice features less than 60 cm high) throughout the year. Flat ice is not always an indicator that no ice movement has occurred. For example, young ice can be completely removed from an area during a storm. When new ice is formed, it may remain intact and quite smooth, giving no indication that significant ice movement had occurred earlier.

Once the sheet ice thickness reaches 30 cm, the ice cover becomes relatively stable, confined by the shoreline of Foggy Island Bay to the south, the McClure Island chain to the north, Tigvariak Island to the east, and the Endicott Development to the west. During seven freeze-up studies conducted from 1979 through 1985 (OSI, 1979; Vaudrey, 1981a-1986a), no freeze-up ice movement in Foggy Island Bay was observed or measured after November 1. The sheet ice can be considered part of the landfast ice zone after mid-November.

Winter

The sea ice regime of the Alaskan Beaufort Sea is usually depicted by a schematic cross-section, which divides the ice into three distinct zones (fast ice, shear or stamukhi zone, and pack ice). While simplistic, this schematic may have some validity in describing the ice that lies to the north of the barrier islands, but it is totally irrelevant to Stefansson Sound and Foggy Island Bay, which are located south of the barrier islands.

The first-year sheet ice constitutes the only significant ice feature in Stefansson Sound during the winter. It attains an average maximum ice thickness of 1.8 to 2.1 m by the end of May, growing roughly 30 cm per month from October through March. As the landfast ice sheet continues to grow throughout the winter, the ice becomes bottomfast when it contacts the seafloor in areas where the water depth is less than about 2 m. The sediments beneath the bottomfast ice become ice-bonded as the freezing front penetrates the seafloor.

During the winter, rapid changes in temperature may produce thermally-induced shrinkage cracks in the floating landfast ice, usually propagating from sources of stress concentration, such as manmade gravel islands (including the SDI), or promontories along the coast (e.g., Point Brower). In addition, a working tidal crack can be expected at the perimeter of the floating fast ice along the shoreline and around any grounded ice feature. Other than these minor cracking events, the first-year sheet ice in Stefansson Sound and Foggy Island Bay remains virtually motionless throughout the winter — with measured monthly ice movement rates ranging from 0 and 200 cm/month based on data compiled by OSI (1976; 1978a,b; 1980) and Vaudrey (1996).

Breakup

The transition from winter to breakup season begins in late April or early May, when the daylight hours are lengthening and air temperatures are on the increase. By early to mid-May, the ice sheet has lost sufficient bearing capacity that ice roads can no longer support over-ice operations.

Before the sea ice starts to show apparent signs of deterioration, melting snow in early May helps swell the upland river channels. The bottomfast ice in the shallow water offshore of the river deltas forms a dam, which causes the flood waters of the Sagavanirktok, Kadleroshilik, and Shaviovik rivers to pour out over the top of the sea ice during late May or early June. Typically by mid- to late June, about 2 to 3 weeks after the flooding has ceased, most of the landfast ice within the overflood zone will have melted in place from a combination of the fresh, relatively warm, water and the increased heat absorption by the dirty ice.

Warm air temperatures initiate meltpool formation on the top of the landfast ice sheet, especially where the surface is contaminated with dirt. In late May or early June, meltpools usually cover less than 10% of the landfast ice area beyond the overflood limits. Just before breakup in late June, the number of meltpools increases dramatically, covering approximately 40 to 50% of the sheet-ice surface.

Breakup is defined as the time when the ice concentration goes from 10 tenths to 9 tenths or less. The breakup mechanism for sheet ice is related to lines of weakness that develop along a series of meltpools or old thermal or stress cracks in concert with in-situ sheet-ice deterioration. Melting of the landfast ice reduces confinement, and wind stress may cause breakup along a line of meltpools or along existing cracks. During late June or early July, any 20-kt wind that begins to blow probably will initiate breakup of the floating landfast ice in Foggy Island Bay. The median breakup date is July 4.

Summer

The area in and around Stefansson Sound usually becomes open water by the third week in July, about 2 to 3 weeks after the initial breakup. Open water is defined as 1 tenth or less ice concentration. There is almost a 50% chance of an ice invasion which is greater than 1 tenth ice concentration, shortly after the appearance of the first open-water. Each invasion usually has a duration of about 1 week. Fewer than 10% of these invasions will contain small multiyear ice fragments.

Vaudrey (1997) computed summer season ice statistics for three ice concentration levels from a 44-year data base (1953-96). In severe summers, there is an 18% chance of having 2 to 3 ice invasions of greater than 1 tenth ice concentration. Higher ice concentrations of 3 tenths and 5 tenths are possible, but not likely. There is a 23% chance of having one invasion of 3 tenths ice concentration and a 9% chance of having one invasion of 5 tenths ice concentration. However, the chances of having more than one invasion of 3 tenths or 5 tenths ice concentration is virtually zero in Foggy Island Bay. There are typically 77 days between first open-water and freeze-up, but the total number of days of open water is dependent on the number and duration of summer ice invasions.

2.4.7.2 Ice Features

First-Year Ice Sheet

The predominant ice feature in Stefansson Sound and Foggy Island Bay is first-year sheet ice that remains landfast throughout the winter, typically from early November through June. During the winter, the landfast sheet ice grows relatively undisturbed. Sheet-ice thickness is predicted empirically as a function of air temperature using the method of Bilello (1960). Table 2.4-7 presents the average predicted monthly landfast ice-sheet thickness, along with the 10-year minimum and 100-year maximum ice thickness (Vaudrey, 1997).

The sheet-ice growth rate is generally about 30 cm per month between November and April, and the landfast sheet ice attains an average thickness of 1.8 m by April 1. Growth after April 1 slows due to warming air temperatures, but the landfast ice may add another 15 cm of thickness by the end of May. The 100-year maximum undeformed first-year ice thickness is 2.29 m. Auger-hole ice-thickness measurements made in Stefansson Sound during freeze-up in 1980 through 1982, midwinter in 1978 and 1984, and early June in 1984 through 1986 differed from the predicted ice thicknesses by only 3 to 5 cm (Vaudrey, 1988a).

Ice Ride-up and Pile-up

Ice ride-up occurs when the ice sheet is driven by a storm wind relatively intact up a beach, coastal pad or manmade island. If the advance of the ice is halted by the slope or by a vertical obstruction, such as a sheet pile wall or tundra bluff, the sheet ice breaks up into individual blocks which form an ice pile-up at or near the waterline. Several factors influence the susceptibility of a given location to ice ride-up, pile-up, and possible encroachment or override. Motion of the sheet ice is initiated by wind stress acting on the ice surface, but the single most important factor in initiating a ride-up or pile-up event is the loss of confinement of the sheet ice. Reversal of the wind direction is the usual cause of confinement loss, due to the presence of cracks or small leads in the nearshore ice.

The most common event is a combination of ice ride-up and ice pile-up, which occurs when the ice sheet rides up the slope some distance until increasing frictional resistance causes the ice to rubble and form a pile-up. If the ice pile-up grows to a sufficient height that its peak is above the work surface elevation of a coastal pad or manmade island, ice blocks at the top of the pile can tumble down onto the work surface. Such an event occurred at BPXA's Endeavor Island (3.5-m water depth), which is located adjacent to the Endicott MPI, in October 1982 (Vaudrey, 1983b) when a 30- to 40-kt southwesterly storm (with an estimated return period of 20 years) created an ice pile-up high enough (7.5 m) to permit 20-cm-thick ice blocks to encroach 3 to 5 m onto the work surface of the island.

The coastline, barrier islands, and manmade islands in the Alaskan Beaufort Sea are subject to ice movement against them during both freeze-up (early October through late November) and breakup (late June through early July). However, the risk of ice ride-up and encroachment at the proposed SDI pad expansion during breakup is considered to be inconsequential due to: (1) rotting ice from the river overflood and (2) higher frictional resistance of the slope protection at the shoreline of the SDI (which cause the sheet ice floes to break up into small blocks and start to form a rubble pile).

The data base for determining the susceptibility of the proposed Liberty pad expansion at the SDI to ice ride-up and pile-up consists of a combination of 8 years (1978 through 1985) of personal observations by Kovacs (1983 and 1984) and Vaudrey (1981; 1982a,b; 1983a,b; 1984a,b; 1985a,b; and 1986a,b); 4 years (1949, 1955, 1976, and 1977) of aerial photography analysis by Harper and Owens (1981); and a literature review of historical accounts by Kovacs and Sodhi (1980 and 1988).

Frequent ice ride-up and ice pile-up events have occurred at manmade gravel islands located near the SDI. Tern Island, which is located 15 km east of the SDI, experienced ice ride-up or ice pile-up events during each of four successive freeze-up seasons (1982 through 1985) and during three of four breakup seasons (1982 through 1984) after construction. One such event is shown in

Figure 2.4-5. A similar experience of frequency and intensity of ice ride-up and pile-up was observed at the Duck III manmade gravel island (located about 3 km east of the SDI) during the freeze-up and breakup seasons of 1982 through 1985. As an example, on October 15-17, 1984, a 15- to 20-kt westerly storm drove 15-cm-thick ice past Duck, creating a 5- to 6-m-high pile-up on the western side of the island (Figure 2.4-6).

A recently completed study for the proposed Liberty pad expansion at the SDI estimated a 100-year ice-pile-up height of approximately 13 m (Vaudrey, 2007). For the six slope protection alternatives considered, the predicted ice encroachment distances ranged from 4.3 to 13.7 m.

Rafted Ice, Ridges and Rubble Piles

Because the sheet ice becomes relatively stable within 4 weeks after freeze-up in early October, deformed first-year ice features, such as rafted ice, ridges, and rubble piles, are present in limited extent in Stefansson Sound and Foggy Island Bay.

Rafted ice is an ice sheet consisting of two or more sheet thicknesses caused by overriding. Very thin ice may grow, under light pressure, in a pattern of finger rafting to produce ice floes composed of as many as 10 layers, each 5 to 10 cm thick. Rafted ice rarely occurs in Foggy Island Bay after the ice thickness reaches 30 cm.

Small (60- to 90-cm-high) first-year ridges may develop infrequently across Foggy Island Bay during early freeze-up ice movement. A ridge, which is a linear ice feature, forms as a result of buckling when two ice floes collide. Very little, if any, ridge building occurs after the ice becomes landfast sometime in November.

Rubble piles, which are grounded ice features of areal, rather than linear, extent, are composed of ice broken into blocks of different shapes. Rubble piles rarely occur in the protected bays and lagoons inside the barrier island chain, unless they form as part of an ice pile-up event against the shoreline, a barrier island, or a manmade gravel island. As with rafting and ridging, rubble piles typically occur only during a 4-week period after freeze-up when the ice sheet is thin and susceptible to movement, and during breakup in late June or early July. Three rubble piles were observed inside the barrier island chain between 1978 and 1985. The features had similar dimensions: 300 to 450 m long, 50 to 100 m wide, with an above-water height of 7 to 10 m (Vaudrey, 1980; Vaudrey, 1983a; Vaudrey, 1984a).

Multiyear Ice

Multiyear ice is sea ice that has survived at least one melt season. Multiyear ice invasions of the nearshore Beaufort Sea occurred on several occasions in the early 1980s prior to and during freeze-up, but no multiyear ice has ever been observed floating around in Foggy Island Bay. A handful of multiyear ice fragments 15 to 30 m in diameter have been observed in the lagoons during 2 of the 7 years (1979-1985) in which freeze-up studies were conducted. These fragments were grounded on shoals at entrances between barrier islands, such as the Newport Entrance north of Tigvariak Island. In consequence, multiyear ice fragments do not represent a hazard to the proposed Liberty pad expansion at the SDI.

2.4.7.3 Ice Movement

All ice motion is dominated by winds. During breakup and early freeze-up, when the ice is more confined, the ice movement rate is about 2 to 3% of the wind speed. When ice floes move in relatively open water, the ice movement rates are roughly 4 to 5% of the sustained wind speed.

Ice movement in Stefansson Sound is generally in a west-northwest or east-southeast direction, following the “bow-tie” pattern of prevailing easterly or westerly storm winds (Climatic Atlas, 1988).

Movement rates of freeze-up, breakup, and summer ice have been computed from ARGOS satellite-positioning buoys (Colony, 1979; Cornett and Kowalchuk, 1985; St. Martin, 1987; Thorndike and Cheung, 1977a and 1977b; Vaudrey, 1987; Vaudrey, 1989a) and from ice floe monitoring (Tekmarine, Polar Alpine Inc., and OCTI, 1985). Table 2.4-8 presents cumulative frequency distributions of ice drift speed during freeze-up and breakup based on daily ice-movement rates computed from ARGOS-buoy records collected in the eastern Beaufort Sea between 1979 and 1987 and from three site-specific ARGOS GPS stations deployed between Northstar and West Dock during the 1996 breakup season (Vaudrey and Dickins, 1996). The speeds depicted in Table 2.4-8 are daily averages for long-term ice movements, but short-term ice drift speeds, averaged over a period of 2 to 6 hours, can be significantly higher. Extreme values for ice movement rates are in the range of 2.5 to 3.0 kt.

Movement of the landfast ice sheet occurs during the winter. Oceanographic Services, Inc. (OSI, 1976; 1978a,b; 1980) performed 4 consecutive years (1975-76 through 1978-79) of ice movement measurements using wireline stations. Four of these stations were located in Stefansson Sound. The ice-movement rates for the 20-year and 100-year return periods are 3.5 m/hr and 5.8 m/hr, respectively, based on a statistical analysis (Miller, 1996; Vaudrey, 1997) of the maximum hourly ice-movement rates recorded during each measurement year. The net ice movement by month for January through April for 3 years of ice measurements by Oceanographic Services, Inc. is summarized in Table 2.4-9. Although the 100-year ice movement rate is predicted to be 5.8 m/hr, more than 99% of the time the ice movement rate was less than 30 cm/hr.

Vaudrey (1996) reported similar ice movements measured in the winter of 1995-96 at a single wireline station located in 6.4 m of water in Stefansson Sound, 6 km south of Reindeer Island and 24 km west-northwest of the SDI. The maximum ice movement rate was 95 cm/hr based on 10-minute data and 21 cm/hr based on hourly data. The net movement was 134 cm for January, 73 cm for February, and 9 cm for March and April, resulting in an average ice movement rate of 56 cm/month over the 4-month period.

2.4.7.4 Sea Ice Changes

Satellite imagery obtained between 1979 and 2006 suggests that the areal extent of sea ice during summer months has declined throughout most of the Arctic Ocean. In contrast, evidence for reduced sea ice thickness during this period developed from upward-looking sonar is inconclusive (Serreze et al., 2007).

Wendler et al. (2003) observed a decrease in sea ice concentrations in coastal regions of the North Slope between 1972 and 1994 (Figure 2.1-7). This finding correlates with an air temperature increase of approximately 1.1°C during the same period. Sea ice concentrations were found to decline in all months except January. The decline was most pronounced in July and August, with changes on the order of 20% over the 23-year period. Declines during winter months were more modest, at about 3% over the period of record.

Using satellite imagery, Mahoney et al. (2006) identified the possibility of a reduced duration of landfast ice presence along the Arctic Coast of Alaska during the last three decades. An earlier onset of thawing temperatures in the spring and a later incursion of pack ice in the fall are contributors to this trend. Breakup along the Beaufort Sea coast in recent years (1996-2004) was estimated to begin 21 days earlier than in the 1970s, while the formation date of landfast ice during the same period was found to have changed little since the 1970's (Mahoney et al., 2007). Ice-free conditions were found to occur approximately one month earlier along the Beaufort Sea coast (Eicken et al., 2006). Similarly, Dickins and Oasis (2006) identified a trend of longer open-water seasons during the past decade when compared to the duration of ice-free conditions documented between 1950 and 1984.

The implications of the reduced extent of sea ice for regional oceanography include a longer open-water season and greater areas of open-water available for wave generation. Extended open-water seasons will result in more total wave energy reaching the coast, which in turn could increase shoreline erosion rates. Notwithstanding the trend towards diminished ice cover in the Beaufort Sea, there is no clear evidence that the severity of the wave climate has increased. Oceanweather, Inc. (2005) speculates that the wave-generating potential of the predominantly easterly and westerly storms is not significantly affected by the northerly migration of the ice edge.

2.5 MARINE WATER QUALITY

Marine water quality is measured by the physical and chemical characteristics of the water. Seawater contains naturally occurring constituents derived from atmospheric, terrestrial, and freshwater environments, as well as those derived from human activities (pollution). Due to limited industrial activity, most contaminants in the Beaufort Sea and on the North Slope occur in low levels.

Industrial activities are the primary source of pollutants entering the marine environment. These contaminants may be classified as either physical, chemical, or biological. Suspended solids are the principal physical pollutant. Chemical pollutants include both organic (e.g., crude and refined oil) and inorganic substances (e.g., trace metals). Waterborne viruses, protozoa, or bacteria, and excessive biological growth can be characterized as biological pollution.

2.5.1 Salinity and Temperature

Temperature and salinity in the Beaufort Sea are summarized in the Liberty Project FEIS (USDOI, MMS, 2002). Freshwater discharge from the Sagavanirktok River influences the temperature and salinity of Foggy Island Bay. The impact is greatest near the time of the spring freshet, when river flow rates typically are highest. The freshwater initially creates a brackish nearshore zone with salinities of 10 to 15 parts per thousand (ppt). As mixing commences, salinities increase to 15 to 25 ppt with water temperatures ranging from 0 to 9°C. The nearshore waters become relatively well-mixed as the open-water season progresses, with salinities greater than 25 ppt and temperatures decreasing to 0 to 2°C. During the winter, under-ice water temperatures ranging from -2 to 0°C have been recorded in Foggy Island Bay, while measured salinities have ranged from 21 to 30 ppt during the winter.

Numerous measurements of water temperature and salinity in Foggy Island Bay and the Sagavanirktok River delta were obtained on several occasions during the 1980s as part of the Endicott Environmental Monitoring Program (LGL Ecological Research Associates Inc. and Northern Technical Services, 1983; Hachmeister et al., 1987; Short et al., 1990; Short et al., 1991; Morehead et al., 1992a; Morehead et al., 1992b; Morehead, Dewey, and Horgan, 1993). Water temperature and salinity near the SDI are highly variable during the open-water season due to the proximity of the Sagavanirktok River and circulation of nearshore water masses. Water temperatures in the Sagavanirktok River tend to fluctuate with air temperatures. During the 1982 monitoring program, for example, the river water temperatures varied from 17°C in July to 2°C in September. It is not uncommon for water temperatures near the SDI to vary from 10°C to 0°C during the summer. Similarly, salinities in the region may vary from 0 ppt (fresh river water) to 26 ppt (consistent with shelf bottom water).

2.5.2 Dissolved Oxygen

Dissolved-oxygen levels in the Beaufort Sea are summarized in the Liberty Project FEIS (USDOI, MMS, 2002). Like many cold climate waters, dissolved-oxygen levels in the Beaufort Sea typically are near saturation. Dissolved-oxygen levels during the open-water period are reported to range between 8 and 12 mg/l, while under-ice dissolved-oxygen concentrations during the winter are reported to range between 7.6 and 13.2 mg/l. However, areas with limited circulation can turn anoxic before spring breakup. Biological oxygen demand in Foggy Island Bay is reported to be less than 1 mg/l.

2.5.3 Turbidity

Satellite imagery and data for total suspended solids (TSS) show that turbid waters are generally confined to water depths less than 5 to 8 m inside the barrier islands (USDOI, MMS, 2002. Turbidity is caused by the presence of fine-grained particles in the water column. These particles are derived from river runoff, coastal erosion and resuspension of seafloor sediments by waves and currents.

During the open-water period of July to September, concentrations of TSS vary in response to water depth, wind conditions and the presence of sea ice. In Foggy Island Bay, concentrations of TSS are typically in the range of 5 to 15 mg/l during July and August, with occasional values greater than 30 mg/l as shown in Tables 2.5-1 and 2.5-2 (Rummel, 1987; Dunton et al. 2005). During the 1982 open-water season, a TSS concentration of 400 mg/l was recorded in the nearshore waters of the Sagavanirktok River delta (LGL Ecological Research Associates Inc. and Northern Technical Services, 1983).

Dunton et al. (2005) made extensive measurements of TSS in Foggy Island Bay during 2001 and 2002. Maximum values for TSS (20 to 25 mg/l during summer 2001) were found in shallow water along the Endicott Causeway (Figure 2.5-1). Concentrations of TSS were generally less than 10 mg/l near the originally proposed Liberty Island location (Figure 2.5-1 and Trefry et al., 2004a). Dunton et al. (2005) showed that light attenuation increased directly with increasing concentrations of TSS and that new growth of kelp in the Boulder Patch was indirectly related to levels of TSS during the summer.

As summarized in Table 2.5-3, concentrations of TSS during the open-water period are well correlated to winds and storm events. For example, the maximum values for TSS observed during summer 1999 (Table 2.5-3) were found immediately following a 5-day storm with greater than 25-kt winds. However, during summer 1999, Foggy Island Bay was not sampled until well after the storm subsided, and thus the 1999 data show a smaller maximum value than reported for the overall coastal Beaufort Sea (Table 2.5-1).

During the ice-covered period, concentrations of TSS are believed to be very low. Trefry et al. (2004a) reported background levels of TSS in Foggy Island Bay of 0.1 to 0.6 mg/l under ice during April 2000 with a similar range of TSS under ice across the study area for the Arctic

Nearshore Impact Monitoring in the Development Area (ANIMIDA) study area during 2001 and 2002 prior to the onset of spring runoff. Weingartner et al. (2001 and 2005) deployed year-round moorings inside the barrier islands, including one in Foggy Island Bay from 1999 to 2002. Transmissivity (T) at the moorings was greater than 80% and relatively uniform under ice from February to May. Lower values for transmissivity (i.e., higher TSS) were observed under ice from November to February, indicating that there may be late fall or early winter events that promote some sediment resuspension under ice. This finding is consistent with a previous study which reported TSS levels of 2.5 to 76.5 mg/l under ice along the pipeline route for the then-proposed Liberty Project (Montgomery Watson, 1997 and 1998).

During spring runoff in late-May to mid-June, a large pulse of suspended sediment is discharged into Foggy Island Bay from the Sagavanirktok River. Rember and Trefry (2004) found maximum levels of TSS of 400 to 600 mg/l in the Sagavanirktok River for several days during the spring event in 2001 (Figure 2.5-2). Maximum values for TSS in the Sagavanirktok River during the spring floods of 2002 and 2004 were 300 to 350 mg/l due to lower river flow and, in 2002, a period of cooling and refreezing during the spring meltwater event. Concentrations of TSS from 63 to 314 mg/l were reported during breakup for the Sagavanirktok River from 1971 to 1976 by the U.S. Army Corps of Engineers (Envirosphere Company, 1993). During July through September, concentrations of TSS in the Sagavanirktok River range from 0.2 to 30 mg/l (Rummel, 1987; Trefry et al., 2004a). Values for TSS at the higher end of this summer range are directly linked to rain storms.

Spring runoff from the Sagavanirktok River enters Foggy Island Bay as a 0.5- to 2-m-thick layer under the ice with concentrations of TSS that range from 5 to 50 mg/l (Trefry et al., 2006). Alkire and Trefry (2006) traced the flow of river water under ice to the barrier islands during the spring floods of 2004, and Trefry et al. (2006) showed the distribution of TSS in the Sagavanirktok River plume under the ice.

2.5.4 Hydrogen Ion Concentration (pH)/Acidity/Alkalinity

A description of the acidity/alkalinity of Beaufort Sea waters is provided in the Liberty Project FEIS (USDOI, MMS, 2002). Typical pH values for seawater range from 7.8 to 8.2, while freshwater pH values generally range from 6.0 to 7.0. During the open-water season, pH values in the central part of the Beaufort Sea are reported to range from 7.8 to 8.2. Under-ice pH values during the winter are reported to range between 6.8 and 8.1.

2.5.5 Trace Metals

Trace metals can be useful indicators of industrial impacts because metals are sometimes enriched in the raw and finished materials used in modern industry. Bottom sediments are the ultimate sink, or depository, for trace metals released into the marine environment, and thus many environmental assessments of metals in the environment begin with sediment studies.

Previous studies of trace metals in sediments from the coastal Beaufort Sea have generally shown that metal concentrations are highly variable, but at natural levels with minimal localized inputs from development (Sweeney and Naidu 1989; Snyder-Conn et al., 1990; Crecelius et al., 1991; Naidu et al., 1997, 2001; Valette-Silver et al., 1999). Snyder-Conn et al. (1990) identified elevated levels of Ba, Cr, Pb and Zn in areas adjacent to one or more disposal sites for drilling effluent. Crecelius et al. (1991) found elevated levels of Ba at a few sites in western Harrison

Bay and Cr near the mouth of the Canning River, with no other indications of metal contamination.

The MMS ANIMIDA (1999-2003) and Continuation of ANIMIDA Programs (2004-2007) were specifically designed to investigate the distribution of 16 trace metals (Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Tl, V and Zn) near the Liberty Prospect, the Northstar area and in the coastal Beaufort Sea from Harrison Bay to Camden Bay. Considerable variability was found in the concentrations of all metals as well as total organic carbon (TOC) in surface and subsurface sediments from the study area, including Foggy Island Bay (Table 2.5-4).

Concentrations of selected trace metals in sediments from a given depositional environment commonly follow a strong linear trend versus Al. As a result, the observed variability of trace metal concentrations often can be resolved by normalizing metal values with Al. A range of natural metal/Al ratios has been developed for all 16 metals listed above. Natural levels are defined as concentrations within the prediction interval or at less than 10% above the upper prediction interval (e.g., Cu, Pb, Hg and Ba in Figure 2.5-3). Trefry et al. (2003) reported that only 8 of 1,222 metal concentrations from the broad study area were elevated above natural levels. One of the eight anomalies was for Ba in sediment from Foggy Island Bay near the Liberty Prospect, and five anomalies were found in sediment in the Northstar area.

The historical record of metals in sediments from the coastal Beaufort Sea also was determined during the ANIMIDA Program. Concentrations of trace metals were determined for 104 samples from six cores, including one in Foggy Island Bay (Trefry et al., 2003). Some variability in concentrations of metals was observed in each core, mainly due to variations in the amounts of fine-grained sediment. Overall, concentrations of Ag, Ba, Be, Co, Cr, Cu, Hg, Ni, Pb, Sb, Tl, V and Zn in these cores were not impacted by anthropogenic inputs or diagenesis and show long-term (many decades) deposition of uncontaminated sediments.

More than 50 samples of suspended sediment from the Sagavanirktok River have been collected and analyzed for trace metals since 2000 (Rember and Trefry, 2004; Trefry et al., 2004b). All data for metals in suspended sediment from the river plot within the prediction intervals for natural sediment (e.g., Figure 2.5-3). In general, concentrations of trace metals in suspended sediment from the Sagavanirktok River are higher than in coastal sediments because the suspended particles are clay-rich and do not contain the metal-poor quartz sand and carbonate shell material found in bottom sediments from the Foggy Island Bay.

Sediment quality criteria have been established for several trace metals to help assess possible adverse effects to biota from elevated levels of metals in sediments. Long et al. (1995) introduced an effects range-low (ERL) that is defined as the concentration of a substance that affects 10% of the test organisms and an effects range-median (ERM) that is defined as the concentration of a substance in the sediment that results in an adverse biological effect in about 50% of the test organisms.

Six (Ag, As, Cd, Hg, Pb and Zn) of the 17 metals investigated during this study have been assigned reasonable ERL and ERM concentrations by Long et al. (1995), and these values are listed in Table 2.5-4. None of the concentrations of the these metals in the coastal Beaufort Sea sediments, including Foggy Island Bay, exceeded their respective values for the ERM (Table 2.5-4). Therefore, adverse biological effects as the result of trace metals are not expected to be a frequent occurrence at any site in the study area. Furthermore, no concentrations of Ag, Cd or Pb from this study exceeded the respective values for the ERL (Table 2.5-4), indicating that adverse biological effects from these four metals would be rare. One sediment sample (of 192 total) collected near West Dock contained Hg and Zn at levels that were slightly greater than the ERL

(Table 2.5-4). Overall, sediments sampled in Foggy Island Bay and the coastal Beaufort Sea were not contaminated with metals and would rarely cause adverse effects to benthic organisms.

Concentrations of dissolved metals in Foggy Island Bay and throughout the coastal Beaufort Sea are similar to or less than the world average values in coastal and marine areas (Table 2.5-5). With respect to dissolved trace metals, the area seems pristine. Concentrations of dissolved metals in the incoming water of the Sagavanirktok River also are low relative to typical river water (Table 2.5-5), most notably for As, Cr and Hg. These data provide no indication of contamination from dissolved metals in Foggy Island Bay.

Trace metals in marine systems may be assimilated into the food chain and lead to adverse effects to the marine biota and ultimately to humans. In the ANIMIDA/cANIMIDA programs, concentrations of trace metals were determined for clams, amphipods and some fish collected in 1999, 2000 and 2002 (Brown et al., 2004, 2006). For Ba, Cd, Cu, Pb, V and Zn, samples had been previously collected and analyzed in 1986 and 1989 (Boehm et al., 1990).

Mean concentrations of Ba, Cu, Pb, V and Zn in clams (*Astarte* sp.) sampled during 1986, 1989, 1999 and 2000 were relatively uniform (see Figure 2.5-4 for Cu, Pb and Zn). Such uniformity is encouraging because body burdens for metals can be used as a long-term indicator of metal availability. This uniformity also suggests that no detectable shifts in metal levels in *Astarte* have occurred between 1986 and 2000. Some variability in concentrations among years was observed (e.g., Hg in Figure 2.5-4). However, these shifts are sometimes related to the amount of sediment, albeit small, in some samples. In addition, the small number of pools of samples limits the statistical power of the data. No evidence for metal contamination has been found for clams, amphipods or fish (Brown et al., 2004, 2006).

2.5.6 Hydrocarbons

As previously described in the Liberty Project FEIS (USDOI, MMS, 2002), concentrations of aliphatic and aromatic hydrocarbons in sediments from the coastal Beaufort Sea are high relative to other undeveloped Outer Continental Shelf sediments. However, the hydrocarbons in the study area are mainly derived from natural outcrops of coal and shale and from natural petroleum seeps on land that are drained into rivers and into the coastal Beaufort Sea.

Recent data on organic parameters for surficial sediments from Foggy Island Bay are summarized in Figure 2.5-5, and show total polynuclear aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPHC), and total steranes and triterpanes (total S/T). Sediments in Foggy Island Bay and along the coastal Beaufort Sea contain a mixture of primarily terrestrial biogenic hydrocarbons and lower levels of petroleum hydrocarbons. This assemblage is clearly dominated by plant wax normal (i.e., straight-chain) alkanes in the n-C27 through n-C33 carbon range (Brown et al., 2004).

The PAH distributions for most of the surficial sediments (Brown et al., 2004) show that the PAHs are primarily of a combined fossil-fuel origin (i.e., petroleum and coal) with a biogenic component (perylene), and lesser contributions of pyrogenic or combustion-related compounds (e.g., 4-, 5-, and 6-ring PAHs). The petrogenic PAHs account for approximately 90% of the Total PAH less perylene throughout the study area. Perylene, a naturally occurring PAH, was abundant in surficial sediments, often the most abundant single PAH compound in the overall PAH distribution.

Concentrations of hydrocarbons in the sediments in Foggy Island Bay are generally within the observed historical range for these parameters in the overall study area (Brown et al., 2004).

Background concentrations of total PAHs (a sum of 2- to 6-ringed parent and alkylated PAHs) in recent Alaskan surficial sediment studies range from less than 10 to 1,000 ppb. Typically, PAH profiles indicate significant levels of a fossil fuel-type signature, which appears to be sourced in organics shales brought to the sediments from river runoff and coastal peat. At one location in Foggy Island Bay (station L08), concentrations of total PHC were about 2.5 times greater than background levels, and the source of the PHC was from unknown diesel input. Based on the PAH compositional results (i.e., petrogenic PAHs vs. pyrogenic PAHs), no significant changes in PAH composition were observed on an annual basis at Northstar due to construction and production activities.

The PAH data were correlated with silt+clay in Figure 2.5-6 to show that concentrations of these organic substances are directly related to the abundance of higher surface area, silts and clays. Collectively, concentrations of PAH normalized to silt+clay show little evidence of localized inputs of North Slope-related petroleum hydrocarbons to the sediments in the vicinity of the Liberty Prospect, Northstar or the coastal Beaufort Sea.

Values for the ERL and ERM have been developed for 13 individual PAH compounds and three classes of PAH (low- and high-molecular-weight PAH, and total PAH) by Long et al. (1995). A comparison of the total PAH from all ANIMIDA and cANIMIDA sediments from 1999, 2000, 2002 and 2004 (Figure 2.5-7) shows that none of the total PAH concentrations determined for Foggy Island Bay and throughout the coastal Beaufort Sea exceeded the ERL. The mean total PAH values from each study region were generally an order of magnitude lower than the ERL. Similarly, the individual PAH concentrations did not exceed the ERL for the individual 13 PAH, which could be compared directly. In summary, based on sediment quality criteria, the concentrations of PAH found in the study area sediments are not likely to pose an ecological risk to marine organisms in the area.

Data from 1999, 2000, 2002 and 2004 for total polynuclear aromatic hydrocarbons, total petroleum hydrocarbons, and steranes/triterpanes (S/T) in clams (*Astarte* and *Cyrtodaria*) and amphipods (*Anonyx*) indicate that hydrocarbons in the sediment system are not readily bioavailable, as these species exhibit little ability to bioaccumulate saturated and aromatic hydrocarbons from sediment or from the overlying water column (Brown et al., 2004, 2006). Concentrations of PAH are very low (e.g., Figure 2.5-8 from 2000), showing consistent concentrations of contaminants over time in the study area.

2.6 FRESH WATER ENVIRONMENT

2.6.1 Sagavanirktok River

Onshore access and portions of the Liberty Project area lie entirely within the Sagavanirktok River delta. The Sagavanirktok River is 180 mi long and has a drainage area of 5,750 mi^2. About half of the basin area occurs in the Brooks Range, one-third within the Foothills physiographic province, and the remainder in the Arctic Coastal Plain. The river is bordered by the Franklin Bluffs to the east and the Kuparuk and Putuligayuk river basins to the west. A summary of hydrologic data for the Sagavanirktok River is provided in Table 2.6-1.

The Sagavanirktok is braided in the lower half of the river. About 25 mi upstream of its mouth, the river bifurcates into the West and East Channels, each consisting of a number of braided subchannels ranging from 200 to 1,200 ft wide within floodplains ranging from 1,000 to 7,000 ft wide. The East Channel, identified as the Main Channel on USGS maps, generally carries about equal flows to the West Channel. Thaw-lake terrain between the East and West channels indicates that the river has not occupied the intervening area for the past 10,000 years, since the early Holocene (SAIC, 1993a).

Channel patterns in the lower Sagavanirktok and its distributaries are formed primarily during summer high-flow events, which cause bank erosion and scour, and bear heavy sediment loads. Although overbank flows occur nearly every year during breakup, frozen ground conditions result in only minor changes to the channel and floodplain during the spring flooding (USDOI, BLM, 2002).

2.6.1.1 Hydrology

North Slope rivers are classified based on the physiographic province of their headwaters (Walker, 1973). Major rivers, including the Sagavanirktok River, have headwaters in the Brooks Range, while smaller rivers and streams originate in the Arctic Foothills or on the Arctic Coastal Plain. The Brooks Range consists of rugged east-west trending mountains that rise from the foothills to elevations above 8,000 ft. In the Sagavanirktok River, the initial snowmelt from the upper basin flows over the frozen river surface and ponds behind snowdrifts and icings. As breakup progresses, small snowdrifts thaw or are overtopped, and the accumulated meltwater is released downstream until it ponds behind larger snowdrifts. The storage and release process results in a peaked hydrograph, often followed by a rapid recession.

Flows are minimal in the Sagavanirktok during winter. Streamflow begins in May or early June during spring breakup flooding. Flows continue throughout the summer and decrease or stop shortly after freeze-up in early October. The mountains of the Brooks Range trap moisture and can receive significant rainfall (Hodel, 1986), resulting in occasional rainfall-induced floods that may exceed the spring breakup flood. Average, minimum and maximum daily flows measured in the Sagavanirktok River near TAPS Pump Station 3 are shown in Figure 2.6-1.

Long-term hydrologic data for North Slope streams are sparse. Drainages near the project area for which long-term discharge data are available include the Kuparuk, Sagavanirktok and Putuligayuk rivers. Because the data are limited, statistical procedures have been applied by the U.S. Geological Survey (USGS) to the limited data to correlate peak streamflow to the physical and climatic basin characteristics (Curran et al., 2003). For North Slope streams, the resulting equations for estimating peak streamflows are based solely on the area of the drainage basin. Watershed models, which are often used to predict river floods based on precipitation input and basin geometry, do not adequately simulate North Slope breakup floods.

2.6.1.2 Flood Frequency and Stage

Continuous water-level measurements and associated river flows have been recorded for the Sagavanirktok from 1971 to 1978, and from 1983 to present at USGS Gauge Stations 15910000 and 15908000. The present gauge site, which is about 90 mi upstream of the delta near TAPS Pump Station 3, measures flow from about 35% of the Sagavanirktok River basin. Breakup and peak flow measurements have also been performed at the Endicott Road bridge site at the West Channel during most years from 1970 to present (Earl and Wright, 1980; McDonald, 1981, 1983, 1984, 1988, 1990a, 1990b; Bell and Associates, 1993, 1995, 1997-2004). Separate flood-frequency analyses have been performed for the Sagavanirktok River Bridge (Earl and Wright, 1980; McDonald, 1984; PND, 2003) and for the upstream gauging stations near Pump Station 3 (Jones and Fahl, 1994; Curran et al., 2003).

Although rainfall floods on the North Slope are typically smaller than the annual breakup event, the Sagavanirktok has been noted as an exception. The largest floods measured in the Sagavanirktok at Pump Station 3 occurred during rainfall events. However, this station gauges flow only from the southern third of the drainage basin, consisting of mountainous terrain characterized by increased precipitation (Kane and Carlson, 1973). In contrast to the upper gauging station, annual hydrographs at the Sagavanirktok River Bridge show behavior typical of other North Slope streams, with annual peak flows during spring breakup. In addition to larger flows, breakup floods produce higher river stages in the coastal plain than rainfall floods because parts of the channel and floodplain are occluded by snow and ice. Twenty-two years of breakup stage and discharge data have been recorded at the West Channel bridge (Table 2.6-2).

Discharge data collected from both the West and East channels of the Sagavanirktok in 1982 and from 1985 to 1990 (Gallaway and Britch, 1983; Envirosphere, 1987, 1990, 1991; SAIC, 1991, 1993a, 1993b) are particularly useful for evaluating the proportion of flow carried by the West and East channels. The peak flow in the West Channel has ranged from about 35 to 75% of the total river flow between 1982 and 1990, and averages 50% (PND, 2006a). Figure 2.6-2 shows the flow distribution in the Sagavanirktok River delta, while Figure 2.6-3 and Table 2.6-3 present breakup flood magnitudes and frequencies at the Sagavanirktok West Channel Bridge.

2.6.1.3 Erosion and Sedimentation

The Sagavanirktok River has a substantial delta, indicating a general magnitude of sediment transport in this river. Sediment transport in North Slope streams is relatively low compared to streams in more southern latitudes due to the limited open-water flow season, the occurrence of high breakup flows while the river bed and banks are still frozen, permafrost, and subsequent low summer flows (Childers and Jones, 1975; Lewellen, 1972). The majority of sediment transport occurs during annual breakup flooding and rare high-volume rainfall floods, as evidenced by gravel bed material in the larger rivers. The Sagavanirktok River is degradational for most of its length, and is only aggradational for the last 15 mi.

2.6.1.4 Ice Conditions

Icings are large bodies of ice that form when water from a river or spring seeps onto the surface during winter. Because water is stored in the icings, downstream streamflow is initially reduced (Sloan, Zenone, and Mayo, 1976). Channel ice in the Sagavanirktok River can develop thicknesses greater than the 2 m typically observed on tundra ponds (BPXA 2001) as a result of groundwater springs or winter overflow building layer upon layer of ice (Carey, 1973; Hodel, 1986). The ability of the Sagavanirktok and other large rivers to carry this thick ice downstream during breakup flooding is limited, however, by the river depth.

Ice jams at the head of the Sagavanirktok River delta during breakup can divert discharge from one channel to the other (Chezhian, 2004). Channel ice at the Sagavanirktok West Channel Bridge has been the subject of an annual ice-cutting program, depending on ice conditions, since the early 1980s, and appears to have prevented major ice jams from occurring at the West Channel bridge. The total duration of significant ice movement in a given river reach is no more than a few days (Walker, 1973; PND, 2005).

2.6.2 Lakes

Thaw lakes dominate the landscape of the coastal plain, originating as small ponds in low-centered ice-wedge polygons (Sellman et al., 1975). The ponds coalesce to form lakes, which develop a northwest-southeast orientation over time due to wave action from winds prevailing out of the northeast. Lake recharge results from snowmelt and rainfall within the lake basin and spring breakup flooding and overbank flows from nearby streams. Lakes subject to stream overflows during breakup flooding may be replenished annually. Other lakes may have residence times as long as 25 years (USDOI, BLM, 2003). Summer evaporation measured in lakes near Prudhoe Bay averaged about 5 inches (Mendez et al., 1998).

Lakes are a readily available fresh water source in the project area (Sloan, 1987). Shallow lakes less than 6 ft deep freeze to the bottom during most winters. Lake depth is a primary factor in winter water supply for this reason, and lakes are classified accordingly as shallow or deep. Shallow lakes that freeze completely in the winter are directly underlain by permafrost. Deep lakes, which do not freeze to the bottom, are underlain by a thaw depression in the permafrost table that generally does not exceed 20 ft (Sellman et al., 1975). Shallow lakes begin to freeze in September and become ice-free by late June, up to a month earlier than most deep lakes (Hobbie, 1984).

Deep lakes, along with gravel mine sites and river channels, are potential sources for fresh water supply for ice road construction in the project area. Several lakes along the Endicott Road and Badami Pipeline alignment have been tapped for ice road water sources, primarily for Badami. In addition, manmade reservoirs in the Sagavanirktok River delta (Duck Island Mine Site), Shaviovik River delta (Shaviovik Reservoir) and lower East Badami Creek (Badami Reservoir) have been used for water supply.

2.6.3 Surface Water Quality

Rivers in the project vicinity have been sampled by the U.S. Geological Survey (Feulner, Childers, and Norman, 1971; Kemnitz et al., 1993) and as part of the Endicott Monitoring Program (Envirosphere Company, 1987). Most fresh waters in the project area are pristine, soft, dilute calcium-bicarbonate waters. Near the coast, sodium chloride (salt) concentrations predominate over bicarbonate concentrations (USDOI, BLM, 1998, 1978; Prentki et al., 1980). Water chemistry in lakes and ponds in the project area is highly variable and dependent on the distance from the Beaufort Sea, frequency of flooding, and whether the lakes and ponds are tapped (connected to river channels most of the year) or perched (isolated from rivers channels most of the year).

The arctic freeze/thaw cycle plays a controlling role in water quality. In winter, surface waters less than 6 ft deep will freeze solid (Hobbie, 1984). In such waters, major ions and other "impurities" are excluded from downward-freezing ice in autumn and forced into the underlying sediment. Most of the ions remain trapped in the sediment after melt-out the following spring, giving these waters a very low dissolved-matter concentration. During the summer, dissolved matter concentrations slowly increase as ice in the bottom sediment melts and the sediments compress (Miller, Prentki, and Barsdate, 1980). Waters deeper than about 6 ft remain unfrozen. In these waters, ions and impurities are excluded from downward-freezing ice and forced into the deeper water column or underlying sediment, with a proportionate increase in concentrations of dissolved materials. As a result, distinct off-flavor and saline taste affect the potability of water from lakes and river pools by late winter.

Water temperatures in the Sagavanirktok River exhibit a seasonal pattern of general warming in June and July followed by cooling during August through mid-September (SAIC, 1994). Monthly average temperatures for a 6-year period (1985-1990) were 46 to 55°F in June, 50 to 56°F in July, 44 to 53°F in August, and 36 to 44°F in September. Based on 14 years of data, the mean date when the Sagavanirktok Delta is frozen in (used as a milestone to indicate the Sagavanirktok River was also frozen in) is October 12, ranging from October 1 to October 25 (SAIC, 1994).

2.6.3.1 Turbidity

Turbidity is a measure of water clarity and varies seasonally in the project area in relation to sediment transport by the major rivers during flooding. Rivers originating in the foothills or Brooks Range have steeper gradients and carry higher suspended-sediment loads, resulting in higher turbidity than smaller streams originating within the Arctic Coastal Plain. Nearly the entire annual sediment load in rivers is carried between May and October, with approximately 70% flowing to the river deltas during breakup in May and June, when suspended-sediment concentrations can reach above 500 mg/l (ARCO, 1997; USDOI, BLM, 1978). Later in summer, suspended-sediment concentrations decrease significantly (USDOI, BLM, 1998). Total suspended solids in the Sagavanirktok River have been measured between 0.2 and 30.0 mg/l in summer, with turbidities ranging from 0.4 to 24.0 NTU (nephelometric turbidity units).

2.6.3.2 Alkalinity and pH

Alkalinity is a measure of the acid-buffering capacity of water. Fresh waters in the arctic tundra are only weakly buffered (USDOI, BLM, 1998, 1978; Prentki et al., 1980; Hershey et al., 1995; O'Brien et al., 1995). In lakes and ponds, alkalinities during snowmelt are about twofold lower than midsummer alkalinities, which are on the order of 20 mg/l as calcium carbonate ($CaCO_3$). Alkalinities in coastal streams are higher, ranging from about 15 to 80 mg/l as $CaCO_3$ in summer, with higher values at lower flow rates. Winter alkalinities in unfrozen pools beneath the ice are on the order of 150 to 200 mg/l as $CaCO_3$.

The pH is a measure of water acidity and alkalinity. A pH of 7 indicates a neutral balance of acid and base, between 5.0 and 6.5 indicates slightly acidic water, and below 4.5 indicates acidic water. A pH between 6.5 and 8.5 is considered necessary to protect aquatic wildlife (ADEC, 2002), and is normal for most surface waters. Rainwater has a pH of 5.5 due to carbon dioxide in the atmosphere. Plants and aquatic life tend to buffer the pH of surface waters and keep the pH in the range of 6.5 to 8.5.

In shallow lakes and ponds, pH values are often depressed to below 7.0 due to snowmelt runoff. After snowmelt, their pH values usually increase to between pH 7.0 and 7.5 (Prentki et al., 1980; O'Brien et al., 1995). The initial low pH is due to acidity of snow on the North Slope, which has a median pH of 4.9 (Sloan, 1987). This low pH, which is below the pH 5.5 expected for uncontaminated precipitation, is thought to be a result of sulfate fallout from arctic air masses industrially contaminated from pollution sources in Eurasia (BLM and MMS, 1998). In tundra brown-water streams (so-called because of the color caused by tannins) and some foothill streams, pH values can be less than 6.0, with acidity attributable to naturally occurring organic acids (Hershey et al., 1995; Milner, Idrons, and Oswood, 1995; Everett, Kane, and Hinzman, 1996). In streams and rivers, pH values are higher, seasonally ranging between 6.5 and 8.5 (USDOI, BLM, 1978; Kogl, 1971).

2.6.3.3 Salinity

Salinity of coastal waters in the summer varies in the range of 20 to 6 ppt, dropping rapidly to fresh water as the river channels in the deltas are approached. Average salinity measurements are typically highest in river channels (12.5 ppt), intermediate in tapped lakes (7.2 ppt), and lowest in perched lakes (1.0 ppt) (Schell, 1975. The differences in salinity correspond with varying concentrations of dissolved minerals.

As the flows from the major rivers decrease in early fall and storm surges associated with westerly winds occur, fresh water left in the delta channels from the summer flow is gradually replaced by seawater (Schell, Kinney, and Billington, 1971). The denser saltwater flows inward along the channel bottom with accompanying outflow of fresh water on the surface. The principal result of the saltwater intrusion is to create isolated marine environments in separate channels. The extent of marine water intrusion up the river deltas depends on surge height and river flow. Storm surges, which can exceed 10 ft on the Beaufort Sea coast, are more important in the water exchange process during the summer than lunar tides, which average less than 1 ft in the project area (Norton and Weller, 1984; Selkregg et al., 1975). Lunar tides are dominant in winter, however, when ice cover restricts storm surges.

2.6.3.4 Oxygen

North Slope streams are typically near saturation with dissolved oxygen during the summer due to aeration of the flowing waters. Summer concentrations of dissolved oxygen in clear-water streams and lakes in the project area range from 8 to 12 mg/l (Kogl, 1971). Brown-water streams, ponds and lakes generally have lower dissolved-oxygen concentrations. Oxygen saturation values in ponds during the summer months generally fall below 100%, although a range between 60 and 120% has been observed (Prentki et al., 1980). Oxygen values can be much lower — less than 10% saturation — in vegetated shorelines or in water pooled on wet tundra (USDOI, BLM, 1998). In these locations, chemical processes in the underlying sediment deplete oxygen from the water as rapidly as the water can take up oxygen from the air.

During the winter, large streams and deeper coastal-plain lakes may become supersaturated with oxygen when dissolved oxygen is excluded from ice as it forms, and the exclusion adds more oxygen than underwater respiration by benthic organisms removes (USDOI, BLM, 1978; Prentki et al., 1980; O'Brien et al., 1995). Late winter measurements of oxygen in unfrozen pools beneath ice cover in smaller rivers indicate significant residual oxygen (9 mg/l) and 70 to 99% saturation (USDOI, BLM, 1998). Larger rivers with deep channels also maintain adequate (for fish use) to supersaturated winter-oxygen concentrations (USGS, 2003). Decreasing oxygen concentrations are more likely in ponds during the winter because aeration and photosynthesis by aquatic vegetation, which both increase dissolved oxygen concentrations, do not occur under the inhibiting effects of ice cover and darkness.

2.6.3.5 Organic Nutrients

Nitrogen and phosphorus are the primary nutrients required for algae productivity and availability of food for fish. Low nitrogen concentration is often the limiting factor in phytoplankton productivity in coastal marine water, while low phosphate concentration is the limiting factor in fresh water in the rivers. Streams have relatively high summer concentrations of nutrients until the water reaches the Beaufort Sea, where phytoplankton consume most of the nitrate. Nitrogen concentrations are generally higher in the spring than in the fall because freezing concentrates nutrients in the waterbodies. Nutrient levels in lakes and ponds are much lower than in the major rivers. Samples taken in 1971 had nitrate and nitrite concentrations that were almost undetectable in lake and pond water (Alexander et al., 1975). Phosphate concentrations were also much lower in lakes and ponds than in the large rivers. Another source of organic nutrients is regeneration of ammonia through the conversion of dissolved organic nitrogen by heterotrophs under the winter ice (Schell, 1975). Phosphate concentrations in freshwater bodies are generally very low.

2.6.3.6 Hydrocarbons

The peat that underlies the North Slope carries substantial hydrocarbon content. This content is evidenced by natural sheens that occur in ponds or flooded footprints in the tundra, foam on the downwind shoreline of lakes on windy days, and elevated hydrocarbon levels in sediments with peat. These phenomena are naturally occurring and are not the result of industrial activities.

Pond waters away from development in the Prudhoe Bay area contain 0.1 to 0.2 parts per billion (ppb) total aromatic hydrocarbons, similar to concentrations in pristine marine waters (Woodward et al., 1988). Hydrocarbons derived from the various sources are detectable as elevated levels of saturated and polycyclic aromatic hydrocarbons (PAH) in Colville River sediment and in Harrison Bay sediment (Boehm et al., 1987a). Additional pyrogenic PAH compounds are present in tundra soils and form a depositional record of atmospheric fallout from tundra fires. Concentrations of indicator hydrocarbons from these multiple sources are high and chemically similar to those found in petroleum, thus making it difficult to detect or distinguish anthropogenic contamination from natural background due to fires. Similarly, high levels of hydrocarbons found in other major North Slope rivers have been attributed to natural sources (Boehm et al., 1987a; Yunker and MacDonald, 1995).

2.6.3.7 Trace Metals

Lake and stream waters on the North Slope are generally low in trace metals compared to most temperate-zone fresh waters (Prentki et al., 1980). However, naturally occurring copper, zinc, cadmium, and lead have commonly been found at concentrations above the criteria established to protect aquatic life from toxic effects (ADEC, 2002; USGS, 2003). These metals come from soils in the undeveloped watersheds. The variations in water quality are part of the natural environment for fish and wildlife in the project area and do not result from manmade disturbances (USACE, 1998). In measurements made in ponds near Barrow in 1971-72, dissolved copper concentrations were on the order of 1 ppb, dissolved lead 0.7 ppb, and dissolved zinc 5 ppb.

2.6.3.8 Potability

Potable water is fresh water that is free from micro-organisms, parasites, and any other substances at a concentration sufficient to present a potential danger to human health. Surface water is the primary source of potable water on the North Slope. Treatment according to State of Alaska Drinking Water Regulations (8 AAC 80) is required for any potable drinking water system. Secondary standards provide specific parameters that define allowable contaminant concentrations. Additionally, water must have a generally agreeable taste and odor to be considered potable.

Surface waters in the project area generally do not meet potable water standards without treatment. Ponds and local streams are often brown-colored from dissolved organic matter and iron (USDOI, BLM, 1998), and fecal coliform often exceeds Alaska standards. Fecal contamination from avian, caribou and lemming populations is the primary source of water quality reduction below drinking water standards in the project area (USDOI, BLM, 1998; Ewing, 1997; Gersper et al., 1980; ADEC, 2003), and cold water temperatures prolong the viability of fecal coliform. Thus, some smaller waterbodies in the project area may exceed State of Alaska standards for fecal coliform for drinking water or water recreation due to local wildlife abundance (there is no State standard applicable to growth and propagation of natural aquatic life or wildlife). Larger lakes and rivers with higher water volumes tend to be less contaminated with fecal coliform.

2.6.4 Groundwater

The availability of groundwater is limited in the project area by impermeable permafrost, which is almost continuous throughout the North Slope and extends to depths of 2,000 ft or greater in the Prudhoe Bay area (Sloan, 1987; Lachenbruch et al., 1988). Groundwater occurs in thawed zones above, within and beneath the base of this permafrost. Water occurring within the 1- to 4-ft-thick seasonal thaw zone (active layer) is directly connected to and part of the surface water resource.

2.6.4.1 Shallow Groundwater

Shallow groundwater is present in localized unfrozen layers, or *taliks*, within the permafrost beneath deep rivers and lakes. Large rivers and lakes deeper than about 6 ft do not freeze to the bottom in winter and transfer heat downward, allowing a layer of unfrozen sediments to develop (Sloan, 1987). These unfrozen zones beneath and connected to surface waterbodies are called “open” taliks and are recharged from surface snowmelt and precipitation. Recoverable quantities of groundwater may be present where the thaw zone occurs in high-permeability gravel or sand sediments. Such shallow groundwater is likely to be present in the project vicinity beneath areas of the Sagavanirktok River and deep, large lakes.

Groundwater is also found in confined “closed” taliks within the permafrost. These formations can result from groundwater flow, or when lakes fill in with sediment, reducing the heat input and allowing the surface to freeze over and encase the unfrozen zone. The volume of groundwater that can be recovered from closed taliks is limited because they are cut off from recharge sources. Dissolved salts within the groundwater prevent freezing, but also make the water potentially harmful to surface vegetation and unsuitable for drinking without treatment (USDOI, BLM, 2003; Williams, 1970).

2.6.4.2 Deep Groundwater

Wells drilled in the Prudhoe Bay area of the North Slope indicate that the base of permafrost is approximately 2,000 ft deep (Lachenbruch et al., 1988). Deep groundwater beneath the permafrost (subpermafrost water) is recharged slowly from areas to the south in the Arctic Foothills and the Brooks Range by infiltration of meltwater (Nelson and Munter, 1990). Subpermafrost groundwater from wells drilled near Barrow and Prudhoe Bay have encountered highly mineralized groundwater (Sloan, 1987; Kharaka and Carothers, 1988). Based on this data, it is likely that subpermafrost groundwater beneath the project area will be brackish or saline, and not suitable for human consumption or surface use (Williams and Van Everingdon, 1973).

2.7 BENTHIC AND BOULDER PATCH COMMUMITIES

2.7.1 Plankton Communities

Primary production in the Beaufort Sea is considerably lower than other oceans of the world. In Stefansson Sound, annual production is typically 5 to 20 g of carbon per m^2 (Schell et al., 1982). Although phytoplankton abundance is greatest in nearshore waters less than 5 m in depth, per-unit-area production is actually higher offshore where waters are less turbid and there is greater penetration of sunlight. Phytoplankton abundance is highest in late July and early August when sunlight is the strongest. Because of the low primary production, zooplankton communities are characterized by low diversity and low biomass (Cooney, 1988). More than 100 species of zooplankton have been reported in the Alaskan Beaufort Sea, with copepods being, by far, the most dominant taxon (Horner, 1981; Richardson, 1986).

2.7.2 Benthic Communities

The marine benthic community in Prudhoe Bay in areas outside of the Boulder Patch is characterized by an infauna assemblage of polychaete worms, tiny mollusks, and benthic amphipods (Feder and Schamel, 1976; Broad et al., 1979; WCC, 1979; Griffiths and Dillinger, 1981; Feder and Jewett, 1982; Carey, Scott and Walters, 1984). A review of arctic invertebrate literature indicates that many of these nearshore benthic marine invertebrates are circumpolar (Carey et al., 1974). Stable infaunal communities occur seaward of the 1.8-m isobath. This is approximately the maximum depth to which landfast sea ice forms in 1 year. Lack of water in the areas shoreward of 1.8 m, plus the scouring effect of the ice during breakup, prevents establishment of permanent communities. Most stations within the 1.8-m contour are comprised of sediments dominated by fine sand, while the sediments deeper than 1.8 m contained more silt.

The nearshore Arctic Coast, including Prudhoe Bay, was explored using grabs and trawls as part of the National Oceanic and Atmospheric Administration (NOAA) Outer Continental Shelf Environmental Assessment Program (OCSEAP) (Broad et al., 1978, 1979, 1981). Broad et al. (1979) reported mean biomass values at three Prudhoe Bay sites as 4.93, 27.6, and 34.08 g/m^2. Polychaete worms and small mollusks were the predominant infaunal organisms. Dominant epifaunal organisms included the isopod *Saduria entomon* and *S. sabini*, nemerteans, and benthic amphipods. Mollusks consisted of 75 to 80% of total biomass, and polychaetes, 10 to 15%. *Portlandica arctica* and *Macoma* spp. were the most abundant bivalves.

From August 1974 until present, benthos in Prudhoe Bay has been sampled and monitored as various docks, causeways, and production islands have been constructed in the area. In the summers of 1974 and 1975 sampling occurred in the west side of Prudhoe Bay in the West Dock vicinity (Feder and Schamel, 1976; Feder et al., 1976; Feder, Shaw, and Naidu, 1976). A total of 38 invertebrate species in eight phyla were collected, with polychaetes and amphipods being the dominant groups. Extensive sampling covering much of Prudhoe Bay occurred in August, 1978, in connection with the Waterflood Project (ARCO Oil and Gas Co.), when a total of 6,430 individuals representing 91 taxa were collected (WCC, 1979). The ten most abundant species, primarily polychaete worms and amphipod crustaceans, accounted for 75% of the specimens collected. Distribution of the species was patchy; only ten taxa occurred in 20% or more of the samples. The seven most abundant and widespread animals were *Pontoporeia affinis* and *Onisimus glacialis* (amphipods), *Ampharete vega*, *Scolecolepides arctius, Pygospio elegans, Prionospio cirrifera*, and *Chaetozone setosa* (polychaetes) and *Saduria entomon* (isopod). During additional Waterflood Project sampling in July 1981, 6,378 individuals were obtained in 86 taxa (Feder and Jewett, 1982). The five most abundant species were the polychaetes *Prionospio cirrifera*, *Tharyx* sp., *Ampharete vega*, *Pygospio elegans*, and *Chaetozone setosa* which accounted for 73% of the total number of individuals recorded.

Dominant motile invertebrates that live near the seafloor include amphipods, mysids, copepods, and other swimming crustaceans. They are food for some fishes, birds, and marine mammals. Other invertebrates, such as bivalves, snails, crabs, and shrimp, are food for some marine mammals such as whales and bearded and ringed seals (Frost and Lowry, 1984).

2.7.3 Boulder Patch Communities

The Stefansson Sound Boulder Patch, located 20 km northeast of Prudhoe Bay in the Alaskan Beaufort Sea (Figure 2.7-1), supports the only known kelp bed on the Alaskan Arctic Coast that is characterized by abundant red and brown algae and a diverse assortment of invertebrate life attached to a collection of boulders, cobbles, and pebbles (Dunton, Reimnitz and Schonberg, 1982). The estimated area of Boulder Patch with >25% rock cover is 35.7 km^2 and 10 to 25% rock cover is 32.9 km^2 (Gallaway, Martin and Dunton, 1999). This area of hard substrate was discovered in Stefansson Sound, Alaska, by marine geologists during the summers of 1971 and 1972. It lay unexplored until the summer of 1978 when joint geological and biological investigations revealed it was clearly the richest and most diverse biological community yet discovered in the Alaskan Beaufort Sea (Reimnitz and Ross, 1979; Dunton, 1979; Dunton and Schonberg, 1981; Dunton, Reimnitz and Schonberg, 1982; Toimil and England, 1982; Toimil and Dunton, 1983; Busdosh et al., 1985). The Boulder Patch kelp community is a unique feature on the northern Alaskan shelf, which is blanketed predominantly by silty sands and mud (Barnes and Reimnitz, 1974) with an infaunal assemblage dominated by polychaete worms, small mollusks and crustaceans (Feder and Schamel, 1976; Broad et al., 1978; WCC, 1979; Griffiths and Dillinger, 1981; Feder and Jewett, 1982). Although gravel makes up the substrate around the bases of the barrier islands (Beehler et al., 1979a, 1979b), the surface sediment covering most of Prudhoe Bay and adjacent coastal shelf areas is composed of 21% fine silt, 16% silt, 20% very fine sand, and 28% fine sand (Chin et al., 1979).

2.7.3.1 Arctic Kelp

The arctic kelp *Laminaria solidungula* is a predominant member of the Boulder Patch kelp bed community and serves as both food and shelter for a diverse assemblage of marine invertebrate fauna (Dunton, Martin and Mueller, 1992). The growth and productivity of *L. solidungula* is related to its underwater light environment, which varies considerably on both spatial and temporal scales. Continuous measurement of the amount of photosynthetically active radiation (PAR) reaching the plants was examined in August 1984 and continuously from August 1986 to August 1991. Maximum daytime levels of PAR showed large seasonal differences, ranging from 0 to 15 µmol photons per m^2 per sec during the ice-covered period to between 0 and 250 µmol photons per m^2 per sec during the open-water season (Dunton et al., 1992). Periods of decreased water transparency during the summer and large patches of turbid ice in winter were the major causes of low or undetectable levels of PAR. The lowest annual quantum budget for *L.*

solidungula ranges from 45 to 50 mol per m^2 per yr, which represents only about 0.2% of total surface PAR. Although *L. solidungula* possesses a very low light requirement for net photosynthetic carbon production, data indicate that this species is living at its physiological limits in the Beaufort Sea Boulder Patch.

Polar marine plants have a variety of adaptive responses that help compensate for lower irradiances at high latitudes. For example, the endemic arctic kelp *Laminaria solidungula* completes over 90% of its annual linear growth during the dark 9-month ice-covered winter period (Dunton and Schell, 1986). Kelp use carbon reserves accumulated during the previous summer when waters are predominantly free of ice and light is available (Chapman and Lindley, 1980; Hooper, 1984; Dunton, 1985; Henley and Dunton, 1995; Dunton and Schell, 1986). Photosynthetic production during the open-water period is usually sufficient to compensate for respiratory demands and allow accumulation of carbon storage compounds. Suspended sediments decrease water transparency and may significantly reduce annual kelp productivity (Dunton, 1990; Best et al., 2001).

Growth and production of the endemic arctic kelp *Laminaria solidungula* is regulated primarily by PAR during the open-water period. Variation of underwater PAR caused by changes in water transparency can have significant effects on the annual productivity of this species (Dunton, 1990). *L. solidungula* has been found to thrive at low light levels and is thus well adapted to the Arctic. It has the lowest irradiance saturation level (38 µmol per m^2 per sec) of any member of its genus and is photoinhibited at irradiance levels of 123 µmol per m^2 per sec (Dunton and Jodwalis, 1988). Its compensation level (2.1 µmol per m^2 per sec) is well below the levels of 5 to 9 µmol per m^2 per sec for other congeneric species (Dunton and Schonberg, 1990). *L. solidungula* benefits from light increases up to 38 µmol per m^2 per sec, but no beneficial effect occurs above this level. However, the plants benefit fully from any increases in light received during the winter-spring period because ambient light levels are usually well below the saturation level (Dunton and Jodwalis, 1988).

In low-light environments, plant production is more a function of exposure to saturating levels of PAR than to the total amount of photons received over the course of a growing season. In 1988, annual quantum budgets for *L. solidungula* varied from 45 to 50 mol per m^2 per sec, near the annual minimum light requirement reported in other studies for the lower limit of *Laminaria* spp. However, the time the plants were exposed to saturating levels of PAR in 1988 was considerably less than in other years. This was correlated with significant reductions in thallus tissue density and carbon content during the summer open-water period in 1988. Percentage of dry to wet weight (tissue density) dropped from about 16 to 10%, and carbon content, from 35 to 28%. The drop in both indices indicated that 1988 summer open-water PAR was insufficient for maintaining maximum photosynthetic carbon fixation. The decreased storage of carbohydrate reserves, which are used for tissue expansion during the dark ice-covered period, resulted in significantly reduced linear growth in all plants the following year (1989). Under saturating irradiances, young and adult plants exhibited similar rates of carbon fixation on an area basis, but under light limitation, fixation rates were highest in adult plants for all tissues. Continuous measurement of in-situ quantum irradiance made in summer showed the maximum PAR can be less than 12 µmol per m^2 per sec for several days when high wind velocities increase water turbulence and decrease water transparency (Dunton and Jodwalis, 1988).

Continuous measurements of photon flux fluence rate (PFFR) made during the ice-covered spring months, when the sun's duration above the horizon is increasing toward 24 hours a day, reveals a transmittance ranging between 0.001 to 0.6% of surface PFFR. This is well below the lower light limit of kelp growth (0.5 to 1.0%) suggested by Lüning and Dring (1979), Lüning (1981) and Hiscock (1986), and corresponds to an average maximum of about 1 µmol per m^2 per sec, which is nearly seven times lower than reported for the same period by Chapman and Lindley (1980) in the Canadian High Arctic. The great variation in PFFR beneath the ice canopy among years and among sites is directly related to density of sediment inclusions within the ice, supporting the diving observations noted by Dunton, Reimnitz, and Schonberg (1982), Dunton (1984), and Reimnitz and Kempema (1987) on the large-scale heterogeneity of turbid ice in Stefansson Sound. The absence of any consistent pattern of under-ice PAR among years and between sites in Stefansson Sound reflects the random occurrence of this phenomenon on both temporal and spatial scales, one that has broad implications with respect to the productivity in *Laminaria solidungula* (Dunton and Schell, 1986).

There are few quantitative estimates of kelp biomass in the Boulder Patch. In areas of >25% rock cover, Dunton, Reimnitz and Schonberg (1982) recorded a biomass of 262 g per m^2 compared to 67 g per m^2 in areas of 10 to 25% rock cover. Accurate estimates of kelp biomass are critical, since these values are used in models to predict changes in areal net production in response to changes in water column transparency. Measurements of annual production in arctic kelp based on in situ measurements of blade production are 6 to 10 g per m^2 yr carbon (Dunton and Schell, 1986). Linear kelp growth from 1997 through 2004 was measured at seven sites within the Boulder Patch (Aumack, 2003; Dunton, unpublished data). These growth data are comparable to previous studies (Dunton, 1990; Martin and Gallaway, 1994). Annual *Laminaria solidungula* elongation displayed spatial and temporal variability (Figure 2.7-3). The substantial decrease at all sites except DS-11 in kelp blade elongation in 2000 reflects reduced water transparency during summer 1999, especially near the shoreline. High light attenuation from elevated TSS levels was most likely the result of a series of major storm events that occurred in August and October 1999 (Weingartner and Okkonen, 2001). Consistently high blade elongation rates recorded in *L. solidungula* plants collected from DS-11 reflect both the offshore location of this site relative to other sites and its higher percentage of rock cover (Martin and Gallaway, 1994). Linear growth over 8 years at the seven sites ranged from 16 cm (nearshore site L-2) to 28 cm (offshore site DS-11), with an overall mean of 20 cm. The summers of 2001 and 2002 were the highest light years as reflected in the greatest blade elongation during the following winter (an average of 33 and 28 cm, respectively). An extremely low amount of growth was measured following the stormy summer of 2003 (mean elongation, 6 cm) (Dunton, unpublished data).

The contribution by kelp to overall coastal productivity is therefore considerable and can account to 50 to 75% of the total productivity of the system (Dunton, Reimnitz and Schonberg, 1982). This energy is passed on to other trophic levels either directly through herbivory or indirectly through bacterial transformation of particulate detritus. Direct evidence for the incorporation of kelp carbon into nearshore arctic is documented by Dunton and Schell (1986, 1987). Distinct seasonal changes in the stable carbon isotope ($\delta\ ^{13}C$) values of several animals indicated a diet shift to an increased dependence on kelp carbon during the dark winter period when phytoplankton were absent. For example, up to 50% of the body carbon of mysid crustaceans, which are key prey species for birds, fishes, and marine mammals, was composed of carbon derived from kelp detritus during the ice-covered period. The $\delta\ ^{13}C$ values of macro-algal herbivores (snails and chitons) reflected their algal food preference, while the majority of species appear to eat a combination of algae and phytoplankton. The selective suspension-feeding bryozoans and hydrozoans reflected a phytoplankton-based diet.

2.7.3.2 Boulder Patch Epifauna

The number of species, numerical abundance and total biomass of the epilithic faunal assemblage of the Boulder Patch is significantly greater than reported from any area along the Alaskan Arctic Coast and represents nearly every major marine taxonomic phylum (Dunton and Schonberg, 1979, 1980, 1981; Dunton, 1979; Dunton, Reimnitz and Schonberg, 1982; Dunton, 1984; Dunton, Martin and Gallaway, 1985; Martin and Gallaway, 1994, Gallaway and Martin, 1987; Gallaway, Martin and Dunton, 1988; LGL Ecological Research Associates, Inc. and Dunton, 1989, 1990, 1991, 1992; Martin and Gallaway, 1994; Dunton and Schonberg, 2000). Nearly all boulder and cobble surfaces are covered by algae and epilithic invertebrates. Many organisms found in the Boulder Patch are previously unreported from the Alaskan Beaufort Sea because they require hard substrate for attachment. About 158 epilithic taxa were collected with an average abundance of 18,441 organisms per m^2 and average biomass of 283 g per m^2 (Table 2.7-1). The wet-weight biomass of the epilithic community is dominated by red and brown macroscopic algae (59% of total), with invertebrates and fishes constituting about 41% of the total biomass.

The most conspicuous member of the community is the kelp *Laminaria solidungula*, although less common kelp species also occur. Beneath this kelp overstory are several species of red algae (*Phycodrys rubens*, *Phyllophora truncata*, *Neodilsea integra*, *Odonthalia dentata*, *Rhodomela confervoides* and the encrusting algae *Lithothamnium*). The predominant faunal groups by weight (Figure 2.7-2) are fishes (9%), porifera (9%), mollusks (7%), bryozoans (5%), cnidarians (4%), and polychaetes (3%) (Dunton and Schonberg, 2000). Sponges and soft corals are the most conspicuous invertebrates due to their large size, abundance, and striking shapes and colors. Two sponges (*Choanites lutkenii* and *Phakellia cribrosa*) and a pink soft coral (*Gersemia rubiformis*) are widespread throughout the Boulder Patch. The chiton *Amicula vestita* constitutes the greatest percentage of molluskan biomass and is one of the few species that grazes directly on the kelp. Clams, mussels, snails, chitons, bryozoans, hydroids, tubicolous polychaetes, sea stars, sea anemones, and sea squirts are common on the rocks or attached to other biota. Interspersed between the rocks were lyre and hermit crabs. Several species of bottom-dwelling fishes are present in the Boulder Patch that include the fourhorn sculpin, great sculpin, snailfish, prickleback, eelpout, arctic flounder. Arctic cod and motile crustaceans (mysids, amphipods, and isopods) are common is the water column adjacent to the Boulder Patch community (Dunton, Reimnitz and Schonberg, 1982).

2.7.3.3 Boulder Patch Infauna

The sediments between boulders and cobbles within the Boulder Patch support a richer infaunal community than sediments from areas outside the kelp beds in Stefansson Sound. These differences in infaunal abundance and biomass between the Boulder Patch and peripheral sediment areas reflect the contribution of algal carbon to the benthic system. Benthos from samples taken between rocks in a densely populated area (site DS-11) included 140 taxa with mean density estimates of 4,830 per m^2 and biomass estimates of 30 g per m^2 (Dunton and Schonberg, 2000). Benthos in bottom grab samples from the western fringes of the Boulder Patch exhibited abundances of 3,800 individuals m^{-2} and biomass estimates of 46 g m^{-2} (Toimil and Dunton, 1983).

Measurements of $\delta\ ^{13}C$ also demonstrated the contribution of algal carbon to the community in the Boulder Patch. Measurements of $\delta\ ^{13}C$ were used to assess the importance of kelp carbon versus phytoplankton carbon to resident fauna in the Boulder Patch (Dunton and Schell, 1987). Individuals of the same species were collected from three types of areas: center of kelp bed (site DS-11), fringe, and outside Boulder Patch. In nearly all cases, the $\delta\ ^{13}C$ values at the kelp DS-11 were 1.5% heavier than the same animals collected at the fringe or outside the kelp community — which supports the hypothesis that many organisms assimilate carbon derived from kelp. Other studies have also documented the importance of benthic macroalgae and algal epiphytes as carbon sources for consumers (Fry, 1984; Kitting, Fry and Morgan, 1984). Approximately 98% of the carbon produced annually in the Boulder Patch comes from kelp and phytoplankton. Dunton (1984) estimates that benthic microalgae contribute about 2% of the annual carbon produced in the Boulder Patch. It also demonstrates that although most kelp carbon is channeled through the detrital food web, its abundance and high nutritional value ensure its relatively efficient transfer throughout the benthic community.

2.7.3.4 Boulder Colonization

Recolonization studies of benthic boulders and cobbles addressed how quickly the benthic community would recover from disturbance. The results of recolonization studies show that development of an epilithic assemblage of organisms is a slow process in the Arctic. Fourteen 0.05-m^2 plots of rock at DS-11 were denuded with paint scrapers at 3-month intervals beginning in August 1978 and ending in May 1979. After 3 years, at least 50% of the substratum remained bare on all plots, but most were over 75% bare (Dunton, Reimnitz and Schonberg, 1982). The recolonization that occurred was by encrusting coralline algae, a foliose red alga, hydroids, and tiny tube-dwelling polychaetes. The factors influencing establishment of epilithic community on the denuded boulders in the Arctic are similar to those identified as important in the establishment and development of communities in temperate regions by Dayton (1971), Dunton (1977), and Osman (1977). They include the stability of the substratum; temporal variability in the composition and abundance of larvae and spores; biological interactions such as predation, herbivory, and competition; and the growth rates of species that settle. In the Boulder Patch, most of the colonizing organisms first appeared in the early winter months. This may be due to the lack of sediment covering the plots at that time. The sediment cover was substantial on the denuded plots during summer and fall, and if small organisms existed, they could not be seen.

Colonization of bare boulders placed at sites in the Boulder Patch in August 1984 also occurred slowly. Colonization in 1986 and 1987 was described as negligible (Martin et al., 1988), although there was early episodic colonization dominated by the polychaete *Spirorbis* sp. In 1990, 6 years after deployment, a boulder placed at site DS-11 had five colonizing species. Two taxa that were evident in the 1989 photograph of this boulder were not seen in 1990, possibly due to heavy siltation of the rock. Finally, a more recent recolonization experiment which began in summer 2002 revealed nearly identical results compared to previous studies (Brenda Konar, University of Alaska, Fairbanks, pers. comm.). It is likely that the naturally occurring periodic inundation by sediment in the Boulder Patch adversely affects the process of recolonization by effectively blocking larvae or spores from reaching the rock surface, or by smothering epilithic biota with a stature less than 1 or 2 mm (Dunton, Reimnitz and Schonberg, 1982). The availability of primary substratum for recolonization is thus substantially limited during periods of sedimentation.

2.7.3.5 Sedimentation

Although the Sagavanirktok River delta discharges about 6 mi southwest of the Boulder Patch, the boulders do not appear to have been buried over time by riverine sediments. Currents are predominantly wind-driven during the open-water period, when easterly winds dominate. Therefore, the net drift is westward during the summer, moving riverine sediments away from the Boulder Patch (Barnes, Reimnitz and McDowell, 1977; Matthews, 1981). Peak discharge occurs in June following river breakup, but very little sediment accumulates within the sound during this period (Reimnitz and Ross, 1979). The rivers discharging into Stefansson Sound supply only sand-size and finer materials into the water column (Dunton and Schonberg, 2000). Sedimentation traps showed that silt constituted the highest percentage (58.5%) of the material collected between May and August, 1981. Clay (38.3%) and sand (3.2%) constituted the remaining fractions (Dunton, Reimnitz and Schonberg, 1982). The percentage of organic matter of the sediment was 8.4%.

In the Boulder Patch, sedimentation is potentially greatest during late summer and early fall when 1 to 5 mm of sediment accumulate on the seafloor and coat the biota (Dunton, Reimnitz and Schonberg, 1982). The changes in water transparency, particularly the very poor conditions, are predominantly products of storms and associated shifts in wind-induced currents. Benthic sediments are lifted from the Boulder Patch and resuspended during severe storms, preventing burial of the rich biological community. The sediments remain suspended for long periods and settle slowly following freeze-up in October (Dunton, Reimnitz and Schonberg, 1982). Other studies (Dunton, 1984; Dunton and Schell, 1986) have demonstrated that low winter levels of PAR are related to high sediment concentrations in the ice canopy. These sediments are almost entirely incorporated into the ice canopy during freeze-up in October (Reimnitz and Dunton, 1979; Barnes and Fox, 1982; Dunton, Reimnitz and Schonberg, 1982). Due to the inclusion of fine sediments and particulates into the ice canopy, light transmission into the water column can be completely blocked even during periods of 24-hour daylight which occur in spring. The spring bloom of ice microalgae, which is common in most arctic coastal areas (Alexander, 1974; Hsiao, 1980), does not occur under turbid ice. Turbid ice also blocks light from reaching much of the benthic macroalgal community except during open-water season. The distribution of turbid ice is widespread in the vicinity of the Boulder Patch.

Niedoroda and Colonell (1991) described sediment transport patterns in Stefansson Sound based upon sediment, oceanographic, and meteorological data from 1986. During west winds (~30% of the time), they found that sediment from the nearshore was moved eastward and offshore. Greatest deposition occurred on the upper shoreface, particularly at depths between 2 and 4 m. During east winds (~60% of the time), sediment transport was to the west. Overall, these findings suggest that the event-scale patterns of erosion and deposition in Stefansson Sound are dominantly in the cross-shore direction out to depths of 2 to 4 m. There is a substantial westward net transport of sediments as a result of the greater frequency of east winds.

Water depths in Stefansson Sound do not exceed 10 m and range from 3 to 9 m within the Boulder Patch, but this shallow benthic environment is largely protected by the offshore islands and shoals from gouging by deep-draft ice. The circulation dynamics vary seasonally and in response to the formation and disappearance of the landfast ice. The winter ice field within Stefansson Sound is landfast, with minimal movement from mid-October through June (Weingartner and Okkonen, 2001). Currents are very weak (<2 cm/sec to undetectable) from mid-October through June, the period of total ice cover (Matthews, 1981). Sedimentation decreases though the winter, with less than 1.25 mm accumulated on the seafloor between mid-November and late February. Little or no sedimentation was documented between February and May, when maximum water visibility (greater than 20 m) was observed. Freeze-up is usually complete by mid-October, with ice reaching a maximum thickness of 2 m by early May. Breakup of most landfast ice in Stefansson Sound occurs before mid-July, although it can occur as early as late June. Breakup is usually followed by a rapid increase in light levels, which remain elevated throughout most of July and August. Winds and currents are strongly correlated during the open-water season, when current speeds typically exceed 10 cm/sec (Weingartner and Okkenen, 2001).

2.7.3.6 Total Suspended Solids

Growth and productivity of kelp within the Stefansson Sound Boulder Patch community are regulated primarily by photosynthetically active radiation (PAR) availability during the summer open-water period. During the 2001-2002 summer periods, the inherent optical properties (IOPs) of Stefansson Sound waters were measured in conjunction with suspended sediment concentrations for input into a radiative transfer equation (RTE) (Aumack, 2003). Highest total suspended solid (TSS) levels were in nearshore areas during both summers and were coincident with increased light attenuations. Lower TSS concentrations and attenuations were measured offshore. Data input to the RTE provided a TSS-concentration-specific attenuation coefficient to be used in conjunction with a productivity model. Using this technique, researchers estimated daily and annual kelp productivities throughout the Boulder Patch. Results suggest that light availability during the summer open-water period is heavily influenced by suspended sediment concentrations in the water column and that higher kelp productivities occur offshore, a result of lower sediment concentrations.

PAR availability in the summer open-water period is not constant and is largely a function of water transparency, measured by the amount of total suspended solids in the local area (Henley and Dunton, 1995). TSS are particles in the water column that diminish subsurface irradiance. These particles include clay, silt, sand, decaying vegetation and animals, or any inanimate particulate matter (Kirk, 1983). TSS originates from erosion, industrial or natural discharge, run-off, dredging, and flocculations. As these suspended particulates move through the water column, they reflect and absorb sunlight, thereby reducing light availability for macroalgal photosynthesis and biomass production. Ultimately, reduced kelp production means less food and habitat for organisms dependent on the kelp forest.

TSS interpolations throughout Stefansson Sound reflect higher water turbidity characteristic of eroding coastlines. TSS measurement along the SDI and Endicott Island shorelines were often three to four times higher (23.0 to 24.2 mg/l) than those at more seaward locations. Values of TSS in the Boulder Patch ranged from 4.2 to 14.3 mg/l (mean 6.8 mg/l), and offshore areas near Narwhal Island measured 2.6 to 2.8 mg/l (Aumack, 2003). Results show a strong relationship between water column TSS and light attenuation at all measured wavelengths. High attenuation coefficients and consequent low light penetration were found near the SDI and Endicott Island. Low attenuation, or high light penetration, corresponds directly to low TSS levels in northern and eastern Stefansson Sound. Offshore waters, typically associated with lower TSS values, had higher light penetration through the water column. The majority of the Boulder Patch, including areas with dense kelp population (>25% rock cover), is found predominantly in offshore waters where attenuation measurement were consistently less than 3.6/m (Aumack, 2003).

Coastal regions receiving high river discharge or shallow waters with unconsolidated sediments often have high b:a ratios (>30), a direct result of increased TSS. Absorption (a) occurs when photons are absorbed throughout the water column by colored dissolved organic matter (CDOM), biological organisms, suspended sediment, and the water itself (Kirk, 1983; Van Duin et al., 2001). Scattering (b) does not remove any photons but increases the effective path length traveled by a photon, thereby increasing the probability of the photon being absorbed (Kirk, 1983; Van Duin et al., 2001). High ratios of scattering coefficient to absorption coefficient (b:a) are typically associated with areas of increased turbidity (Kirk, 1994). Coastal regions receiving high river discharge or shallow waters with unconsolidated sediments often have high b:a ratios (>30), a direct result of increased TSS, which is typically correlated with photon scattering rather than absorption (Kirk, 1994). Connections between PAR, TSS, and kelp production have been quantified using a production model which is based on a clear-sky irradiance model designed by Gregg and Carder (1990). An RTE and concentrations-specific attenuation coefficients were inserted into the model using data collected in 2001 and 2002. The RTE, *Laminaria solidungula* production vs. irradiance calculations, and annual/hourly TSS and irradiance insertions combined the work of several different parties and can be made available (Dunton, pers. comm.). However, the accuracy of the model requires application of real in-situ (terrestrial and underwater) light data and better estimates of kelp biomass under different concentrations of rock cover.

Spatial and temporal TSS variations alter the number of hours kelp are exposed to levels of saturating irradiance (H_{sat}). The number of hours saturating irradiance has been reached for *Laminaria solidungula* in the Boulder Patch has ranged from as low as 39 hours to as high as 171 hours in a single summer (Dunton, 1990). The highest TSS levels (23.0 to 24.2 mg/l) occurred in nearshore areas during summer 2001 and were coincident with increased light attenuation (11.4 to 14.0/m) (Aumack, 2003). Results clearly demonstrate that suspended sediment concentrations have varying but substantial effects on light availability and subsequent kelp production during the summer open-water period. Increasing average TSS concentrations from 1 to 10 mg/l within ranges measured in situ decreased annual production by an order of magnitude.

2.8 FISH

A total of 28 species of fish have been identified in the freshwater and coastal marine habitats of the central Alaskan Beaufort Sea (Table 2.8-1). Detailed biological and ecological background descriptions of these species are provided in USDOI, MMS (2002) and USDOI, BLM (2005). USDOI, MMS (2002) describes Beaufort Sea fish as either freshwater, marine, or migratory.

- **Migratory Fishes:** Migratory fishes can be further segregated into anadromous and amphidromous species. Anadromous fishes are hatched and initially reared in freshwater river systems before migrating to sea where they spend most of their lives before returning to their natal streams as adults to spawn (Myers, 1949; Craig, 1989). Arctic cisco are considered anadromous because, although they overwinter in major river systems, non-spawners are believed to remain in brackish water deltas and do not move far upriver into strictly freshwater habitats (Morrow, 1980). Amphidromous fishes cycle annually between freshwater and coastal marine environments (Myers, 1949; Craig, 1989). They spawn and overwinter in rivers and streams but migrate out into coastal waters for several months each summer to feed. The utility of amphidromy is that it allows fish to take advantage of the more plentiful food resources present in arctic coastal waters during summer.

- **Freshwater Fishes:** Freshwater species largely remain within river, stream, and lake systems year round, although they may venture out during summer into coastal areas where waters are brackish.
- **Marine Fishes:** Marine fishes spend their entire lives at sea, although some species may migrate into nearshore coastal waters during summer.

The following descriptions of key fish species found in the proposed development area are extensions of descriptions found in USDOI, MMS (2002).

2.8.1 Freshwater Fishes

Freshwater species may be found in coastal waters during summer in areas of low salinity but typically occur in low numbers (Fechhelm et al., 2005). Greater concentrations of fish would be found in rivers and streams proximal to the development area; however, most species are dispersed widely across the drainage systems of the North Slope. That proportion of any freshwater population falling within the Liberty Project area would constitute a minor fraction of the overall stock.

2.8.2 Marine Fishes

Of the marine species that occupy nearshore Beaufort Sea waters during summer, most occur sporadically and typically in very low numbers (Fechhelm et al., 2005). The exceptions are arctic cod, arctic flounder, and fourhorn sculpin. Fourhorn sculpin and arctic flounder are demersal species that have circumpolar nearshore distributions in brackish and moderately saline nearshore waters (Scott and Crossman, 1973; Morrow 1980). Neither species is found far offshore (Morrow, 1980). Both species migrate into brackish coastal habitats during summer to feed, and may travel considerable distances up rivers. Fourhorn sculpin have been reported as far as 144 km upstream in the Meade River (Morrow 1980). A background synopsis of arctic cod may be found in USDOI, MMS (2002).

2.8.3 Migratory Fishes

2.8.3.1 Anadromous Fishes

The most abundant anadromous species found in the Liberty Project area is the arctic cisco. Despite anecdotal accounts that there may be small spawning runs of arctic cisco in Alaska (USDOI, MMS, 2002), none have been documented. Beaufort Sea arctic cisco are believed to originate from spawning grounds in the Mackenzie River system of Canada (Gallaway et al., 1983). Newly hatched fish are transported westward by wind-driven coastal currents and take up residence in the Sagavanirktok and Colville rivers (Fechhelm et al., 2005). Beginning at about age 5, fish enter the Colville River subsistence fishery (Moulton and Seavey, 2004). Arctic cisco remain associated with the Colville River until the onset of sexual maturity beginning at about age 7, at which time they are believed to migrate back to the Mackenzie River to spawn (Gallaway et al., 1983). The coastal dispersal corridor for young arctic cisco initially moving from Canada to the Sagavanirktok and Colville rivers passes through the Liberty Project area. Adults migrating back to the Mackenzie River to spawn likewise would pass through the area.

Arctic cisco appear to be truly anadromous in that, except for spawning, they may spend most of their life in brackish to marine waters, including during the winter (Scott and Crossman, 1973; Morrow, 1980). In Alaska, adult arctic cisco overwinter in the lower reaches of the Colville River where salinities are brackish (Moulton and Seavey, 2004). During summer they migrate along the coast to feed and are one of the most abundant species found in the coastal waters of Prudhoe Bay and vicinity (Fechhelm et al., 2005). The Liberty Project area lies well within the coastal foraging range of the Alaskan arctic cisco population.

2.8.3.2 Amphidromous Species

The Sagavanirktok River is believed to support one of the larger Dolly Varden populations in Arctic Alaska (Yoshihara, 1972). Amphidromous Dolly Varden also spawn in many of the "mountain streams" between the Sagavanirktok and Mackenzie rivers (Craig, 1989). Amphidromous Dolly Varden migrate considerable distances along the coast during the summer, and the extensive alongshore and open-water migrations reported for this species suggest they may be more tolerant of marine conditions than other arctic amphidromous species. Dolly Varden have been taken as far as 15 km offshore in the Alaskan Beaufort Sea (Thorsteinson, Jarvala, and Hale, 1990), and dietary evidence has led to speculation that Dolly Varden feed offshore among ice floes in mid- and late summer (Fechhelm, 1999). The Sagavanirktok population is characterized by a large out migration soon after breakup and a return migration in late August and September (Fechhelm et al., 2005). The Sagavanirktok River delta is, therefore, the principal migratory pathway for this stock to and from foraging and overwintering grounds.

Amphidromous least cisco in the Alaskan Beaufort Sea occur in "tundra" rivers that lie west of and including the Colville River (Craig, 1989). There are no known spawning populations associated with the Sagavanirktok River or with the "mountain" rivers that lie along the 600 km of coastline between the Mackenzie and Colville rivers (Craig, 1984). Least cisco are one of the principal species targeted in the fall Colville River subsistence fishery (Moulton and Seavey, 2004). Amphidromous least cisco from the Colville River disperse long distances along the coast during summer and are one of the most abundant species found in the Prudhoe Bay area (Fechhelm et al., 2005). Adults can disperse as far east as Brownlow Point (Griffiths et al., 2002). The Liberty Project area is well within the summer feeding dispersal range of this species.

The Sagavanirktok River harbors a disjunct spawning population of broad whitefish (Gallaway et al., 1997; Patton et al., 1997). Juveniles appear to be intolerant of high salinities and typically remain in close proximity to the Sagavanirktok River delta (Fechhelm et al., 1992). Adults undergo more extensive coastal migrations (Morris, 2000) and during summer may disperse as far east as Brownlow Point (Griffiths et al., 2002). Because of the restricted range of juvenile fish, the Sagavanirktok Delta can be considered the primary nursery area for the stock. For adult fish, the Liberty Project area lies well within their summer foraging range.

Humpback whitefish spawn and overwinter in the Colville River but not in the Sagavanirktok River (Fechhelm, 1999). Like broad whitefish, humpback whitefish are intolerant of high salinity conditions and remain in brackish nearshore waters and river deltas during summer. Prior to the 1996 installation of a 200-ft breach in the West Dock Causeway, few humpback whitefish were caught in coastal waters east of the structure. Since its installation, adult humpback whitefish are much more abundant in the Sagavanirktok Delta and probably range short distances east of the delta's eastern edge (Fechhelm et al., 2005). Small humpback whitefish are rare in Prudhoe Bay, suggesting that the Liberty Project area is well outside their Colville River foraging range.

2.8.4 Essential Fish Habitat

A background discussion of the Magnuson-Stevens Fishery Conservation and Management Act of 1996 (MSA) and Essential Fish Habitat (EFH) is provided in USDOI, MMS (2002) and USDOI, BLM (2005). Pursuant to NOAA, NMFS (2005), the *Preliminary Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska*, it is the current position of NMFS that pink salmon and chum salmon are the only two species of fish found in the Beaufort Sea that are amenable to EFH regulation and consideration (Jon Kurland, Director, NMFS Habitat Conservation Division, Juneau, pers. comm.; Lawrence Peltz, NMFS Habitat Conservation Division, Anchorage, pers. comm.). This is also the position of MMS (Jeff Childs, pers. comm.). Presently, there appear to be small spawning runs of both species in the Colville River and possible some Beaufort Sea rivers to the west, and along the Chukchi Sea. There is no evidence of spawning stocks associated with the Sagavanirktok River or any Alaskan watershed to the east.

Pacific salmon fisheries in the Alaska are managed under a combination of domestic and international regulations and treaties (NOAA, NMFS, 2004). Salmon fisheries are managed by ADF&G within State waters, where most of Alaska's commercial fishing occurs. Commercial fishing within the Exclusive Economic Zone (EEZ) is limited to Southeast Alaska, and Federal management there is deferred to ADF&G. Harvests of chinook, coho, and sockeye salmon in Southeast Alaska are managed by agreement with Canada under the Pacific Salmon Treaty. Management of salmon fisheries in international waters of the North Pacific is under the auspices of the North Pacific Anadromous Fish Commission, which consists of four countries (Canada, Japan, Russia, and the U.S.). Federal management of salmon stocks is largely directed by fishery management plans designed to limit the bycatch of salmon in non-salmon directed fisheries within the North Pacific EEZ (NOAA, NMFS 2004).

By definition, the coastal waters in and around the Liberty Project area should not be classified as EFH for chum and pink salmon despite their marginal presence in the Alaskan Beaufort Sea. EFH pertains to habitat "required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem" (50 CFR Part 600). There are no federally-managed commercial salmon fisheries in the Beaufort or Chukchi seas, and it is highly doubtful that the low numbers of pink and chum salmon that regularly migrate from the Beaufort Sea to the Bering Sea constitute a meaningful component of the commercial fisheries there. There are also no federally-managed fisheries for other species within the Beaufort and Chukchi seas, thereby rendering moot the bycatch fishery management plan issue. Again, it is highly unlikely that Beaufort Sea pink and chum salmon comprise a meaningful portion of bycatch within the North Pacific EEZ.

The MSA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" [MSA §3(10)]. Current theory holds that, upon emergence into coastal waters, the small numbers of salmon that are spawned in the Colville River and rivers west migrate to the warmer waters of the Bering Sea and do not return to the Beaufort Sea until time of spawning (Craig and Haldorson, 1986). No juvenile salmon have ever been observed the Prudhoe Bay area in over 26 years of study (Fechhelm, Buck, and Link, 2006). The few adults that have been caught in the Liberty Project area occur in late summer and are likely stray adult spawners returning to the Colville River. They have already grown to sexual maturity and are no longer feeding. Thus, there is no evidence that the waters in the vicinity of the proposed Liberty Project are used by salmon for any of the ecological requirements defined in the MSA.

Based upon available data, EFH for the Liberty area would include all waters of the Colville River and Delta, likely the eastern end of Simpson Lagoon around Oliktok Point, and all of the coastline stretching from the Colville River west to the Bering Sea and into the North Pacific Ocean.

In recent years, concern has been expressed that global warming could allow southern stocks of Pacific salmon from the Bering Sea to expand northward into arctic waters where they might establish spawning populations (Babaluk et al., 2000; Stephenson, 2006). Such an expansion would depend upon a number of physical and biological factors the relevance and importance of which are highly problematic and speculative. Even if such a future expansion does take place, it is more than likely to occur beyond or toward the end of the production life of the Liberty Project.

2.9 MARINE MAMMALS

The Liberty FEIS (USDOI, MMS, 2002) and BPXA (1998) describe seals and polar bears in the proposed Liberty area, and these descriptions are summarized and incorporated herein by reference. The Liberty Project could affect ringed and bearded seals and polar bears, which are common in the area. Other species that are uncommon or rare in the project area include beluga whales and walruses. Bowhead whales and polar bears are addressed under endangered species (Section 2.13).

2.9.1 Ringed Seals

Widely distributed throughout the Arctic, ringed seal is the most abundant seal species in the Beaufort Sea. Aerial surveys have been conduced in May and June as ringed seals become visible when they haul out on sea ice. Satellite-linked time-depth recorders have been used to evaluate the time spent basking on sea ice. Bengtson et al. (2005) reported that ringed seal density in the eastern Chukchi Sea ranged from 1.62 to 1.91 seals/km^2 based on surveys conducted in 1999 and 2000. These density estimates were made using a correction factor to allow for seals that were not hauled out and thus not visible during the surveys. Ringed seal density was greater in nearshore fast and pack ice than in offshore pack ice. Frost et al. (2004) reported ringed seal densities ranging from 0.81 to 1.17 seals/km^2 in the Beaufort Sea during surveys conducted from 1996 to 1999. Moulton et al. (2005) reported slightly lower ringed seals densities ranging from 0.39 to 0.83 seals/km^2 in the central Beaufort Sea during surveys near the Northstar project form 1997 to 2001. Ringed seal densities during aerial surveys can be affected by a number of factors including water depth, location of ice edges, time of day, weather conditions (i.e., cloud cover, temperature, wind conditions), and survey date (Frost et al., 2004; Kelly et al., 2005). Seal densities reflect changes in the ecosystem's overall productivity in different areas (Stirling and Oritsland, 1995). There is some evidence from recent surveys that ringed seal numbers in the central Beaufort Sea may be reduced compared to those reported in the early 1980s (Moulton et al., 2002). Moulton et al. (2002) suggested that ringed seals in the central Beaufort Sea may prefer areas with intermediate water depth around 10 to 20 m and that few seals occur in areas with water depths <3 m.

Ringed seals probably are a polygamous species. When sexually mature, they establish territories during the fall and maintain them during the pupping season. Pups are born in late

March and April in lairs that seals excavate in snowdrifts and pressure ridges. During the breeding and pupping season, adults on shorefast ice (floating fast-ice zone) usually move less than individuals in other habitats; they depend on a relatively small number of holes and cracks in the ice for breathing and foraging. During nursing (4-6 weeks), pups usually stay in the birth lair. This species is a major resource that subsistence hunters harvest in Alaska.

2.9.2 Bearded Seals

Bearded seals are found throughout the Arctic and usually prefer areas of less stable or broken sea ice, where breakup occurs early (Cleator and Stirling, 1990). Early estimates of the Bering-Chukchi Sea bearded seal population range from 250,000 to 300,000 animals (Popov, 1976 and Burns, 1981 in Angliss and Outlaw, 2005). During aerial surveys in the eastern Chukchi Sea in 1999 and 2000, Bengtson et al. (2005) reported bearded seals density estimates ranging from 0.07 to 0.14 seals/km^2. These estimates were not corrected for seals that were undetectable during the surveys, and it was not possible to calculate a population estimate for the Bering-Chukchi Sea population. Estimates on the abundance of bearded seals in the Beaufort Sea and in Alaskan waters currently are unavailable, although bearded seals are reported annually during aerial surveys for other marine mammals (Treacy 2002a, b). Consequently, there is no current reliable population estimate for the Alaskan bearded-seal stock. Bearded seals stay on moving ice habitat in the Beaufort Sea. Their densities in the western Beaufort Sea and in the Liberty area are highest during summer and lowest during winter. Their most important habitat in winter and spring is active ice or offshore leads.

Pupping takes place on top of the ice from late March through May mainly in the Bering and Chukchi seas, although some pupping takes place in the Beaufort Sea. Bearded seals do not form herds but sometimes form loose groups. Bearded seals are a secondary subsistence food for Barrow residents and provide a relatively low percentage of the total subsistence diet (Braund, 1993).

2.9.3 Walruses

The North Pacific walrus population was estimated at about 201,000 animals in 1990 (Gilbert et al., 1992), comprising about 80% of the world population. In general, most of this population is associated with the moving pack ice year-round. Walruses spend the winter in the Bering Sea; the majority of the population summers within certain areas of the Chukchi Sea, including the westernmost part of the Beaufort Sea. Although a few walruses may move east throughout the Alaskan portion of the Beaufort Sea to Canadian waters during the open-water season, the majority of the Pacific population occurs west of 155° W. longitude north and west of Barrow, with the highest seasonal abundance along the pack-ice front.

Nearly all the adult females with dependent young migrate into the Chukchi Sea during the summer, while a substantial number of adult males remain in the Bering Sea. Spring migration usually begins in April, and most of the walruses move north through the Bering Strait by late June. Females with calves comprise most of the early spring migrants. During the summer, two large arctic areas are occupied — from the Bering Strait west to Wrangell Island and along the northwest coast of Alaska from about Point Hope to north of Point Barrow. With the southern advance of the pack ice in the Chukchi Sea during the fall (October-December), most of the walrus population migrates south of the Bering Strait. Solitary animals occasionally may overwinter in the Chukchi Sea and in the eastern Beaufort Sea. Walruses are uncommon in the Liberty Project area.

2.9.4 Beluga Whales

The beluga whale, a subarctic and arctic species, is a summer seasonal visitor throughout offshore habitats of the Alaskan Beaufort Sea. Based on a correction factor of 2 to account for bias related to animals that may be underwater and unavailable to count during surveys, the most recent estimate for the Beaufort Sea beluga stock is 39,258 animals (Angliss and Outlaw, 2005). Most of this population migrates from the Bering Sea into the Beaufort Sea in April or May; however, some whales may pass Point Barrow as early as late March and as late as July. The spring-migration routes through ice leads are similar to those of the bowhead whale. A major portion of the Beaufort Sea population concentrates in the Mackenzie River estuary during July and August. The eastern Chukchi Sea beluga stock currently is estimated to be at a minimum of about 3,710 whales (Angliss and Lodge, 2004). In the Arctic, belugas feed primarily on arctic and saffron cod, whitefish, char, and benthic invertebrates (Hazard, 1988).

Fall migration through the western Beaufort Sea occurs in September or October. Although small numbers of whales have been observed migrating along the coast, surveys of fall distribution strongly indicate that most belugas migrate offshore along the pack-ice front (Frost, Lowry, and Burns, 1988; Treacy, 1988-1998. Beluga whales are an important subsistence resource of Inuit Natives in Canada and also are important locally to Iñupiat Natives in Alaska. The mean annual harvest of beluga whales by Alaska Natives in the Beaufort Sea was 53 whales between 1999 and 2003 (Angliss and Outlaw, 2005 and references therein). The mean annual take of Beaufort Sea beluga whales in Canadian waters was 99 whales during the same time period. The Beaufort Sea beluga-whale stock is not considered to be “depleted” under the Marine Mammal Protection Act, or “threatened” or “endangered” under the Endangered Species Act.

2.9.5 Underwater Acoustics

Measurements of underwater ambient noise and sound transmission loss were made at the Liberty prospect during summer 1997 (Greene, 1998), and winter measurements were made during exploratory drilling at Liberty in winter 1997 (Greene, 1997). (Note that sounds were recorded at the proposed Liberty Island location and the currently proposed Liberty SDI location.) The results are summarized here. Comparisons are presented with similar measurements made near the Northstar prospect in 1996-1997 and at the Seal Island (Davis et al., 1985) and Sandpiper (Johnson et al., 1986) prospects in the 1980s.

2.9.5.1 Ambient Noise

Ambient noise was measured in 30-second segments every 15 minutes from August 1 to September 13, 1997 at two seafloor recorders 570 m apart. Ambient noise varied with average hourly wind speed measured from a barge that was usually located within 55 km (30 n. mi.) of Liberty. The correlation coefficients between the wind speed and the broadband (20 to 5000 Hz) ambient noise level were $r = 0.831$ based on the northwest recorder and $r = 0.746$ for the southeast recorder. For wind speeds of 0, 10, 20 and 30 kt, typical overall ambient noise levels in the 20 to 5000 Hz band were 85, 94, 104 and 114 dB re 1 μPa, respectively. The overall median levels approximated the levels expected for Sea States 0 to 2, based on the standard Knudsen fiducials extended to low frequency. The 5th percentile levels were below those expected for Sea

State 0 at all frequencies below 3150 Hz, and the 95th percentile levels varied between those expected for Sea States 2 and 6. For the data from both recorders taken together, the median 20 to 5000 Hz band level for the 44 days was 97 dB re 1 µPa, or 9 dB above the corresponding level for Knudsen's Sea State 0. The 5th and 95th percentile levels were 78 and 110 dB re 1 µPa, respectively. The levels were consistent with other ambient noise measurements made in similar locations at similar times of the year.

These summer measurements complemented winter measurements made during February 1996. The measured ambient levels in winter (Greene, 1997) were generally lower than those measured in summer.

To study the short-term variability of the ambient noise in relation to longer term averages, 10 segments were selected from the seafloor recorder data. These segments were selected from times of low, high, and moderate noise levels. In 9 of the 10 cases, the 0.25-second averages were less than the 30-second average for over half the time. The one exception was the minimum noise case when the median 0.25-second average equaled the 30-second average. This indicates that if an animal is capable of recognizing sounds during short periods (on the order of 1/4-second in duration), it probably could hear a sound that is slightly weaker than the average (long-term) noise level. It could do so during periods when the ambient noise level is lower than average. This result is consistent with similar observations made northeast of Pt. Barrow during May (Greene et al., unpubl.).

The frequency distribution of ambient noise was studied by observing the distribution of 1/3-octave band levels. When the ambient noise is predominantly attributable to wind and waves, the 1/3-octave band levels decrease at about 2 dB/octave with increasing frequency. However, the results from the Liberty seafloor recorders showed median levels decreasing with increasing frequency from 20 to 50 Hz but increasing with frequency from 50 to 1000 Hz. It is likely that sources other than wind and waves (such as distant vessels) contributed to the general ambient noise at Liberty.

2.9.5.2 Sound Transmissions

Acoustic transmission loss was measured on July 31, 1997, using as sources a four-element sleeve gun array and a minisparker. Both were tethered to a tug anchored at Liberty. Received sounds were recorded quantitatively at distances up to 8.1 km southeast and 10.1 km north of Liberty. Acoustic transmission loss was determined from those recordings.

For both sources, the broadband spreading losses were close to spherical, i.e., -20 log (R), over distances to 350 m. At greater ranges, the sounds from the array of sleeve guns diminished generally according to -25 log (R) while the minisparker sound diminished at approximately -10 log (R), corresponding to cylindrical spreading. This difference is attributed to the sleeve-gun array being a relatively low frequency source (63 to 800 Hz) compared to the minisparker (315 to 3150 Hz). Besides these logarithmic spreading losses, there was an additional linear loss of about -0.0020 dB/m for the sleeve gun array and -0.0033 dB/m for the minisparker. The higher linear loss rate for the minisparker corresponds to higher absorption and scattering losses at higher frequencies.

Propagation loss rates varied with frequency. There were some consistent trends in the relationships between frequency and loss rates; however, there were also some patterns that were not explained by a simple physical model.

The results of this study can be used to predict the received levels vs. distance of sounds from industrial sound sources that will operate at Liberty during construction and operation of oil production facilities. Those received levels can be compared to the expected range of ambient noise levels, thereby determining distances beyond which the industrial sounds will probably be masked.

2.9.5.3 Comparisons with Related Ambient Noise

There have been numerous other measurements of ambient noise in different parts of the Beaufort Sea during various times of year. Simultaneously with the 1997 Liberty prospect study, a 6-day series of measurements was obtained offshore of the barrier islands 60 km northwest of Liberty in water 25 m deep (Greene et al., 1998), offshore from Northstar. The 5th percentile and 95th percentile levels were generally higher offshore from Northstar. At frequencies below 125 Hz, median levels offshore were generally lower than those at Liberty. Conversely, above 125 Hz, the offshore medians tended to be higher than those at Liberty. The shallower water at Liberty (6.4 vs. 25 m) is important in limiting low frequencies and therefore resulting in less ambient sound at low frequencies.

The median levels at Liberty were between the idealized spectra for Sea States 0 and 2, while the Northstar medians at frequencies <100 Hz were below those expected for Sea State 0 — very quiet.

Ambient noise in the Northstar area (25 km northwest of Prudhoe Bay) in a water depth of 12 m was also studied in fall 1984. Ambient noise was received by three hydrophones on the bottom near Seal Island, at the site that became Northstar (Davis et al., 1985). The median and 95th percentile levels from Seal Island show that the ambient noise was high-pass filtered at about 60 Hz by the shallow water channel. Components of ambient noise below about 63 Hz were weak. At a water depth of 12 m, 60 Hz is the frequency for which the water depth is equal to one-half wavelength. At higher frequencies, the negative slope of the spectrum levels with increasing frequency parallels the nominal sea-state spectra. The medians are at levels corresponding to about Sea State 1.

Ambient noise was also studied offshore of the barrier islands during 8 days in fall 1985. Ambient noise was recorded via a single bottom hydrophone 450 m from Sandpiper Island (Johnson et al., 1986) at a water depth of 15 m. Sandpiper Island is about 16 km from Northstar and 66 km northwest of Liberty. During the recording period, no storms with winds about 20 knots occurred at Sandpiper, but the 5th percentile levels were notably higher than those in the shallower water at Liberty. A drill rig on Sandpiper was in cold standby — a generator was running for camp power.

Ambient noise was also studied northeast of Pt. Barrow in May during 4 years: 1989-91 and 1994. Sounds were recorded from sonobuoys and from hydrophones deployed over the edges of ice floes (Greene et al., unpublished). Ice cover varied from 75 to 100%. The median levels measured at the Pt. Barrow and Liberty sites tend to agree across a range of frequencies despite the wide variety of water depths and the high percentage of ice cover northeast of Pt. Barrow in spring compared to the shallow open water at Liberty.

In comparison with the other data, the natural background noise at the Liberty site was relatively low in winter and high in summer.

2.10 MARINE AND COASTAL BIRDS

About 70 species of birds may occur in the Liberty area (USDOI, MMS, 2002). Nearly all species are migratory, inhabiting Arctic Slope or Beaufort Sea habitats from May to September. Major groups that are common to abundant in this area during all or part of this period include:

- Loons and Waterfowl
- Shorebirds
- Seabirds
- Raptors and Owls
- Passerines

Those bird species that are abundant and occur regularly in the Liberty area are listed in Table 2.10-1. Among the birds in the Liberty area, shorebirds and passerines are numerically dominant followed by waterfowl (Table 2.10-2). Birds that use nearshore coastal waters (20-meter depths or less) include loons, waterfowl and seabirds (Fischer and Larned, 2004; Johnson et al. 2005). Birds that may overwinter in the onshore development area include raptors, owls, ptarmigan and the passerine the common raven. River deltas, tundra habitats and coastal lakes and ponds are used by all bird species during summer.

2.10.1 Annual Cycle

2.10.1.1 Spring Migration

Waterfowl migrate eastward across northern Alaska along a broad front over land and sea during mid-May to mid-June. Exposed habitats, mainly in river deltas, attract some birds early during migration. The availability of open water leads offshore (mainly within 10 km of barrier islands) largely determines seaduck migration routes and timing. Between 250,000 and 1,000,000 long-tailed ducks nesting in western arctic North America migrate through the Beaufort Sea region each spring (Dickson and Gilchrist, 2002; Robertson and Savard, 2002), along with king eiders, common eiders and many other Arctic nesting species. Loons and eiders gather in spring runoff water in river deltas during late May and early June until local nesting areas are free of snow, and gather in river channels near nesting habitat until open water develops around the margin of lakes and ponds used for nesting. Most shorebirds are first noted dispersed across tundra breeding areas as soon as snow-free areas appear. Gulls and some ducks may arrive during late April in the Point Brower area of the Sagavanirktok River delta (USDOI, MMS, 2002). Migratory raptors and owls generally depart wintering areas in March to early April and arrive on the Arctic Coastal Plain in late April to early May. Many migrants follow offshore lead systems and would not cross the coastal area where the Liberty development will be located. Migrant Lapland longspur and snow buntings arrive as snow-free areas become available, probably during May in most years.

2.10.1.2 Nesting and Broodrearing Periods

Lesser snow geese and brant nest on Howe and Duck islands in the Sagavanirktok River Delta and common eiders, glaucous gulls and arctic terns nest on nearshore delta islands and barrier islands in the Liberty project area (Figure 2.10-1). Loons, tundra swans, greater white-fronted geese, Canada geese, and other waterfowl nest, forage, rear their broods, and molt in wetland habitats in the river deltas and across the onshore portion of the proposed project Liberty area (Figure 2.10-2). Important broodrearing areas for snow geese and brant from early July to

Late August are salt marsh and coastal sedge habitats throughout Foggy Island Bay, including the eastern Sagavanirktok River Delta, Kadleroshilik River delta, and Shaviovik River delta (Noel, Johnson, and Butcher, 2004; Johnson, 2000a, Johnson 1998) (Figure 2.10-2). In the area between Prudhoe Bay and the Badami development, nest densities for several species ― including Pacific loon, Canada goose, black-bellied plover, pectoral sandpiper, dunlin, stilt sandpiper, and red phalarope — reach their highest levels in coastal habitats surrounding the lower Kadleroshilik River (TERA, 1995). Male buff-breasted sandpipers (puviaqtuuq - *Tryngites subruficollis*), an uncommon breeder on the coastal plain, have been observed occupying a lek on an island in the lower Kadleroshilik River (USDOI MMS, 2002).

2.10.1.3 Post-Nesting Period

From mid-July to early September, long-tailed ducks (and lesser numbers of eiders and scoters) aggregate in coastal lagoons to feed and molt before migrating westward in the fall (Figure 2.10-3). Simpson Lagoon and Leffingwell Lagoon (east of Mikkelsen Bay) are important traditional molting areas for this species, but the nearshore area around the Liberty project has not been used (Noel, Johnson and O'Doherty, 2005; Johnson et al., 2005). Many coastal plain waterfowl depart the area by the middle or end of August, but some loons and tundra swans may be found in remaining open-water areas through September, long-tailed ducks through October, and some king and common eiders remain into early November (Johnson and Herter, 1989).

Among phalaropes and some sandpipers, the nonincubating members of pairs leave nesting areas on the tundra (early July), soon after the eggs are laid, and concentrate in coastal habitats. The other parent and fledged young follow in several weeks. In mid-August, juveniles form large flocks on coastal and barrier island beaches, foraging intensively on outer beaches, lagoon shorelines, and mudflats. Shorebirds move widely on a daily basis during staging, and residency time within a staging are may range from 10 to 25 days (Powell, Taylor, and Lanctot, 2005). Most shorebirds have departed the area by mid-September. Large flocks of glaucous gulls and black-legged kittiwakes (*Rissa tridactyla*) migrating from nesting areas in the Canadian arctic also pass through the Liberty area during September. By mid to late-September most seabirds have left the Arctic Coastal Plain, although some juvenile and adult gulls may remain at landfills through November. In late August to mid-September, arctic peregrine falcons and gyrfalcons forage in coastal areas, often preying on juvenile shorebirds. Passerines tend to flock following breeding, and some migrants may remain in the Liberty area into September.

2.10.2 Habitats

2.10.2.1 Offshore Marine Waters

Eiders migrated westward through offshore waters from early July to November (Johnson and Herter, 1989). Bird densities generally are low in offshore areas, with long-tailed ducks ≤11 birds/km^2 seaward of the barrier islands east of Foggy Island Bay, and ≤3 birds/km^2 farther offshore (Fischer and Larned, 2004; Johnson et al., 2005). During aerial surveys in 1999-2001, common eiders, king eiders, and long-tailed ducks dominated in late June (Fischer and Larned, 2004) and king eiders dominated offshore. By late August, king eiders still were numerous, but long-tailed ducks also occurred in large numbers, mainly <50 km of the coast.

2.10.2.2 Nearshore Marine Waters

In the Liberty area, shallow waters in Foggy Island Bay and salt marsh habitat along the Sagavanirktok, Kadleroshilik, and Shaviovik river deltas provide the most protected areas for molting, feeding and brood-rearing geese (Figure 2.10-2). Shallow lagoons provide important feeding and staging habitat, particularly for post-breeding molting long-tailed ducks, eiders, and scoters (Figure 2.10-3; Truett and Johnson, 2000). Simpson Lagoon-Gwydyr Bay in the west, and Leffingwell Lagoon in the east, support tens of thousands of post-breeding long-tailed ducks (Fischer and Larned, 2004; Johnson et al., 2005; Noel, Johnson, and O'Doherty, 2005). Pacific loons (singles or pairs) primarily use shallow water close to shore, but may occur up to 60 km from shore (Fischer and Larned, 2004). Red-throated loons have been observed more than 50 km from shore, but like yellow-billed and Pacific loons primarily use nearshore waters (Fischer and Larned, 2004). In Alaskan Beaufort Sea shallow nearshore waters, Pacific loons were most abundant from Cape Halkett to Prudhoe Bay, red-throated loons were most abundant between Oliktok Point and Brownlow Point, and yellow-billed loons were most abundant in Harrison Bay (Fischer and Larned, 2004).

2.10.2.3 Barrier Islands

These sparsely vegetated gravel islands provide nesting habitat for common eiders, glaucous gulls, and arctic terns. Barrier islands provide nesting habitat for common eiders, especially islands with accumulated driftwood and free of predators (Johnson, 2000b, Noel et al., 2005). Cross Island, Pole Island, and Lion Point (gravel spit northwest of Tigvariak Island) have been especially important islands for nesting common eiders (Figure 2.10-1; Johnson, 2000b; Noel et al., 2005). Very high densities of molting/feeding long-tailed ducks occur along the leeward (south) sides of barrier islands, particularly in the Jones-Return Island group, and the Stockton-Maguire-Flaxman island group (Figure 2.10-3). Notable numbers of molting common and king eiders also aggregate near Flaxman, Pole, and Belvedere islands (Figure 2.10-3; Fischer and Larned, 2004). High densities of staging shorebirds may use the inner shores of barrier islands (Powell, Taylor, and Lanctot, 2005). The occurrence of many species on barrier and other islands in particular has been noted by Native residents: Etta Ekolook recalled aaqhaaliq (long-tailed duck) molting in the Tigvariak Island area, mitqutailaq (arctic tern**)** nested at Tigvariak, and occasional niglingaq (brant**)** passed by; Mary Akootchook and Josephine Itta have seen many amauligruaq (common eider) and quinaluk (king eider) at Flaxman, Pole, and Belvedere islands, niglingaq (brant) near Flaxman, and aqargiq (ptarmigan, *Lagopus* sp.) and ukpik (snowy owl) on the islands; Thomas Napageak cites Pole Island as an important nesting area for eiders and other waterfowl; and Jennie Ahkivak recalls accompanying her father to Cross Island each spring to hunt ducks (USDOI, MMS, 2002).

2.10.2.4 Tundra

Shorebirds are likely to be found in any type of tundra (Troy, 2000). The most numerous shorebird species in the Liberty area prefer wet tundra habitats (sandpipers, phalaropes) or nest on or near well-drained gravelly areas (plovers). Tundra habitats available to shorebirds include dry, moist and wet tundra, flooded tundra, sparsely vegetated areas, ponds, and lakes. In general, the highest nest densities tend to occur in drier areas (moist or wet tundra) and in areas with extensive micro-relief (polygon rims, strangmoor). Seabirds such as arctic terns, Sabine's gulls and glaucous gulls nest individually or in small colonies in tundra habitats often associated with large thaw lake basins, especially those with complex lake shorelines and small islands. Short-eared owl and snowy owl nest on tundra across the Arctic Coastal Plain, but the number of the breeding birds probably reflects the abundance of their primary microtine food (lemmings) (Pitelka, Tomich, and Treichel, 1955). The northern harrier, also a ground nesting species, is a fairly common visitant on the Arctic Coastal Plain (Johnson and Herter, 1989) and may occasionally nest there (nest record on Colville River Delta; Burgess et al., 2003). Longspurs and ptarmigan tend to favor the drier types of tundra, especially in the absence of micro-relief (TERA, 1993). Following breeding, saline tundra and sparsely vegetated areas may be important (TERA, 1994).

2.10.2.5 Other Habitats

Salt marsh and sedge habitats in river deltas in the outer Sagavanirktok, Kadleroshilik, and Shaviovik deltas are heavily used by molting geese, especially snow geese and brant from the Sagavanirktok Delta, and local and molt migrant white-fronted and Canada geese (Figure 2.10-2; Noel, Johnson, and Butcher, 2004; Noel, O'Doherty, and Johnson, 2003; Johnson, 2000a). River deltas in the Liberty area (outer Sagavanirktok and Shaviovik), particularly the outer mud flats, are heavily used by shorebirds (Andres, as cited in Nickles et al., 1987); this probably also is true of the Kadleroshilik. Vegetated river bars are used by many tundra nesting species including black-bellied plover (tullikpak - *Pluvialis squatarola*), American golden plover (tullik - *Pluvialis dominica*), ruddy turnstone (tullignaq - *Arenaria interpres*), rock ptarmigan (niksaaktun - *Lagopus matus*), and Lapland longspur and was the site of a buff-breasted sandpiper lek in June 2001 (USDOI, MMS, 2002). Four buff-breasted sandpipers consistently occupied a lek area on a riverine island, where males were observed giving "wing flash" territorial displays (USDOI, MMS, 2002).

Gyrfalcons, peregrine falcons, golden eagles, and rough-legged hawks primarily nest on cliffs in the Brooks Range and Foothills regions to the south, but these species forage on the Arctic Coastal Plain during summer. Peregrine falcons and rough-legged hawks have also, however, bred near the coast using artificial substrates for nesting (Ritchie, 1991; Ritchie, Schick, and Shook, 2003). Where artificial structure has been created, some passerines have used these sites. Ravens nest on towers and buildings; (Day, 1998; Ritchie, Schick, and Shook, 2003), snow buntings nest in pipeline vertical support members and other cavities (Troy, 1992), and redpolls (saksakiq - *Carduelis flammea*) nest on/in many artificial structures.

2.10.3 Abundance

Abundance estimates for breeding birds based on systematic aerial and ground-based surveys for the Arctic Coastal Plain and within the Liberty area are presented in Table 2.10-2. Between the Colville and Canning rivers during July and August 1999-2002, red-throated loons were most abundant in Simpson Lagoon/Gwydyr Bay and Pacific loons were most abundant in Simpson Lagoon/Gwydyr Bay and east of Mikkelsen Bay (Noel, O'Doherty, and Johnson, 2003). Relative densities for red-throated and yellow-billed loons in the Liberty area were <0.01 loons/km^2, and for Pacific loons was <0.01 to 0.21 loons/km^2 based on breeding pair surveys from 1998 to 2001 (Mallek, Platte, and Stehn, 2002).

Peak activity areas for broodrearing snow geese during the 22-year period 1980-2002 were in the Sagavanirktok, Kadleroshilik, and Shaviovik river deltas (Figure 2.10-2; Noel, Johnson, and Butcher, 2004; Johnson, 2000a), with densities ranging from 3.3 to 13.2 birds/km^2 (Noel, Johnson, and Butcher, 2004). Systematic surveys of coastline transects between Oliktok Point and Brownlow Point during 1998-2002 (Noel, O'Doherty, and Johnson, 2003) indicated that peak activity areas for post-breeding molting white-fronted and Canada geese was along shorelines in Simpson Lagoon-Gwydyr Bay and the Shaviovik River delta. Peak densities of white-fronted geese in these areas ranged between 200 and 1,000 birds/km^2 and for Canada geese ranged between 50 to 200 birds/km^2. No white-fronted or Canada geese were recorded near the Liberty area during these surveys (Noel, O'Doherty, and Johnson, 2003). Peak activity areas for molting and brood-rearing brant during 1998-2002 were west of the Liberty area along the shores of Simpson Lagoon-Gwydyr Bay (peak densities: 200 to 1,000 birds/km^2). In 2000, 50 to 200 brant/km^2 were recorded in the Shaviovik River delta, but none were recorded near the proposed Liberty Development area during any year (Noel, O'Doherty, and Johnson, 2003).

Peak activity areas for long-tailed ducks during the post-breeding seasons (late July through August) in 1998-2002 were Simpson Lagoon-Gwydyr Bay, and the Leffingwell Lagoon areas to the west and east, respectively, of Liberty. The nearshore around the Liberty area did not support significant numbers of long-tailed ducks (Noel, Johnson, and O'Doherty, 2005). Nearest to Liberty (to the northeast), the McClure Islands complex was an important area for molting long-tailed ducks, with aggregations of 2,000 to 3,000 birds recorded in some years during 1998-2002 (Noel, O'Doherty, and Johnson, 2003). Average densities in this area ranged between 0.01 and 500 birds/km^2, markedly lower than the peak densities of 2,000 to 2,500 birds/km^2 recorded in Leffingwell Lagoon, to the east (Noel, O'Doherty, and Johnson, 2003).

Common eider peak activity areas during surveys in 1998-2002 were east of Liberty, in the Stockton-Maguire islands area (Noel, Johnson, and O'Doherty, 2005). Near the Liberty area, the McClure Islands complex was an important brood-rearing and molting area for common eiders and lesser numbers of king eiders and scoters (Fischer and Larned, 2004; Noel, O'Doherty, and Johnson, 2005). Densities of common eiders averaged between 10 and 20 birds/km^2 during 1998-2002, with peaks in some years (e.g., 2002) as high as 50 to 100 birds/km^2 (Noel, O'Doherty, and Johnson, 2003). Densities of king eiders and all scoters never exceeded 10 birds/km^2 in this area (Noel, O'Doherty, and Johnson, 2003).

Glaucous gulls are the most abundant seabird in the Liberty area (Noel, O'Doherty, and Johnson, 2003; Fischer and Larned, 2004). Glaucous gulls between the Colville and Canning rivers were most abundant in Simpson Lagoon/Gwydyr Bay and near Cross Island (Noel, O'Doherty, and Johnson, 2003). Densities of glaucous gulls in offshore Alaskan Beaufort Sea marine waters were higher in areas with low ice cover and ranged from 0.04 to 0.08 gulls/km^2 within the 10- to 20-m contours (barrier islands to 30 km from shore) and from 0.01 to 0.08 gulls/km^2 beyond the 20-m depth contour (beyond 30 km from shore) (Fischer and Larned, 2004).

Nest density for all birds combined in the Kadleroshilik River area was 69.7 km^2 in 1994 (TERA, 1995). The most abundant shorebirds were semipalmated sandpiper, pectoral sandpiper, dunlin, red phalarope and red-necked phalarope (TERA, 1995). The highest shorebird nesting densities generally occur in areas of mixed wet and dry habitats, whereas birds often move to wetter areas for brood rearing.

2.10.4 Population Status

Arctic Coastal Plain breeding pair surveys indicate that Pacific loons have remained stable at about 23,000 individuals, and red-throated loons have increased by about 3.5 % per year from

1985 to 2005 (Mallek, Platte, and Stehn, 2006). No trend was apparent in the number of yellow-billed loons estimated from these surveys, but survey variability was high and power to detect trends was low; this area appears to support about 3,300 individuals with less than 1,000 nesting pairs (Earnst, 2004). Population trends for most waterfowl species have remained unchanged since 1986 or 1992; notable exceptions are long-tailed duck, which has significantly declined, and tundra swan and arctic tern, which have significantly increased (Table 2.10-2; Mallek, Platte, and Stehn, 2006). Both Fischer and Larned (2004) and Johnson et al. (2005) also documented significant declines in long-tailed duck density in nearshore molting areas in the central Alaskan Beaufort Sea. Long-tailed duck populations in northwestern Canada have also declined (Dickson and Gilchrist, 2002; Robertson and Savard, 2002).

The snow goose colony on Howe Island in the Sagavanirktok River Delta area, west of Liberty, increased steadily through the early 1990s, but declined markedly due to egg predation by grizzly bears and foxes during 1994-2003 (Johnson and Noel, 2005). A sharp increase in the number of nesting snow geese and brant was noted on Howe Island in 2004 and this snow goose colony has continued to increase (Rodrigues, McKendrick, and Reiser, 2006) after predatory grizzly bears were removed (Johnson and Noel, 2005).

Dunlin and buff-breasted sandpipers are the only shorebirds regularly occurring in the project area that are listed as "Species of High Concern" in the Alaska Shorebird Conservation Plan (Alaska Shorebird Working Group, 2004). Trends in shorebird abundance in the Prudhoe Bay area indicate a decline in dunlin, during the period 1981-1992 (Troy, 2000). Across the coastal plain, glaucous gull and Sabine's gull numbers show no trend during July 1992-2005, while arctic terns appear to be increasing and jaegers (1984-2005) appear to be decreasing (within 10% probability) (Mallek, Platte, and Stehn, 2006). Within the lagoon system between the Colville and Canning rivers, glaucous gull abundance showed no significant (within 5% probability) trends with time during July-August 1978-2001 (Noel, Johnson, and Gazey, 2006). The passerines of greatest concern in Alaska due to small or declining populations are olive-sided flycatcher, blackpoll warbler, Smith's longspur, and rusty blackbird (Alaska Department of Fish and Game, 2005). All of these species have occurred in the project area but none is known to breed, nor is expected to occur on a regular basis.

2.11 TERRESTRIAL MAMMALS

Among the terrestrial mammals that occur in the Liberty area, the caribou, muskoxen, grizzly bear, and arctic fox are the species that could be affected by development. Mammals likely to occur in the project area are listed in Table 2.11-1.

2.11.1 Caribou

The Central Arctic Caribou Herd ranges within the project area. Its summer range extends from Fish Creek, just west of the Colville River, east to the Katakturuk River and from the Beaufort Sea coast inland south approximately 48 km (Figure 2.11-1; Lenart, 2005a; Arthur and Del Vecchio, 2004). Central Arctic Herd caribou winter in the northern and southern foothills and mountains of the Brooks Range (Lenart, 2005a). Some caribou of the Porcupine Caribou Herd may occur on the coastal plain near the Liberty area during summer, but few calve there or use the area after calving (Griffith et al., 2002). Calving by the Central Arctic Herd occurs in early June, usually within 30 kilometers of the Beaufort Sea coast. There are two calving groups, based on the locations of the calving-concentration areas. One calving area is east of, and one west of the Sagavanirktok River (Arthur and Del Vecchio, 2004; Lenart, 2005a; Cronin et al., 1997). The Liberty Project is near the eastern calving and post-calving ranges of the Central Arctic herd. Mid-June calving densities in the area bounded by the Beaufort Sea coast south to 69° 54.5' N latitude between the Sagavanirktok River and Bullen Point ranged from 0.62 caribou/km^2 to 2.38 caribou/km^2 during 2000 to 2003 with most caribou 5 km or more from the coast in the 1,487 km^2 survey area (Figure 2.11-2; Noel and Cunningham, 2003; Jensen, Noel, and Ballard, 2003; Jensen and Noel, 2002; Noel and Olson, 2001).

Caribou calving in the eastern area may occur within the Liberty area during late June, July and August (Arthur and Del Vecchio, 2004; Lenart, 2005a). Caribou densities between the Sagavanirktok River and Bullen Point south to 70° N latitude ranged from 0.01 caribou/km^2 to 8.43 caribou/km^2 during 2000 to 2003 within the 1,043 km^2 survey area (Noel and Cunningham, 2003; Jensen, Noel, and Ballard, 2003; Jensen and Noel, 2002; Noel and Olson, 2001). The most consistent pattern of caribou distribution within this area during July was use of riparian and coastal insect-relief habitats, typically sandbars, spits, river deltas, gravel river bars, and some barrier islands, by large groups (mean group size 50 to 500) of caribou (Figure 2.11-2; Noel and Cunningham, 2003).

The Central Arctic Herd increased from 5,000 animals in the 1970s to 13,000 in the early 1980s to 23,000 in the early1990s and then declined to 18,000 in the mid 1990s. The decline in the mid 1990s has been attributed to decreased productivity related to changes in calving distribution and increased energy expenditure during the insect season for cows in the eastern portion of the calving range caused by oil field infrastructure (Cameron et al., 2005). However, other factors may be responsible for the changes in herd numbers (e.g. winter mortality, emigration/immigration, Cronin et al. 1997; Cronin, Whitlaw, and Ballard, 2000). The Central Arctic Herd was last estimated at 31,857 caribou in July 2002, a 17% increase from the July 2000 estimate of 27,128 and a 61% increase from the July 1997 estimate of 19,730 caribou (Lenart, 2005a). This increase has been attributed to high parturition rates, high early summer calf survival and low adult mortality (Lenart, 2005a).

Wolves, grizzly bears, and golden eagles prey on caribou, although predation during calving and post-calving may be low for the Central Arctic Herd (Murphy and Lawhead, 2000). Winter mortality may have been higher in the 1990s, because more Central Arctic Herd caribou wintered south of the Brooks Range where wolves may be more abundant and snowfall is heavier (Lenart, 2005a). Harvest and hunting pressure on the Central Arctic Herd increased in the early 1990s due to hunting restrictions on interior Alaska herds and increased access to the Central Arctic Herd with opening of the Dalton Highway to public traffic. Total reported harvest has increased from an average of about 331 in the 1990s to about 470 in the 2000s, with an estimated harvest (reported and unreported) of 813 to 863 in 2004-2005 (Lenart, 2005a).

2.11.2 Muskoxen

Muskoxen were extirpated from northern Alaska by the late 1800s (Allen, 1912; Lent, 1998). From 1969 to 1970, 64 muskoxen from Greenland were reintroduced to northeastern Alaska, mostly in the Arctic National Wildlife Refuge (ANWR) but some also near the Kavik River (Jingfors and Klein, 1982). Since that time, the population has expanded its range east into Canada, west into the NPR-A, and south to areas near the Yukon River (Lenart, 2005b). The Alaskan North Slope population increased in size until the mid 1990s, appeared to stabilize around 550 animals until 2000, and then declined to about 195 by 2005 (Lenart, 2005b). The recent decline in total numbers can be attributed to a localized decline in the ANWR, as aerial counts in 1990 documented 332 and 122 muskoxen in the ANWR and between the Canning and Colville Rivers, respectively, and then 9 and 186 muskoxen in the same respective areas in 2005 (Lenart, 2005b). While emigration from the ANWR may have caused some of the decline in that area, reduced net productivity and recruitment were also evident (Reynolds, Wilson, and Klein, 2002; Lenart, 2005b). Predation by bears or variability in weather that affects forage availability may have been responsible for reduced survival of young and adults (Reynolds, Wilson, and Klein, 2002; Reynolds, Shideler, and Reynolds, 2002).

Muskoxen occur on the Arctic Coastal Plain year-round and use habitats along river corridors, floodplains, foothills, and bluffs in all seasons (Reynolds, Wilson, and Klein, 2002). Muskoxen usually produce single calves and overall have low reproductive potential relative to most ungulate species (Lent, 1988). Most females sampled from northeastern Alaska first bred successfully at 3 years of age, experienced reproductive pauses between calves of 2 or 3 years, and stopped calving by 15 years of age (Reynolds, 2001); these numbers may indicate less production than average for the species (Klein, 2000). Calves are usually born from April through June (Lent, 1988).

Muskoxen eat sedges, forbs, and willow leaves in summer and primarily sedges in winter (Klein, 2000). Spatial habitat models may be used to identify local areas likely to be selected seasonally by muskoxen such as wetter low-lying areas in summer and drier more rugged areas in winter (Lent, 1988; Danks and Klein, 2002). During summer, muskoxen form relatively small groups and travel more widely than during winter when groups tend to be larger and more sedentary (Reynolds, Wilson, and Klein, 2002; Lenart, 2005b). Lenart (2005b) noted a female that moved about 100 miles in a 2-month period during spring, traveling with a larger group for at least half that distance. Aerial surveys have documented relatively small groups near the coast between the Sagavanirktok River and the Badami Unit during spring and summer. Groups of muskoxen were located near the coast next to the Sagavanirktok, Kadleroshilik, Shaviovik, and Kavik Rivers and also on Tigvariak Island (Figure 2.11-3). Group sizes ranged from 1 to 18, with a total of 98 muskoxen observed, though many individuals were likely recounted among surveys. The greatest number of muskoxen documented during a single survey period was 28 individuals among 3 groups on June 1-14, 2002. Calves were present in 1 of these groups near the Kadleroshilik River (Jensen, Noel, and Ballard, 2003).

Grizzly bears kill calf and adult muskoxen, and may become more efficient with experience (Reynolds, Shideler, and Reynolds, 2002). Muskoxen have been legally hunted east of the Canning River since 1982 and between the Canning and Colville Rivers since 1990 (Lenart, 2005b). Subsistence hunting was preferentially allowed until 1998 when registration and drawings hunts were initiated (Lenart, 2005b). The annual harvest has been <4% of the population size and has primarily targeted bulls (Lenart, 2005b).

2.11.3 Grizzly Bears

Alaskan grizzly bears range north to the Beaufort Sea coast, but the coastal plain is considered marginal bear habitat due to severe climate, short growing season, and limited food resources (Shideler and Hechtel, 2000). Grizzly bears have low reproductive potential compared to other North American terrestrial mammals (Pasitschniak-Arts and Messier, 2000). Shideler and Hechtel (2000) reported lower cub mortality for bears feeding on anthropogenic food sources in North Slope oil fields relative to those feeding on natural food sources alone, but higher postweaning human-kills may have compensated for greater initial net production. The population trend of grizzly bears between the Colville and Canning rivers is probably stable (Shideler and Hechtel, 2000; Stephenson, 2003). Densities of grizzly bears tend to be lower on the coastal plain (0.5 to 2 bears/1000 km^2) than in the foothills of the Brooks Range (10 to 30 bears/1000 km^2; Carroll, 1995), but densities in the oil fields were relatively high with about 60 to 70 resident bears or 4 per 1000 km^2 (Shideler and Hechtel, 2000).

Because of permafrost, grizzly bear den sites on the coastal plain are generally restricted to well-drained habitats such as pingos, stream banks, hillsides, and sand dunes where insulating snow cover tends to accumulate in the southwestern lee of prevailing winds. Dens are typically used only once (Shideler and Hechtel, 2000). In the North Slope region, bears enter dens between late September and early November and exit between March and May (Shideler and Hechtel, 2000). Cubs are born sightless and helpless in the den during mid-winter (Pasitschniak-Arts, and Messier, 2000). Bears may select well-drained riparian habitats for vegetative forage in spring; wetter herbaceous meadows, riparian habitats, and ground squirrel mounds in summer; and inland areas with berries during the fall (Shideler and Hechtel, 2000). Grizzly bears frequently prey on ground squirrels, and also on bird eggs and nestlings, rodents, fox pups, caribou calves, adult and calf muskoxen, and marine mammal carcasses. Anthropogenic food sources may also be used when available [BP Exploration (Alaska) Inc., 1998]. The average annual home range for 5 radio-collared adult females was about 3,000 km^2; they may travel up to 50 km per day (Shideler and Hechtel, 1995, 2000). Combined field and genetic studies show that bears move across the North Slope, with considerable gene flow among bears in the western Brooks Range, the Prudhoe Bay region, and ANWR (Cronin et al., 2005).

Spring and summer aerial surveys of the coastal area between the Sagavanirktok River and the Badami Unit from 1998 to 2003 documented the presence of grizzly bears (Figure 2.11-3). Spring and summer surveys of the same area in 2001 and 2002 documented 19 bears among 10 groups. Juveniles were present in at least 2 groups (Jensen and Noel, 2002; Jensen, Noel, and Ballard, 2003). Most of the 10 groups were near riparian corridors such as the Shaviovik, Kavik, and Kadleroshilik rivers and were at least 10 km from the coast. The greatest number of bears observed during a single survey period was 5 bears among 3 groups on June 13-14, 2002 (Jensen, Noel, and Ballard, 2003).

Human hunting is the primary source of mortality of adult grizzly bears (Pasitschniak-Arts and Messier, 2000). Wolves and wolverines can kill bear cubs but are not present in appreciable numbers on the Arctic Coastal Plain (Shideler and Hechtel, 2000). Adult male bears may also kill cubs (Ballard et al., 1993). The Alaska Department of Fish and Game manages a sustainable annual harvest of about 5% of the North Slope bear population between the Colville and Canning rivers (Stephenson, 2003). Most bears are taken during the fall by resident hunters. The annual harvest consists mostly of males and has averaged 13.5 bears per year from 1989 to 2002 (Stephenson, 2003). A relatively large number of bears was taken in defense of life or property in 2001, perhaps as a result of reduced anthropogenic food availability in the oil fields (Shideler and Hechtel, 2000; Stephenson, 2003).

2.11.4 Arctic Foxes

Arctic foxes are typically found north of the foothills on Alaska's North Slope (Burgess, 2000). Reproductive potential of the arctic fox is highest among carnivores but influenced by availability and variability of food resources that include rodents, nesting birds and eggs, marine mammal carcasses, and seal pups (Smith, 1976; Quinlan and Lehnhausen, 1982; Tannerfeldt and Angerbjorn, 1998; Anthony, Barten, and Seiser, 2000). Fox populations may cycle in response to prey populations such as lemmings, but anthropogenic or marine resources may buffer against such oscillations (Burgess, 2000; Roth, 2003). Periodic rabies epizootics may also affect arctic fox populations (Ballard et al., 2001; Mork and Prestrud, 2004). Foxes often cache food, may readily switch between prey sources, and are capable of removing over 1,000 eggs per fox per year from nesting bird colonies (Stickney, 1991; Samelius and Alisauskus, 2000).

Arctic foxes may move onto the Beaufort Sea ice in winter to scavenge from polar bear kills, but stable anthropogenic food sources may reduce seasonal movements (Eberhardt, Garrott, and Hanson, 1983b). Similarly, natal den densities were higher within the oil fields near Prudhoe Bay (1 per 15.2 km^2) than on adjacent undeveloped tundra (1 per 28.1 km^2; Ballard et al., 2000). Undeveloped areas east of Prudhoe Bay have even lower den densities (Burgess, 2000). Arctic fox dens tend to be fixed features on the landscape and are often located in pingos and low ridges, and next to streams in well-drained sandy soils where snow accumulation is minimal (Chesemore, 1967; Burgess, 2000). Foxes may also den in culverts and road embankments, and underneath buildings (Eberhardt, Garrott, and Hanson, 1983a; Ballard et al., 2000). Many dens are not used in a given year, and the proportion used appears to rely on availability of local food resources (Chesemore, 1967; Eberhardt, Garrott, and Hanson, 1983a).

Spring and summer aerial surveys of the coastal area adjacent to the Liberty Project area between the Sagavanirktok River and the Badami Unit in 2001 and 2002 documented the presence of arctic foxes and active dens (Figure 2.11-3; Jensen and Noel, 2002; Jensen, Noel, and Ballard, 2003). Locations of foxes were distributed widely both north-to-south and east-to-west across the study area. Dens were also distributed widely across the study area, but 2 were within 1 km of the Badami pipeline west of the Kadleroshilik River. The greatest number of foxes observed during a single survey period was 6 individuals (4 at dens) on June 17, 2001 (Jensen and Noel, 2002).

Predators of foxes near the project area are mainly brown bears and golden eagles that primarily take pups (Garrott and Eberhardt, 1982; Burgess, 2000). Harvest data for arctic foxes are not available for northeastern Alaska, but indications from trapper reports are that foxes remain common, and trapping pressure has decreased since the late 1980s due to low fur prices (Stephenson, 2001).

2.12 VEGETATION AND WETLANDS

The proposed Liberty development will occur by expanding the existing Endicott Satellite Drilling Island (SDI) located on the Endicott Causeway to support ultra extended reach drilling. No terrestrial vegetation will be directly affected by the expansion of SDI. Support for the expansion of SDI will include the development of a gravel mine source located along the Endicott road, approximately 7.5 miles northeast of the Deadhorse Airport. The proposed mine site is adjacent to the existing Duck Island Mine Site.

The coastal plain in the development area is a vast expanse of wetlands dominated by permafrost landscape features; patterned, polygonized ground and wind-driven thaw-lake complexes. Topographic relief is subtle, giving rise to broadly meandering streams and expansive braided river systems. The gravel mine source and associated ice road route is located on the east side of the western most channel of the Sagavanirktok River Delta.

The braided channel system of the Sagavanirktok forms an extensive delta region which supports diverse plant communities. Calcareous sediments transported from the Brooks Range have a regional influence on soil conditions (Walker and Everett, 1991). In contrast to the acidic soils found across much of Alaska's North Slope, loess deposits from the Sagavanirktok River are evident in the slightly alkali soil pH in this region. This gradient is also manifest at the species level within plant communities of the area (Walker, 1985).

The location of the mine and ice road can be generally described as a complex of wet and moist sedge meadow communities dominated by *Carex aquatilis* and *Eriophorum angustifolium*. *Arctophila fulva* is often present in wetter areas and shallow flooded habitats. Drier habitats support species of *Dryas*, other forbs and grasses, as well as several species of *Salix*. Seasonal flooding and sloughs are common and give rise to barren or sparsely vegetated habitats.

In order to precisely define and quantify vegetative communities, land cover mapping of the mine area and potential ice road routes is scheduled to occur in summer 2007. To remain consistent with existing land cover maps in the Prudhoe Bay region, the area will be mapped using Walker's vegetation and land cover classification scheme. Walker's approach involves categorizing sites with respect to site moisture regime and dominant plant growth forms (and landform type when plant cover is very sparse or non-existent).

2.13 THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) of 1973 defines an endangered species as any species that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as any species that is likely to become endangered within the foreseeable future. Endangered bowhead whales and threatened spectacled and Steller's eiders may occur in the general area of the Liberty Project (USDOI, MMS, 2002). Since polar bears have recently been nominated by the U.S. Fish and Wildlife Service for listing under the Endangered Species Act, they are also discussed in this section.

2.13.1 Birds

2.13.1.1 Spectacled Eider

The spectacled eider is a seaduck that nests in arctic Russia and western and northern Alaska, and winters in the Bering Sea. The Alaska breeding population has declined markedly especially on the Yukon-Kuskokwim Delta (Stehn et al., 1993) leading to listing under the Endangered Species Act as threatened throughout its range (58 FR 27474). Subsequent research has revealed the species to be widespread on the North Slope (Larned, Stehn, and Platte, 2005). Details on spectacled-eider biology can be found in Petersen, Grand, and Dau (2000).

An estimated 6,916 spectacled eiders seasonally occupy the Arctic Coastal Plain (Larned, Stehn, and Platte, 2005). This value is an index unadjusted for eiders undoubtedly present but undetected. Abundance of spectacled eiders decreases from west to east across the Arctic Coastal Plain. Most high-density areas are west of Harrison Bay, and relatively few pairs are found east of the Shaviovik River. The Liberty Project area is located near the eastern limit of the North Slope spectacled eider range where spectacled eiders breed in low densities (Larned, Stehn, and Platte, 2005; Rodrigues and Ireland, 2006). The relative abundance of spectacled eiders in the Liberty Project area is shown in Figure 2.13-1.

Spectacled eiders may occur in the Liberty area from late May through mid-September. Spectacled eiders return from wintering grounds in the Bering Sea to the Arctic Coastal Plain in late May or early June. Routes traveled during their spring migration are not well-known, but the North Slope segment may be overland (TERA, 1999). Some spectacled eiders trapped in June near Deadhorse continued on to the Kadleroshilik River, supporting an overland migration for this portion of the route (Troy, 2003).

Spectacled eiders are dispersed nesters (Petersen, Grand, and Dau, 2000). Breeding-pair surveys indicate spectacled eiders may be present across most of the Liberty area (Larned, Stehn, and Platte, 2005). Nesting has been confirmed at many sites in the Prudhoe Bay oil field (TERA, 1993, 1997), and in the vicinity of the Kadleroshilik and Shaviovik rivers (USDOI, MMS, 2002). Few spectacled eiders are found in the area east of the Shaviovik River (Larned, Stehn, and Platte, 2005; TERA, 2002), but nesting may occur at least as far east as the Okpilak River in ANWR.

Migrant and staging spectacled eiders may occur in offshore waters from late June to September. Post-breeding males depart tundra-nesting areas and may move to nearshore marine habitats during mid- to late June, at the onset of incubation. Females leave from late June through mid-September, depending on their breeding success — failed breeders depart earliest. Shipboard surveys (Divoky, 1984) and aerial surveys (Fischer, Tiplady, and Larned, 2002) detected many eiders but no spectacled eiders within the Liberty area. Results from satellite tracking suggest that relatively few post-breeding male spectacled eiders use the Beaufort Sea, and the few that do use it are restricted to the limited ice-free areas such as river deltas (Troy, 2003). Female Spectacled Eiders were found to make extensive use of the Beaufort Sea post-breeding, with the highest use area near Smith Bay. The second most important area in the Beaufort Sea for female spectacled eiders was near the Stockton Islands offshore of the eastern end of the Liberty area (Troy, 2003). Given the relatively small proportion of the North Slope population of spectacled eiders breeding east of the Sagavanirktok River, it is unlikely that a large number of spectacled eiders occur in marine waters of the Liberty area. However, telemetry data from a relatively small number of female spectacled eiders suggest at least some use of marine habitats offshore of the Liberty project area.

After leaving the coastal plain, spectacled eiders molt in a few locations in arctic and eastern Russia or Ledyard Bay in northwestern Alaska before continuing on to staging areas near St. Lawrence Island and wintering areas in the central Bering Sea (Petersen, Larned, and Douglas, 1999).

2.13.1.2 Steller's Eider

The Alaska breeding population of Steller's eider was listed as threatened in 1997 (59 FR 35896), because the nesting range and population were thought to have decreased substantially (Quakenbush et al., 2002). Although historical data suggest that Steller's eiders formerly occurred across much of the Alaska Arctic Coastal Plain, including in the Liberty area, there have been no recent (post-1970) sightings between the Sagavanirktok River and the Alaska–Canada border (Quakenbush et al., 2002) and the species is considered a casual (i.e., not annual) visitant in the Liberty area. Although there are numerous recent sightings of this species in the Prudhoe Bay area, and a record of a flight-capable brood near Prudhoe Bay in 1993 (Quakenbush et al., 2002), there are no unequivocal records of nesting east of Prudhoe Bay (e.g., Rodrigues, 2002; TERA, 2002; Ritchie, Schick, and Shook, 2003). Aerial surveys for eiders on the Arctic

Coastal Plain indicate a wide distribution, but with only a few sightings between the Colville and Sagavanirktok rivers (Quakenbush et al., 2002) and none east of the Sagavanirktok River (Larned, W., USFWS, pers. comm.; Larned, Stehn, and Platte, 2005). Finally, the extent of offshore use is poorly known (USDOI, MMS, 2002), but recent aerial surveys in this region have not identified Steller's eider (e.g., Noel, Johnson, and O'Doherty, 2002; Fischer, Tiplady, and Larned, 2002). A female-plumaged Steller's eider observed near Northstar in early October 2004 (Day, R., ABR, pers. comm.) may be the only offshore record in this part of the Beaufort Sea.

2.13.1.3 Other Birds That May Achieve ESA Protection Within the Life of the Project

Several additional birds that occur in the Liberty area have been reviewed for consideration for protection under the Endangered Species Act. These include long-tailed duck, yellow-billed loon and buff-breasted sandpiper. The status of long-tailed ducks was reviewed (Wilbor, 1999), and the U.S. Fish and Wildlife Service has not proposed this species for listing. The yellow-billed loon was petitioned for listing on March 30, 2004 and a status assessment and conservation plan was developed (Earnst, 2004) but no decision on listing this species has been made. The status of the buff-breasted sandpiper population was reviewed in 2002 (Gotthard and Lanctot, 2002), and in a review of high-priority shorebirds, the U.S. Shorebird Conservation Plan (2004) upgraded the status of the buff-breasted sandpiper from "high concern" in 2002 to "highly imperiled" in 2004. Because there is a potential that yellow-billed loons and buff-breasted sandpipers may achieve protection under the Endangered Species Act within the life of the Liberty Project, they are described in more detail below.

Yellow-billed Loon

The total world-wide population of yellow-billed loons is estimated at 16,000 individuals, of which the northern Alaska breeding grounds support on average 3,369 individuals, including <1,000 nesting pairs/year. No declining trend was apparent in the number of yellow-billed loons estimated from breeding-bird surveys on the Arctic Coastal Plain, but survey variability was high and the power to detect trends was low (Earnst, 2004).

Yellow-billed loons first arrive in northern Alaska during the last 10 days of May. Individuals and small groups gather in open river channels, and larger flocks gather in marine bays until sufficient open water develops around the margin of lakes and ponds used for nesting. Loons generally nest and lay eggs during mid to late June, with hatch in mid to late July and young can fly by mid- to late September (Earnst, 2004).

Most yellow-billed loons nest between the Meade and Colville rivers on the Alaskan Arctic Coastal Plain, although they may also breed sparsely east of the Colville River to the Canning River (Earnst, 2004). Relative density of yellow-billed loons in the Liberty area was <0.01 loons/km^2 based on breeding-pair surveys during July 1998-2001 (Mallek, Platte, and Stehn, 2002). Yellow-billed loons require nesting and brood-rearing lakes that are large enough to allow take-off from open water, form an ice-free moat around shore in early spring that protects nests from wind-blown ice and allow adults to take off, support a substantial population of small fish, have a section of gently sloping shoreline for nesting and brooding, and have sheltered areas where young chicks can rest and hide (Earnst, 2004).

Adult yellow-billed loons with territories near the coast as well as non-breeding individuals may travel to marine waters to forage (Earnst, 2004). In the shallow nearshore waters of the Alaskan Beaufort Sea, yellow-billed loons were most abundant in Harrison Bay during July

(Fischer and Larned, 2004). Yellow-billed loon sightings between the Colville and Canning rivers were most numerous in the Simpson Lagoon area, with a few sightings near the McClure and Stockton islands in the Liberty area (Noel, O'Doherty, and Johnson, 2003).

Adults leave their territories during late August to mid September and successful breeders leave soon after their chicks can fly. Yellow-billed loons sometimes remain in open rivers until forced out by ice in late September to early October. Adults may migrate separately from offspring, and may migrate following leads in the pack ice far from shore in the Chukchi Sea and Beaufort Sea. Yellow-billed loons reach wintering sites off the coast of Japan, North Korea, and the Yellow Sea between North Korea and China where they remain by the end of November (Earnst, 2004).

Buff-breasted Sandpiper

Northern Alaska breeding grounds support 20% of the 25,000 worldwide population and 50% of the Western Hemisphere breeding population of buff-breasted sandpipers. The small total North American population of 15,000 individuals and an apparently declining population trend have raised concerns about this species (Gotthardt and Lanctot, 2002). Historically buff-breasted sandpipers were common in North America. Commercial hunting in the late 1800s and habitat degradation were suspected to have driven this species to near extinction by the early 1990s (Lanctot and Laredo, 1994).

Buff-breasted sandpipers migrate in small flocks, probably at night, and are thought to use traditional sites during migration. Their favorite stopovers include: short-grass pastures, dry ponds, airports, cemeteries, lawns, sod fields, and other grasslands. They leave wintering grounds in early February to mid-March and head north from stopovers in Texas, Oklahoma, Nebraska, Iowa, Missouri, Saskatchewan and Alberta to arrive on arctic breeding grounds during late May or early June (Lanctot and Laredo, 1994).

Buff-breasted sandpipers use drier habitat than most other shorebirds and depend on drier sloping areas or polygonal-featured tundra for nesting (Lanctot and Laredo, 1994). Habitats used by buff-breasted sandpipers vary by sex and breeding stage: displaying males first occur in areas free of snow such as barren ridges, creek bands, and raised, well-drained areas with reticulate-patterned ground and sparse vegetation (such as *Dryas* sp.) (Dry Prostrate-shrub Tundra and Barrens), Within 3 to 5 days of their arrival, most males are found displaying together in leks on non-patterned ground, moist sedge, and cotton grass meadows with closely spaced tussocks and with dwarf willow thickets (Moist Dwarf-shrub, Tussock Graminoid; Wet Graminoid Tundra mixed with Moist Graminoid Prostrate-shrub Tundra). Most males abandon these sites within 1 to 2 weeks to display closer to nest sites, typically on dry slopes with numerous sedge tussocks (Dry Prostrate-shrub Tundra and Barrens), on moss-willow-varied tussocks (Moist Dwarf-shrub, Tussock-graminoid Tundra), and in moist or wet sedge-graminoid meadows on non-patterned or strangmoor ground (Wet Graminoid Tundra). Brood-rearing females use moist and emergent vegetation along and in stream beds (Moist Graminoid Prostrate-shrub Tundra; Wet Graminoid Tundra) (Lanctot and Laredo, 1994).

The number of adults counted on breeding grounds varies dramatically year to year. Nest densities at Milne Point ranged from 0.3 to 1.3 nests/km^2 and at Prudhoe Bay ranged from 0.5 to 1.0 nests/km^2, and post-season densities were 0.0 to 2.4 birds/km^2 (Gotthardt and Lanctot, 2002).

2.13.2 Mammals

2.13.2.1 Bowhead Whale

The bowhead whale was listed as endangered on June 2, 1970. No critical habitat has been designated for the species, although the National Marine Fisheries Service (now NOAA Fisheries) recently received a petition to designate critical habitat for bowhead whales.

The Western Arctic stock of bowhead whales was estimated to be 8,000 individuals in 1993 with a range between 6,900 and 9,200 individuals with a 95% confidence interval (Zeh, George, and Suydam, 1995; Hill and DeMaster, 1999). Zeh, Raftery, and Schaffner (1995) subsequently revised this population estimate by incorporating acoustic data that were not available when the earlier estimate was developed. The revised estimate of the population was between 7,200 and 9,400 individuals in 1993, with 8,200 as the best population estimate, and the estimate recognized by the International Whaling Commission. This revised population estimate also was the population estimate used by NOAA Fisheries in their stock assessments (Hill and DeMaster, 1999; Angliss, Lopez, and DeMaster, 2001). An alternative method produced an estimate of 7,800 individuals with a 95% confidence interval of 6,800 to 8,900 individuals. Zeh, Raftery, and Schaffner (1995) estimated that the Western Arctic stock increased at a rate of 3.2% per year from 1978 to 1993. Recently George et al. (2004) reported that the Western Arctic bowhead population numbered approximately 10,470 animals in 2000. The minimum population estimate calculated by Angliss and Lodge (2004) for the Western Arctic bowhead stock is 8,886 whales. The increase in the estimated population size is most likely due to a combination of improved data and better censusing techniques, along with an actual increase in the population. The historic population before commercial whaling was estimated at 10,400 to 23,000 whales in 1848 — compared to an estimate of between 1,000 and 3,000 animals in 1914 near the end of the commercial-whaling period (Woody and Botkin, 1993).

Information on many aspects of bowhead-whale natural history is discussed in the Liberty FEIS (USDOI, MMS, 2002). Topics discussed include wintering areas and habitats, spring and fall migration routes, tagging studies that describe bowhead movements and speed, effects of oceanographic conditions on bowhead migration, results of aerial survey data collected in the Liberty Project area, traditional knowledge of bowhead movements, and aging techniques. The Liberty FEIS points out that little is known about natural mortality in the Bering, Chukchi, and Beaufort seas, or about age at sexual maturity or mating behavior and timing.

The Liberty FEIS also contains a lengthy discussion of bowhead feeding behavior and prey availability. Based on contents of stomach samples, some level of feeding occurs during spring migration and the area west of Barrow may be an important feeding area in some years. Bowhead feeding has also been reported in the eastern Beaufort Sea and the Amundsen Gulf region in Canada during the summer and in the Beaufort Sea during fall migration, but the importance of these areas in the annual activity budgets of bowheads is not known. A study by Richardson (1987) concluded that food consumed in the eastern Beaufort Sea did not contribute significantly to the overall bowhead whale population's annual energy needs, although the area may be important to some individual whales in some years. The amount of feeding that occurs in the Beaufort Sea during fall migration appears to vary from year to year.

More recently, Lee et al. (2005) studied stable isotope in bowhead baleen and suggested that the Western Arctic population of bowhead whales acquires the bulk of its annual food intake from the Bering-Chukchi system, where the whales spend much of the fall plus the winter and early spring. The data indicate that bowheads acquire only a minority of their annual diet from the eastern and central Beaufort Sea where they spend the summer. However, subadults apparently feed in the central and eastern Beaufort Sea more frequently than adults. Lee et al. (2005) indicate that their conclusions are based on some uncertainties and that additional sampling would be valuable in refining the present estimates and the overall understanding of seasonal feeding by bowheads.

Near Kaktovik in the fall, bowheads apparently feed primarily on copepods and to a lesser extent on euphausiids (Lowry and Sheffield, 2002). However, in the western Beaufort Sea near Barrow fall bowhead whale diet was dominated by euphausiids. Stomach samples of 14 whales taken in spring at Barrow contained almost entirely euphausiids and 6 had nearly all copepods (Lowry and Sheffield, 2002). Significantly more copepods were reported in spring versus fall bowhead-stomach samples.

Bowhead whales migrate parallel to the north coast of Alaska during fall. Fall migration typically begins out of the Canadian Beaufort Sea in late August and early September (Schick and Urban, 2000) and continues through the Alaskan Beaufort Sea throughout October. A peak in the number of whales transiting through the Beaufort Sea typically occurs in the middle of September. Inupiat whalers from Kaktovik and Nuiqsut (based from Cross Island) each harvested 4 bowhead whales near the middle of September 2006 (Pausanna, 2006).

During the westward autumn migration bowhead whales are generally seaward of the barrier islands with annual variability in the mean distance offshore (Treacy, 2002a). The mean distance of migrating bowheads from shore in the Beaufort Sea west of Prudhoe Bay in 2000 (17.7 km) was less than for any single year (1982-2000) and much less than the cumulative mean (35.4 km; Treacy, 2002a). Blackwell et al. (2004) also reported interannual variability in the proximity of migrating bowheads to shore in the southern portion of the bowhead migration corridor near Prudhoe Bay. The migration corridor tended to be closer to shore in 2003 than the previous 2 years. Bowheads appear to migrate farther offshore during heavy-ice years and nearer shore during years of light sea-ice (Treacy, 2002b; Monnett and Treacy, 2005).

2.13.2.2 Polar Bears

Polar bears were nominated for listing by the U.S. Fish and Wildlife Service in late 2006. Though not officially listed at the writing of this EIA, the bears are likely to be listed as threatened during the life of the Liberty Project.

Estimates for the Southern Beaufort Sea polar bear population (from Icy Cape to Cape Bathurst, Northwest Territories, Canada) have varied considerably over the last decade. This population was estimated to be approximately 1,800 bears during the mid- to late 1990s (Amstrup, 1995; Wiig, Born, and Garner, 1995; Gorbics, Garlich-Miller, and Schliebe, 1998). Population modeling as recently as 2001 suggested that the population could be more than 2,500 bears, if the number of males had increased in the same proportion as the number of females (Amstrup, McDonald, and Stirling, 2001). This population was reported to have increased over the past 20 to 30 years at 2% or more per year and was believed to be increasing slightly or stabilizing near its carrying capacity (Amstrup, 1995). However, in 2006 it was reported that this population may be comprised of approximately 1,526 bears (Regehr, Amstrup, and Stirling, 2006). Furthermore, both yearling cub survival and the physical stature of adult males were reported to have declined during the period from 1990 to 2006 compared with 1967 to 1989. Both trends were observed in the Canadian polar bear population of western Hudson Bay before the occurrence of a significant population decline (Regehr et al., 2006)

Polar bear seasonal distribution and local abundance vary widely in the Alaskan Beaufort Sea. Amstrup, Durner, and McDonald (2000) assumed that a bear density of 1 bear/25 km^2 occurs in seasonal concentration areas. Much lower densities occur beyond 100 mi offshore and higher densities near ice leads, where seals concentrate during the winter. Evans et al. (2003) estimated that polar bear density in the eastern Chukchi and western Beaufort seas was 1 bear/147 km^2. Another study estimated overall polar bear density from Point Barrow to Cape Bathurst as 1 bear every 141 to 269 km^2 (Amstrup, Stirling, and Lentfer, 1986). Sea ice and food are the two most important natural influences on polar bear distribution.

Drifting pack ice off the coast of the Alaskan Beaufort Sea probably supports more polar bears than either shorefast ice or polar pack ice, probably because young seals are abundant in this habitat. Durner et al. (2004) studied polar bear use of sea-ice habitats and reported that female polar bears preferred areas with relatively shallow water and high ice concentration. Polar bears sometimes concentrate along Alaska's coast when pack ice drifts close to the shoreline, at bowhead whale-carcass locations such as Cross and Barter islands (Kalxdorff et al. 2002), and when shorefast ice forms early in the fall. During fall and winter, polar bears may occur along the Beaufort Sea coast and on barrier islands. Kalxdorff et al. (2002) reported 97 polar bear sightings during four aerial surveys along the mainland coast and barrier islands between Harrison Bay and Kaktovik during fall 2001. Moulton and Williams (2003) reported 46 sightings of polar bears during spring aerial surveys while monitoring marine mammals for BPXA's Northstar development in 2002. Most of the sightings were located near and north of Cross Island, and no sightings were reported in the Liberty area. Polar bears are mobile and bears from the Chukchi and northern Beaufort seas often occur in the southern Beaufort Sea (Amstrup, McDonald, and Durner 2004).

Pregnant and lactating females with newborn cubs are the only polar bears that occupy winter dens for extended periods. Durner, Amstrup, and Fischback (2003) reported that dens in northern Alaska were constructed in ice and snow and usually consist of a simple chamber with a single entrance/egress tunnel, although multiple chambers and tunnels were reported at some dens. Dens were located on or associated with pronounced landscape features such as coastal and river banks, lake shores and an abandoned oil field gravel pad. Durner, Amstrup, and Ambrosius (2001, 2006) mapped the locations of suitable polar bear denning habitat on the Alaskan Arctic Coastal Plain including the Liberty project area.

In addition to being protected by the Marine Mammal Protection Act and proposed to be listed under the Endangered Species Act, polar bears and their habitats are covered further by the International Agreement on the Conservation of Polar Bears. This 1976 agreement among Canada, Denmark, Norway, the Union of Soviet Socialist Republics, and the United States addresses protection of "habitat components such as denning and feeding sites and migration patterns." A bilateral agreement between the United States and Russia to conserve polar bears in the Chukchi/Bering seas also was signed in October 2000.

The Marine Mammal Protection Act banned polar bear hunting with the exception of subsistence hunting by Alaska Natives. The North Slope Borough/Inuvialuit Game Council's Polar Bear Management Agreement for the southern Beaufort Sea was signed in 1988 and includes sustainable harvest quotas based on estimated population size, sustainable harvest rates for female polar bears, and information regarding the sex ratio of the subsistence harvest. Brower et al. (2002) concluded that this agreement has been successful in containing the total harvest and the harvest of females within sustainable limits but stress the need for improved harvest monitoring awareness and the need to prevent overharvest of female bears. Impacts to subsistence activities resulting from listing the bear under the Endangered Species Act have not yet been determined.

2.14 CULTURAL RESOURCES

Cultural resources in and/or near the Liberty area include sites and materials of prehistoric Native American (e.g., habitation sites, lithic scatters, and isolated finds), historic European and Euro-American, and historic Iñupiat origin (e.g., traditional cabin and subsistence sites, campsites, burial grounds, and other traditional land-use areas, landscapes, symbols, and place names).

Sources for information about cultural resources include:

- The Alaska Heritage Resources Survey (AHRS) maintained by the Alaska Department of Natural Resources, Office of History and Archaeology (ADNR, OHA, 2005);
- The Traditional Land Use Inventory (TLUI) maintained by the North Slope Borough (NSB, 2003); and
- Reports associated with oil and gas exploration and development. In particular, the Liberty Project Environmental Report (LGL, WCC, and Applied Sociocultural Research, 1998) and the Liberty Development and Production Plan Final EIS (USDOI, MMS 2002) provided relevant information.

The TLUI is a list of important cultural sites and subsistence use areas, with the core information being the traditional knowledge and accounts of elders applied to the land use history and patterns of individual communities including the village of Nuiqsut (e.g., NSB, 1976, 1978; Hoffman, Libbey, and Spearman, 1988; Brown, 1979; Ito-Adler and Hall, 1986; and IAI, 1990a); Kaktovik (e.g., Jacobson, n.d.; Jacobson and Wentworth, 1982; Pedersen et al., 1985; and IAI, 1990b); and overviews of cultural resources in the Beaufort Sea region (e.g., NSB, 1977, 1980, 1981, n.d.; Nielson, 1977; Hall, 1981; Libbey, 1981; Okakok, 1981; Pedersen n.d., 1995; Galginaitis et al., 1984; Pedersen and Coffing, 1984; Coffing and Pedersen, 1985; IAI, 1985, 1990a). Research pertaining to cultural resources in the Beaufort Sea region is included in lease sale EISs (e.g., USDOI, BLM, 1979, 1982; USDOI, MMS, 1984, 1987, 1990a,b, 1996a,b, 1997); development EISs (e.g., USDOI, BLM, 2004a,b, 2005; USDOI, MMS, 2002; USACE and ERT, 1984); and focused survey reports conducted as part of the permitting process for individual wells and other exploratory/development projects including the Liberty Development Project (e.g., Lobdell, 1980, 1985, 1986, 1990, 1991, 1993, 1995, 1996, 1998a,b,c; Lobdell and Lobdell, 1999, 2000a, b; WCC, 1981; Duane Miller and Associates, 1997; Watson Company, 1999; Reanier, 2000, 2002, 2003). Lobdell (1998a, 1998b) conducted cultural resources surveys for the Liberty Project in 1997 and 1998. No previously unknown or unrecorded cultural resources were identified during these surveys, and while no cultural resources were within the project footprint originally proposed, two historic sites were located within 1 mi of originally proposed project components.

The area of potential effect of the alternatives originally considered in the Liberty Project FEIS included an area that encompassed a manmade gravel island located in Foggy Island Bay with full production facilities, subsea pipeline, the area around the landfall of this pipeline from the production facility, and the tie-in of this pipeline with the Badami Sales Oil Pipeline. The Liberty project now includes an expansion of the existing Endicott Satellite Drilling Island for the well pad and existing infrastructure. Two alternatives (well pads located at Pr. Brower and near the Kadleroshilik River and using Endicott and Badami, respectively, as processing hosts) are onshore developments that take advantage of existing infrastructure. These onshore alternatives do not expand the potentially affected area.

Section 4.1.11 contains details on the permitting process that will be followed to assure the avoidance or mitigation of cultural resources — including in the new gravel mine site planned for the project.

2.14.1 Prehistoric Resources in the Area of Potential Effect

The Office of History and Archaeology reports sites with prehistoric components in the Beaufort Sea Planning Area; however, no prehistoric sites have been reported within the proposed Liberty Project area (Lobdell, 1998a; ADNR, OHA, 2005). Three prehistoric sites are located near the original Liberty Project area along the coast — Foggy Island Bay House Ruin (XBP-061), Foggy Island Bay House Ruin 2 (Kisim Inaa) (XBP-052, TLUIXBP-034), and Shaviovik River Cache (XBP-068) (ADNR, OHA, 2005; NSB, 2003).

2.14.2 Historic Resources

As noted, the North Slope Borough's TLUI is a compilation of subsistence resource/use locations, landmarks, place names, travel routes, and special significance locales that exist in the living memory of the Iñupiat people. There are 32 documented historic/TLUI sites in or near the planning area. It should be noted that 10 of these sites are associated with the Bullen Point Short Range Radar Site (formerly POW-3) (ADNR, OHA, 2005; NSB, 2003; HGC, Inc., 2005). Various TLUI documents identify these locations with the same set of names, but in different places (see IAI, 1990a). Lobdell (1998a, 1998b) conducted cultural resources surveys for the Liberty Project in 1997 and 1998, but he did not identify previously unknown or unrecorded cultural resources during these surveys. While no cultural resources were identified within the proposed project footprint, two historic sites (XBP-024 and XBP-026) were located within 1 mi of proposed alternative project components. The Liberty Environmental Report (LGL, WCC, and Applied Sociocultural Research, 1998) documented 11 historic or TLUI sites in the original project area that should be avoided by exploration or development activities including:

- An historic site (XBP-022) at Point Brower (Lobdell, 1980);
- A documented use area (Agligvuarak or Foggy Island [TLUIXBP-006], IAI, 1990a) to the south of XBP-022;
- Two historic sites (XBP-023, XBP-024) on the mainland coast of Foggy Island Bay;
- A documented use area (Koganak Inaat or Quganam Inaa [TLUIXBP-007], IAI, 1990a) centered near XBP-023;
- An historic site (XBP-025) on the west side of the mouth of the Kadleroshilik River (Lobdell, 1980);
- A documented use area (Qalgusilik, IAI, 1990a) directly to the east of the mouth of the Kadleroshilik River;
- A documented use area (Sikiagruum Inaa [TLUIXBP-040], IAI, 1990a) near the mouth of the Kadleroshilik River;
- An historic site (XBP-026) on the east side of a small creek flowing into Foggy Island Bay east of the Kadleroshilik River (Lobdell, 1980);
- A documented use area (Kisim Inaa [XBP-062, TLUIXBP-034], IAI, 1990a) to the southwest of XBP-026;

- A documented use area (Ekoolook Inaat or Ikuluum Inaa [TLUIXBP-008], IAI,1990a) on a point on the coast near the middle of Foggy Island Bay, east of the mouth of the Kadleroshilik River; and
- Three Native Allotment applications.

2.15 SOCIOECONOMICS

2.15.1 Economy

The discussion of economics addresses the affected environment in a national, State, and local (particularly Alaska North Slope [ANS]) context. This section incorporates by reference the relevant material on economics contained in the original Liberty Project Environmental Report (LGL, WCC, and Applied Sociocultural Research, 1998, 1998), Liberty Development and Production Plan FEIS (USDOI, MMS, 2002), other North Slope EISs completed since 2002, including the Alpine Satellite Development Plan (USDOI, BLM, 2004a); the Northwest National Petroleum Reserve-Alaska Final Amended Integrated Activity Plan (USDOI, BLM, 2004b); the Northeast National Petroleum Reserve-Alaska Final Amended Integrated Activity Plan (USDOI, BLM, 2005); the Proposed OCS Lease Sales 193 (USDOI, MMS, 2006a), 195 (USDOI, MMS, 2004), and 202 (USDOI, MMS, 2006b; see also USDOI, MMS, 2003); the TAPS Right-of-Way Renewal (USDOI, BLM, 2002); and the National Research Council study of the cumulative effects of oil and gas activities on Alaska's North Slope (NRC, 2003).

The description of the affected environment from an economic perspective can be summarized simply as follows: domestic crude oil production is critically important at the national, State, and local (North Slope Borough) levels.

2.15.1.1 National Level

As recently as the end of World War II, the United States was self-sufficient in crude oil. Since then, the rate of increase of U.S. crude oil consumption greatly outpaced that for domestic production and the U.S. has become a net importer. Current projections (EIA, 2005) indicate that U.S. dependence on foreign oil producers will grow to 70% of U.S. demand by 2025. Additional imports adversely affect the balance of trade — particularly as oil prices have climbed substantially since the Liberty FEIS — exacerbate domestic inflation, reduce the gross domestic product, and increase reliance on imports from countries that are unstable and/or unfriendly to the United States.

2.15.1.2 State Level

Petroleum contributes significantly to gross state product, employment (and high-paying employment), and revenues. For example, the combination of petroleum taxes and royalties since production began on the North Slope annually contributed between 60 and 90% of total State unrestricted fund revenues. Since the Liberty FEIS was completed in 2002, these revenues from the North Slope have approximately tripled from approximately $1 billion to $2.8 billion (ADOR Revenue Sources Book, 2006).

Petroleum is also important to the State economy because it is the funding source for Alaska's largest financial asset — the Alaska Permanent Fund. The Permanent Fund was established in 1978 to be a savings account to hold a share of the royalties (petroleum production owned by the State of Alaska) received by the State. The rationale for its establishment was that the fund would grow over time as production declined and eventually the earnings of the fund would substitute for oil production as a source of revenues to help support necessary public spending on education and other public programs. Since the fund's inception, the Alaska constitution has required that 25% of royalties be deposited into the fund. In addition, annual deposits to offset the erosion of the value of the fund due to inflation have been made since the early 1980s, and on occasion, special deposits have also been added to the principal, which cannot by law be spent. The fund is invested in a diverse portfolio of stocks, bonds, and real estate, and has grown in value to nearly $33 billion as of the end of June 2006 (http://www.apfc.org/theapfc/faq.cfm).

2.15.1.3 Local Level

The Liberty FEIS provides data on the contribution of taxes on petroleum facilities to the North Slope Borough. According to the 2005 NSB Annual Financial Report, nearly $200 million of the $315 million total NSB revenues came from property taxes, almost exclusively on oil industry facilities. This same report (page iii) stated:

> "Since 1968, oil and gas exploration and development on Alaska's North Slope has become the principal industry in the Borough and the employer of the bulk of the Borough's workforce.[1] The other service providers, including the government sector, exist primarily due to the presence of the oil and gas industry."[2]

The NSB communities have also been affected by growth in the capacity of State government to provide services to local communities as a result of the petroleum revenues flowing to the State. Enhancement of the quality of primary and secondary education is the most obvious example of service improvement, but others such as health care, transportation infrastructure, and public safety have also benefited. These services produce additional jobs and income for local residents. Petroleum revenues have also allowed the State to keep the tax burden on Alaskan households low, and along with the Permanent Fund Dividend, have significantly increased the discretionary income of all Alaskan households, supporting a large number of jobs in this and other regions of the State. As noted by MMS (USDOI, MMS, 2002):

> "Social services have increased dramatically since 1970, with increased Borough budgets and grants acquired early on by the Iñupiat Community of the Arctic Slope, and later by the Arctic Slope Native Association and other borough nonprofits."

Revenues from the oil industry have been important to the success of Native corporations, such as the Arctic Slope Regional Corporation, and this success in turn provides jobs for Alaska Natives and dividends for shareholders (see e.g., USDOI, MMS, 2002; NRC, 2003).

In short, all levels of government stand to gain economically from increased domestic crude oil production and other measures (e.g., conservation initiatives and the development of alternative energy sources) to reduce dependence on imported oil. Higher crude-oil prices adversely affect the national government, but benefit Alaska. Development of the Liberty Project will not solve the nation's energy problem, but is fully consistent with the National Energy Strategy. Liberty is one of the projects included in the State's projections of future oil production and revenues. Quantitative estimates of the economic impacts associated with development of the

[1] This presumably refers to indirect employment as a result of revenues.
[2] http://www.north-slope.org/nsb/default.htm.

Liberty Project are provided in the discussions of the economic impacts of the proposed action and no-action alternative.

2.15.2 Sociocultural Systems

"Sociocultural systems" as used in the Liberty FEIS (USDOI, MMS, 2002) encompass: "…the social organization and cultural values of a society." Included under this rubric, the FEIS provided a profile of the sociocultural systems that characterize the North Slope communities of Barrow, Nuiqsut, and Kaktovik — communities that might be impacted by this development. The quantitative data included in this section were based largely on the results of the 1990 Census. Results of the 2000 Census are now available[3] and several EISs incorporate these data, including the Alpine Satellite Development Plan (USDOI, BLM, 2004); the Northwest National Petroleum Reserve-Alaska Final Amended Integrated Activity Plan (USDOI, BLM, 2004b); the Northeast National Petroleum Reserve-Alaska Final Amended Integrated Activity Plan (USDOI, BLM, 2005); the Proposed OCS Lease Sales 193, (USDOI, MMS, 2006a), 195 (USDOI, MMS, 2004), and 202 (USDOI, MMS, 2006b; see also USDOI, MMS, 2003); the TAPS Right-of-Way Renewal (USDOI, BLM, 2002); and the National Research Council study of the cumulative effects of oil and gas activities on Alaska's North Slope (NRC, 2003). Another useful report published since the Liberty FEIS was written by Northern Economics, Inc. (2006). All are incorporated by reference.

2.15.2.1 Demographics

Although new Census data are available, these data do not materially alter the findings and conclusions presented in the Liberty FEIS. Selected demographic information in summary form includes:

- The NSB is the largest borough in Alaska, accounting for 15% of the area of the State. Were the NSB a State, it would rank 12th in area (at 89,000 mi^2 in area, this borough is slightly larger than the State of Minnesota). The borough includes eight villages: Anaktuvuk Pass, Atqasuk, Barrow, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright.
- Table 2.15-1 provides additional demographic information on the NSB communities including year incorporated, land and water area, population (in total and by gender), median age, median 1999 household income, percentage of families below the poverty level, selected housing characteristics, available health services, schools, transportation and communications,[4] and alcohol restrictions.[5] The Census of 2000 counted 7,367 persons as residents of the NSB — for an average population density of approximately 1 person/12.1 mi^2.

[3] And, for some demographic data such as population, the Alaska State Demographer has estimates for 2005. These are available electronically at http://www.commerce.state.ak.us/dca/ commdb/CF_BLOCK.htm. However, 2000 Census data are used here to provide all data for a common year.

[4] This includes television and Internet access. Both media are implicated in social change. For example, the possible impacts of television on Alaska Natives is addressed in Erlich, R. 1996. Criminal Justice in the Northwest Arctic Borough, *Alaska Justice Forum* 13(3), available at: http://justice.uaa.alaska.edu/forum/13/3fall1996/a_nwarct.html.

[5] Alcohol restrictions are included because substance abuse is of concern to NSB residents (see e.g., USDOI, MMS, 2002). As noted therein: "In the past decade, all communities in the North Slope Borough have struggled with banning the sale, use, and possession of alcohol, and the issue of whether a community will become 'dry' or stay 'wet' is constantly being brought before local voters." For additional detail on alcohol restrictions and their effects see Goldsmith et al. (2004).

- Ethnically, more than 70% of the NSB population is all or partially Iñupiat. The NSB accounts for approximately 4.6% of the Alaska Native population of the State (Goldsmith et al., 2004). As shown in Table 2.15-1, there are significant ethnicity differences among the NSB villages; Barrow's population is approximately 64% Iñupiat, whereas this percentage is consistently higher in the seven smaller villages.[6] For comparison, the percentages of American Indian and Alaska Native persons in Alaska and the total U.S. are 15.6% and 0.9%, respectively (http://quickfacts.census.gov/qfd/states/02000.html).
- For the most part, communities in the NSB have younger populations than the U.S. as a whole. For example, according to 2000 Census estimates, the median ages of residents of Barrow, Kaktovik, and Nuiqsut were 28.8, 32.1, and 23.8 years of age, respectively. Median ages of all Alaskan residents and all U.S. residents were 32.4 and 35.3 years of age, respectively.[7] Goldsmith et al. (2004) show that Alaska Natives are a young population compared with other Alaskans and other Americans.
- Median household incomes for Barrow, Kaktovik, and Nuiqsut were $67,097, $55,625, and $48,036, respectively — reflecting enhanced earning opportunities in Barrow compared to the other two communities. Corresponding figures for Alaska and the United States were $51,571 and $41,449, respectively (http://quickfacts.census.gov/qfs/states/02000.html). These figures need to be interpreted with care, however, as costs of living are higher in the NSB than in the major cities of Alaska or the other states (see e.g., Goldsmith et al., 2004).
- Table 2.15-1 provides 2000 Census data on the percentage of housing units lacking complete plumbing facilities, kitchen facilities, and telephone service for the NSB communities. These percentages are greater than corresponding percentages for the rest of the United States, which reflects the remoteness of the region and the cost and logistical difficulties of providing certain services in the Arctic.

2.15.2.2 Social Organization and Cultural Values

The Liberty FEIS (USDOI, MMS, 2002) provides an in-depth discussion of the nature of Iñupiat life. Key points are discussed below.

Kinship is the foundation for social organization in Iñupiat communities and plays an important role in all aspects of Iñupiat life. Iñupiat households were historically comprised of large extended families and were part of a larger community kinship unit. An Iñupiat household on the North Slope may contain a single individual or group of individuals who are related by marriage or ancestry. Iñupiat households generally depend on the regular involvement of extended family members in providing economic support. Iñupiat social organization includes not only household and family kinship ties, but a larger social network of friends and kin. These networks are linked through overlapping memberships and are involved in the organization of formal and informal subsistence groups. Iñupiat social networks determine how subsistence resources are harvested, distributed, and consumed. Sharing is a regular and expected part of

[6] As noted in USDOI, MMS (2002), the ethnicity of Barrow has changed in recent years: "In 1970 the Iñupiat population of Barrow represented 91% of the total population…By 1990, Iñupiat representation had dropped to 63.9%."

[7] U.S. Department of Commerce, U.S. Census Bureau, 2001. *Age: 2000, Census in Brief.*

maintaining strong kinship bonds, and a generous person is regarded with esteem in the community.

Traditional Iñupiat cultural values focus on a close relationship to the land, natural resources, the supernatural, and the community, its needs, and its support of individuals. Historically and traditionally, survival in the Arctic centered on the pursuit of subsistence resources and the knowledge needed to find, harvest, process, store, and distribute the harvest. Iñupiat culture depends on the intergenerational transmission of traditional knowledge and beliefs about subsistence resources including observations of game behavior, how to use those observations to successfully locate and harvest game, and how hunters and their families should behave to ensure successful future harvests. Despite recent economic, technological, and social changes in the region, subsistence remains an essential and vital part of Iñupiat life and provides the basis for cultural values and social organization. The process of obtaining, refining, and passing on subsistence skill is inextricably linked to the Iñupiat culture, which is based on interdependent family groups and a tradition of sharing harvested resources. The majority of North Slope residents self-identify as subsistence hunters and harvesters, and they continue to participate in subsistence activities throughout the year.

Subsistence activities play an important role in defining Iñupiat cultural values such as social organization, cooperation and sharing, and the formation of kinship ties (USDOI, MMS, 2002). Cultural values are exemplified by bowhead whale hunting, which has been a central part of Iñupiat culture for at least 1,000 to 1,500 years. Bowhead whale hunting remains the center of Iñupiat spiritual and emotional life; it embodies the values of sharing, association, leadership, kinship, arctic survival, and hunting prowess; and it is at the core of Iñupiat cultural identity. The whale hunt encompasses key Iñupiat values and provides the basis for social organization in many Iñupiat communities (Galginaitis and Funk, 2004). Individual organization of whaling crews is often an indicator of a larger organizational pattern within the Iñupiat community and often defines social ties and leadership roles (USDOI, MMS, 2002). The whale hunt is a village-wide cooperative event. In addition to the boat crews who participate in yearly whale hunts, most people in the villages are involved in other aspects of support, such as butchering and processing (Richardson and Thomson, 2002). Structured sharing of subsistence resources is evident both within and among communities, forming kinship bonds and social networks between individuals and villages. These relationships are essential to maintaining cultural values and social structure. Disruptions to individual harvest success could potentially affect the Iñupiat system of sharing, a process which is vital to the social structure of Iñupiat communities (USDOI, BLM, 2005).

While Iñupiat lands are important for the harvest areas and resources they provide, they also hold a deeper meaning to the residents of the North Slope communities. Traditionally, areas were named for the extended family groups that inhabited them, and eventually, the Iñupiat divided the area into people of the land (Nunamiut) and people of the coast (Taermiut) (Spencer, 1976 as cited in USDOI, BLM, 2005). For example, some of the people who resettled Nuiqsut identified themselves as Kuukpikmuit, or “people of the Colville River Delta.” Maintaining a connection to this land is a priority for residents in these Iñupiat communities.

2.15.2.3 Institutional Organization of the Communities

The Liberty FEIS (USDOI, MMS, 2002) provides information on organizations operating in or around the North Slope Borough. Key points include:

- The majority of community services in North Slope communities are provided by the NSB, which is also the largest employer of North Slope residents and provides local services such as public safety, public utilities, fire protection, and some public health services. NSB revenues, primarily from oil industry taxation, fund these services. (See section on economics.)
- The Arctic Slope Regional Corporation, which was formed under the Alaska Native Claims Settlement Act, runs a number of subsidiary corporations on the North Slope and throughout Alaska. Most communities also house local governments that provide varying degrees of services to North Slope villages. These include village corporations, Traditional Village Councils, Indian Reorganization Act Councils, and city government. Village corporations are important entities for the local economy (e.g., Ukpeagvik Iñupiat Corporation in Barrow, Kuukpik Corporation in Nuiqsut and Kaktovik Iñupiat Corporation in Kaktovik). The role of Native Corporations is discussed at length in a recent report prepared for MMS (Northern Economics, Inc., 2006).
- Non-governmental organizations include the Alaska Eskimo Whaling Commission, the Iñupiat Community of the Arctic Slope, and the Kuukpikmiut Subsistence Oversight Panel, Inc. These organizations, particularly the former, have recently become more active and visible in regional governance (USDOI, MMS, 2002).

2.15.2.4 Other Ongoing Issues

The Liberty FEIS (USDOI, MMS, 2002) notes that current sociocultural systems are undergoing change and strain. This conclusion is shared in more recent EISs. Previous EISs discussed issues pertaining to changes in employment, increased income, decreased Iñupiaq fluency, and increased crime and substance abuse rates (e.g., USDOI, MMS, 1987, 1990a, 1996, 1998; USDOI, BLM, 1998). Despite relative economic well-being, North Slope residents have come under increased stresses on social well-being as well as cultural integrity and cohesion (USDOI, MMS, 2002; USDOI, BLM, 2004a,b, 2005).

2.15.3 Subsistence and Area Use Patterns

Subsistence is a key element of the Iñupiat lifestyle. The ideology, tradition, and practice of subsistence resource harvest, use, and sharing are crucial underpinnings of Iñupiat society today. The associated systems of rules and practices constitute a body of knowledge that underlies Iñupiat peoples' behavior and defines who they are as a people. Subsistence activities are a key determinant of Iñupiat conceptions of the universe and their role in it. While many Iñupiat people participate in the wage economy, use modern equipment and tools, and wear imported clothing, these new items are incorporated, used, and conceived of in intrinsically Iñupiat ways integral to their culture.

Information on subsistence was summarized in the original Liberty Development Project Environmental Report (LGL, WCC, and Applied Sociocultural Research, 1998) or the Liberty FEIS (USDOI, MMS, 2002). Subsistence has been extensively discussed in more recent EISs and EAs, including the Alpine Satellite Development Plan (USDOI, BLM, 2004); the NE NPR-A Final Amended Integrated Activity Plan (USDOI, BLM, 2005), the Proposed OCS Lease Sales 193 (USDOI, MMS, 2006a), 195 (USDOI, MMS, 2004), and 202 (USDOI, MMS, 2006b; see also USDOI, MMS 2003); the TAPS Right-of-Way Renewal (USDOI, BLM, 2002); and the

National Research Council study of the cumulative effects of oil and gas activities on Alaska's North Slope (NRC, 2003). The material in these publications is incorporated by reference. Key content is summarized below.

2.15.3.1 Subsistence Areas

The Liberty FEIS (USDOI, MMS, 2002) provides a short description of the subsistence areas for Nuiqsut, Kaktovik, and Barrow. These are summarized in the map shown in Figure 2.15-1. (Figure 2.15-2 provides more detail for Nuiqsut.) The Liberty reservoir (also shown in this figure) is near the Nuiqsut and Kaktovik subsistence areas, which are discussed below.

Nuiqsut

Nuiqsut hunters harvest resources over an expansive area of the North Slope. Nuiqsut's subsistence marine-resource harvest area includes the Beaufort Sea from Cape Halkett in the west to Flaxman Island in the east, and up to 30 mi offshore (Figure 2.15-1). Cross Island is the center of Nuiqsut's subsistence bowhead-whale hunting.

Nuiqsut whalers have accompanied Kaktovik whalers when conditions near Cross Island have been extremely unfavorable for whaling (heavy ice). Before oil development at Prudhoe Bay, the onshore area from the Colville River delta in the west were historically important to the Iñupiat for subsistence harvests of caribou, waterfowl, furbearers, fish and polar bears. More recently, safety and security concerns in certain developed areas, including Prudhoe Bay, have placed access limits on Iñupiat subsistence users. Access policies vary among oil field units (see e.g., USACE, 1997).

Kaktovik

Kaktovik is located on Barter Island on the northern edge of the Arctic National Wildlife Refuge. Kaktovik subsistence users use an area of up to 11,400 mi^2 extending along the coast from Demarcation Point to Foggy Island, including the offshore barrier islands, and to the foothills and low passes of the Brooks Range via several river drainages (Pederson, 1990) (Figure 2.15-1). Summer resource harvests tend to take place along the coast and barrier islands, while winter harvests tend to take place inland along river courses such as the Hulahula, Shaviovok, and Sadlerochit rivers (Pederson, 1990).

Barrow

As with other communities adjacent to the planning area, Barrow residents enjoy a diverse subsistence resource base that includes both marine and terrestrial animals (ADCED, 2005). Barrow harvesters' lifetime subsistence-harvest area as documented in Pederson (1979) can be seen in Figure 2.15-1.

2.15.3.2 The Cultural Importance of Subsistence

Subsistence is part of a rural economic system, often termed a mixed, subsistence-market economy, wherein families invest their resources in small-scale, efficient technologies to harvest wild foods (Alaska Department of Fish and Game [ADF&G], 2000). Subsistence resource harvests provide a reliable economic base for domestic family units who have invested in equipment and transportation to conduct these important activities. Subsistence resource harvests support extended families and others through redistribution to elders, co-workers, and other channels. These activities also support collective harvest activities associated with participation in whaling crews, and the cycle of public events based on whaling traditions (Bodenhorn, 2003). In practice, wage employment is a means to support subsistence activities, although the two are mutually interdependent.

Subsistence meets the self-limiting needs of families and small communities, not primarily on commercial market production. Participants in this mixed economy in rural Alaska augment their subsistence production by cash employment. Cash wages provide the means to purchase the equipment, supplies, and fuel used in subsistence activities.

Subsistence activities, particularly bowhead whale hunting, continue to be the basis for Iñupiat culture, values, and tradition (Bodenhorn, 2003). The Iñupiat maintain connections to their traditionally used lands and resources through elder-directed, multigenerational use and re-use of camps, cabins, and areas of importance. The Iñupiat continue to base their social calendar on solitary and cooperative hunting of seasonally available subsistence resources. Subsistence users continue to share their resources through kin-based networks over an even greater area than in the historic period, transporting subsistence foods to relatives in urban Alaska and beyond (Stephen R. Braund & Associates and Institute of Social & Economic Research [SRB&A and ISER], 1993). Elders are valued for their knowledge and insight, and are cared for and respected by their communities. Iñupiat celebrations and festivals are still important local and regional events and some celebrations, previously suppressed or abandoned, are being organized and held again (SRB&A and ISER, 1993). More recent recurring events, including basketball tournaments and the World Eskimo Indian Olympics, function to maintain and enhance contacts between communities and regions.

2.15.3.3 Annual Cycle of Harvest Activities

Each of the NSB villages has a broadly similar annual cycle of harvest activities. Those for Barrow, Kaktovik, and Nuiqsut are given in NRC (2003).

2.15.3.4 Subsistence-Harvest Seasons and Harvest Success Profile

Two major subsistence-resource categories occur on the North Slope: the coastal/marine and the terrestrial/aquatic (USDOI, MMS, 2002). In the coastal/marine group, the food resources harvested are whales, seals, walrus, waterfowl, and fish, while in the terrestrial/aquatic group, the resources sought are caribou, freshwater fish, moose, Dall sheep, grizzly bear, edible roots and berries, and furbearers. Each of the NSB villages has a characteristic subsistence harvest pattern, although there is substantial year-to-year variability. Although subsistence harvests differ from community to community, the resource combination of caribou, bowhead whales, and fish was identified as the primary grouping of resources harvested (USDOI, MMS, 2002).

Specific data on subsistence harvests for Barrow, Kaktovik, and Nuiqsut have been published (Brower and Opie, 1997; USDOI, BLM, 2004a, 2005; USDOI, MMS, 2002, 2003, 2004, 2006a,b; USACE, 1999) and are incorporated by reference. Because Nuiqsut is the closest village to the proposed Liberty Development Project and might be expected to experience greater effects, more detailed data are provided for this community below.

A diverse seasonal abundance of terrestrial mammals, fish, birds, and other resources is available in the Nuiqsut area, where traditional subsistence activities revolved around caribou, marine mammals, and fish, with moose, waterfowl, and furbearers as important supplementary resources. The Colville River is the largest river system on the North Slope and supports the largest overwintering areas for whitefish (Craig, 1987). Nuiqsut is geographically remote from its whaling camp on Cross Island, necessitating a long trip through the barrier islands to West Dock and then due north to whaling camp (Brown, 1979).

The seasonal availability of many important subsistence resources controls the timing of subsistence harvest activities (Table 2.15-2).

ADF&G collected subsistence harvest data for Nuiqsut in 1985 and 1993, selecting 1993 as the most representative year for subsistence harvest data (Tables 2.15-3 and 2.15-4) (ADF&G, 2001). Estimates of Nuiqsut's total annual subsistence harvests in recent years were 160,035 pounds in 1985, 150,196 pounds in 1992, and 267,818 pounds in 1993 (Table 2.15-3). The 1993 harvest of 742 pounds per capita of wild resources represents approximately 2 pounds per day per person in the community. In 1985, fish and land mammals accounted for 86% of Nuiqsut's total subsistence harvest, and marine mammals contributed 8%. In 1993, fish, land mammals, and marine mammals accounted for approximately one-third each (Table 2.15-3). The importance of subsistence to Nuiqsut residents is shown in high participation rates for 1993 in households that use (100%), harvest (90%), try to harvest (94%), and share (98%) subsistence resources (Table 2.15-4).

Nuiqsut landed no bowheads in 1985 or 1994. The community harvested two bowheads in 1992 and three in 1993. In years when bowhead whale, fish, and terrestrial mammal subsistence harvests are successful, such as 1992 and 1993, each of these resources may provide nearly one-third of the subsistence resource harvest (Tables 2.15-3 and 2.15-4 and Figures 2.15-3 and 2.15-4) (Fuller and George, 1999). In 1992, bowhead whales (32%), caribou (22%), and fish (25%) comprised 79% of Nuiqsut's annual subsistence harvest. In 1993, bowhead whales (29%), whitefish (29%), and caribou (31%) comprised 88% of Nuiqsut's annual subsistence harvest in terms of edible pounds (Table 2.15-4 and Figure 2.15-4) (Fuller and George, 1999).

Bowhead Whales: Since completion of the Liberty FEIS (USDOI, MMS, 2002) additional information on bowhead whale harvests and effort has been developed for Nuiqsut.[8] This new information is summarized below.

Even though Nuiqsut is not located on the coast (it is approximately 16 to 17 mi inland and 18 to 33 mi via the river, depending on which channel is taken to the Beaufort Sea), bowhead whales are a major subsistence resource for this community. Bowhead whaling is usually undertaken between late August and early October from Cross Island, with the exact timing depending on ice and weather conditions. Variable ice conditions may extend the season to 2 months or contract it to less than 2 weeks. Nuiqsut whalers use aluminum or fiberglass boats, 18 to 24 ft long, with outboard motors to hunt bowheads in open water in the fall, unlike spring whaling in Barrow where the hunt is staged from the edge of ice leads using skin boats. Nuiqsut residents report that they harvest bowhead whales most frequently within 10 mi of Cross Island, but hunters often travel much farther from the island.

Historically, the entire coastal area from Nuiqsut east to Flaxman Island and the Canning River delta has been used for whaling, but whaling to the west of Cross Island has not been as productive as hunting closer to the island, and whaling too far to the east requires long tows of the whales back to Cross Island for butchering, creating the potential for meat spoilage (IAI, 1990a). The recent Nuiqsut subsistence bowhead whale (aġviq) hunting area is depicted in Figure

[8] Additional whaling harvest information for Barrow can be found in USACE (1999); USDOI, BLM (2004a,b); USDOI, MMS (2003) and for Kaktovik in USDOI, MMS (2003) and USACE (1999).

2.15-5. The general Nuiqsut harvest area for bowhead whales is located off the coast between the Kuparuk and Canning rivers.

Whalers currently travel to Cross Island to conduct fall bowhead whaling. They have also used Pingok and Narwhal islands as bases and may still have structures on Narwhal Island. Cross Island has cabins for the crews to stay in and equipment for hauling up and butchering the whales. Nuiqsut hunters typically travel out either the Nigliq or the main Colville channel of the Colville River delta (depending on water levels) and travel along the coast inside or just outside the barrier islands. Depending on conditions, whalers usually stop at West Dock for coffee before heading due north for Cross Island. In the past, work groups may start fishing and hunting other species to support the whalers after setting up camp (USDOI, BLM, 2004a), but in the last several years most of the whalers' energy has been directed towards whaling (Galginaitis and Funk, 2003a,b, 2004, 2005a; Galginaitis, 2005). A successful whale harvest may contribute up to a third of Nuiqsut's entire subsistence harvest by weight for all resources. The meat and muktuk are shared with other rural Alaskan communities and cities, contributing a valued identity food to Iñupiat who reside away from the North Slope.

A summary of whale harvest by Nuiqsut crews is presented in Table 2.15-5. Nuiqsut whalers attribute at least part of their relative lack of success in the 1970s and 1980s to interference from oil and gas exploration, as well as poor weather and ice conditions in some years, and a difficult logistical situation. These factors are also evident in the 3 years with the greatest incidence of "struck and lost" whales (1989-1991 or 1992). Once Cross Island was established as a logistical center for Nuiqsut whaling and Nuiqsut whalers gained experience there, harvest success became more regular. Cross Island is a low, sandy barrier island with a raised area built from gravel for past oil and gas exploratory drilling. Cross Island is about 3 mi long and 450 ft wide, and is constantly changing due to erosion and redeposition.

Summary characteristics for the 2001-2004 whaling seasons are presented in Table 2.15-6 (Galginaitis and Funk 2003a,b, 2004, 2005; Galginaitis 2005b). Additional information is provided in the Lease Sale 202 EA (USDOI, MMS, 2006b).

Figure 2.15-5 displays Global Positioning System (GPS) tracks for most scouting activity for Nuiqsut whalers for 2001, 2002, and 2003 by year. The density of the tracks indicates that boats typically (but not always) tend to stay close to each other. This reflects the cooperation that Nuiqsut whalers generally display. The similarities from one whaling season to the next in terms of number of crews and boats, length of season, days of scouting, and harvest are fairly high.

Caribou and Caribou Use Areas: Because oil development is associated with onshore pipelines, roads, and production facilities, it is important to consider terrestrial as well as marine subsistence resources. Nuiqsut hunters harvest several large land mammals, including caribou and moose. Caribou may be the most preferred land mammal in Nuiqsut's diet, and during periods of high availability, they provide a source of fresh meat throughout the year. Subsistence caribou harvest data are shown in Table 2.15-4 (ADF&G, 2001; Brower and Hepa, 1998). In 1985, Nuiqsut hunters harvested an estimated 513 caribou, providing approximately 60,000 edible pounds of meat or 38% of the total subsistence harvest (ADF&G, 2001). Fuller and George (1999) estimated that 278 caribou were harvested in 1992. A 1993 ADF&G subsistence study estimated a harvest of 672 caribou, providing approximately 82,000 edible pounds of meat or 31% of the total subsistence harvest (ADF&G, 2001). In 1993, 74% of Nuiqsut's households harvested caribou, 98% used caribou, 79% shared caribou with other households, and 79% received caribou shares (ADF&G, 2001).

A subsistence harvest survey covering the period from July 1994 to June 1995 reported that 258 caribou were harvested by Nuiqsut hunters, or 58% of the total subsistence harvest in edible pounds (Brower and Hepa, 1998) (Table 2.15-4). Brower and Hepa (1998) note that this was a relatively low number of caribou harvested compared to reported harvests for earlier years, and that no bowheads were taken that year. Subsistence harvest data are variable and it is difficult to pinpoint "assignable causes" given this variability. Explanations offered by local hunters for the decreased harvest were: (1) the need to travel longer distances to harvest caribou than in the past, (2) the increasing numbers of musk ox that hunters believe keep caribou away from traditional hunting areas, (3) restricted access to traditional subsistence hunting areas due to oil exploration and development in these areas, and (4) disruption of caribou migration into traditional Nuiqsut harvest areas (Brower and Opie, 1997; Brower and Hepa, 1998).

Geographic and seasonal variation in caribou harvests are depicted in the recent Alpine Satellite Development Plan (ASDP) EIS (USDOI, BLM, 2004a), which illustrates the intensity of harvest effort for caribou for numerous locations used by Iñupiat subsistence hunters. Harvest areas are often associated with TLUI sites, cabins, camps, and Native allotments that often have harvest locations for other species nearby. These harvest locations may be used in winter (October through May), summer (defined as the open water period, including June through September), or both, and they may be accessed by foot, boat, all-terrain vehicle and snowmachine.

Fish and Fish Use Areas: Nuiqsut has the largest documented subsistence fish harvest on the Beaufort Sea coast (Moulton, 1997; Moulton, Field and Brotherton, 1986). Fish provide the most edible pounds per capita of any subsistence resource harvested by Nuiqsut (Table 2.15-3). Fish, a traditional staple of both coastal and terrestrial Iñupiat, may vary in numbers seasonally and from year to year, but normally provide a substantive contribution to subsistence resource harvests. Subsistence harvests of fish are not subject to seasonal limitations under federal fisheries management, and no permit is required for rural harvesters.

Nuiqsut resource users have a long history of subsistence fishing in the Colville River and its tributaries from the Colville River delta to the confluence with the Ninuluk Creek, the Nigliq Channel, and nearby Fish and Judy creeks and the innumerable lakes in the region. Nuiqsut fishermen also use coastal areas east to the Kuparuk River and fish around several barrier islands, including Thetis and Cross islands. Families set nets near Nuiqsut in the Nigliq Channel when time, transportation needs, or funds do not permit longer trips from town, particularly during the school and work year.

Figures 2.15-6 and 2.15-7, derived from Moulton (2002), show the highly variable nature of the subsistence fish harvest in the Colville River delta and Nigliq areas. Fishing effort ranged by area from 19 to 1,407 net-days, although there is no clear correspondence between the harvest and harvest effort, because low efforts brought more fish as in 1993, while high efforts as in 2002 resulted in few fish harvested even considering the reduced number of sites sampled. As shown in the Moulton data, the arctic cisco harvest at the five monitored set-net harvest sites in that study range from a 1993 peak of nearly 47,000 to a 1988 low of approximately 6,100, nearly one-eighth the number of the peak. This variability demonstrates the importance of having alternative species and harvest strategies available should poor fish harvests coincide with reduced terrestrial or marine mammal harvests.

Seals and Seal Use Areas: Seals are hunted nearly year-round (Table 2.15-2), but the majority of the seal harvest occurs during the open-water season. In the spring, seals may be hunted once the landfast ice goes out. Present day sealing is most commonly done at the mouth of the Colville River when it begins flooding after ice breakup in June. Seal meat is eaten, but the dietary importance of seals comes primarily from seal oil, which is served with almost every meal that includes subsistence foods. Seal oil is also used as a preservative for meats, greens, and berries. Seal meat and oil are traded to residents of Anaktuvuk Pass for dried caribou and other products. Seal skins are important in the manufacture of clothing and, because of their beauty, spotted seal skins often are preferred for making boots, slippers, mitts, and parka trim. In practice, however, ringed seal skins are used more often in the making of clothing because the harvest of this species is more abundant. Seal skins are used for handicrafts and other articles, are bartered, or are sold (USDOI, BLM, 2004a).

Ringed (natchiq), spotted (qasigiaq), and bearded (ugruk) seals are important subsistence resources for Nuiqsut hunters. In April and May, hunters ride out to Harrison Bay on snow machines and look for breathing holes, cracks in the ice and open water where seals might surface to breathe. By the second week in June, open waters on the Colville River and much of Harrison Bay allow hunters to take boats out on a route locally called “around the world,” following the Nigliq Channel to Harrison Bay, west to Atigaru Point, then along the ice edge out as far as 28 miles, then to Thetis Island (Amauliqtuq), east to Oliktok Point, then back south through the main channel of the Colville River.

Polar Bears: The harvest of polar bears (nanuq) by Nuiqsut hunters begins in mid-September and extends into late winter. Polar bear meat is sometimes eaten, although only limited harvest data are available. The NE NPR-A Final Amended IAP/EIS (USDOI, BLM, 2004b) notes: “Nuiqsut residents have indicated that polar bears are not an important subsistence resource for the community and if taken would be an incidental harvest.”

Beluga Whales: Nuiqsut residents indicate that beluga whales are not important to the subsistence cycle of the community, although some sources have mentioned beluga whales being taken incidentally during the bowhead harvest (USDOI, BLM, 1998).

Walrus: ADF&G subsistence survey data indicate that two walrus were harvested in the 1985/1986 harvest season, but no new walrus data for the community have been gathered since then (ADF&G, 2001). Walrus are probably taken incidentally during seal hunting (NSB, 1998). During the 2004 whaling season, walrus were seen (and heard) on Cross Island for the first time in anyone’s memory.

Moose and Moose Use Areas: Moose (tuttuvak) are normally harvested by boat in August upriver from Nuiqsut on the Colville, Chandler and Itkillik rivers, but the timing of harvest varies depending on hunting seasonal regulations. Local residents have indicated that the weather is not suited for moose hunting in September due to winds and fall whaling occupies much of the community during the month of September.

Harvest data for moose are indicated in Table 2.15-4. In 1985, hunters reported a harvest of 13 moose (ADF&G, 2001). In 1993, nine moose were reported harvested by surveyed subsistence households (ADF&G, 2001, Brower and Hepa, 1998). A subsistence-harvest survey conducted by the NSB DWM for the period from July 1994 to June 1995 reported five moose harvested or 5% of the total edible pounds harvested that season (Brower and Hepa, 1998).

Moose are hunted from the Colville River Delta area upstream to Ninuluk Creek, up the drainages of the Itkillik River and Fish and Judy creeks, and up some side streams off the Colville River. One hunter mentioned going almost to the Killik River confluence looking for moose, while several others reported Fish and Judy creeks, the Chandler and Anaktuvuk river confluences, several side streams and channels of the Colville River and the Itkillik River area as prime moose hunting areas (USDOI, BLM, 2004a). Although relatively small numbers of moose are harvested, they are a valued component of the subsistence harvest in Nuiqsut, and hunters spend considerable effort in their pursuit. Moose offer a large amount of meat per animal harvested because of their relatively large size compared to other terrestrial mammal subsistence resources. Moose, when harvested, are very commonly shared with the rest of the community at large.

Waterfowl and Waterfowl Use Areas: The most important species of waterfowl for Nuiqsut hunters are the Canada and white-fronted goose and brant; eiders are also harvested.

The only upland bird hunted extensively is the ptarmigan (ADF&G, 2001; Brower and Hepa, 1998). Recent data indicate the subsistence bird harvest provided 5% of the total subsistence harvest (Brower and Hepa, 1998) (Table 2.15-3). Waterfowl hunting occurs mostly in the spring, beginning in May, and continues throughout the summer. In the summer and early fall, such hunting usually occurs as an adjunct to other subsistence activities, such as checking fish nets.

Waterfowl harvested by the Iñupiat of Nuiqsut occupy two habitats in the greater Nuiqsut area. Ducks, geese, and brant molt and nest in the wet tundra to the north of Nuiqsut. Eiders nest on the sandy areas of the Colville River Delta and the barrier islands, molting after their arrival. Both groups of waterfowl raise their young in the area until fall, when they migrate south. Nuiqsut hunters harvest waterfowl in May and June during the migration using snow machines and boats. The hunters harvest the migrating birds from snow blinds built to the south, near Sentinel Hill and Ocean Point or at Fish Creek. Once the river breaks up, hunters look for birds by boat, and start to look for eiders in the delta and in Harrison Bay at the ice edge as summer approaches. Hunters end the waterfowl harvest when the birds are on their nests (USDOI, BLM, 2004a).

The NSB collected waterfowl harvest data for 1994-1995, 2000 and 2001 (Brower and Hepa 1998; USDOI, BLM, 2004a). Goose hunting areas include the Fish and Judy creeks area, the Colville River Delta, the area around Nuiqsut extending to the Fish and Judy creeks area, along the Colville River up to Sentinel Hill, the area around Ocean Point, and along the Itkillik River. As shown in the ASDP EIS (USDOI, BLM, 2004a), more than three-quarters of geese, including white fronted and Canada, were harvested in the Fish and Judy creeks area and the Colville River Delta. Most of the remaining geese were harvested up the Colville River from Ocean Point to Umiraq. Interviewed subsistence users in Nuiqsut related that the harvest sequence for migratory waterfowl proceeds from the south, and that those harvested upriver are the first birds of the season (USDOI, BLM, 2004a).

Furbearers: As discussed in the ASDP EIS, Nuiqsut fur hunters described three species of terrestrial furbearers as being especially important: wolf (amġuq), wolverine (qavvik), and fox (USDOI, BLM, 2004a). Once there is adequate snow in the winter for snowmachine travel, generally by November, hunters begin the pursuit of wolf and wolverine in earnest. The harvest area for furbearers extends from the eastern edge of the Colville River Delta along the coast almost to Admiralty Bay and then south along the Ikpikpuk River to the Colville River and eastward to the Toolik River, north and crossing the Dalton Highway to Franklin Bluffs, and west and north back to the Colville River Delta.

Berries and Plants: Berries (akpik) of numerous varieties are harvested in the Fish and Judy creeks area, and along the Colville, Chandler, Anaktuvuk, and Itkillik rivers. Plants such as masu (Eskimo potato), medicinal plants, and greens are harvested when families are out at camp hunting and fishing in the late summer. Berry picking is still considered a job primarily for women and children, but men pick berries on occasion. Berry varieties include salmonberries (aqpik) and blueberries (asiaq). Berries are primarily harvested in August, when many families are out moose hunting up the creeks and rivers of the area, and often they will pick buckets or large freezer bags full of berries. These are taken home and stored in ice cellars or freezers for later use in agutuq, or Eskimo ice cream, made from whipped seal or other fat, sugar, plants, and berries.

2.15.4 Land Ownership

The land and waters in the project area are owned by either the State or Federal Government; there is no private land.

2.15.5 Environmental Justice

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (59 *Federal Register* 7629), requires each Federal agency to make the consideration of environmental justice part of its mission. Section 1-101 states:

> "To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions…"

Other portions of this order require agencies to develop strategies to address environmental justice (1-103), research, data collection, and analysis (Section 3-3), and, of particular relevance to this analysis, requirements to collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence (4-401). EISs drafted after the effective date of this order contain sections on environmental justice.

In particular, Alaska Iñupiat Natives, a recognized minority, are the predominant residents of the North Slope Borough. Therefore, it is important to address whether or not the environmental impacts of the proposed Liberty project will have disproportionately high and adverse impacts on North Slope Borough residents.

3. ENVIRONMENTAL CONSEQUENCES

This section discusses the environmental consequences of the proposed Liberty Project and alternatives. Consequences of the proposed project are discussed in terms of expansion of the Endicott Satellite Drilling Island (SDI), onshore construction, and drilling and oil productions. Separate sections are provided on the impacts of oil spills, the effects of alternatives, and the cumulative effects of the project.

3.1 SDI EXPANSION

3.1.1 Air Quality

The ambient air pollutant impacts due to construction of the SDI expansion are expected to be within the limits of the National and Alaska Ambient Air Quality Standards (AAQS). Pollutants will be emitted from temporary operations and/or mobile equipment such as diesel-fired construction equipment, and temporary electrical generators. Pollutant emissions from marine vessels are expected to be negligible because marine traffic, in general, will not be used to support construction of the SDI expansion. Fugitive particulate-matter emissions will result from gravel mining operations and gravel placement operations, but will be minimized through fugitive-dust abatement techniques such as road watering. As part of the air permitting process, the Alaska Department of Environmental Conservation (ADEC) will review the construction equipment inventory and the construction plans to ensure compliance with the National and Alaska AAQS. A dispersion modeling analysis of project emissions will be included in the air permit application and will demonstrate National and Alaska AAQS compliance. An ambient-air-quality monitoring station has been in operation on the SDI since February 2007 to provide data to support air quality permitting.

3.1.2 Sediment Suspension and Transport

Expansion of the SDI requires the placement of approximately 860,000 yd^3 of gravel fill. The material will be placed progressively outward from the existing pad perimeter. The pad expansion footprint is approximately 704 by 1,394 ft**.** The gravel fill and slope protection will be placed through the ice during the winter, commencing after ice road construction and concluding prior to breakup.

It is anticipated that the placement of gravel fill will increase suspended sediment concentrations in the marine waters in the immediate vicinity of the construction site and create a turbidity plume that extends to nearby areas. The total suspended solids (TSS) concentrations and the nature of the plume depend on the properties of the gravel fill, water depth at the site, current speed, and current direction (BPXA, 1998).

Measurements of TSS concentrations attributable to gravel island construction are limited. During construction of Endeavor Island in the summer of 1980, suspended sediment concentrations were found to increase by about 70 mg/l above ambient levels within 30 m of the island and to increase by about 10 mg/l at a distance 1,830 m from the site (NORTEC, 1981; as reported in BPXA, 1998). Results from turbidity monitoring performed in summer 2003 during replenishment of the Northstar Island gravel berm indicate that turbidity increased approximately 20% on average relative to the baseline condition in the near field (Coastal Frontiers, 2003b). The associated plume rarely was detectable beyond 500 m from the site and typically dissipated within 2 hours.

During the winter construction of BF-37, a gravel island located about 3 km north of the Endicott Main Production Island (MPI), the concentration of suspended sediments near the island did not increase significantly (Toimil and England, 1982; Toimil and Dunton, 1983 and 1984; as reported in BPXA, 1998). Suspended sediment concentrations were measured during the first 7 days after fill placement commenced at radial distances of 140 and 170 m from the island. The maximum TSS concentration increase relative to ambient conditions was 3 mg/l. It was speculated that the sediment plume was limited by low under-ice current speeds, ice bonding of fine-grained material, and formation of silt/ice agglomerates.

Suspended sediment concentrations and turbidity plume characteristics were estimated previously for the original Liberty Island concept (Ban et al., 1999). The methods and assumptions used for this analysis are employed here to assess the worst-case impact of gravel-fill placement operations for expansion of the SDI pad. The key assumptions are given below:

- Gravel placement rate: 15,500 m^3/day
- Fines content in gravel fill: 10%
- % resuspension of fines: 12%
- Particle size of fines fraction: 5 to 100 microns
- Density of gravel fill: 2600 kg/m^3
- Density of fine particles: 1784 kg/m^3
- Under-ice current speed: 2 cm/sec

Applying the above assumptions for the worst-case scenario yields a release of fine-grained material to the marine environment of 186 m^3/day. This equates to a mass flux (M) of 5.6 kg/sec. The resulting concentration of suspended sediments in the immediate vicinity of the site is estimated by the following relationship:

$$C_o = M/Q \qquad (1)$$

where:

C_o = concentration of suspended sediments
M = mass flux of suspended fines (5.6 kg/sec, derived above)
Q = flow rate (Eq. 2)

The flow rate is defined by the following relationship:

$$Q = vDH \qquad (2)$$

where:

v = under-ice current speed (2 cm/sec)
D = width of pad expansion (215 m)
H = water depth (≈3 m, as discussed in Section 2.3.2)

Using the variables given above and applying Equations 1 and 2 yield TSS concentrations at the immediate project site of about 430 mg/l for the worst-case scenario. These values are higher than those estimated for the Liberty Island concept due to the shallower water depths at the SDI site. Although the estimated turbidity is high by winter standards, the concentrations are only slightly higher than the range previously reported for Foggy Island Bay during the summer (Section 2.5.3). The increased turbidity is anticipated to be a short-lived impact, with most of the suspended material settling out within or adjacent to the footprint of the pad expansion.

The extent of the turbidity plume can be estimated by applying Stokes' Law (Equation 3 below) to calculate the fall velocity of the suspended particles and then determining the travel distance required for those particles to reach the seafloor as a function of the water column below the ice canopy and the current speed (Equation 4). Stokes' Law is given below:

$$w = g\, d^2\, (\rho_p - \rho_{sw})/18\mu \qquad (3)$$

where:

w = particle fall velocity
g = acceleration due to gravity (9.8 m/sec^2)
d = particle diameter (5 to 100 microns)
ρ_p = density of particle (1,784 kg m^3)
ρ_{sw} = density of seawater (1,026 kg/m^3)
μ = dynamic viscosity of seawater (0.0014 kg/m^3)

Applying Stokes' Law for particle sizes between 5 and 100 microns yields fall velocities ranging from 0.00074 cm/sec to 0.29508 cm/sec.

The suspended particles will be transported under the ice canopy by currents until they settle to the seafloor. Assuming gravel placement operations commence on January 1 when the average ice thickness is 0.9 m (Section 2.4.7), the height of the water column below the ice would be approximately 2.1 m. The travel distance for a given particle size is given by the following relationship:

$$D = v\, H_{under\text{-}ice} / w \qquad (4)$$

where:

D = travel distance
v = under-ice current speed (2.0 cm/sec)
H = height of the water column below the ice (2.1 m)
w = particle fall velocity (given by Stokes' Law)

The predicted travel distance for various particle sizes is shown in Table 3.1-1. Fine sands (>75 µm) will settle out of suspension almost immediately, migrating only about 20 m before reaching the seafloor. Silts (75 to 5 µm) are predicted to settle between 25 and 5,700 m from the project site. Finer particles (clays and colloids) would travel greater distances; however, these fractions are not anticipated in significant quantities.

A large portion of the suspended material will settle to the seafloor within or adjacent to the footprint of the SDI pad expansion. The finer fractions (<50 µm) are expected to be transported as a plume to either the northwest or southwest by the prevailing currents. The predominant under-ice current direction is westerly/northwesterly (occurring 60 to 70% of the time on average). Under these conditions, the turbidity plume is predicted to migrate along the Endicott

Causeway between the SDI and the MPI. Particles greater than 5 μm likely will be deposited on the seafloor within 6 km of the project site in a narrow band near the junction of the seafloor and the landfast ice (1- to 2-m water depth). During the more infrequent periods of easterly flow, the plume is anticipated to migrate southeasterly along the bathymetric contours.

The plume migration estimates are believed to be conservative in that:

- Gravel placement operations are anticipated to be conducted when the ice thickness is greater than 0.9 m and the corresponding water column height under the ice canopy is less than the assumed 2.1 m;
- The turbidity plume will be migrating toward shallower waters under the predominate northwest currents;
- The speed of easterly directed currents may be less than the estimated 2 cm/sec due to sheltering effects of the Endicott Causeway; and
- The sheet pile wall will be installed simultaneously with gravel placement in winter, thus reducing plume migration.

Minor reshaping of the south and west pad sideslopes is anticipated shortly after breakup or during the open-water season. This activity may result in a slight increase in TSS concentrations for a short period of time. The naturally occurring turbidity levels are generally high during this time of the year due to river discharge and wave-induced suspension of fine material. Under the predominantly easterly winds, the turbidity plume associated with this activity is anticipated to migrate northwest along the Endicott Causeway. The shelter provided by the causeway would limit the ability for the plume to migrate towards the Boulder Patch during westerly wind events. During periods of high river discharge, the turbidity plume will be entrained with the river plume and dispersed into Foggy Island Bay.

3.1.3 Oceanography

The proposed SDI pad expansion is not expected to have any significant impact on regional oceanography during the construction period. Minimal localized and short-term impacts can be anticipated.

The primary impacts are expected to occur at the time of river breakup, when the overflood may be partially diverted by the ice road. The expanded SDI pad footprint is anticipated to have a limited and localized influence on the river overflood. There also may be an increased propensity for strudel scouring at the project site due to removal of the ice sheet around the pad perimeter during construction. Currents in the immediate vicinity of the pad expansion will be affected during the breakup and open-water periods, but the current patterns and velocities are not expected to be substantially different from those at the existing SDI facility.

3.1.4 Marine Water Quality

As discussed in Section 3.1.2, TSS concentrations in the immediate vicinity of the project site may increase by up to 430 mg/l during gravel placement operations. While the estimated turbidity is high by winter standards, the concentrations are only slightly greater than the range previously reported for Foggy Island Bay during the summer. A large portion of the suspended material is predicted to settle within or adjacent to the footprint of the SDI pad expansion. The finer fractions will create a turbidity plume along the Endicott Causeway, likely dissipating within 6 km of the project site. These conditions will exist temporarily when gravel is placed in the water. Because the amount of material placed below water is less than half of the projected gravel fill volume required for the expansion, the increased turbidity should not persist through the entire winter construction period. In addition, the sheet pile wall will be installed in the winter, further reducing plume migration. These conditions are not anticipated to exceed previously documented TSS concentrations in Foggy Island Bay.

A potential for small equipment spills (oil, diesel fuel, and hydraulic fluid) exists during the construction period. Any spills on the gravel pad or ice surface will be cleaned up immediately. A release to marine waters is unlikely. During the winter, such a spill would be confined within the perimeter of the excavated ice sheet and cleaned up immediately.

3.1.5 Benthic and Boulder Patch Communities

The SDI expansion will cover a bottom area of approximately 20 acres. Although this represents permanently lost habitat to benthic invertebrates, the area is miniscule compared to the total habitat available in coastal waters. The habitat loss would have no measurable effect on lower trophic organisms. The SDI extension is sited entirely outside of the Boulder Patch and no habitat will be lost directly.

The SDI expansion is located near the perimeter of the Boulder Patch community, which begins a short distance north and east of the Endicott Causeway. A large segment of the Liberty oil reserves lay beneath the Boulder Patch. Movement of the Liberty development to SDI from its original offshore site directly in the Boulder Patch is facilitated by the use of uERD technology. The technology enables subterranean access to oil and gas reserves within several lateral miles of the wellhead. Moving the primary well site outside the Boulder Patch greatly reduces the risk of impact to this unique community.

3.1.5.1 Marine Access

Significant marine access is not expected to be required to support Liberty construction and operation. A sealift by barge is planned to transport the ***LoSal*™** EOR process and power generation modules to the existing MPI dock. A dock will be provided at the SDI as a contingency for providing limited marine access in support of rig mobilization and demobilization.

The two predominant ways in which barge traffic could adversely affect biological communities of the Boulder Patch are through physical disturbance associated with propeller wash, and from barge and tug discharges (see below). Water depths in the Boulder Patch range from 3 to 9 m. Most of the Boulder Patch consists of rocks and gravel less than 20 mm in size. Large rocks are scarce but may reach diameters of 1 m. At these depths, excessive propeller downwash could disturb epilithic fauna and cause the braking or detachment of kelp. Barge traffic will be routed around Boulder Patch to mitigate the potential for physical damage.

3.1.5.2 Refined-Oil Spills

Small refined-oil spills (diesel fuel, engine lube, fuel oil, gasoline, and grease) can occur whenever machinery is in use. Small refined-oil discharges from boat traffic or operations on the SDI would not mix deep enough in the water column to affect the Boulder Patch and other deep-water benthos. Discharges in shallow docking areas or in the immediate vicinity of the SDI could contaminate nearby benthos, but the effect would be highly localized and temporary. Overall, small oil discharges from boat traffic and construction activities are not expected to have measurable effects on benthic biota or the biota of the Boulder Patch.

3.1.5.3 Water Quality (Suspended Sediments)

A detailed discussion of the potential effects of turbidity and sediment settlement on the Boulder Patch community can be found in the Liberty FEIS (USDOI, MMS, 2002). Expansion of the SDI will increase suspended sediment concentrations in the marine waters in the immediate vicinity of the construction site and create a turbidity plume that extends to nearby areas. The turbidity is expected to be high by winter standards but well within the range reported for Foggy Island Bay during summer. The increased turbidity is expected to be a short-lived impact, with most of the suspended material settling out immediately adjacent to the SDI expansion area (see Section 3.1.2). It is projected that large grain (≥15 microns) suspended sediments will settle to the seafloor within 300 m of the SDI and will not reach the Boulder Patch. Finer particles 5 microns in size will deposited on the seafloor within 3 km of the site. Any settlement within the Boulder Patch would be temporary. Settlement occurs on the seafloor and kelp beds naturally during late summer and early fall, but late fall storms regularly resuspend the sediments and transport it away from the Boulder Patch (Dunton and Schonberg, 2000). Because water currents are so slow during winter, sediments from the SDI expansion could settle on kelp or could freeze into the ice cover, thereby reducing light penetration for kelp growth under the ice during spring. The effect would again be temporary, being limited to the initial winter of construction.

Overall, increased turbidity and sediment is not expected to have a meaningful effect on the Boulder Patch community. The general benthos could be impacted in the immediate vicinity of the SDI, but the area affected would be insignificant relative to the size of the overall nearshore benthic community. Any effect would be temporary.

3.1.5.4 Oceanography

The proposed SDI expansion is not expected to have any impact on regional oceanography. Currents in the immediate vicinity of the pad expansion will be affected during the open-water period but will not differ much from patterns associated with the present SDI pad. No effect on either Boulder Patch or the overall benthic community is expected.

3.1.6 Fish and Essential Fish Habitat

3.1.6.1 Noise/Activity Disturbance

The expansion of the SDI will occur during winter when most of the surrounding waters will be frozen to the bottom. Fish presence in the immediate vicinity will be nominal and restricted to marine species in waters deeper than 6 ft beginning seaward of the SDI. Activities and noise associated with the expansion will have no meaningful effect on fish populations.

Excluding the sealift of the ***LoSal*™** modules, other prefabricated facilities are currently planned to be trucked to the development site along existing roads and bridges. Construction noise from facility installation on the expanded SDI during summer may disturb fish in the immediate vicinity of the activity. Because marine fishes are widely distributed in their range and largely unrestricted in their movements, noise and activity associated with the SDI expansion would not have a measurable effect on marine populations. Adult and sub-adult anadromous and amphidromous fishes range far up and down the coast, and any noise disturbance would be localized and unlikely to interfere with coastal distributions. If construction noises were stressful, fish would merely avoid them. Juvenile broad whitefish, least cisco, and arctic cisco are more restricted to the Sagavanirktok Delta in summer, but there is sufficient habitat for them to avoid noise in the immediate area of the SDI. Overall, noise and activities associated with installation of facilities are not likely to have any meaningful effect on local fish populations.

3.1.6.2 Habitat Loss

The SDI extension will cover a bottom area of approximately 20 acres. This represents permanently lost habitat to fish, but the area is a small fraction of the total habitat available in coastal waters. The habitat loss should have no meaningful effect on local fish populations. Infrastructure support such as causeways, bridges, permanent roadways, and culverts are already in place in support of the Endicott facilities and, excluding a possible upgrade to the existing West Sagavanirktok River Bridge or construction of a new bridge, no additions are planned. No additional fish habitat in the project area will be affected, and no Essential Fish Habitat (EFH) will be affected.

3.1.6.3 Marine Access

Significant marine access is not required to support Liberty construction and operation. A sealift by barge is planned to transport the ***LoSal*™** EOR process and power generation modules to the existing MPI dock. A dock will be provided at the SDI as a contingency for providing marine access in support of rig mobilization and demobilization.

The limited sealift-barge traffic will have no measurable effect on fish. Physical and noise disturbances during approach and docking will be localized and affect only a tiny fraction of the coastal habitat used by fish during summer. If such localized activities are stressful, fish can easily avoid the area. Barge activity will also be temporary.

No EFH will be affected.

3.1.6.4 Refined-Oil Spills

Refined-oil spills associated with machinery operations tend to be quite small and could be cleaned up before reaching surrounding waterbodies. Mandatory safety measures and protocols designed to limit the occurrence and frequency of refined-oil spills are an integral part of industry operations on the North Slope. During winter operations, ice cover would prevent spills from reaching fish habitat. If small spills associated with summer construction work on the SDI were able to leach into surrounding waterbodies, the affected area would be highly localized and would not affect feeding grounds and migratory corridors within the lower Sagavanirktok Delta.

Because they tend to be small in volume, any discharge reaching surrounding waters would affect only a small portion of fish habitat. Small refined-oil spills associated with the SDI expansion are not expected to have any measurable effect on arctic fish populations in the project area, and no EFH will be affected.

3.1.6.5 Water Quality (Suspended Sediments)

Expansion of the SDI will increase suspended sediment concentrations in the marine waters in the immediate vicinity of the construction site and create a turbidity plume that extends to nearby areas. The turbidity is expected to be high by winter standards but well within the range reported for Foggy Island Bay during summer. The increased turbidity is expected to be a short-lived impact and would affect only a tiny portion of the habitat used by marine fish.

3.1.6.6 Oceanography

The proposed SDI expansion is not expected to have any impact on regional oceanography. Currents in the immediate vicinity of the pad expansion will be affected during the open-water period but will not differ much from patterns associated with the present SDI pad. These minor changes in oceanography will have no measurable effects on marine or anadromous fish, and no EFH will be affected.

3.1.7 Marine Mammals

Marine mammals are a large component of the Beaufort Sea ecosystem in the vicinity of the SDI. Three species of seals are native to the region: ringed seal (*Phoca hispida*), spotted seal (*Phoca largha*), and bearded seal (*Erignathus barbatus*). The Pacific walrus (*Odobenus rosmarus divergens*) may occasionally occur in the development area. Beluga whales (*Delphinapterus leucas*) are common offshore during the open-water season. Polar bears (*Ursus maritimus*) inhabit marine environments throughout the year and may use habitats near the project area for denning. Because polar bears have recently been nominated for listing as a threatened species under the Endangered Species Act, discussions of this species are included in the Threatened and Endangered Species sections of this EIA. The bowhead whale (*Balaena mysticetus*) is also listed as endangered under the Endangered Species Act and is addressed in the Threatened and Endangered Species sections.

3.1.7.1 Noise/Activity Disturbance

Noise and activity associated with the SDI expansion will not cause disturbance to beluga whales because the expansion will occur during winter when beluga whales are absent from the area. Activities related to facility installation that occur during the summer are not likely to affect beluga whales because they migrate well offshore from the barrier islands and are not common in the SDI area.

Noise and activities during the SDI expansion could affect seal behavior and distribution in the area, but the extent of disturbance is likely to be minimal. Underwater noise is unlikely to travel more than 2 km because of the rapid attenuation of industrial sounds in shallow waters (Blackwell and Greene, 2001). Blackwell, Greene, and Richardson (2004) reported underwater broadband sound levels from Northstar Island activities during winter reached background levels at distances of 3 to 4 km from the island. In addition, some seals may become habituated to industrial sounds, thus minimizing potential disturbance. Blackwell, Lawson, and Williams (2004) reported that 23 seals showed little to no reaction to industrial noises during 55 hours of observation, and some seals were as close as 46 meters to the island. Two of the 23 seals looked at the island, 10 seals looked at a helicopter, and 1 seal returned to the water from the ice as a helicopter approached. Helicopters would be used during emergency situations only and would not be likely to disturb seals near the SDI. Moulton et al. (2002, 2003, and 2005) reported that limited winter industrial activity at Northstar Island did not appear to significantly affect ringed-seal density in the spring. Williams et al. (2006b) reported no relationship between ringed seal use of subnivean structures and the distance of those structures from Northstar Island. It is unlikely that large numbers of seals would be impacted by noise and activity disturbances during the SDI expansion and facility installation.

3.1.7.2 Small Spills or Leaks

It is unlikely that small spills or leaks of oil, chemicals, or wastewater arising from the Liberty Project at the SDI will impact marine mammals. Such discharges would likely be contained and cleaned up immediately and are unlikely to enter the marine environment.

3.1.7.3 Marine Access

The sealift required to transport Liberty Project facilities has the potential to temporarily displace marine mammals adjacent to the route. Disturbances are most likely to arise when a barge passes near swimming beluga whales, walruses, or seals, or near seals, and walruses hauled out on ice. Underwater noise from vessel traffic was detected up to 27 km from the source by Blackwell and Greene (2006) during monitoring work near Northstar Island, but the radii in which marine mammals would be displaced is likely to be much smaller. Any disturbance to marine mammals from a sealift would be temporary, lasting from 1 minute to 1 hour (USDOI, MMS, 2002). There is the potential for a vessel to strike a marine mammal causing injury or death, but a strike would be very unlikely with currently only one sealift proposed for the project.

3.1.7.4 Loss of Habitat

Expansion of the SDI will increase the current footprint on the seafloor by 20 acres, which will be lost as seafloor habitat for marine mammals. Small numbers of seals might use this area to feed. Frost et al. (2004) reported that ringed-seal densities on landfast ice in the Alaska Beaufort Sea from 1996 to 1999 ranged from 0.57 to 1.14 seals/km^2 and were highest in water depths from 5 to 35 m. Moulton et al. (2002) reported that ringed-seal densities on landfast ice in the Alaskan Beaufort Sea from 1997 to 1999 were 0.39, 0.35, and 0.56 seals/km^2, respectively, with the highest densities occurring in 5 to 15 m of water. Seal densities were significantly lower in shallow water <3 to 5 m (Moulton et al., 2002; Frost et al., 2004). Water depths surrounding the SDI are generally 3 m or less, and it is unlikely that large numbers of seals use this habitat. Based on the larger seal density of 1.14 seals/km^2 in deeper water reported by Frost et al. (2004), habitat that might support approximately 0.10 seals could be lost due to gravel placement for the SDI expansion. Habitat loss for seals and other marine mammals from the SDI expansion is likely to be negligible.

3.1.7.5 Water Quality (Suspended Sediments)

The SDI working surface and seafloor footprint will be expanded from 11 to 31 acres through gravel placement. Suspended sediments resulting from construction activities during gravel placement will increase water turbidity in the area immediately around the expansion.

3.1.7.6 Summer Erosion

The SDI is located in the Sagavanirktok River delta. Large river deltas naturally experience pulses of erosion and turbidity from rain and runoff events. Increased turbidity from SDI expansion is anticipated to be short-lived, and most suspended material is expected to settle to the seafloor within or adjacent to the footprint of the pad expansion (See Section 3.1.2 for greater detail). Erosion from the expansion of the SDI should not be substantial enough to create changes in the water quality that will be likely to affect marine mammals.

3.1.8 Marine and Coastal Birds

Among the marine and coastal birds within the Liberty area, the species most likely to be affected by the development are species that are abundant in the vicinity of the project (snow geese), species with small total population sizes (yellow-billed loon, red-throated loon, jaegers, tundra swan, brant, buff-breasted sandpiper), and species with declining population trends (red-throated loons, long-tailed ducks, dunlin, phalaropes, sandpipers).

3.1.8.1 Noise/Activity Disturbance

Noise from installation of sheetpile slope protection during January to March would not affect migratory birds. Noise from grading and compaction activities and the installation of well pad facilities during July to December would disturb and potentially displace small flocks of molting long-tailed ducks and a few foraging red-throated loons and Pacific loons in the vicinity of the SDI. Nesting common eiders (~16 nests, Figure 2.10-1) and glaucous gulls (~4 nests, Figure 2.10-1) on the exploration pad for Duck Island 1 & 2, located west of the expanded SDI pad, would also be disturbed by noise construction related noises at SDI.

Disturbance could primarily interrupt nesting, foraging and resting behaviors. Disturbance during nesting could lead to nest destruction or abandonment with subsequent death of eggs or young (Johnson, 2000b). Disturbance during foraging would decrease foraging efficiency and increase kleptoparasitism (i.e., stealing of food items) by glaucous gulls, which would negatively affect long-tailed duck, eider, and loon energetics. Disturbance due to gravel pad grading and compactions and installation of well pad facilities would be short-term, limited to one summer, and would involve at most several hundred birds in the vicinity of the SDI; no population-level effects are anticipated.

3.1.8.2 Water Quality (Suspended Sediments)

Erosion of the expanded SDI during the summer would increase turbidity in the vicinity of the expansion. Increased turbidity would hinder capture of prey by marine birds such as long-tailed ducks, common eiders, red-throated loons and Pacific loons, which dive for fish and invertebrate prey. Reduced water quality would be limited and would potentially affect at most several hundred birds in the vicinity of the SDI — no population-level effects are anticipated.

3.1.8.3 Oceanography

The SDI expansion would potentially change water movements and sediment deposition around Duck Island 1 & 2, leading to alteration of the oceanographic processes that have shaped this abandoned exploration pad that is presently used by nesting common eiders and glaucous gulls. The exploration island could either become attached to the expanded SDI, or could be reshaped by an erosion channel between the SDI and the island. In either case, it is possible that access by arctic fox and bear may be enhanced by its proximity to the expanded SDI, thereby making this habitat unsuitable for nesting, as has been observed at the Endicott Causeway (Johnson, 2000b). Should loss of this nesting habitat occur, approximately 16 common eider and 4 glaucous gull nests would be displaced. These birds would likely relocate to nearby suitable nesting habitats, and no population-level effects are anticipated.

3.1.8.4 Bird Strikes

Additional facilities on both the MPI and SDI would lead to an incremental increase in bird strike mortality especially for migrating sea ducks, which fly low and fast along coastal areas during spring and fall migrations. With the exception of the drilling rig, the proposed additional buildings are low-profile, are situated near existing buildings, and would not likely contribute substantially to additional collision mortality. Most mortality would be low numbers (dozens of birds), but large flocks (hundreds of birds) may collide with structures especially during periods of low visibility. The drilling rig, which will be approximately 250 ft tall, will be on the SDI for at least 3 years and may contribute to an increase in bird strikes when present.

BPXA design engineers will consult with the USFWS to examine ways to reduce artificial nesting possibilities. However newly constructed facilities may create nesting habitats for ravens and snow buntings, and foraging perches for ravens. Creation of artificial nesting habitats for ravens have influenced their distribution across the North Slope and may lead to increased predation on tundra-nesting birds in the project vicinity (USFWS, 2003). Additional facilities on the MPI and SDI are not anticipated to significantly increase bird-strike mortality, and no population-level effects are anticipated.

3.1.8.5 Marine Access

Late-summer barge traffic to the MPI and/or SDI would cause short-term displacement of a few molting and foraging long-tailed ducks, common eiders, red-throated loons and Pacific loons; no population-level effects are anticipated.

3.1.8.6 Small Spills or Leaks

Minor spills and leaks of oil, chemicals, or wastewater would primarily affect the quality and abundance of prey species for diving seabirds. However, discharges with small amounts of oil or other contaminants that could reduce water repellency of seabird feathers would add to the thermal stress of molting birds such as long-tailed ducks. A few long-tailed ducks, common eiders, red-throated loons and Pacific loons would be affected; no population-level effects are anticipated. Speed limits also can be imposed during these months to reduce collision potential.

3.1.8.7 Increased Road Traffic

Increased traffic along the Endicott Road would be most intense during installation of well pad facilities, the drilling rig, ***LoSal*™** process plant, pipelines, and drilling operations. Increases in traffic from well pad facility and ***LoSal*™** process plant construction would occur during summer and fall. Increased summer traffic would disturb birds along the Endicott Road, especially if traffic volumes are constant throughout the 24-hour day and occur during the months of July and August. This increased traffic would reduce road-crossing opportunities for birds, lead to collision mortality, and facilitate predation of snow goose and brant broods. Operational levels of traffic on the Endicott Road have not led to distributional changes for brood-rearing snow geese (Johnson, 1998; Johnson, 2000a), and because construction-traffic levels would be short-term increases during two summers, no population-level effects are anticipated.

3.1.9 Terrestrial Mammals

Among the terrestrial mammals that occur in the Liberty area, caribou, muskoxen, grizzly bear, arctic fox, arctic ground squirrels, and lemmings are the species potentially affected by development.

3.1.9.1 Noise/Activity Disturbance

Noise in the outer delta may displace caribou from coastal insect-relief habitats such as mud flats, nearshore islands such as Howe Island, and coastal spits. Prolonged displacement of caribou from these insect-relief habitats is not likely from the intensity and duration of activity proposed, and no population-level impacts are anticipated. Muskoxen are seldom observed in the project area; therefore, very few individuals would be affected, and no population-level impacts are anticipated.

3.1.9.2 Oceanography

Alteration of longshore currents, sediment deposition patterns, or Sagavanirktok Delta circulation patterns can lead to increased sediment deposition around Howe Island or Duck Island, thereby facilitating predator access to these islands and their colonial-nesting snow geese, brant, and glaucous gulls. Easy access across shallow water or ice to these areas with high concentrations of readily accessible forage, eggs, goslings, and adults would have a positive effect on local bears and foxes.

3.1.9.3 Increased Road Traffic

Construction traffic along the Endicott Road would be heaviest during installation of well pad facilities, the drilling rig, and the ***LoSal*™** EOR process plant and drilling operations during summer and fall. Traffic levels of more than 15 vehicles/hour would hinder crossing of the Endicott Road by large groups of caribou, which may exclude them from some coastal insect-relief habitats (Murphy and Lawhead, 2000). Caribou do not usually calve in the Sagavanirktok River delta; therefore, changes in calving-caribou habitat use or distribution due to project construction are not anticipated. Oil field policies give caribou the right-of-way when crossing roads. Large groups of caribou crossing the road may cause traffic delays of up to several hours.

Many caribou in the vicinity of the North Slope oil fields are habituated to typical construction traffic levels. Collision mortality would likely increase with the increasing traffic levels and the increasing size of the Central Arctic Caribou Herd. However, mortality would likely remain low, with no population-level effects anticipated.

Increased traffic would lead to increased collision mortality for arctic ground squirrels and arctic foxes. Grizzly bears and muskoxen rarely occur in the project area and are not likely to be hit by trucks. A few collisions may occur over the life of the project resulting in injury or death of a few individuals. Speed limits and driver safety programs are designed to reduce collisions of vehicles with large mammals, and population effects are not anticipated.

3.1.10 Wetlands and Vegetation

Expansion of the SDI will greatly reduce the impact to wetlands and vegetation associated with the Liberty development compared to the other alternatives. The most significant impacts to wetlands and vegetation will occur during development of the gravel mine site (discussed in Section 3.2.7) and transportation of materials and personnel to and from development areas.

3.1.10.1 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil, chemicals, or wastewater arising from the Liberty Project at the SDI will impact wetlands and vegetation. The SDI is composed of gravel fill deposited to support Endicott development and is largely barren of vegetation. Such minor discharges would likely be contained and cleaned up immediately.

3.1.10.2 Increased Road Traffic to Site

Traffic along the Endicott Road would increase to accommodate Liberty development and construction activities. Fallout from dust plumes associated with vehicle traffic has the potential to alter wetland characteristics and vegetation communities. The highest levels of traffic would likely occur during facility installation and infrastructure construction. Xeric, prostrate shrub-dominated communities and non-vascular species of moss and lichen are the most susceptible to impacts. Potential thinning of the vegetative canopy and altering of species composition would be the most common result of increased traffic and associated dust fallout (Auerbach et al., 1997; Everett, 1980; Walker and Everett, 1987).

3.1.11 Threatened and Endangered Species

Three species listed as threatened or endangered under the Endangered Species Act occur in the Liberty Project area: the bowhead whale (*Balaena mysticetus*), spectacled eider (*Somateria fischeri*), and Steller's eider (*Polysticta stelleri*). Polar bears have been nominated for protection under the Endangered Species Act. Though not officially listed as of this writing, they are addressed in this section of the EIA for consistency purposes.

Potential impacts from the Liberty Project will not affect whales or birds during the winter when they are absent from the project area. Bowhead whales migrate east through the Alaskan Beaufort Sea during the spring using open leads offshore from landfast ice. Bowhead whales migrate west through the Alaskan Beaufort Sea during fall and use a migratory corridor offshore from the barrier islands. Spectacled eiders nest in low densities throughout the Prudhoe Bay region and have the potential to be present from May through October. Steller's eiders have declined in this area and are rare in the general vicinity of the Liberty Project during nesting.

The following section addresses possible consequences of the SDI expansion and facility installations with respect to these species. Liberty Project activities are unlikely to affect bowhead whales during spring due to their significant distance offshore, and information below focuses on their fall migration when potential impacts are likely to be greater.

3.1.11.1 Noise/Activity Disturbance

The noise and disturbance related to gravel deposition for the SDI expansion that will take place during the winter months of January through March will have no impact on bowhead whales that are wintering in the Bering Sea during these months. Following breakup, the newly deposited gravel will be machine-graded and vibra-compacted, a technique that uses a vibratory roller to condense gravel substrate. Noise from the compaction that may occur during the bowhead migration will not be likely to affect bowhead whales that are migrating offshore.

Any potential impacts will be mitigated by (1) the distance of migrating bowheads from the sound source, (2) the timing of the bowhead migration in the offshore waters of the project area, and (3) the rapid attenuation of sound likely to occur in the shallow waters of the project area. During the westward autumn migration bowhead whales are generally seaward of the barrier islands with annual variability in the mean distance offshore (Treacy, 2002a). The mean distance of migrating bowheads from shore in the Beaufort Sea west of Prudhoe Bay in 2000 (17.7 km) was less than for any single year (1982-2000) and much less than the cumulative mean (35.4 km; Treacy, 2002a). Blackwell et al. (2004) also reported interannual variability in the proximity of migrating bowheads to shore in the southern portion of the bowhead migration corridor near Prudhoe Bay. The migration corridor tended to be closer to shore in 2003 than the previous 2 years.

Underwater acoustic measurements at nearby Northstar Island during the open-water period indicated that construction noise was inaudible beyond 1.85 km (Blackwell and Greene, 2001). This attenuation distance for construction noise is significantly less than the distance between SDI and the bowhead whale fall migration corridor. The peak of the bowhead migration in the offshore waters of the project area occurs during August and September, thus, migrating bowheads will not be affected by activities associated with the SDI expansion proposed for June and July. Consequently, noise and activity disturbances related to SDI expansion would not be likely to affect bowhead whales. However, unforeseen events resulting in a delayed sealift during the bowhead whale migration could result in unanticipated disturbances to bowhead whales. Furthermore, seasonal variations in bowhead whale distribution could result in feeding aggregations of whales closer to shore than is typically noted. This scenario could also result in unforeseen disturbances to bowhead whales.

McDonald et al. (2006) noted subtle offshore displacement of the southern edge of the bowhead whale migration corridor ranging from 0.66 to 2.24 km during times of industrial activity on Northstar Island during the 2001-2004 migrations. However, Northstar Island is located about 5 km farther offshore than the SDI. Blackwell and Greene (2006) reported underwater industrial sounds from Northstar Island during the summer reached background levels at distances of 2 to 4 km from the island. Water depth near the SDI is shallower than near Northstar Island, and underwater noise would likely attenuate more rapidly in the SDI area. Additionally, the barrier islands act as another impediment to industrial sounds originating in nearshore areas (USDOI, MMS, 2002). It is unlikely that whales would be significantly disturbed or displaced by SDI facilities installation.

Much of the SDI expansion is scheduled to take place during the winter when both species of eider are absent from the project area. Noise and activity disturbances continuing into the spring nesting season will likely have minimal effects on nesting threatened eiders. Both species select nest sites in tundra habitats at inland locations removed from the proposed development. There is the potential for noise and activity to displace male eiders and females with broods that may be using marine habitats in the immediate area of the SDI. However, potential impacts should be minimal due to the large amount of available habitat in the surrounding area and the low density of these two eider species in the region. Any impact on eider populations resulting from these activities would be difficult to separate from their natural population dynamics, although any impact on eider populations would be considered significant given their highly sensitive status (USDOI, MMS, 2002).

USDOI, MMS (2002) estimated that 1 to 3 polar bears within 1.5 km of the offshore island construction project originally proposed for the Liberty development could be temporarily disturbed by noise and activities during winter construction activities. There has been some concern that denning female polar bears could be impacted by noise from the SDI expansion. Polar bears sometimes choose terrestrial den sites near the coast, along lakeshores, on riverbanks, and in other areas with unique topographical features (Durner et al., 2001; Durner et al., 2003). Durner et al. (2001) identified large areas along the coast and adjacent areas along the Sagavanirktok River near the SDI that are suitable for terrestrial maternal-den sites. Additionally, the proportion of maternal dens in terrestrial versus pack-ice habitats appears to be increasing in recent years. Fischbach, Amstrup, and Douglas (2007) reported that the proportion of dens on pack ice declined from 62% during 1985 to 1994 to 37% during 1998 to 2004. Changes in ice quantity and quality related to climate change could result in increased numbers of terrestrial maternal-den sites near the Liberty Project area in future years (Fischbach, Amstrup, and Douglas, 2007). Ice-road construction that is scheduled to begin in January could disturb polar bears in nearby maternal den sites because denning is typically initiated during November and December. Bears leaving den sites with cubs during March and April could also be disturbed by noise and activity. However, some polar bears may quickly habituate to industrial noise when it is not associated with other stimuli (Perham, 2005). Habituation to noise by some polar bears would be likely to lessen the total number of bears disturbed by noise and activity.

Food and associated odors could attract polar bears during the SDI expansion. This could result in hazing to drive bears from the area, or in destruction of problem bears. Current North Slope practices are designed to minimize or eliminate the potential for polar bear attraction to developed areas. It is unlikely that polar bears would be seriously impacted by noise and activity disturbances from the SDI expansion.

3.1.11.2 Water Quality (Suspended Sediments)

The SDI working surface and seafloor footprint will be expanded from 11 to 31 acres through gravel placement. Suspended sediments resulting from construction activities during gravel placement will have the potential to increase water turbidity.

3.1.11.3 Summer Erosion

Erosion of fine sediment and increased turbidity in waters surrounding the SDI is very unlikely to impact bowhead whales or either eider species. The main migratory corridor used by bowhead whales during their annual migration is outside the barrier islands nearly 15 km offshore from the SDI. This corridor makes bowhead occurrence near the SDI very unlikely. Furthermore, summer erosion and increased turbidity occur naturally and are properties inherent to large river deltas like the Sagavanirktok River.

Eiders would be able to move to adjacent habitats, and due to the low densities of threatened eiders in the project area, few birds would likely be affected.

3.1.11.4 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil, chemicals, or wastewater from the Liberty Project at the SDI will impact bowhead whales, polar bears, or spectacled eiders. Such minor discharges would likely be contained and cleaned up immediately and are unlikely to enter the marine or terrestrial environments used by them.

3.1.11.5 Increased Road Traffic to Site

Increased road traffic to Liberty facilities at the SDI is not expected to have any effects on bowhead whales in the offshore, marine environment.

Increased traffic along the Endicott Road could disturb eiders in the area during the nesting season. Disturbance to birds from vehicle traffic on the North Slope has been noted for brant and for Canada and white-fronted geese, and the extent of disturbance was shown to be directly correlated with the birds' distance from the road (Murphy et al., 1988; Murphy and Anderson, 1993). Disturbance to birds (e.g., "heads up" behavior) was most apparent within 50 m of roads, but some disturbance was reported as far as 150 to 210 m from the road (Murphy and Anderson, 1993). These disturbances occurred most often prior to nesting and during brood-rearing and fall staging when geese gathered to feed in open areas near roads. Susceptibility to this potential disturbance on eiders could depend on the stage of reproduction. Anderson et al. (2003) reported pre-nesting pairs of spectacled eiders in the Kuparuk oil field were located closer to roads than nesting females.

There is also the possibility for increased road traffic to obstruct the movement of spectacled eiders, especially during brood-rearing and molting periods when birds are flightless. TERA (1996) reported that spectacled eider broods traveled an average of 0.53 km each day during the first week following hatching, and broods were known to cross roads repeatedly. Reduced speed limits have been implemented on the Endicott Road in past years as a mitigation tool for minimizing impacts on snow geese broods. A reduction of speed limits could help minimize the impacts from increased road traffic on spectacled eiders resulting from development of the Liberty Project. Additionally, the nesting density of spectacled eiders in the Liberty Project area is low, and it is likely that few birds would be disturbed by increased road traffic.

3.1.11.6 Marine Access

The sealift required for the Liberty Project will be unlikely to create any prolonged disturbance to bowhead whales. Bowhead whales tend to avoid most marine vessels at distances of 1 to 7 km depending on the type of vessel (Richardson and Malme, 1993). However, bowhead whales in the Beaufort Sea avoided an icebreaker-supported drillsite by at least 25 km in 1992 (Richardson, 1995).

The Liberty project currently includes a single sealift in the 2012 open-water season of the ***LoSal*™** plant and other equipment. As is typical for most sealifts to the central Beaufort Sea, this sealift is scheduled to be completed early in August prior to the main migration of the Bowhead whale and fall subsistence whaling depending upon weather and ice conditions. Should the sealift be delayed into September for any reason, then BPXA will coordinate this activity with the Alaska Eskimo Whaling Commission (AEWC) and Barrow and Nuiqsut Whaling Captains' Associations through a Conflict Avoidance Agreement (CAA) or other communication mechanisms. Consistent with safe navigation and ice conditions, the sealift may be routed inshore to avoid migrating bowhead whales and subsistence whaling.

The sealift required for transport of the ***LoSal*™** EOR unit for the Liberty Project would also have the potential to displace eiders feeding in offshore marine habitats in the Chukchi and Beaufort seas. Eiders using offshore marine habitats could be temporarily displaced from preferred feeding habitats, but impacts would be minimal and displaced eiders would be able to use adjacent habitats or return to preferred habitats after passage of the sealift.

3.1.11.7 Bird Strikes

There is the potential for eider mortality to result from collisions with Liberty Project structures at the SDI because eiders fly at relatively low altitudes over the water (Johnson and Richardson, 1982). Day et al. (2005) reported the mortality of 36 eiders as a result of collisions with facilities at Northstar Island and Endicott over a 4-year period. These birds were all common and king eiders, but the presence of spectacled eiders in the Liberty Project area makes them susceptible to collisions with project facilities, particularly the drilling rig. However, spectacled eider density is low in the Liberty Project area, and Steller's eider is rare in the area. The low numbers of these two species in the area will decrease the potential for collisions with Liberty facilities at the SDI.

3.1.12 Socioeconomics and Related Impacts

This section discusses the possible socioeconomic and related impacts (including subsistence-harvest resources, sociocultural, and environmental justice) associated with the SDI expansion. As noted in the above paragraphs, possible impacts of SDI expansion could arise from noise/activity disturbance, small operational spills of refined products (no large crude spills from drilling or production) and the temporary presence of construction workers in the area.

In the affected environment section subsistence-harvest data are presented. These data indicate that (in terms of total subsistence harvest for the potentially affected communities) the major subsistence foods include caribou, bowhead whales, and various types of fish (e.g., cisco and broad whitefish). Conclusions regarding possible impacts of SDI construction on important subsistence resources are addressed in several sections above and can be summarized as follows:

- **Section 3.1.6, Fish and Essential Fish Habitat:** Noise and activities associated with installation of facilities are not likely to have any meaningful effect on local fish populations (Section 3.1.6.1). No additional fish habitat in the project area will be affected and no Essential Fish Habitat (EFH) will be affected (Section 3.1.6.2) because of SDI expansion. Small refined-oil spills associated with the SDI expansion are not expected to have any measurable effect on arctic fish populations in the project area and no EFH will be affected (Section 3.1.6.4). Overall, altered water quality associated with the expansion of the SDI is not expected to have any measurable effect on marine or anadromous fish and no EFH will be affected (Section 3.1.6.5). Minor changes in oceanography will occur, but will have no measurable effects on marine or anadromous fish and no EFH will be affected (Section 3.1.6.6).
- **Section 3.1.9, Terrestrial Mammals:** Noise in the outer delta area may displace caribou from coastal insect-relief habitats, but prolonged displacement is not likely and no population-level impacts are anticipated (Section 3.1.9.1).
- **Section 3.1.11, Threatened and Endangered Species (bowhead whale, spectacled eider, Steller's eider, and polar bear [proposed]):** No significant impacts on any of these species are anticipated as a result of noise/activity disturbance. Food and associated odors could attract polar bears during the SDI expansion, which could result in hazing to drive bears from the area or in the destruction of problem bears. Polar bears are unlikely to be seriously impacted by noise and activity disturbances from the SDI expansion. Small spills or leaks of oil, chemicals, or wastewater from the Liberty Project are unlikely to impact bowhead whales, polar bears, or spectacled eiders (Section 3.1.11.4).

In addition to the above, potentially significant impacts might occur on the subsistence bowhead harvest if the sealift occurred during critical migration and hunting periods. However, if the sealift were delayed into September for any reason, BPXA would coordinate the sealift activity with the Alaska Eskimo Whaling Commission (AEWC) and Barrow and Nuiqsut Whaling Captains Associations through a Conflict Avoidance Agreement (CAA) or other communication mechanisms. Consistent with safe navigation and ice conditions, the sealift may be routed inshore to avoid migrating bowhead whales and subsistence whaling.

Thus, there are not expected to be any significant effects on possible subsistence-harvest resources resulting from noise/activity disturbance or small operational spills of refined products during SDI expansion. And, if the sealift were delayed, measures would be taken to mitigate any significant effect.

The Liberty FEIS (USDOI, MMS, 2002) estimated that the entire project would generate 870 full-time equivalent (FTE) construction jobs and an additional 1,248 indirect FTE jobs for 1 year in Alaska during 14 to 18 months of construction. However, the new alternatives are likely to have significantly smaller labor impacts, and only some of these would be associated with SDI expansion. For example, the maximum annual number of workers required during SDI expansion (and associated onshore construction) is estimated to be 116. In principle, adverse sociocultural impacts could arise from either significant adverse impacts on subsistence harvest resources or an influx of substantial numbers of workers. However, neither impact is anticipated. Therefore, there would be no significant sociocultural impacts associated with the SDI expansion.

Significant adverse sociocultural or subsistence resource impacts would raise environmental justice issues, because (as noted elsewhere in this EIA), the majority of the population is a recognized minority. However, absent these impacts, which are not anticipated, no environmental justice issues would be raised as a result of SDI expansion.

3.1.13 Waste Management

All waste from the Liberty Project would be handled in accordance with State, Federal, and local regulations. Use of permitted disposal wells and other approved disposal methods will result in zero surface discharge of drilling wastes and — in conjunction with BPXA's waste minimization policy — will result in little or no impact from waste disposal. See Section 10 of the Liberty DPP for more information on waste handling.

3.2 ONSHORE CONSTRUCTION

3.2.1 Air Quality

The ambient air pollutant impacts due to onshore construction of the permanent Liberty facilities are expected to be within the limits of the National and Alaska AAQS. Pollutants will be emitted from temporary operations and/or mobile equipment such as diesel-fired construction equipment, and temporary electrical generators. Pollutant emissions from marine vessels are expected to be negligible because, with the exception of a single sealift, marine vessels will not be used to support construction of the SDI expansion. Pollutant emissions from aircraft are expected to be negligible for the same reason. Fugitive particulate-matter emissions may result from local traffic, but will be minimized through fugitive-dust abatement techniques such as road watering. As part of the air permitting process, ADEC will review the construction equipment inventory and the construction plans to ensure compliance with the National and Alaska AAQS.

A dispersion modeling analysis of project emissions will be included in the air permit application and will demonstrate National and Alaska AAQS compliance. An ambient-air-quality monitoring station has been in operation on the SDI since February 2007 to provide data to support air quality permitting.

3.2.2 Hydrology

The SDI is accessed by the existing Endicott Road. Increased use of this road for the Liberty Project may require construction of a new bridge at the Sagavanirktok West Channel to provide higher capacity. Environmental consequences of this action will be negligible because the new bridge will be nearly identical in length to the existing bridge, and will be constructed immediately upstream of the existing bridge. For this reason, flow patterns through the bridge will not change. Construction-related consequences will be minimized by installation of bridge piers, abutments, and other "in-water" portions of the new bridge during the winter, when the river and ground are frozen.

3.2.3 Fish and Essential Fish Habitat

3.2.3.1 Ice Road Construction

The ice road that will support winter expansion of the SDI will run from the proposed mine site to the SDI, and will parallel the existing Endicott Road. The ice road will cross under one of the Endicott bridges and run across grounded sea ice to the south side of the SDI. There are no indications that deep-water fish overwintering habitat exists anywhere along the proposed route. Although tundra ponds are a dominant feature of the Arctic Coastal Plain, water depths in most cases are insufficient for overwintering, and most are not accessible to fish (Hemming, 1995). The possible exception would be where the roadway crosses under the middle breach. Both the inner and outer breaches contain centerline channels of up to 4,000 m^2 in area where depth exceeds 2 m and which have maximum depths of about 5 m (Dewey, Morehead, and Wilson, 1993). At these depths they more than likely provide some overwintering habitat for fish. It is further likely that the middle breach also contains some overwintering area the extent of which is unknown.

A second 3-mi-long ice road may be built on the lagoon side of the Endicott Causeway between the MPI and SDI. In addition to running along the length of the causeway, the ice road will parallel a scour channel that also runs along the lagoon side of the causeway. In places, channel depth can reach 2.5 m and be approximately 100 m wide (Davis et al., 1992). Although not excessively deep, the channel may be up to 3,000 m in length. Assuming maximum winter ice thickness of 2 m, under-ice free water only 0.5 m in depth would still translate into 150,000 m^3 of potential fish overwintering habitat. A mild winter with a maximum ice thickness of 1.5 m could provide 300,000 m^3 of potential fish overwintering habitat. Such a volume of overwintering area is considerable. Of 22 fish overwintering sites surveyed in the lower Sagavanirktok River and Delta, under-ice free-water habitat ranged in volume from 4,000 to 57,000 m^3 (Adams and Cannon, 1987; Schmidt, Griffiths, and Martin, 1989).

The construction of an ice road over shallow overwintering habitat can cause additional freezing. Overwintering habitat could be lost, oxygen levels could decrease, and overwintering fish could be adversely affected. However, the extent to which fish use the Endicott Causeway channel as overwintering habitat is unknown, as are the actual winter dimensions of the channel.

Even if this potential habitat were lost for a winter, the long-term effects on fish stocks would be minimal. North Slope fishes regularly endure population fluctuations associated with especially harsh winters. If the ice roads are limited to the grounded-ice area along their route, damage to any potential fish overwintering habitat would be minimized. BPXA intends to conduct a hydrologic survey in the summer of 2007 to assess ice road routes so as to avoid fish overwintering areas.

It is projected that ice roads will require 22 million gallons of freshwater per year during the peak construction season. The primary source of freshwater for ice roads will be the Duck Island Mine Site, which is believed to hold on the order of 600 million gallons of water. The mine site has never been breached (Hemming, 1988) and is therefore assumed not to contain fish.

No EFH will be affected.

3.2.3.2 Mine Site Development

The extension of the SDI will require 860,000 yd^3 of gravel to be mined from a site just east of the existing Duck Island mine site in the Sagavanirktok River delta. Gravel will be removed from an area of approximately 18 acres, with the primary excavation area developed as a single cell, and the entire development mine site, including a stockpile area for overburden, will be approximately 35 acres in size. Although located within the floodplain, the proposed mine site does not appear to occur in a deep-water area where large-scale fish overwintering might take place. The excavation would eliminate some shallow water areas that are likely used by freshwater fish during summer, but the amount of loss would be small relative to the summer freshwater habitat available within the Sagavanirktok River delta.

Abandoned and flooded gravel mine sites in or near river beds and floodplains can serve as suitable habitat for fish year-round. A detailed discussion of mine site reclamation and fish enhancement studies on the North Slope is provided in USDOI, MMS (2002). The utility of reclaimed, flooded mine sites depends on their permanent access to surrounding stream or river channels, depth, sufficient oxygen concentration, and sufficient primary and invertebrate production to sustain summer populations. A permanent connection to surrounding streams and rivers allows fish to move in and out of a site throughout the open-water season. In the absence of a direct connection, sites can be seasonally or sporadically connected to the surrounding drainages. Seasonally connected waterbodies are flooded during breakup, while sporadically connected waterbodies are flooded only during high-water years (USACE, USDOD, 1997; USDOI, MMS, and BLM, 1998). To serve as viable overwintering habitat, mine-site water must be deep enough to provide sufficient under-ice free water during winter, and be of a volume sufficient enough to prevent oxygen depletion during the long period of winter ice cover.

No EFH will be affected.

3.2.3.3 Pipeline Construction

The only pipeline construction associated with the project will be confined to the existing causeway running from the SDI to MPI. The two Liberty Project pipelines will run approximately 3 mi from the SDI to Endicott MPI and will parallel the existing inter-island pipelines. The new pipelines will be located entirely on the existing gravel causeway and will not physically affect fish habitat. Construction noise is not likely to affect fish, and if it does the impact will be localized and avoidable. These are the only pipelines planned for construction. If construction noises do disturb fish, the effect would be localized and avoidable.

3.2.3.4 West Sagavanirktok River Bridge

BPXA is evaluating whether to upgrade the existing West Sagavanirktok River Bridge or construct a new bridge. If BPXA elects to construct a new road bridge, it would be installed approximately 22 feet upstream of the existing bridge. New ice breaking piers would be installed immediately upstream of the new road bridge. The bridge would be constructed in a single winter season (2009-2010). River ice would be thickened to facilitate construction. Piers would be driven into the river bed using specialized piling equipment.

At least two deep-water overwintering holes are located near the existing bridge and pipeline crossing (Morris, 2000). One is located directly adjacent to the roadway bridge (Bjerklie, 1991a, 1991b, 1993). The hole has maximum depth of about 3 m, with an average depth of about 2.5 m and a cross-river width of 70 m (Bjerklie, 1991a, 1991b, 1993). The upstream and downstream extent of the hole is unknown, but the site probably represents major overwintering habitat for several species of fish. In the Sagavanirktok watershed, freshwater species such as grayling, round whitefish, and burbot often overwinter collectively in the few deep-water sanctuaries that are available (Bendock, 1981). The overwintering sites near the bridge also appear to be a major overwintering area, and possibly a spawning area, for broad whitefish (Morris, 2000).

Bridge construction would occur in winter. The risk to fish during winter operations would be possible disturbance of overwintering areas near the crossing site. Streambed disturbance in areas where there is under-ice free water could increase turbidity, and if oxygen-demanding materials are discharged, decreased oxygen levels could be stressful or even lethal to fish. Morris (2000) found that under natural conditions, water quality at overwintering sites in the Sagavanirktok River degrades considerably over the course of the winter. Space becomes more cramped as ice cover thickens and oxygen levels decline. All of the sites that he surveyed were considered either marginal or failed. Such conditions indicate that any fluctuation in environmental conditions can potentially have significant effects on fish overwintering survival. It is possible that noise from construction activities could also stress overwintering fish.

New pilings be installed upstream of the bridge, and if those pilings cause gravel buildup in the river bed, then overwintering habitat could be permanently lost. Disturbance during construction or permanent loss of habitat in the vicinity of the construction site would not likely result in irreparable damage to fish populations. Stock estimates for broad whitefish 120 to 250 mm in length indicate that the Sagavanirktok population expands and collapses on a regular basis (Gallaway et al., 1997). Population estimates for the period 1982-1984 and 1988-1992 ranged from a low of 25,800 in 1984 to 432,341 in 1990. It is highly doubtful that a population of this size would rely on a single overwintering site to sustain stock integrity. Craig (1989) postulated that North Slope fish populations reduce their chances of extinction by spreading their members over many overwintering sites, and a significant impact at any one site would not eliminate all members of the population.

No EFH will be affected.

3.2.4 Marine Mammals

3.2.4.1 Ice Road Construction (Winter Only)

The Liberty Project at the SDI will involve construction of an ice road approximately 11 km long from a mine site adjacent to the Endicott Road to the SDI. The proposed route will be located adjacent to the Endicott Road and will transit approximately 6.4 km of tundra habitat and

4.8 km of marine environment. Noise and activities from ice road construction could impact marine mammals in the area.

Beluga whales and Pacific walruses are absent from the Liberty Project area in winter. Ice road construction and use will occur in winter and will have no effect on beluga whales or walruses.

Adult seals and their pups could be displaced during ice road construction, but seal density near the coast along the ice road route is low (Moulton et al., 2002). Moulton et al. (2002, 2003, and 2005) reported that limited winter industrial activity at Northstar Island, including ice roads, did not appear to significantly affect ringed-seal density in the spring. Williams et al. (2006b) reported no relationship between ringed-seal use of subnivean structures and the distance of those structures from ice roads associated with Northstar Island. Additionally, water along much of the proposed ice road route could be shallow enough to freeze to the bottom during winter and be unsuitable for use by seals. Ice-road construction for the SDI expansion would have little effect on seal abundance or distribution.

3.2.4.2 Pipeline Construction (SDI to MPI)

The Liberty Project at the SDI will involve construction of two new pipelines between the MPI and SDI along the Endicott Causeway during the winter. No marine mammals are expected to be close enough to be impacted by this activity

3.2.4.3 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil, chemicals, or wastewater arising from the Liberty Project pipeline construction will impact marine mammals. Such minor discharges would likely be contained and cleaned up immediately, and it is unlikely that any would enter the marine environment.

3.2.5 Marine and Coastal Birds

3.2.5.1 Ice Road Construction

Noise and activity during ice road construction will not affect migrant birds but may displace or attract a few resident birds such as ptarmigan, ravens, and snowy owls. Some tundra-nesting and foraging habitats (~39 acres) would be temporarily unavailable during the spring following ice road construction. The ice road and associated snowdrifts will not melt before early-arriving shorebirds establish breeding territories and nesting sites. Tundra-habitat alteration would temporarily displace 13 shorebirds and 10 Lapland longspur based on average regional densities of these birds (Table 2.10-2). Forage under the ice road and drifts would similarly not be available for snow geese and greater white-fronted geese during early spring arrival.

Snow geese use wet meadows along the north side of the Endicott Road to grub for rhizomes during early spring, prior to nesting on Howe Island. The proposed ice road, north of the Endicott Road, crosses through early-spring foraging habitats and summer brood-rearing habitats used by snow geese, tundra swans, and brant (Figure 2.10-2). Late melting of the ice road will delay the development of sedges and other forage species. The delay in forage maturation decreases the fiber content and increases the nutritional value as forage for brood-rearing geese in July and August (Gadallah and Jefferies, 1995; Piedboeuf and Gauthier, 1999). Ice road construction would alter local nesting distributions and habitat usage during spring and summer. These changes would be short-term and localized, and no population-level effects on birds are anticipated.

3.2.5.2 Mine Site Development

Gravel excavation and hauling from the newly developed mine site will occur during winter when most birds do not remain on the Arctic Coastal Plain. A few resident birds such as ptarmigan, ravens, and snowy owls may be exposed to noise and therefore be displaced from habitats near the mine site.

About 35 acres of tundra habitats potentially used by nesting shorebirds, passerines, jaegers and snowy owls will be disturbed. Total tundra-habitat alteration could displace approximately 10 shorebirds and 8 Lapland longspur based on regional densities of these birds (Table 2.10-2). Several tundra-swan pairs with and without broods, and common eiders and glaucous gulls use the lake immediately west of the Duck Island Mine Site (Figure 2.10-2; LGL, 2002 unpublished data). The mine site is also in the area typically used by brood-rearing snow geese and tundra swans (Figure 2.10-2).

Minor spills or leaks of oil or chemicals during gravel mine development would degrade habitats used by nesting and brood-rearing waterfowl and loons. Mine site development would alter habitats used by a few loons, waterfowl, shorebirds, seabirds, snowy owls, and Lapland longspurs, but these birds would be expected to relocate to other nearby suitable habitat, and no population-level effects are anticipated.

3.2.5.3 West Sagavanirktok River Bridge

Bridge upgrade or new bridge construction activities would primarily occur during the winter and would not disturb migrant birds. A few resident species such as ptarmigan, ravens, and snowy owls may be exposed to noise and displaced from habitats near the bridge site. Small areas of tundra habitat along the bridge approaches would be disturbed. Bridge spans may create nesting habitats for ravens and snow buntings. Construction-related changes are expected to be short-term and would affect a few individual birds. Creation of artificial nesting habitats for ravens could increase predation on local tundra-nesting birds (USFWS, 2003). The addition of a second bridge structure would potentially increase the amount of artificial raven nesting habitat.

3.2.5.4 Pipeline Construction (SDI to MPI)

Because the pipelines are scheduled to be constructed in winter when most birds are absent from the North Slope, impacts from pipeline construction are expected to be minimal. Some ravens may be attracted to the activity in search of anthropogenic food sources, but proper handling of food and food waste will minimize or eliminate those concerns.

3.2.6 Terrestrial Mammals

3.2.6.1 Ice Road Construction

Ice road construction and use would cause disturbance to caribou that may remain on the Arctic Coastal Plain during winter. Ice roads provide a hard surface, which as compared to deep snowdrifts, caribou may prefer for travel. Visibility for drivers may be limited due to darkness and snowstorms during winter months; these factors increase the likelihood of vehicle-collision mortalities for caribou and muskoxen. However, there are strict rules in the oil fields about vehicle travel during periods of poor visibility to ensure personnel safety. Because most caribou and muskoxen move south into the foothills and mountains of the Brooks Range during winter, very few collision mortalities have occurred during these months. If the growth of the Central Arctic Herd results in more caribou remaining on the Arctic Coastal Plain during winter, the likelihood of collisions with vehicles and equipment will increase.

Areas of suitable grizzly-bear denning habitat occur throughout the Sagavanirktok River delta along river channel and flood terrace banks, and on stabilized-sand-dune ridges. Construction of the ice road over or very close to a grizzly bear den would cause death, injury, or disturbance for individual bears or female bears with newborn cubs. About 60 to 70 grizzly bears frequent the oil field area (Shideler and Hechtel, 2000). BPXA will work with the Alaska Department of Fish and Game to identify known bear dens in the vicinity of the planned ice roads. The ice road would avoid known dens. Identification of arctic-fox den structures would also prevent injury and destruction of fox den sites. Fox den structures may be used repeatedly for centuries. Older dens are large, easily recognizable structures located on mounds, low hills, or ridges with thin snow accumulations, many entrances, and altered vegetation types (Burgess, 2000). Some resident arctic foxes that remain at den sites throughout the winter (Burgess, 2000) would be displaced by den site destruction or disturbance, and would likely to seek shelter under modules and open crawl spaces beneath buildings at nearby oil field facilities.

Ice roads built on top of lemming burrows and runways and arctic ground squirrel burrows that exist under the snow would lead to death of hibernating ground squirrels and destruction of these sites. Ground squirrel burrows are located on mounds, river bluffs, stabilized sand dune ridges, and other well-drained locations throughout the project area. Ice road construction and disturbance would affect a few individuals, and no population-level effects on grizzly bears, arctic foxes, arctic ground squirrels, or lemmings are anticipated.

Minor fuel or antifreeze spills may leach into nearby underground burrows causing death of arctic ground squirrels, foxes, and lemmings. Antifreeze spills on the ice road may attract arctic foxes, squirrels, and lemmings, and would cause injury or death if ingested in sufficient quantity. A few individuals would be affected, and no population-level effects are anticipated from these spills and leaks.

3.2.6.2 Mine Site Development

A few individuals or small groups of caribou may remain in the project area during winter, but most will move south into the foothills and the Brooks Range and would not be exposed to disturbance from mine site excavation. Some tundra habitats used by caribou and muskoxen for foraging would be lost or altered due to mine site excavation, but the areas would be minimal compared to available habitats, and no population-level effects are anticipated.

Grizzly denning and foraging habitats would be potentially lost or altered in the excavation area. Excavation of the mine site in areas containing arctic ground squirrel burrows or arctic fox dens would cause death of a few hibernating ground squirrels and destruction of burrows and fox dens. As with ice road construction, identification and avoidance of active grizzly bear dens and arctic fox den structures would prevent injury to these animals and destruction of their dens.

As described for ice road construction, minor spills or leaks of such materials as fuel or antifreeze from vehicles and equipment used during mine site construction may occur and contaminate den sites. Antifreeze spills may attract arctic foxes and would cause injury or death of a few individuals if ingested in sufficient quantity. Population effects are not anticipated from these spills and leaks.

3.2.6.3 West Sagavanirktok River Bridge

A few individuals or small groups of caribou may remain in the project area during winter, but most will move south into the foothills and the Brooks Range and would not be exposed to noise and activities associated with the bridge upgrade or new bridge construction. Bridge design would presumably allow passage of caribou, muskoxen, and grizzly bears beneath the bridge and would not block movements of these animals along riparian corridors. Small areas of river-bluff habitats used by bears for denning and foraging would be lost. Grizzly bears that den at or very near the bridge site would be killed, injured, or disturbed by winter construction. At bridge approaches, alteration of tundra habitats supporting arctic ground squirrel burrows or arctic fox dens would cause death of a few hibernating ground squirrels and destruction of the burrows and fox dens. Identification and avoidance of active grizzly bear dens and arctic fox den structures would prevent injury to grizzly bears and destruction of fox den sites.

The addition of a second bridge structure would increase the reach of river covered by bridges within this section of the Sagavanirktok River. These two structures, in addition to the pipelines crossing the river downstream from the bridges, may make this area less attractive to caribou and muskoxen for movement along the riparian corridor. The additional shade created by these multiple overpasses, however, would provide shade habitats that caribou may use to avoid parasitic bot and warble flies which are negatively phototaxic.

Minor spills or leaks of such materials as fuel or antifreeze at the construction site may attract arctic foxes, and ingestion of the antifreeze in sufficient quantities would cause injury or death. Overall, population-level impacts from bridge construction activities are not expected.

3.2.7 Wetlands and Vegetation

The most significant disturbance to wetlands and vegetation will potentially occur during the onshore construction phase of Liberty. Development of the gravel mine site, transporting materials during construction activities, and improvements to transportation corridors will have varying levels of impact to wetlands and vegetation.

3.2.7.1 Ice Road Construction

Onshore ice-road construction will primarily be used during the SDI expansion to transport gravel fill from the mine site to the SDI. Additional ice roads may be used to bypass the West Sagavanirktok River Bridge or during construction of the new bridge. The impact from ice roads varies with topography and soil moisture conditions. Moist or wet meadow communities typically show little to no sign of disturbance after the ice road has melted (Payne et al., 2003; Yokel et al., 2003). Drier sites, elevated microsites, and tussock-type tundra are at a relatively greater risk for disturbance (Jorgenson, 1999; Pullman et al., 2003). Ice-road construction has the potential to compact the subnivean layer, damage or kill off some plants, and remove standing dead material from the aerial canopy (Walker et al., 1987).

It is unlikely that minor spills or leaks of oil or chemicals arising from ice road activities will impact wetlands and vegetation. Such minor discharges would likely be contained and cleaned up immediately.

3.2.7.2 Mine Site Development

The primary mine cell will cover an area of approximately 18 acres. Vegetation, mineral surface soils, and unusable gravels removed from the mine will be stockpiled adjacent to the excavated areas. Including the stockpiled material, a total area of approximately 35 acres will be used for the mining operation. Excavation, mining, and stockpiling of materials will destroy vegetation in that area. Development will follow an approved mining and rehabilitation plan.

3.2.7.3 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil or chemicals arising from mine site activities will impact wetlands and vegetation. Such minor discharges would likely be contained and cleaned up immediately.

3.2.7.4 West Sagavanirktok River Bridge

Upgrade of the West Sagavanirktok River Bridge or construction of a new bridge will rely on ice roads to support construction activities. The impact associated with ice roads is discussed in Section 3.2.7.1 above.

Bridge upgrade or construction activities would result in increased traffic to and from the construction site. A portion of the construction would be conducted during winter months which would reduce the level of dust fallout to some degree. Fallout from dust plumes associated with vehicle traffic has the potential to alter wetland characteristics and vegetation communities. Xeric, prostrate shrub-dominated communities and non-vascular species of moss and lichen are the most susceptible to impacts. Potential thinning of the vegetative canopy and altering of species composition would be the most common result of increased traffic and associated dust fallout (Auerbach et al., 1997; Everett, 1980; Walker and Everett, 1987).

3.2.7.5 Rig and Facilities Installation

Traffic along the Endicott Road would increase to accommodate drill rig construction and fabrication and installation of module and infrastructure components. Fallout from dust plumes associated with vehicle traffic has the potential to alter wetland characteristics and vegetation communities, as discussed in Section 3.2.7.4 above.

3.2.7.6 Pipeline Construction (SDI to MPI)

It is unlikely that minor spills or leaks of oil or chemicals arising from new pipeline construction will impact wetlands and vegetation. The causeway along which the pipelines will be constructed is gravel fill placed during the Endicott development and largely barren of vegetation. Such minor discharges would likely be contained and cleaned up immediately.

Construction activities along the SDI to MPI road are not adjacent to any tundra that would be affected by dust fallout. However, in support of construction activities it would be expected that traffic along the main Endicott Road would increase. Fallout from dust plumes associated with vehicle traffic has the potential to alter wetland characteristics and vegetation communities, as discussed in Section 3.2.7.4 above.

3.2.8 Threatened and Endangered Species

3.2.8.1 Ice Road Construction (Winter Only)

The Liberty Project at the SDI will involve an ice road approximately 11 km long from the Duck Island mine site to the SDI. The proposed route will be located adjacent to the Endicott Road and transits approximately 6.4 km of tundra habitat and 4.8 km of marine environment. Ice road construction could result in temporary disturbance to spectacled eider habitat from the ice-road footprint during the nesting season when eiders are present in the project area. Polar bears in maternal dens sites may be affected by ice-road construction activities.

Bowhead whales are not present in the project area during winter when the ice road will be used. Bowhead whales will not be affected by habitat loss related to ice road construction.

Spectacled and Steller's eiders are absent from the Liberty Project area during winter when the ice road will be built. Ice from ice roads has the potential to linger over tundra after the surrounding snow has melted in spring. Lingering ice on the ice-road footprint could prevent this strip of tundra habitat from temporarily being used as nesting habitat for spectacled eiders. Tundra compaction beneath ice roads can result in structural changes to the plant community following melting of the ice (Walker, 1996), which could temporarily affect eider use within the ice road footprint. The compacted tundra may not recover for many years, making it unsuitable as eider habitat. This potential impact could be minimized by selecting an ice road route which avoids tundra near known eider-nesting locations and favors habitat not preferred by eiders.

Ice-road construction involves withdrawing water from deep lakes in areas adjacent to the road. Bergman et al. (1977) reported that spectacled eiders at Point Storkersen used deep *Arctophila* lakes during pre-nesting, nesting, and post-nesting periods. Deep *Arctophila* lakes also have been used by brood-rearing spectacled eiders in NPR-A (Derksen, Rothe, and Eldridge, 1981). In addition, spectacled eiders often select nest sites near the edge of lakes, often within 1 m of the shore. Withdrawal for ice roads that lowers the water level of lakes could affect spectacled eider nesting habitat. Most lakes would likely return to pre-withdrawal levels during spring flooding (Rovansek, Hinzman, and Kane, 1996), but care should still be taken when selecting lakes for water sources for ice roads. Water taken from deep open and deep *Arctophila* lakes should be minimized or avoided as these lakes may be used by spectacled or Steller's eiders. However, these are the lake types most suitable as water sources for ice-road construction from an industry perspective.

Potential impacts on polar bears from ice road construction are a concern. The Liberty project is already covered by an Incidental Harassment Authorization (IHA) to address potential takes of small numbers of polar bears. Furthermore, BPXA will implement a Liberty-specific polar bear interaction plan to minimize potential impacts on polar bears. It is recommended that BPXA consult with resource agencies and polar bear specialists before building ice roads to obtain the most current information regarding polar bears in the project area.

Noise and activity during ice road construction could disturb polar bears at maternal den sites (Blix and Lentfer, 1991). Potential denning habitat occurs in the project area (Durner et al., 2001), and the number of den sites on terrestrial habitats relative to those on pack ice may be increasing (Fischbach, Amstrup, and Douglas, 2007). However, polar bears are known to tolerate and habituate to industrial activity. Amstrup (1993) reported denning polar bears to have tolerated ice road traffic only 400 m from the den site. Perham (2005) reported that polar bears quickly habituate to industrial noises when it is not associated with other stimuli. Ice roads are not likely to create a significant impact on polar bears in the Liberty Project area.

3.2.8.2 Mine Site Development

The proposed mine site is located immediately east of the Duck Island mine site on a partially vegetated gravel bench adjacent to the Sagavanirktok River. The extraction cell is slated to be approximately 18 acres, and the entire mine site footprint will be approximately 35 acres. Habitat loss could potentially occur for spectacled and Steller's eiders.

Loss of Habitat

There will be no habitat loss for bowhead whales as a result of mine site development in support of the Liberty Project for the SDI option.

Gravel mining would have the potential to result in a loss of habitat for spectacled eiders. Spectacled eiders have been observed in this area along the Sagavanirktok River delta during aerial surveys (TERA, 1996). Density estimates for spectacled eiders in this area have ranged between 0.04 and 0.32 eiders/km^2 (TERA, 1996) and 0.01 to 0.61 eiders/km^2 (Larned et al., 2006). Spectacled eider density at the mine site could be up to 0.61 individuals/km^2; however, the surround areas have lower estimated densities of spectacled eiders. Due to the low density of spectacled eiders in the general area of the proposed mine site, few spectacled eiders would likely be displaced by mine site development. Based on the greater density of 0.61 eiders/km^2 reported by Larned et al. (2006), the 35 acres of disturbed land at the mine site might represent habitat loss for approximately 0.09 spectacled eiders.

Small Spills or Leaks

Bowhead whales or polar bears would not be affected by minor spills or leaks of oil or chemicals originating from the Liberty Project mine site development. Such minor discharges would likely be contained and cleaned up immediately. Bowhead whales migrate 15 km or more offshore, and any discharge from the mine development would be unlikely to enter the offshore environment.

It is unlikely that such minor discharges would impact spectacled or Steller's eiders. Additionally, threatened eiders would not be present in the project area in winter during mine-site development.

3.2.8.3 West Sagavanirktok River Bridge

BPXA is considering its options for a possible West Sagavanirktok River Bridge upgrade or construction of a new bridge. Most of the construction would likely take place during winter months when threatened and endangered species are absent from the development area.

Noise/Activity Disturbance

Bowhead whales will not be in the project area during bridge upgrading or construction of a new bridge. There will be no impacts on bowhead whales from noise and activity originating from such work.

The bridge upgrade or new bridge construction would take place during winter when eiders are on wintering grounds. There will be no direct impacts on threatened eiders.

There will be no direct impacts to polar bears from bridge construction activities. Should a polar bear den be discovered in the vicinity of the bridge work, appropriate mitigation measures will be employed.

Loss of Habitat

There would be no loss of habitat for bowhead whales from the bridge upgrade or new bridge construction, and there will be no significant habitat loss for spectacled and Steller's eiders. There is currently a bridge at this location, and a bridge upgrade or new bridge would not result in loss of eider habitat.

There would be no loss of habitat for polar bears due to bridge construction.

Small Spills or Leaks

Bowhead whales are unlikely to be impacted by minor spills or leaks of oil or chemicals originating from bridge construction. Bowhead whales migrate 15 km or more offshore from the coastline, and any minor discharge during bridge construction activities would be cleaned up immediately and not be likely to enter the offshore environment. Additionally, bowhead whales are absent from offshore environments during winter when bridge construction would occur.

It is unlikely that such minor discharges would impact spectacled or Steller's eiders. Any discharges resulting from construction activities would be within containment or cleaned up immediately and would not be likely to enter marine or terrestrial habitats. Additionally, these two species are absent from the Sagavanirktok River delta during winter.

3.2.8.4 Pipeline Construction (SDI to MPI)

The Liberty Project at the SDI will involve construction of two new pipelines between the MPI and SDI along the Endicott Causeway. Some activities associated with pipeline construction may have the potential to impact threatened and endangered species.

Noise/Activity Disturbance

Noise and activity disturbances as a result of construction of Liberty pipelines between the MPI and SDI would be unlikely to impact bowhead whales. Pipeline construction would take place during the winter and would not influence bowhead whales wintering in the Bering Sea. Spectacled and Steller's eiders are absent from the project area in winter, and the birds will not be impacted by this activity.

Impacts of industrial noise and activity from construction at the SDI on polar bears are described in detail in the above sections and would be similar to the effects of winter pipeline construction. Any effects of pipeline construction are likely to be minimal and temporary because polar bears are likely to habituate to industrial sounds if those sounds are not associated with other stimuli (Perham, 2005).

Small Spills or Leaks

Bowhead whales or polar bears are unlikely to be impacted by minor spills or leaks of oil or chemicals originating from construction of pipeline between the MPI and SDI. Such minor discharges would be held with in containment or would be cleaned up immediately. Also, bowhead whales migrate 15 km or more offshore from the coastline, and any discharge from the Endicott Causeway would be unlikely to enter their offshore environment.

It is unlikely that such minor discharges would impact spectacled or Steller's eiders. Both occur in low densities in the project area, and any potential impact on them from discharges during pipeline construction would be negligible.

3.2.9 Socioeconomics and Related Impacts

This section discusses the possible socioeconomic and related impacts (including subsistence-harvest resources, sociocultural, and environmental justice) associated with onshore construction. Possible impacts could arise from various construction activities (e.g., ice road construction, mine site development, pipeline construction, and West Sagavanirktok River Bridge work), small operational spills of refined products (no large crude spills from drilling or production), and the temporary presence of construction workers in the area.

Subsistence-harvest data presented in Section 2 indicate that in terms of total subsistence harvest for the potentially affected communities, the major subsistence foods include caribou, bowhead whales, and various types of fish such as cisco and broad whitefish. Conclusions on possible impacts of onshore construction on important subsistence resources are addressed in several sections above and can be summarized as follows:

- **Section 3.2.3 Fish and Essential Fish Habitat:** Ice road construction will not affect EFH (Section 3.2.3.1). Proper mine site design and eventual reclamation would more than compensate for any minor loss in natural habitat and no EFH will be affected (Section 3.2.3.2). New pipeline construction will be located entirely on the existing gravel causeway and will not physically affect fish habitat; construction noise is not likely to affect fish and, if it does, the impact will be localized and avoidable (Section 3.2.3.3) Disturbance during construction (associated with West Sagavanirktok River Bridge work) or permanent loss of habitat in the vicinity of the construction site would not likely result in irreparable damage to fish populations and no EFH will be affected (Section 3.2.3.4).
- **Section 3.2.6 Terrestrial Mammals:** Ice road construction and use could cause disturbance to caribou that might remain on the Arctic Coastal Plain during winter, possibly resulting in an increase of vehicle-collision mortality. Because most caribou and muskoxen move south into the foothills and mountains of the Brooks Range, very few collision mortalities have occurred during these months. But, if the growth of the Central Arctic Herd results in more caribou remaining on the Arctic Coastal Plain during winter, the likelihood of collisions with vehicles and equipment will increase (Section 3.2.6.1). Minor fuel or antifreeze spills associated with ice road development or use or mine site development may have adverse effects on foxes, arctic ground squirrels, and grizzly bears, but no population-level effects are anticipated (Sections 3.2.6.1 and 3.2.6.2). Some tundra habitats used by caribou and muskoxen for foraging would be lost or altered due to mine site excavation, but these areas would be minimal compared to available habitats and no population-level effects are anticipated (Section 3.2.6.2). A few individuals or small groups of caribou may remain in the project area during winter, but most move south and would not be exposed to noise and activities associated with the West Sagavanirktok River Bridge work (Section 3.2.6.3). Minor spills or leaks of fuel or antifreeze in sufficient quantities could cause injury/death to arctic foxes, but overall no population-level impacts from bridge construction activities are not expected (Section 3.2.6.3).
- **Section 3.2.8 Threatened and Endangered Species (bowhead whale, spectacled eider, Steller's eider, and polar bear [proposed]):** Ice road construction could result in temporary disturbance to spectacled eider habitat from the ice-road footprint during the nesting season when eiders are present. Polar bears in maternal den sites may be

affected by ice-road construction activities. Bowhead whales will not be affected by ice-road construction activities (Section 3.2.8.1). Noise and activity during ice-road construction might disturb polar bears at maternal den sites, but these roads are not likely to create a significant impact on polar bears in the project area (Section 3.2.8.1). There would be no habitat loss for bowhead whales as a result of mine site development, but the 35-acre mine site might represent a habitat loss for approximately 0.09 spectacled eiders (Section 3.2.8.2). Small spills or leaks would not be expected to affect either bowhead whales or spectacled or Steller's eiders (Section 3.2.8.2). West Sagavanirktok River Bridge work is not expected to have adverse impacts on either eiders or bowhead whales from noise/activity disturbance, loss of habitat, or small spills or leaks (Section 3.2.8.3). Likewise pipeline construction is not expected to have adverse impacts on the threatened species (Section 3.2.8.4), although there is a potential for noise and activity during summer pipeline construction to displace adult eiders. Nonetheless, eiders would be able to move to adjacent habitats and the potential impact would likely be negligible due to the low density of threatened eiders in the project area. It is unlikely that small spills or leaks would impact bowhead whales or threatened eiders.

Thus, there are not expected to be any significant effects on possible subsistence-harvest resources resulting from onshore construction activities.

The Liberty FEIS (USDOI, MMS, 2002) estimated that the entire project would generate 870 full-time equivalent (FTE) construction jobs and an additional 1,248 indirect FTE jobs for 1 year in Alaska during 14 to 18 months of construction. However, the new alternative is likely to have smaller labor impacts, and only some of these would be associated with onshore construction. For example, the maximum annual number of workers required during onshore construction and associated SDI expansion is estimated to be 116. In principle, adverse sociocultural impacts could arise from either significant adverse impacts on subsistence harvest resources or an influx of substantial numbers of workers. However, neither impact is anticipated. Therefore, there would be no significant sociocultural impacts associated with onshore construction.

Significant adverse sociocultural or subsistence resource impacts would raise environmental justice issues, because (as noted elsewhere in this EIA), the majority of the population is a recognized minority. However, absent these impacts, which are not anticipated, no environmental justice issues would be raised as a result of onshore construction.

3.2.10 Waste Management

All waste from the Liberty Project would be handled in accordance with State, Federal, and local regulations. Use of permitted disposal wells and other approved disposal methods will result in zero surface discharge of drilling wastes and — in conjunction with BPXA's waste minimization policy — will result in little or no impact from waste disposal. See Section 10 of the Liberty DPP for more information on waste handling.

3.3 DRILLING AND OIL PRODUCTION

3.3.1 Air Quality

The ambient air pollutant impacts due to drilling and oil production activities at Liberty are expected to be within the limits of the National and Alaska AAQS and the applicable PSD Class

II increments. Pollutants will be emitted from drilling operations on the SDI and a new gas-fired combustion turbine on the MPI. As part of the air permitting process, ADEC will review the Liberty emission unit inventory to ensure compliance with all applicable New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAPs). ADEC will also determine best available control technology (BACT) for the PSD-affected pollutants. A dispersion modeling analysis of project emissions will included in the air permit application and will demonstrate National and Alaska AAQS and PSD Class II increment compliance. An ambient-air-quality monitoring station has been in operation on the SDI since February 2007 to gather data to support air quality permitting.

3.3.2 Sediment Suspension and Transport

Erosion of the gravel fill material is expected to be minimal following installation. Similarly, the suspension of fine materials also will be minimal. The majority of the fine fractions near the waterline will be winnowed from the fill material by wave action during the first open-water season. While these particles will contribute to TSS concentrations, the impact is anticipated to be very small. The release of fine material from the pad following the initial open-water season is expected to be negligible.

Barging operations are expected to be limited to a sealift for the ***LoSal™*** EOR plant modules. Marine access is a secondary option for rig mobilization and demobilization. Extensive dredging is not anticipated. As a result, increased turbidity associated with marine operations is expected to be minimal, temporary, or non-existent.

3.3.3 Oceanography

The proposed SDI pad expansion is not expected to have any significant impact on regional oceanography. Minimal localized impacts can be anticipated.

During winter, rapid changes in temperature may produce thermally induced shrinkage cracks propagating from the perimeter of the SDI pad expansion (a source of stress concentration). These cracks may provide strudel drainage pathways at the time of river overflood. These conditions are expected to be similar to those that occur at the existing SDI facility.

If ice roads are used to support drilling operations, the thickened ice may act as a partial barrier to river overflood and divert a portion of the flow. The expanded SDI pad footprint is not anticipated to impede the river overflood or affect the extent of overflood on the sea ice. The aforementioned cracks propagating from the perimeter of the SDI pad expansion are expected to be similar to those that occur at the existing SDI facility. The resulting strudel drainage pathways will be displaced slightly relative to the current pad configuration, but the propensity for strudel scouring is not expected to be substantially different from the existing condition.

Currents in the immediate vicinity of the pad expansion will be affected during the breakup and open-water periods. However, the current patterns and velocities are not expected to be substantially different from those at the existing SDI facility. Local wave patterns also will be altered but are anticipated to be similar to existing conditions.

3.3.4 Marine Water Quality

The release of fine material from the pad following the initial open-water season is expected to be negligible.

The SDI pad expansion will be integrated with the existing SDI drainage system. A perimeter road will confine surface water drainage onto the work surface. This containment also will reduce the risk of any incidental equipment spills (oil, diesel fuel, and hydraulic fluid) from reaching marine waters.

The Liberty Project will have zero surface discharges of drilling wastes. Operational discharges will include reject water from the ***LoSal*™** EOR process plant, reverse-osmosis reject water, seawater treatment filter backwash, and sanitary/domestic wastewater. An amendment has been submitted to the NPDES permit renewal request to cover the discharge from the ***LoSal*™** EOR process plant. Stormwater and firewater test discharges will be permitted under the existing NPDES General Permit for Facilities Related to Oil and Gas Extraction.

Issues associated with a crude oil spill are discussed in Section 3.4.

3.3.5 Benthic and Boulder Patch Communities

3.3.5.1 Large Oil Spills

A detailed discussion of the potential effects of large oil spills on lower trophic organisms can be found in USDOI, MMS (1996); USDOI, MMS and BLM (1998); and USDOI, MMS (2002).

Plankton

Studies have shown that large oil spills commonly have no significant effect on plankton populations. Even if spills contact large numbers of plankton, the short regeneration time of these organisms and rapid replacement from nearby waters likely keep any effect to a minimum. Because of their wide distribution, large numbers, rapid regeneration rate, and high fecundity, plankton communities exposed to large oil spills appear to recover quickly (National Research Council, 1985). Any oil spill associated with Liberty operations would likely have only a localized and short-lived effect on plankton communities.

Boulder Patch

A detailed discussion of the potential effects of large oil spills on the Boulder Patch community can be found in USDOI, MMS (2002) based upon the initial offshore alternative of the Liberty Project. Studies indicate that Liberty crude would be particularly resistant to natural dispersion in the water column. It probably would disperse very little and very slowly down into the Stefansson Sound water column. Based upon mixing models, the amount and toxicity of Liberty crude oil reaching subtidal marine plants are expected to be so low that it would have no measurable effect on them, regardless of when the spill occurred.

Oil spill trajectory analysis (Section 3.4.3) indicates that the dispersal plume under east wind conditions would largely bypass the Boulder Patch and would be confined to nearshore waters west of the SDI. Plume deflection under west winds would carry surface oil eastward into Foggy Island Bay and would likewise bypass most of the Boulder Patch.

Other Coastal and Benthic Invertebrates

As discussed above, the inability of Liberty crude oil to substantially penetrate the water column would shield benthic invertebrates from contamination. Oil reaching the nearshore shallows would likely be toxic and probably would have lethal or sublethal effects on some invertebrates that inhabit these areas during summer including mollusks, annelid worms, echinoderms, crustaceans, and amphipods. Based upon estimates made for the initial offshore alternative of the Liberty Project, an assumed large oil spill would be estimated to have lethal or sublethal effects on about one-third of the nearshore benthic invertebrate community (USDOI, MMS, 2002) in the Stefansson Sound area. Recovery for nearshore benthic invertebrates would likely occur in a single season after water quality returns to pre-spill conditions. Because of ice cover, nearshore shallows are devoid of benthic invertebrates during winter. After breakup, most invertebrates move onshore to repopulate the area for the duration of the open-water season.

Nearshore invertebrates that reside in the water column (copepods, mysid shrimp, and euphausiids) have the potential for being affected by surface concentrations of oil. However, because of their widespread distribution, large numbers, and high reproduction rates, the recovery of these species would be quit rapid once water quality returns to pre-spill conditions.

3.3.6 Fish and Essential Fish Habitat

3.3.6.1 Waterflooding

Liberty production waterflooding will use two types of water: 1) high-salinity water, which is a mixture of recycled produced water and additional seawater, and 2) low-salinity water provided by the ***LoSal*™** EOR process. High-salinity injection water (produced water) will be supplied from the existing water injection header on the SDI at a maximum injection rate of 70,000 bpd. The Liberty ***LoSal*™** EOR process will use approximately 120,000 bpd of filtered and desalinated seawater from the existing Endicott seawater treatment plant (STP) in order to produced up to 50,000 bpd of ***LoSal*™** EOR process low-salinity water for injection. The seawater intake used for waterflooding is already permitted.

3.3.6.2 Other Water Usage

The Liberty development will also require water for:

- Construction of the ice road: 22 million gal/yr during the peak construction season
- Drilling rig use: 15 million gal/yr during drilling
- Temporary camp: 2.7 million gal/yr during drilling

Plans currently call for the ice road to be built almost entirely from water in the existing Duck Island Mine site, which is believed to hold on the order of 600 million gallons of water. The Endicott STP can provide an additional 20,000 bpd. Water is also available from several existing sources in the eastern Prudhoe Bay Unit. Should the existing water sources prove insufficient to support Liberty, it may be necessary to remove water from deep-water tundra lakes or rivers. In this event, different sites will be assessed to determine if water withdrawal can proceed within State and Federal agency guidelines.

3.3.6.3 Large Oil Spills

The lethal and sublethal effects of oil spills on fish have been discussed extensively in USDOI, MMS (1996); USDOI, MMS and BLM (1998); and USDOI, MMS (2002). The greatest potential for a large oil spill adversely affecting fish and fish habitat is during the open-water summer season that lasts from May through September. The nearshore shallows in and around the proposed Liberty Project and Endicott Causeway are the obligatory nursery grounds for a genetically distinct stock of broad whitefish that spawn in the Sagavanirktok River. This nearshore area also serves as prime summer feeding grounds for juvenile arctic and least cisco. The Sagavanirktok Delta is a critical migratory pathway for Dolly Varden that annually move between upriver overwintering and spawning sites and offshore feeding grounds. The Liberty Project also lies within the nearshore, brackish-water coastal corridor used by most anadromous and amphidromous species to disperse and forage along the coast. Large number of marine fish, including fourhorn sculpin and arctic flounder, also forage in nearshore waters.

Extensive oil contamination in nearshore areas would likely have lethal and sublethal effects on the anadromous, amphidromous, and marine fish that reside there. Large foraging areas could be lost. It is possible that the nearshore corridor used for migration and feeding dispersals by anadromous and amphidromous species could be broken. Contamination and blocking of the nearshore corridor in late summer could prevent these fish from returning to their obligatory freshwater overwintering grounds in the Colville and Sagavanirktok rivers. Recovery would be more rapid for some species than others. Arctic cisco spawn exclusively in the Mackenzie River in Canada and the least cisco in the Colville River. Large segments of their respective populations would be unaffected by an oil spill in the Liberty area, allowing for a more rapid recovery. Broad whitefish and Dolly Varden stocks that spawn and overwinter exclusively in the Sagavanirktok River could be more seriously impacted, and population recoveries would likely be slower.

Freshwater fish would probably not be affected to any great extent by a large Liberty oil spill. River discharge would prevent contaminated water from moving upriver into freshwater habitats. Although limited numbers of freshwater fish are found in the Sagavanirktok Delta during summer, their numbers are small and likely represent only a tiny fraction of the population.

Fourhorn sculpin, arctic flounder, arctic cod, and saffron cod are the two predominant marine species that occupy nearshore shallow waters during summer. Extensive oil contamination in these areas could have lethal and sublethal effects on any fish that came in contact with the spill, depending on intensity and duration. However, the impact to overall populations would be minimal. Marine fish populations are widespread throughout the Beaufort Sea, and the Liberty Project area represents only a small portion of their summer habitat. Because of their wide, vast distribution and high reproductive rates, the impact of a large Liberty oil spill to marine fish species would be minor.

3.3.7 Marine Mammals

3.3.7.1 Noise/Activity Disturbance

Noise and other disturbances from the proposed drilling activities for the Liberty Project at the SDI could impact marine mammals in the area. Beluga whales are not likely to be affected because of the distance between drilling activities and their migratory corridor well offshore from the barrier islands. Greene and Moore (1995) reported that underwater noise originating from artificial islands is generally inaudible beyond a few kilometers. It was predicted that drilling noise during periods of normal ambient conditions would attenuate to below-audible ranges approximately 2 km from the source. Underwater drilling noise could be audible up to 10 km from the source during unusually calm periods (Greene and Moore, 1995), but most beluga whales would likely be beyond 10 km from the SDI drilling source, and disturbance to beluga whales from SDI drilling activities would be unlikely.

Pacific walruses are absent during winter and rare visitors during summer in the Liberty Project area. It is unlikely that noise from drilling and oil production would impact walruses.

Seals in the area could potentially be disturbed by drilling and oil production activities from the Liberty Project. Numerous acoustical studies have reported underwater distances at which drilling sounds reach background levels. Blackwell, Greene, and Richardson (2004) reported that drilling noise during winter at Northstar Island reached background levels at approximately 9.4 km. Blackwell and Greene (2006) reported underwater broadband sounds associated with oil production at Northstar Island during the open-water season reached background levels at distances of 2 to 4 km. Ringed seals may be able to detect underwater industrial sounds out to 1.5 km in the water and approximately 5 km in the air (Blackwell, Greene, and Richardson, 2004). Moulton et al. (2002, 2003, and 2005) reported that limited winter industrial activity at Northstar Island did not appear to significantly affect ringed-seal density or behavior in the spring. Williams et al. (2006b) reported no relationship between ringed seal use of subnivean structures and the distance of those structures from Northstar Island. In addition, seals may become habituated to industrial sounds near artificial islands (Blackwell, Lawson, and Williams, 2004a). Noise and activity disturbances from drilling and oil production activities at the Liberty Project are unlikely to displace or disturb large numbers of seals.

3.3.7.2 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil or chemicals arising from drilling and oil production at the Liberty Project will impact marine mammals. Such minor discharges would likely be contained and cleaned up immediately. It is unlikely that any discharges would enter the marine environment.

3.3.7.3 Large Oil Spills

A large oil spill originating from the Liberty Project poses the greatest potential to impact marine mammals when measured against all other development-related consequences. The impact on marine mammals from an oil spill would depend on numerous factors, including the species, its age and health status, and the size/behavior of the spill. Seals, beluga whales, and possibly a few Pacific walruses could experience many impacts from direct exposure to oil, including skin and eye irritation, risk of infection, and stress. These effects could even contribute to the death of a few individuals (Geraci and Smith, 1976; Geraci and St. Aubin, 1980; St. Aubin, 1990). Furthermore, ingestion through consuming oiled prey or inhalation could lead to an accumulation of hydrocarbons in the bloodstream and cause death through kidney failure (Oritsland et al., 1981).

3.3.8 Marine and Coastal Birds

3.3.8.1 Noise/Activity Disturbance

Drilling noise would be limited since all drilling rig facilities will be enclosed. Associated noise and activities would continue from 2010 through 2013, potentially disturbing and displacing birds from the vicinity of the SDI. Some individuals will habituate to drilling noise and activity, as evidenced by the numbers of birds continuing to use habitats around the Endicott facilities (Noel et al., 2003). It is possible that the proximity of the newly expanded SDI and increased activity during construction and drilling will lead to nest abandonment by common eiders (~16 nests) and glaucous gulls (~4 nests) on the exploration island for Duck Island 1 & 2, located west of the SDI. Noise and disturbance will be localized, and no population-level effects are anticipated.

3.3.8.2 Small Spills or Leaks

Minor spills or leaks associated with drilling activities, including primarily surface runoff, would degrade foraging and resting habitats for molting long-tailed ducks and a few common eiders, red-throated loons, and Pacific loons. Habitat degradation would be localized, and no population-level effects are anticipated.

3.3.8.3 Large Oil Spills

Large oil spills from the SDI during drilling and production would have a variety of impacts to marine and coastal birds, ranging from small to extensive depending on the size of the spill, time of year, and trajectory of the spill. Details for the mechanisms for oil spill impacts to birds are discussed in Section III of the Liberty FEIS (USDOI, MMS, 2002).

Large spills originating from SDI drilling activities directed offshore of the Endicott Causeway during May to early November would contact flocks of migrant king and common eiders and molting long-tailed ducks, brood-rearing common eiders, and glaucous gulls in the Stefansson Sound region. A major spill during either spring or fall migration periods would significantly increase the number of exposed birds during periods when hundreds to thousands of birds move along the Beaufort Sea coast daily. Spills impacting the nearshore area between Prudhoe Bay and Tigvariak Island during the summer would likely contact 1,100 long-tailed ducks, 604 glaucous gulls, 36 common eiders, 13 king eiders, 20 scoters and 18 loons (Table 2.10-2). These individuals represent 1 to 3% of their populations on the Arctic Coastal Plain. Spilled oil can cause direct mortality by contact resulting in hypothermia, shock, and drowning, or indirect mortality through ingestion during preening or contamination of prey species. Spill losses are expected to be minor for regional populations of birds with stable or increasing numbers, but losses of birds with declining populations, such as long-tailed ducks, may be more significant.

Large spills originating either from the SDI or the pipeline along the Endicott Causeway and Road and reaching the Sagavanirktok River delta during July through September would expose all of the Howe Island nesting snow geese as they leave Howe Island with their goslings and most (62%, 2,367 of 3,816 total geese, 982 adults) of brood-rearing snow geese based on their July 19, 2006 distribution. The Howe Island snow goose colony represents a significant proportion of the snow geese nesting in Arctic Alaska. An estimated 4,200 brood-rearing and staging waterfowl would be exposed to a large spill in the Sagavanirktok River delta (1,494 snow geese, 1,098 white-fronted geese, 1,038 Canada geese, 251 brant, 103 tundra swan, 220 northern pintail, Table 2.10-2) representing 1 to 10% of the Arctic Coastal Plain populations for these species. Spill losses for these species are expected to be minor for most regional populations, with the exception of snow geese. These waterfowl species have exhibited stable or increasing numbers across the Arctic Coastal Plain. Loss of foraging habitats in the Sagavanirktok River delta for these waterfowl, including coastal salt marshes, mudflats and river channel habitats in the Sagavanirktok River delta, would potentially be more problematic (Noel et al., 2004; Sedinger and Stickney, 2000).

A large spill contacting the Sagavanirktok River delta either originating from drilling at the SDI or via a pipeline rupture along the Endicott Causeway and Road during late summer and fall shorebird staging in August and September would directly affect thousands of shorebirds and would degrade and contaminate coastal tundra and mudflat habitats with abundant forage species (Troy, 2000). Reduced foraging habitats and contaminated prey species would reduce survival of migrant shorebirds, with thousands to tens of thousands of migrant shorebirds potentially exposed (Andres, 1994; Powell et al., 2005).

A pipeline rupture along the Endicott Causeway and Road would impact tundra-nesting and foraging habitats, and coastal brood-rearing and foraging habitats. The severity of the habitat impacts would depend on the size and timing of the spill. A small winter spill would most likely be contained and removed with little or no damage to habitats, while a large summer spill would cause extensive habitat damage. Additional habitat damage and disturbance would occur from the cleanup of a large spill and subsequent site restoration. Spill cleanup in coastal areas would disturb nesting, brood-rearing, molting, or staging waterfowl or shorebirds during the initial cleanup. The number of people anticipated for a large spill (300 workers over 6 months) and the duration of cleanup activities (complete cleanup may take 4 years) would displace large numbers of waterfowl (Table 2.10-2) and shorebirds (Powell et al., 2005) from foraging habitats. A major spill from the SDI or from the Endicott pipeline into the Sagavanirktok River would have regional effects on bird productivity and abundance.

3.3.8.4 Waterflooding

The ***LoSal*™** EOR process will produce some discharges of hypersaline water and process waters which may decrease forage quantity, quality, or availability in the vicinity of the discharge. This would then potentially reduce the quality, quantity, and availability of invertebrate and vertebrate forage species for long-tailed ducks, eiders, loons, and glaucous gulls in the vicinity of the discharge. Seawater intake would entrain some forage species, reducing the quantity of available forage. Warm effluent discharges create a thaw area in the ice of the receiving water that is attractive to early-arriving sea ducks such as king eiders, common eiders, and loons. Attraction to these discharge streams exposes birds to contaminants. If the discharge is nutrient-enriched, long-tailed ducks, common eiders, loons, and glaucous gulls would be attracted to the discharge throughout the summer.

3.3.8.5 Bird Strikes

The large size and coastal location of the drilling rig increase the likelihood of collision impacts for migrant seabirds, primarily sea ducks, which fly low and fast along coastal and offshore areas during spring and fall migration. Although there are already substantial structures on the SDI, the addition of the rig will likely increase the incidence of bird strike mortality because of its height. Most mortality would be low numbers (dozens of birds), but large flocks (hundreds of birds) may collide with the structures, especially during periods of low visibility. The rig tower may create nesting habitats for ravens and snow buntings and foraging perches for ravens. Creation of artificial nesting habitats for ravens influences their distribution across the North Slope and may lead to increased predation on tundra-nesting birds in the project vicinity. Because the rig would remain on the SDI from 2010 through 2013, the likelihood of significant bird-strike mortality is reduced due to its short-term presence, and no population-level effects are anticipated from either bird-strike mortality or creation of artificial nesting habitats.

3.3.9 Terrestrial Mammals

Drilling and production operations at the expanded SDI site would be similar to activity levels generated during development of the original Endicott facility. These activities have not appeared to substantially alter the use of the Sagavanirktok River delta area by caribou (Pollard et al., 1996), although reduced crossings of the Endicott Road/pipeline corridor have been noted, especially during periods when traffic levels are greater than 15 vehicles/hour (Lawhead, Byrne, and Johnson, 1993). Before installation of animal-proof dumpsters, numerous grizzly bears and arctic foxes often frequented the Endicott facility and habitats along the Endicott Road. These animals then subsequently caused unusually high levels of depredation of snow geese and other nesting birds at the Howe Island and Duck Island nesting colonies (Johnson and Noel, 2005). After installation of animal-proof dumpsters, and the killing in defense of life and property of several food-conditioned bears known to frequent Howe Island, depredation of Howe Island snow geese has diminished (Rodrigues, McKendrick, and Reiser, 2006).

3.3.9.1 Large Oil Spills

Large oil spills during drilling and production would have a variety of impacts on mammal habitats depending on the size, time of year, and trajectory of the spill. Details for the mechanisms for oil spill impacts to terrestrial mammals are discussed in Section III of the Liberty FEIS (USDOI, MMS, 2002).

A pipeline rupture along the Endicott Causeway and Road would impact coastal tundra habitats. The severity of the impacts would depend on the size and timing of the spill. A small spill during winter would most likely be contained and removed with little or no damage to terrestrial mammal habitats, while a large spill occurring during the summer would cause more extensive habitat damage. Additional habitat damage and disturbance would occur from the cleanup of a large spill and subsequent site restoration. Spill cleanup in coastal areas would disturb caribou, muskoxen, grizzly bears, and arctic foxes. The number of people anticipated for a large spill (300 workers over 6 months) and the duration of cleanup activities (complete cleanup may take 4 years) would displace large caribou groups from foraging and insect-relief habitats in the Sagavanirktok River delta.

Caribou and muskoxen using coastal and delta habitats during summer for insect relief may become oiled or ingest contaminated vegetation. Oiled caribou calves would likely perish due to loss of thermoinsulation, leading to hypothermia; oiled adults would likely perish due to inhalation, adsorption through the skin, or ingestion of oil. Based on survey data collected between 1998 and 2003 (Figure 2.11-3), 20 caribou groups with an average of 75 and a maximum of 2,250 individuals would potentially be exposed to oil and disturbance from a large oil spill and subsequent cleanup activities in the East and West Channels of the Sagavanirktok River delta. The maximum number of caribou potentially exposed represents 7% of the Central Arctic Caribou Herd based on the 2002 census result of 31,857 caribou. Based on survey data collected between 1997 and 2003 (Figure 2.11-3), 1 muskoxen group with an average of 12 and a maximum of 18 individuals would be potentially exposed to oil and disturbance from a large oil spill and cleanup activities in the East and West Channels of the Sagavanirktok River delta. The maximum number of muskoxen exposed represents 9% of the Alaskan North Slope muskoxen based on the 2005 census result of 195 muskoxen. It is unlikely that the maximum number of animals exposed would actually perish due to oil toxicity. No population-level effects to either caribou or muskoxen would be expected due to contact with oil, short-term habitat losses, and/or disturbance from spill cleanup.

Large spills originating from SDI drilling activities reaching coastal habitats in the Sagavanirktok River delta and coastlines from Prudhoe Bay to Tigvariak Island would contaminate beaches and tidal flats. Grizzly bears and arctic foxes would likely ingest oiled birds, seals, or other carrion, which would result in the loss of a few bears and foxes. Bears and foxes would be hazed from the spill area, but may still become oiled or ingest contaminated prey. A few individuals would perish, but no population-level effects are anticipated.

3.3.10 Wetlands and Vegetation

3.3.10.1 Small Spills or Leaks

It is unlikely that minor spills or leaks of oil or chemicals arising from drilling and oil production will impact wetlands and vegetation. Such minor discharges would likely be contained and cleaned up immediately.

3.3.10.2 Large Oil Spills

Since Liberty facilities will be located primarily offshore, the impact to wetlands and vegetation from a large oil spill would be less compared to onshore developments. In the event of a major spill, however, coastal communities could be significantly impacted. Of particular concern would be the impact to coastal salt marshes. Salt marshes and other intertidal community types are considered high-value habitat for some species of birds (Sedinger and Stickney, 2000; Johnson, 2000). The degree of impact would vary depending on the concentration of the spill, time of year, and the affected area with regards to vegetation type, soil structure, and moisture regime. Impacts may range from complete die-off to little or no impact to wetland and other vegetative communities.

3.3.11 Threatened and Endangered Species

3.3.11.1 Noise/Activity Disturbance

Noise and other disturbances from the proposed drilling and oil production activities for the Liberty Project at the SDI are unlikely to impact bowhead whales. Much of the drilling would take place during the winter months when bowhead whales are in the Bering Sea. Drilling which takes place during their annual fall migration would also be unlikely to disturb bowhead whales due to the distance between the source of drilling at the SDI and the bowhead whale migratory corridor 15 km or more offshore. Greene and Moore (1995) concluded that underwater noise originating from drilling on artificial islands is generally inaudible beyond a few kilometers. It was predicted that drilling noise during periods of normal ambient conditions would attenuate to below-audible ranges approximately 2 km from the source. Miles, Malme, and Richardson (1987) predicted the radii of potential bowhead-whale response to drilling on an artificial island to be 0.05 to 1.8 km.

Underwater sound propagation is dependent on numerous factors including not only the sound pressure level at the source, but also ambient and environmental conditions such as sea state, water depth, bathymetry, and substrate type (Richardson et al., 1995). Underwater drilling noise could be audible up to 10 km from the source during unusually calm periods (Greene and Moore 1995). Blackwell, Greene, and Richardson (2004) reported that underwater broadband-sound levels from drilling on Northstar Island reached background levels about 9.4 km from the island. McDonald et al. (2006) reported subtle offshore displacement of the southern edge of the bowhead whale migratory corridor offshore from Northstar Island, but the bowhead migration corridor is closer to Northstar Island (approximately 8 km) than it is to the SDI (approximately 15 km). The SDI has had a drilling operation for years with no apparent impacts to bowhead whales. The Liberty Project is also inshore of the barrier islands, which likely act as an additional sound barrier to the bowhead-whale migratory corridor. It is unlikely that noise from drilling and oil production activities at the SDI for the Liberty Project will impact migrating bowhead whales offshore.

Some of the drilling for the Liberty Project at the SDI is likely to take place during winter when spectacled and Steller's eiders are absent from the project area. Noise and activity disturbances during the spring nesting season will likely have minimal effects on nesting eiders. Both spectacled and Steller's eiders select nest sites in tundra habitats that are not located near the SDI, and airborne noise traveling to adjacent tundra habitats would not likely affect nesting eiders. Noise and activity could displace adult eiders and females with broods in the immediate area of the SDI or eiders using the shore near the SDI for resting. These birds would likely move to adjacent habitats, and potential impacts to threatened eiders would likely be minimal.

Small numbers of polar bears using maternal dens or polar bears passing through the area during fall could be affected by drilling and oil production noise. Polar bears would likely habituate to industrial noise if it was not associated with other stimuli (Perham, 2005), and effects on polar bear abundance and distribution would be minimal.

3.3.11.2 Small Spills or Leaks

It is unlikely that minor spills or leaks or oil, chemicals, or wastewater from the Liberty Project at the SDI will impact bowhead whales, polar bears, or spectacled and Steller's eiders. Such minor discharges would likely be contained and cleaned up immediately and would be unlikely to affect these species.

3.3.11.3 Large Oil Spills

A large oil spill from the Liberty Project at the SDI likely poses the greatest threat to bowhead whales of any development-related consequences associated with the project. Geraci (1990) hypothesized that whales could experience any of the following adverse effects from an oil spill: oiling of the skin, inhalation of harmful vapors, ingestion of contaminated prey/food, fouling of their baleen, decreased food availability, displacement from preferred feeding habitats, death, and other effects. All of these factors have the potential to decrease bowhead whale survival following direct exposure to a large oil spill. There is no empirical evidence supporting bowhead whale mortality as a direct result of contact with spilled oil, but whales could experience death from prolonged exposure to oil (USDOI, MMS, 2002).

Oil spill response activities could also affect bowhead whales if an oil spill occurred. The extent of consequences to whales from oil spill response efforts would depend on the location, timing, amount, and behavior of spilled oil in marine habitat. Effects would be greatest if a spill took place in the bowhead-whale migratory corridor during fall migration and decrease with distance from the corridor. An oil spill during the open-water season in August does not approach the migratory corridor (see Section 3.4.3). Disturbances would likely be related to displacement from noise and activity of spill response vessels. Oil spill response activities could have a positive impact on bowhead whales by displacing individuals to areas away from the spill, thereby reducing the risk of exposure to spilled oil.

A large oil spill would likely pose the greatest threat to spectacled and Steller's eiders in the Liberty Project area. Eiders coming in direct contact with oil would likely experience mortality resulting from oiling of their feathers. Oiling of bird feathers can lead to shock, hypothermia, and drowning (USDOI, MMS, 2002). Eiders surviving the initial phases of exposure to an oil spill could be susceptible to related impacts, including reduced functioning of the endocrine system (impeding detoxification of other body systems), liver damage, loss of weight, and ultimately, decreased production of young (USDOI, MMS, 1996).

Spectacled eiders occur in low densities in the Sagavanirktok River delta. Steller's eiders are a rare occurrence and not expected to be present in the project area. The low densities of threatened eiders in the project area make it unlikely that significant numbers of spectacled or Steller's eiders would be impacted by an oil spill. However, spectacled eiders may occur in flocks in offshore habitats (Fischer et al., 2002), increasing the risk of multiple individuals being affected if a group were to encounter spilled oil. Any consequence affecting population numbers will hinder these species' recovery from their threatened status (USDOI, MMS, 2002).

Oil spill response efforts could impact eiders if a large oil spill were to occur. The extent of consequences to eiders from oil spill response efforts would depend on the location, timing, amount, and behavior of spilled oil. Oil spill response activities could have a positive impact on eiders by displacing birds to areas away from the spill, thereby reducing the risk of exposure to spilled oil.

Polar bears could be directly oiled and die from a loss of insulation provided by their fur. In addition, polar bears may ingest oiled prey or inhale harmful vapors that could lead to an accumulation of hydrocarbons in the bloodstream and cause death through kidney failure (Oritsland et al., 1981). The susceptibility of polar bears to oil spills is not uniform over time. Nearshore densities of polar bears are 2 to 5 times greater during the fall when compared with summer (Durner and Amstrup, 2000). Polar bear use of Beaufort Sea coastal habitats during the autumn has increased in recent years. This trend has correlated with increasing amounts of open water in the Beaufort Sea (e.g., the further Beaufort Sea pack ice has been from shore, the higher the observed densities of polar bears has been in coastal areas; Schliebe et al., 2005). If these trends continue into the future, then it is possible that more polar bears could be impacted by an oil spill from the Liberty Project area during fall.

Polar bears sometimes choose terrestrial den sites near the coast, along lakeshores, riverbanks and other areas with unique topographical features (Durner et al., 2001; Durner et al., 2003). Durner et al. (2001) identified large areas along the coast and adjacent areas along the Sagavanirktok River near SDI that are suitable for terrestrial maternal den sites. Additionally, the proportion of maternal dens located in terrestrial versus pack-ice habitats appears to be increasing in recent years. Fischbach et al. (2007) reported that the proportion of dens on pack ice declined from 62% during 1985 to 1994 to 37% during 1998 to 2004. Changes in ice quantity and quality related to climate change could result in increased numbers of terrestrial maternal den sites near the Liberty Project area in future years (Fischbach et al., 2007). Higher numbers of denning polar bears and cubs in coastal areas could expose more bears to an oil spill from the Liberty Development. This scenario would increase the potential impacts of an oil spill on polar bears.

3.3.11.4 Bird Strikes

There is the potential for eider mortality from collisions with Liberty Project structures at the SDI because eiders fly at relatively low altitudes over the water (Johnson and Richardson, 1982). Day et al. (2005) reported the mortality of 36 eiders as a result of collisions with facilities at Northstar Island or Endicott over a 4-year period. These birds were all common and king eiders, but the presence of spectacled eiders in the Liberty Project area makes them susceptible to collisions with project facilities. Gas flares also pose a threat to birds in flight by creating the risk for collision or incineration (Wiese et al., 2005). However, spectacled eider density is low in the Liberty Project area, and Steller's eider is rare in the area. The low numbers of these two species in the area will decrease the potential for collisions with Liberty facilities at the SDI. Very low numbers of spectacled or Steller's eiders would be affected by collisions with Liberty Project facilities. However, any spectacled or Steller's eider mortalities as a result of collision with Liberty Project facilities would inhibit recovery from their threatened status.

3.3.12 Socioeconomics

Possible socioeconomic impacts are discussed in the Liberty FEIS (USDOI, MMS, 2002), which is incorporated by reference. It is appropriate to provide additional material, however, because of changes in the project and its alternatives. These changes alter the likely environmental impacts of the project, and substantial increases in the price of crude oil (if these prevail in the future) would substantially increase the economic benefits of the project. This section covers the following impacts: economics, subsistence, and sociocultural systems.

3.3.12.1 Economics

The direct economic impacts of the Liberty Project were addressed in the Liberty FEIS (USDOI, MMS, 2002) and include direct and indirect jobs, royalty revenues to Federal and State governments, and tax revenues to the North Slope Borough (NSB). Additional impacts not considered in the original EIS relate to national impacts, such as those on the balance of payments.

The original EIS assumed that the total Liberty production over the economic life of the field would be 120 million barrels (MMbbl) and that the prevailing crude oil price would be $16.30/bbl (see Section 3.6.2 of this EIA). The revised estimate of cumulative production is 105 MMbbl — 12.5% smaller than originally assumed. However, the price of crude oil is over $61/bbl as of this writing, nearly four times that assumed in the FEIS. The Fall *2006 Revenue Sources Book* issued by the Alaska Department of Revenue (Alaska Department of Revenue, 2006) projects lower crude-oil prices in the future than those at present: $41.50/bbl post-fiscal-year (FY) 2014, still substantially greater than those assumed when the FEIS was written.[9] Long-range forecasting of all commodity prices is difficult, and experience shows that forecasting oil prices is particularly challenging. Nonetheless, both the Alaska Department of Revenue and the U.S. Energy Information Administration project crude oil prices substantially greater than $16.30/bbl by the time Liberty begins production. Thus, the revenues to the State of Alaska and the Federal Government are likely to be substantially greater than estimated in the Liberty FEIS. Liberty is obligated to pay the MMS a 12.5% royalty (in value or in kind), and because of the particular

[9] The present Liberty schedule calls for first production in 2011. The Fall 2006 Revenue Sources Book predicts that ANS West Coast prices will be $50/bbl in this year, even higher than the price used for illustrative purposes above.

location of the lease and the agreement that the MMS has with the State of Alaska, the State will receive 27% of that 12.5% royalty, or 3.375%.[10] Additionally, the NSB will receive tax revenues based upon the ad valorem value of the onshore infrastructure and the prevailing tax rate.

The Liberty FEIS did not explicitly discuss potential economic impacts at the national level, but these could be material. The U.S., as recently as World War II, was self-sufficient in oil, but is now a net oil importer. Petroleum imports are an important component of the balance-of-payments deficit. At $41.50/bbl, Liberty's total production of 105 MMbbl has a value of $4.3 billion.

The Liberty FEIS examined the effects of construction activities on the Alaskan economy and the subsistence aspects of the economy and concluded "We do not expect disturbances to affect the cash economies." The new project proposal should have even smaller economic effects associated with construction, because the revised plan exploits more of the existing infrastructure. Sections 3.1.12 and 3.2.9 restate estimates of the number of construction jobs in the Liberty EIS.

The Liberty FEIS estimated that production operations would generate 50 jobs annually for the duration of drilling and 50 jobs annually for the duration of production. Estimates of the number of workers needed for drilling and production in the revised Liberty Project provide for a greater number of workers during the initial drilling operation and fewer operators needed during long-term production. The maximum number of annual drilling jobs is estimated to be 120 over a 4-year period. Once production begins, the estimated annual number of production jobs is 20 workers over a 30-year period. The estimated level of employment, while initially higher than that given in the FEIS, is approximately the same over time and is expected to have minimal impact on the local economy.

In the unlikely event that a large oil spill occurred, the FEIS estimated that a range of 5 to 125 jobs would be generated for 6 months for cleanup activities.

3.3.12.2 Subsistence

The Liberty FEIS (USDOI, MMS, 2002) addressed possible impacts of this project on subsistence and subsistence-harvest patterns. Potential impacts on subsistence are rightly viewed with concern because of the key importance of subsistence and subsistence harvests to residents of the NSB. The FEIS concluded:

> "We do not expect significant impacts to result from any of the planned activities such as discharges and disturbances associated with Alternative I (Liberty Development and Production Plan) or any of the other alternatives. Some significant impacts — adverse effects to spectacled eiders, king and common eiders, long-tailed ducks, subsistence-harvest patterns, sociocultural systems, and local water quality — could occur in the unlikely event of a large oil spill. However, the very low chance of such an event occurring…combined with the seasonal nature of the resources inhabiting the area (for example, eiders are present in the Liberty area 1-4 months of the year), makes it highly unlikely that an oil spill would occur and contact the resources. A resource may be

[10] Royalties are based on the *net wellhead price*, which is the appropriate crude oil price less the pipeline and tanker transportation costs/tariffs. The pipeline tariffs and tanker transportation costs are not based on the price of the oil. Thus, if oil prices increase and pipeline tariffs and tanker transportation costs remain constant, the net wellhead price — and thus Federal and State royalties — will increase by a greater proportion than the oil price.

> present in the area but may not be contacted by oil…None of the component or combination alternatives evaluated [in this] EIS are expected to generate significant impacts from planned activities. If an unlikely oil spill occurred, similar significant effects could occur to spectacled eiders, king and common eiders, long-tailed ducks, subsistence harvests, sociocultural systems, and local water quality for all alternatives."

More specifically, with respect to subsistence-harvest patterns, the Liberty FEIS [Section IIh(1)] concluded:

> "Overall, oil spills could affect subsistence resources periodically in the communities of Nuiqsut and Kaktovik. In the unlikely event of a large oil spill, many harvest areas and some subsistence resources could be unavailable for use. Some resource populations could suffer losses and, as a result of tainting, bowhead whales could be rendered unavailable for use. Tainting concerns in communities nearest the spill event could seriously curtail traditional practices for harvesting, sharing, and processing bowheads and threaten a pivotal underpinning of Iñupiat culture. There is also a concern that the International Whaling Commission, which sets the quota for the Iñupiat subsistence harvest of bowhead whales, would reduce the harvest quota following a major oil spill or as a precaution as the migration corridor becomes increasingly developed to ensure that overall population mortality did not increase. Such a move would have profound cultural and nutritional impact on Iñupiat whaling communities. Whaling communities distant from and unaffected by potential spill effects are likely to share bowhead whale products with impacted villages. Harvesting, sharing, and processing of other subsistence resources should continue but would be hampered to the degree these resources were contaminated. In the case of extreme contamination, harvests could cease until such time as resources were perceived to be safe by local subsistence hunters. Overall, effects are not expected from routine activities and operations.
>
> Tainting concerns also would apply to polar bears and seals and beluga whales, walruses, fish, and birds. Additionally a large oil spill could cause potential short-term but serious adverse effects to long-tailed ducks and king and common eider populations. A potential loss of one or two polar bears could reduce their availability locally to subsistence users, although they are seldom hunted by Nuiqsut hunters except opportunistically while in pursuit of more preferred subsistence resources."

Addressing bowhead whales specifically, the Liberty FEIS [Section III h(2)(2)(a)] added:

> "The potential for bowhead whales to be affected by spilled oil from the Liberty Project is relatively small based on the estimated size of a spill and the relatively low…chance of spilled oil reaching the main bowhead fall migration route outside the barrier islands. However, if a spill occurred and contacted bowhead habitat during the fall whale migration, it is likely that some whales would be contacted by oil. It is likely that some of these whales would experience temporary, nonlethal effects…Traditional practices for harvesting, sharing, and processing subsistence resources could be seriously curtailed in the short term, if there are concerns over the tainting of bowhead whales or their feeding areas from an oil spill."

No new information has been found that would invalidate this original assessment in the Liberty FEIS with respect to the alternatives considered. What has changed is the proposed action, which differs from those evaluated in the Liberty FEIS. Specifically, the new proposed action employs ultra-extended-reach drilling (uERD) from an existing facility — rather than a new offshore location. Such a project reduces the offshore impacts of island and pipeline construction. This change in project scope significantly mitigates the potential impacts related to the Boulder Patch, marine mammals, and concerns of the North Slope Iñupiat communities related to the bowhead whale and subsistence whaling. Development using the existing infrastructure at Endicott further mitigates impacts by avoiding construction of a pad on the shoreline of Foggy Island Bay and an access road and pipeline crossing of the Sagavanirktok River delta. In principle, therefore, the probable impacts of the new proposed action would be the same or smaller than those identified in the Liberty FEIS.

Oil production with the new proposed alternative might also result in crude oil or product spills. Small operational spills of crude or product are virtually certain to occur, but would not be expected to have significant impacts. As discussed in Section 3.4, large crude spills, although unlikely, might also occur. Depending upon the location, timing, amount, and behavior of the spill(s), significant adverse effects on certain species, subsistence-harvest patterns, and sociocultural systems might result. This conclusion is not unique to the Liberty Project; EIS/EAs for other development projects (see e.g., USDOI, MMS, 2003, 2004, and 2006) also conclude that a large oil spill could have significant adverse impacts.

3.3.12.3 Sociocultural Systems

The Liberty FEIS (USDOI, MMS, 2002) concluded:

> "Effects on the sociocultural systems of communities near the Liberty Project area could occur as a result of disturbance from industrial activities; changes in population and employment; and effects on subsistence-harvest patterns. They could affect the social organization, cultural value, and social health of the communities. Together, effects may periodically disrupt, but not displace, ongoing social systems, community activities, and traditional practices for harvesting, sharing, and processing subsistence resources."

As noted above, the new proposed action should result in lower impacts than those anticipated for the original alternatives. Sociocultural impacts would result from a large crude oil spill because of the disruption of subsistence harvests as discussed above.

It is important to note that the total estimated Liberty production is only a very small proportion of the oil already produced on the North Slope and also a small proportion of the oil projected to be produced in the future.

3.3.12.4 Environmental Justice

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (59 *Federal Register* 7629), requires each Federal agency to make the consideration of Environmental Justice part of its mission. Section 1-101 states:

> "To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by

> identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations in the United States and its territories and possessions…"

Other portions of this order require agencies to develop strategies to address environmental justice (1-103); research, data collection, and analysis (Section 3-3); and requirements to collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence (4-401). EISs drafted after the effective date of this order contain sections on environmental justice.

In particular, Alaska Iñupiat Natives, a recognized minority, are the predominant residents of the North Slope Borough (NSB). Therefore, it is relevant to consider whether or not the environmental impacts of the proposed Liberty development project will have "disproportionately high and adverse" impacts on NSB residents.

The Proposed OCS Lease Sale 202 EA (USDOI, MMS, 2006) defines a "significance threshold" for each resource category as a level of effect that equals or exceeds a designated threshold:

> "The significance threshold for Environmental Justice would be disproportionate, high adverse human health or environmental effects on minority or low-income populations. This threshold would be reached if one or more important subsistence resources becomes unavailable, undesirable for use, or available only in greatly reduced numbers for a period of 1 - 2 years; or chronic disruption of sociocultural systems occurs for a period of 2 – 5 years, with a tendency toward displacement of existing social patterns. Tainting of subsistence foods from oil spills and contamination of subsistence foods from pollutants would contribute to potential adverse human-health effects."

The Liberty FEIS (USDOI, MMS, 2002) reached the following conclusion about environmental justice:

> "Alaska Iñupiat Natives, a recognized minority, are the predominant residents of the North Slope Borough, the area potentially most affected by Liberty development. Effects on Iñupiat Natives could occur because of their reliance on subsistence foods, and Liberty development may affect subsistence resources and harvest practices. The Iñupiat community of Nuiqsut, and possibly Kaktovik, within the North Slope Borough, could experience potential effects. In the unlikely event that a large oil spill occurred and contaminated essential whaling areas, major effects could occur when impacts from contamination of the shoreline, tainting concerns, cleanup disturbance, and disruption of subsistence practices are factored together. However, effects are not expected from routine activities and operations. When we consider the little effect from routine activities and the low likelihood of a large spill event, disproportionately high adverse effects would not be expected on Alaskan Natives from Liberty development under the Proposal. Any potential effects to subsistence resources and subsistence harvests are expected to be mitigated substantially, though not eliminated."

Basically similar conclusions were reached for other proposed North Slope projects, such as the multiple-sale EIS and subsequent EAs (see e.g., USDOI, MMS, 2003, 2004, 2006) because disproportionately high adverse effects are not expected to occur from routine exploration and development activities. It is recognized that the threshold for significance of environmental justice impacts might be exceeded in the unlikely event of a large oil spill that impacted key subsistence resources.

The Bureau of Land Management also reached similar conclusions regarding North Slope projects under its jurisdiction. For example, the Alpine Satellite Development Plan Final EIS (USDOI, BLM, 2004) examined environmental justice effects and offered the following comments on oil spills:

> "The analysis of spill impacts shows that very small and small spills are unlikely to have long-term, extensive impacts that would affect water quality, habitat, or subsistence species. Larger spills that are more likely to have impacts that are more extensive have a very low probability of occurrence. Spill impacts, to the extent that they occur, would be episodic, not continuous. Local residents have shown a propensity to avoid resources from areas where spills have occurred because of a lack of confidence that subsistence resources have not been contaminated. This lack of confidence could affect subsistence use for a period beyond the time when any resources affected from the spills would actually persist."

In analyzing development of a much larger field (460 million bbl, compared to 105 million for the Liberty Project), the NE NPR-A IAP (USDOI, BLM, 2005) noted:

> "…the magnitude of effects of a crude oil spill on subsistence resources would depend on the context of the spill, the volume and area covered by spilled product, and the amount of time the product was released before clean-up efforts commenced. Tundra oil spills could affect small numbers of terrestrial mammals and waterfowl unable to avoid the spill area, but would be unlikely to have population level effects. Oil spills directly into a water body, particularly in difficult to contain conditions such as breakup or broken ice, would spread widely and have effects on fish and waterfowl. In the nearshore environment, a large to very large spill, particularly during broken ice or storm conditions, could affect marine mammals including seals, and beluga and bowhead whales."

The NE NPR-A IAP also stated:

> "While any major spill would have serious consequences, the worst, from an environmental justice standpoint, would be one that occurred in a key harvest area or near a community, particularly Nuiqsut."

This same document notes:

> "The Iñupiat people consider contamination from oil spills in nearshore waters to be a catastrophic possibility that would threaten their very existence, primarily because of the potential effects of spills on bowhead whales, which are a very important part of their culture in addition to being a favored food source."

The above excerpts from other North Slope EISs clearly indicate that consideration of environmental justice impacts from oil spills is relevant, but these documents conclude that small oil spills are unlikely to have impacts that reach the threshold of significance. These documents also indicate that large spills could have significant adverse impacts, but that the likelihood of such effects is small.

The conclusion reached in the Liberty FEIS still holds, and the new proposed alternative for Liberty is likely to be environmentally superior to any of the original alternatives. Therefore, while environmental justice concerns are relevant, disproportionate, high adverse effects might occur only in the unlikely event of a large oil spill that (because of location, season, volume, or other factors) were to significantly impact key subsistence resources. As stated in the Liberty FEIS, "any potential effects to subsistence resources and subsistence harvests are expected to be mitigated substantially, though not eliminated." For any of the Liberty Project alternatives, BPXA will implement mitigation measures to minimize the possibility and potential for oil spills (see Section 4.2.4).

3.3.13 Waste Management

All waste from the Liberty Project would be handled in accordance with State, Federal, and local regulations. Use of permitted disposal wells and other approved disposal methods will result in zero surface discharge of drilling wastes, and — in conjunction with BPXA's waste minimization policy — will result in little or no impact from waste disposal. See Section 10 of the Liberty DPP for more information on waste handling.

3.4 FATE AND EFFECT OF OIL SPILLS

3.4.1 Risk of an Oil Spill

As noted in the original Liberty Project documents (LGL, 1998) and the FEIS (USDOI, MMS, 2002), BPXA is required by both State and Federal law to implement approved spill contingency plans (both with the MMS and the ADEC). Implementation of such plans is also the primary means of minimizing the risk of a spill and assuring that spill response will be swift and effective. However, for planning purposes and to estimate the potential direct and indirect effects of an oil spill from the proposed Liberty Project, an oil spill risk analysis has been completed.[11] This section summarizes the oil spill risk analysis presented in detail in Appendix A of this EIA. The risk analysis and the summary below incorporate comments and techniques suggested by the North Slope Borough Science Advisory Committee (NSBSAC, 2003). In particular, the summary below provides information in a plain-language format, avoids extrapolation of data from potentially unrepresentative areas,[12] and provides information on the upper and lower confidence limits on the probability of a large spill.

To quantify the probable crude and refined petroleum (product) spill volumes associated with the operation of the Liberty Project, a database of historical Alaska North Slope (ANS) crude oil and product spill records was developed. The historical spill database was compiled by analyzing industry and government-agency oil spill databases for ANS facilities, including wells, facilities, and other pipelines up to (but not including) Pump Station 1 (PS-1), which marks the beginning of the Trans Alaska Pipeline System (TAPS). The spill projection method employed is based on statistical models used by MMS for ANS and other oil fields.

Figure 3.4-1 presents a flowchart of the general method used to develop the oil spill risk analyses. The spill dataset was divided into three categories: large crude oil spills, small crude oil spills, and product spills. Appendix A describes the process in detail.

[11] Appendix A provides an analysis of potential oil and hydrocarbon spills for the proposed Liberty Development Project. Two types of spills are considered in this analysis (1) spills of crude oil and (2) spills of refined products (e.g., diesel, hydraulic fluids, etc.). For simplicity, these are referred to as crude and product spills in the remainder of this section. Produced water spills are not included in this analysis. In cases where a "mixed spill" occurs, the respective volumes of crude oil and product are calculated by multiplying the total spill volume by the respective percentages of crude or product.

[12] The NSBSAC specifically noted that extrapolation of data from the Gulf of Mexico might be inappropriate.

The data used for this analysis include historical ANS crude and product spills for 1985 to 2006, a time period believed most appropriate for this purpose.[13] The basic assumption is that the likelihood of future crude and product spills associated with the Liberty Development Project can be accurately estimated from prior ANS experience, i.e., that spill rates (per billion barrels produced) for this project will match those of other ANS facilities. This basic assumption may overstate potential spills from Liberty because this project makes efficient use of existing facilities and features few incremental facilities. The Liberty Project design and scope have evolved from an offshore stand-alone development in the outer continental shelf (production/drilling island and subsea pipeline) — as described in the 2002 Liberty FEIS — to use of existing infrastructure involving an expansion of the SDI. As a result, development of Liberty from Endicott significantly reduces potential environmental impacts and project footprint, and does not require construction of new processing and transportation facilities.

Liberty will be developed with very few wells from the expanded SDI using a purpose-built drilling rig to reach the offshore Liberty reservoir located on the OCS. Since the drilling rig will be powered by natural gas, no handling and storage of large quantities of diesel fuel is required for the project. Production from the Liberty wells will be tied into the existing Endicott flow line system with production sent from the SDI via the existing 28-inch corrosion-resistant-alloy three-phase flowline to the Endicott MPI for processing. The Endicott plant internals are constructed of duplex stainless steel for production. After processing at the MPI facilities, Liberty oil will transported through the existing 16-inch Endicott sales oil pipeline (which is a DOT regulated pipeline) to Pump Station No. 1 of TAPS. This pipeline is internally inspected on a cycle of not less than once every 5 years (the last inspection was 2005) using a magnetic flux pig. The Liberty Project will be using the Endicott facilities through a facility sharing agreement with the Duck Island Unit Owners (the agreement is currently being negotiated).

As noted above, Liberty will not have its own infrastructure; the analysis presented here conservatively assumes that the direct and indirect impacts of the Liberty Development Project can be estimated based on a statistical analysis of spills of the other oil fields on the North Slope. This method avoids the methodological difficulties of extrapolating oil spill experience from other areas of the country (or world), such as the Gulf of Mexico.

Because spills are random (not deterministic) phenomena, it is appropriate to use statistical (or probabilistic) methods to describe the number, volume, and likelihood of future spills.

3.4.1.1 Large Crude Spills

Crude spills included in this analysis are subdivided into large spills (those >200 bbl) and small spills.[14] For large crude spills:

- The expected number[15] of large spills throughout the operating life of the Liberty Project is 0.09 based on the estimated production of 105 million bbl and the ANS

[13] See Appendix A for more information. This time period spans over 20 years of ANS oil spill records and provides thousands of reliable spill records for analysis.

[14] MMS traditionally used 1,000 bbl as the threshold for a large spill. However, only one ANS spill >1,000 bbl has occurred from 1977 to the present. The Liberty FEIS used 500 bbl as a threshold, and more recent studies (Eschenbach and Harper, 2006) have considered thresholds as small as 50 bbl. The choice of 200 bbl provides an adequate sample of large spills for statistical purposes and lowers the likelihood that estimates will be biased if the volume distribution of small spills differs from that for large spills.

[15] This is a statistical term of art and denotes the sum of the probabilities of 0, 1, 2, 3…spills times the number of spills, summed over all possible numbers of spills. Another word that might be chosen is the *estimated* number of spills. In this instance, the expected or estimated number of large spills is 0.09 — an impossibility because the number of large

experience that nine large (>200 bbl) spills occurred during the production of nearly 11 billion bbl of crude oil produced over the period from 1985 to 2006.

- The estimated probability (in percentage terms) that *no large spill will occur* is approximately 92%.[16] The estimated probabilities (based on the Poisson model) that there will be 1, 2, or 3 large crude spills over the life of the Liberty Field are estimated to be approximately 7.8%, 0.3%, and <0.01%, respectively.
- The odds against one or more large spills occurring over the project lifetime are estimated to be approximately 11:1. The odds against two or more large spills occurring are nearly 285:1.
- If the future is like the past and the assumed model is correct,[17] the confidence is high (95%) that the actual probability that no large spill will occur during the operation of the Liberty field lies between 85% and 96%. That is, large spills are unlikely.
- If a single large oil spill were to occur, then a reasonable estimate of the probable spill volume, using actual data directly as well as fitting statistical models, is approximately 1,000 bbl. Allowing for the possibility of multiple large spills, the estimated spill volume is only slightly larger than 1,000 bbl. However, because large spills are infrequent, the weighted-average large spill volume is estimated to be only 85 bbl.[18]
- Because there is a distribution of large spill volumes, it is possible that the cumulative large spill volume — given the unlikely event that one occurs — would be greater than 1,000 bbl. Monte Carlo simulations described in Appendix A indicate that the 95% confidence interval on the volume of large spills (given that one occurs) is from 225 to 4,786 bbl.

Finally, it is important to note that, because the project throughput of the Liberty Project is only a small fraction of the total ANS crude oil throughput, *it is more likely that any future large crude oil spill will come from one of the other producing fields than from Liberty.*

The Liberty FEIS (USDOI, MMS, 2002) offered the following comments on the chance of a large spill occurring:

> "The analysis of historical oil-spill rates and failure rates and their application to the Liberty Project provides insights, but not definitive answers, about whether oil may be spilled from a site-specific project. Engineering risk abatement and careful professional judgment are key factors in confirming whether a project would be safe.
>
> We conclude that the designs for the Liberty Project would produce minimal chance of a significant oil spill reaching the water. If an estimate of chance must be given for the offshore production island and the buried pipeline, our best professional judgment is that the chance of an oil spill greater than or equal to 500 bbl occurring from the Liberty Project and entering the offshore waters is on the order of 1% over the life of the field…
>
> We base our conclusion on the results gathered from several spill analyses done for Liberty that applied trend analysis and looked at causal factors. All

spills must be an integer (0, 1, 2, 3, etc). The significance of the expected number is that large spills are expected to be infrequent.

[16] Note that this statement applies only to large spills. Many small spills (see Appendix A) are likely to occur.

[17] This model is conceptually plausible and has been validated by historical experience in the Gulf of Mexico and ANS.

[18] As noted, if a large spill occurs, the volume estimate is approximately 1,000 bbl, but because the probability of a large spill occurring is so low, the weighted average volume of a large spill is much lower.

showed a low likelihood of a spill, on the order of a 1 - 6% chance or less over the estimated 15-20 year life of the field."

While not identical, the projections made in this report are broadly consistent with the results of the Liberty FEIS; both estimates indicate that it is unlikely that a large spill would occur. As to differences:

- The original analysis defined a large spill as one 500 bbl or greater, whereas this analysis uses 200 bbl as the threshold of a large spill.[19] As shown in Appendix A, the probability that no large spill would occur (assuming a 500-bbl threshold) is 94.4% — numerically closer[20] to that estimated in the FEIS. (The 95% confidence interval on the probability that no large spill would occur assuming a 500-bbl threshold is from 88.3 to 97.9%. This confidence interval overlaps the 94 to 99% range specified in the Liberty FEIS.)
- The original spill estimates were based on the definition of a large crude oil spill from the offshore production island and buried pipeline reaching the water. This analysis addresses the occurrence of a large crude oil anywhere in the facility and makes no assumption regarding whether or not the spill reaches the water.
- The estimate developed in Appendix A is based solely on the assumed production volume of Liberty and actual spill statistics from ANS operations updated through 2006. That presented in the FEIS used data from several sources and ultimately was based on engineering judgment.

3.4.1.2 Small Crude and Refined Product Spills

Data from ANS and other areas indicate that small spills of either crude or product are more numerous than large spills, but the average size of a small spill is very much smaller than the average size of a large spill, with the result that since 1985 the aggregate volume of ANS small spills was only about 28% of the total volume of crude oil spilled. Other factors held constant, a smaller spill is more likely to be contained, more readily cleaned up, and less likely to have adverse environmental effects than a large spill. For this reason, most spill analyses focus on larger spills. Nonetheless, small spills should be considered out of concern about chronic effects from numerous small spills.

Appendix A also estimates of the volume of small spills associated with Liberty. For small oil spills:

- The estimated total crude-oil volume (for the operating lifetime of the Liberty Project) based on the observed ratio of the volume of small spills to ANS production is approximately 35 bbl.[21] Assuming a 20-year project lifetime, the average small crude-oil volume spilled per year would be 1.75 bbl/year.
- The 95% confidence interval on the total volume of small crude spills over the lifetime of the project ranges from 6 to 100 bbl.

Product spills, though numerous, are very small on average. Using the same method as that employed to project small crude spills, the following estimates are derived for the expected and 95% confidence limits on the volume of refined product spills:

[19] This choice of 200 bbl as the threshold was made on statistical grounds.
[20] This estimate is within the range of plausible estimates given in the FEIS.
[21] For comparison, the Liberty FEIS estimated that there might be 17 spills less than 1 bbl and 6 spills greater than or equal to 1 bbl and less than 25 bbl. These estimates are broadly consistent with the estimates given in Appendix A.

- The estimated total product volume (for the operating lifetime of the Liberty Project) based on the observed ratio of the volume of small product spills to ANS production is approximately 40 bbl,[22] equivalent to 2 bbl/year over a 20-year project lifetime.
- The 95% confidence interval on the total volume of small product spills ranges from 10 to 125 bbl.

3.4.2 Behavior of Spilled Oil

This section briefly examines the behavior of oil spilled on the Alaska North Slope. Much of the information summarized below is developed in detail in the NPR-A EIS (USDOI, BLM, 1998); the Northstar EIS (USACE, 1999); the Liberty FEIS (USDOI, MMS, 2002); and the Beaufort Sea Planning Area Multi-Lease Sale (USDOI, MMS, 2003). An extensive discussion of the fate and effects of oil spilled on the North Slope is also included in the National Research Council (NRC) report detailing the cumulative effects of oil industry operations on the North Slope (NRC, 2003). All are incorporated by reference in the summary below.

As noted above and in the oil spill risk analysis in Appendix A, crude oil has been spilled during oil production, processing, and transportation on the North Slope. In general, spills are small and contained. However, when oil is released to the environment, the behavior of the oil is controlled by the amount and type of oil spilled, the time of year, and the local environment (USDOI, BLM, 1998). Oil composition and inherent physical characteristics also govern the behavior of a spill with regard to oil movement, level of damage done to the impacted environment, and the weathering process (USDOI, MMS, 2002; NRC, 2003; USACE, 1999).

When spills occur, oil begins to naturally degrade both physically and chemically. This process is known as weathering, or aging, and can occur by spreading, evaporation, dispersion, dissolution, emulsification, microbial degradation, sedimentation, and photo-oxidation (USDOI, BLM, 1998; USDOI, MMS, 2002; NRC, 2003; USACE, 1999). The weathering process is also impacted by wind, waves, current movements, and stranding onto vegetation or shoreline (USDOI, BLM, 1998).

The weathering processes and properties of Liberty crude oil are described in the Liberty FEIS (USDOI, MMS, 2002), which focused on spills to open water, spills to broken ice, and underwater spills as was appropriate for an offshore development using an buried pipeline. While spills to open water or broken ice are still possible with the proposed project, undersea spills are no longer relevant, because a buried pipeline is not included. The Liberty FEIS presents information on the behavior of oil spilled to open water and broken ice.

New information on the behavior of stranded oil has been developed since the Liberty FEIS was produced. In particular, a recent study by Irvine et al. (2006) indicated that stranded oil can persist within boulder-armored beach soils (i.e., beaches where finer sediment and gravel are covered by boulder-sized rocks) even when moderate- to high-energy wave action would be expected to quickly weather the oil. Researchers found that oil washed onto boulder-armored beaches in the Gulf of Alaska remained in a nearly unweathered state for well over a decade. The findings emphasize the importance of considering local geomorphic features during spill response planning or when modeling the persistence of spilled oil.

[22] For comparison, the Liberty FEIS estimated that there would be 53 refined product spills of 0.7 bbl, for a total volume of 37.1 bbl over the life of the project. This is nearly identical to the volume projected in Appendix A and within the confidence interval.

Spills to land are also possible, and small spills are usually contained (USDOI, MMS, 2002; TAPS Owners, 2001), but a large spill may impact tundra (NRC, 2003). An oil spill to snow-covered tundra is not expected to spread over a large area, and if the spill occurs during winter, is not expected to penetrate the frozen soil (LGL, 1998; NRC, 2003). A spill during the summer may penetrate the soil but is not likely to penetrate deep because tundra is water-logged or flooded during summer (LGL, 1998). Vegetation also acts as a natural boom and prevents oil from spreading. However, oil can still become widely dispersed to tundra or snow if a pressurized pipeline ruptures and sprays oil into the air (LGL, 1998; NRC, 2003).

3.4.3 Oil Spill Scenario

An oil spill scenario analysis was completed using the "spray method" of the National Oceanic and Atmospheric Administration (NOAA) GNOME model (it was necessary to use the spray method rather than the point source method in order to force the oil to move past the Endicott Causeway). The GNOME (General NOAA Operational Modeling Environment) model was developed by the Emergency Response Division of NOAA's Office of Response and Restoration (OR&R). It is the oil spill trajectory model used by OR&R Emergency Response Division responders during an oil spill.

The following specifications were entered into the GNOME model to create the trajectories:

- Model Start Date: August 1, 2006
- Start Time: 12:00
- **Duration:** 24 and 72 hours (each duration shown as a separate figure)
- Wind Type: Constant
- Wind Speed: 10 knots
- **Wind Direction:** East-northeast (predominant direction 47.4% of the time during summer)
- **Oil Released:** 1,000 bbl (during a 4-hour period)
- Spill Response: None

As discussed above and summarized in detail in Appendix A, 1,000-bbl was chosen for the amount of oil spilled for this analysis as a probable spill volume. This is a conservative figure for analysis purposes, and a spill from the Liberty Project of this volume is unlikely.

Figure 3.4-2 shows the model output for a 24-hour duration, while Figure 3.4-3 presents the output for a 72-hour duration. It is expected that BPXA would have response activities well underway prior to 72 hours and thus contain the spread of the oil. However, 24 and 72 hours were chosen to represent the spread of spilled oil over a reasonable time frame. As can be seen in the figures, the causeway influences the westward movement of oil from the SDI location. At the end of 24 hours, oil has beached on the causeway and in the Sagavanirktok River delta, while after 72 hours, oil has reached the western shore of Prudhoe Bay.

3.4.4 Effects of Oil Spills

Possible physical, ecological, and sociocultural impacts of oil spills are discussed in the above sections and in the Liberty FEIS (USDOI, MMS, 2002).

3.5 EFFECTS OF ALTERNATIVES

3.5.1 Physical

3.5.1.1 Air Quality

The ambient air quality impact differences between the proposed action and the original Liberty Island option are negligible because either option must demonstrate compliance with the applicable ambient air quality standards and Prevention of Significant Deterioration (PSD) increment levels before the required air permit would be issued by the Alaska Department of Environmental Conservation (ADEC). For the same reason, the ambient air quality impact differences between the proposed action and either the Point Brower Pad or Kadleroshilik Pad options are negligible.

Potential stationary source emissions from the Liberty Island option are higher than the proposed action because the Liberty Island emission unit inventory included emitting equipment needed to prepare sales-quality oil. The proposed action will generally use existing equipment at the Endicott MPI, resulting in a smaller increase in potential emissions.

3.5.1.2 Sediment Suspension and Transport

As discussed in Section 3.1.2, the proposed action will result in a temporary increase in TSS concentrations of up to 430 mg/l above ambient levels in the immediate vicinity of the project site during the winter gravel placement. A large portion of the suspended material is predicted to settle within or adjacent to the footprint of the SDI pad expansion, while the finer fractions are expected to migrate up to 6 km along the Endicott Causeway. The release of fine material from the pad following the initial open-water season is expected to be negligible (Section 3.3.2). Turbidity increases associated with marine operations are expected to be negligible due to the limited need for barge support.

The two onshore development alternatives, consisting of coastal pads at Pt. Brower and on the mainland coastline near the Kadleroshilik River, are expected to have no impacts on TSS concentrations in marine waters during construction. Similarly, appropriate pad-setback distances will prevent release of fine material to marine waters during operation. No marine operations are planned for these alternatives.

Suspended-sediment concentrations and turbidity-plume characteristics associated with construction and operation of the original Liberty Island alternative were estimated previously (Ban et al., 1999). During island construction, the TSS concentration at the project site was predicted increase up to 250 mg/l. While the majority of these particles were estimated to fall out of suspension within 1 km of the island, the finer fractions were expected to create a turbidity plume extending up to 17 km to the northwest. Reshaping of the pad sideslopes after breakup was anticipated to produce a temporary increase in turbidity. The release of fine material from the island following slope protection installation was expected to be negligible. Disturbance of native seafloor sediments during installation of the subsea pipeline was estimated to increase TSS concentrations by as much as 1,000 mg/l at the excavation site. The associated turbidity plume was predicted to extend up to 2 km from the excavation site. Increased turbidity from ocean disposal of accumulated seabed material was estimated to create a 4-km-long plume with TSS concentrations as high as 1,168 mg/l at the stockpile site. Barge activities conducted in support of operations, estimated at a maximum 150 trips per season, were expected to have a modest and temporary effect on turbidity.

3.5.1.3 Oceanography

As discussed in Sections 3.3.2 and 3.3.3, the proposed action is expected to cause only minimal localized effects on oceanography. Stress cracks in the sea-ice sheet propagating from the perimeter of the SDI pad expansion could provide strudel drainage pathways at the time of river overflood. Seasonal ice roads used to support construction or drilling operations may act as a partial barrier to river overflood and divert a portion of the flow. Waves and currents in the immediate vicinity of the pad expansion will be affected during open water, but the conditions are not expected to be substantially different from those at the existing SDI facility.

The two onshore development alternatives are expected to have no impact on regional or local oceanography.

The original Liberty Island alternative is not expected to have any impact on regional oceanography. Minimal localized impacts can be anticipated. Seasonal ice roads used to support drilling and production operations may act as a partial barrier to river overflood and divert a portion of the flow. Waves and currents in the immediate vicinity of the island will be altered during open water, but the impact is expected to be limited to a distance of 2 to 3 times the island diameter (BPXA, 1998).

3.5.1.4 Marine Water Quality

The proposed action will result in a temporary increase in TSS concentrations and the creation of a sediment plume during construction. Turbidity increases associated with operations and barge support are expected to be negligible. A potential for small equipment spills (oil, diesel fuel, and hydraulic fluid) exists during both construction and operations. Operational discharges will be permitted under existing or amended Endicott NPDES permit.

The two onshore development alternatives are expected to have no impact on marine water quality. Operational discharges would be permitted under existing or amended NPDES permits for Endicott or Badami, the host facility alternatives.

The Liberty Island alternative is expected to contribute to turbidity levels temporarily during construction of the island (up to 250 mg/l) and the subsea pipeline (up to 1,000 mg/l). A turbidity plume will be created by both island and pipeline construction. Increased TSS concentrations are expected to be minimal during production (including barge activities). Small equipment spills (oil, diesel fuel, and hydraulic fluid) could occur during both the construction and operations periods. Operational discharges would be permitted under project-specific NPDES permits.

Issues associated with a crude oil spill are discussed in Section 3.5.4.

3.5.2 Biological

3.5.2.1 Benthic and Boulder Patch Communities

The proposed SDI expansion alternative of the Liberty Project will have much less of an impact on the Boulder Patch community than the original Liberty Island alternative (Table 3.5-1). Although both alternatives would permanently cover approximately 20 acres of benthic habitat, the SDI site is entirely outside the Boulder Patch footprint. It was projected that pipeline trenching associated with the Liberty Island would permanently bury up to 14 acres of low-relief kelp and epilithic habitat (USDOI, MMS, 2002). Although this loss is estimated to represent only 0.1% of the Boulder Patch area, the SDI expansion alternative is expected to have no direct loss impact. The area of normal benthic habitat permanently covered by either alternatives constitutes a miniscule portion of available habitat, and neither alternative would have any measurable effect on invertebrate populations. Both the Kadleroshilik and Pt. Brower alternatives are land-based developments and would result in no direct loss of benthos or Boulder Patch.

3.5.2.2 Fish and Essential Fish Habitat

The major advantage that the proposed action has over both the Kadleroshilik and Pt. Brower drilling pad alternatives is that the SDI expansion requires no trans-tundra gravel roadway construction and no trans-tundra pipeline construction (Table 3.5-2). Disturbances to freshwater habitat and freshwater fish from both activities are not issues for the SDI alternative. The only pipeline construction associated with the SDI alternative will be confined to the existing causeway running from the SDI to MPI. The new pipelines will be located entirely on existing structure and will not physically affect fish habitat. There are no indications that deep-water fish overwintering habitat exists anywhere along the proposed route of the ice road that will run from the mine site to the SDI. The section of ice road that will run from the SDI to MPI in support of pipeline construction is in the vicinity of possible fish overwintering habitat, but disturbance can likely be avoided if the road is constructed over grounded ice and as close to the causeway gravel beach as possible.

Gravel roadway construction would require three river crossings for the Pt Brower alternative and two for the Kadleroshilik alternative. There are no specific design details for these crossings, but issues of potential disturbance to fish overwintering habitat and disruptions to fish migrations in summer would need to be addressed. The possible upgrade of the West Sagavanirktok River Bridge or construction of new bridge for the SDI alternative would occur in the vicinity of a known major fish overwintering area (see Section 3.2.3). The absence of any details concerning the potential construction project prevents any meaningful impact assessment at this time.

The SDI expansion will require 860,000 yd^3 of gravel, while the Pt. Brower alternative would require 1,600,000 yd^3 (725,000 yd^3 for the pad, 725,000 yd^3 for roadways), the Kadleroshilik alternative 2,260,000 yd^3 (540,000 yd^3 for the pad, 1,820,000 yd^3 for roadways), and Liberty Island 797,600 yd^3 (island only). While proper mine-site planning and reclamation could enhance freshwater fish habitat in all cases, the SDI alternative would potentially leave the smallest footprint.

The SDI and Liberty Island alternatives would eliminate about the same area of coastal fish habitat. This area is miniscule compared to the amount of coastal habitat available to fish during the open-water season, and the loss would not have a measurable effect on fish populations.

The nearshore shallows in and around the proposed Liberty Project and Endicott Causeway can be considered important fish habitat for a number of anadromous and amphidromous species from both the Sagavanirktok and Colville rivers (see Section 3.3.6). Based upon proximity, a large oil spill associated with the SDI and Pt. Brower alternatives, and to a lesser extent from the Liberty Island alternative, could significantly impact shallow-water habitat of the delta.

3.5.2.3 Marine Mammals

Impacts to marine mammal species resulting from the SDI, Pt. Brower, and Kadleroshilik alternatives will be reduced compared to potential impacts of the offshore island alternative (Table 3.5-3). Potential impacts to marine mammals from noise and activity disturbances of the offshore island alternative could result during all phases of the development. Noise and activity disturbance could occur during ice-road construction and use, gravel hauling for island construction, installation of the subsea pipelines and island facilities, island drilling and production activities, and vessel-based and helicopter support during all phases of the development. Ringed, and possibly bearded, seals could be affected by disturbances from the offshore island development during all portions of the year.

In contrast to the offshore island alternative, most activities associated with the other three alternatives would be land-based and would have little effect on marine mammals.

3.5.2.4 Marine and Coastal Birds

The main project components that would have minor effects on marine and coastal birds for the various alternatives are the development pad or island, communication towers, access roads, power lines or cables, pipeline routes, construction schedule, and gravel mine site size and location. A summary of these project components and their effects on marine and coastal birds is summarized in the Table 3.5-4. Processing facility locations for the various alternatives are Endicott MPI, Badami, and Liberty Island. Processing facilities on Liberty Island would expose more seabirds to collision mortality during spring and fall migrations than either of the existing processing facilities at Endicott MPI or at Badami. Large oil spills from any of the alternatives could potentially have significant effects on marine and coastal birds and their habitats.

3.5.2.5 Terrestrial Mammals

The main project components that would have minor effects on terrestrial mammals under the various alternatives are the development pad or island, access roads, pipeline routes, construction schedule, and the gravel mine site size and location. A summary of these project components and their effects on caribou, muskoxen, grizzly bears, arctic foxes, and arctic ground squirrels is summarized in the Table 3.5-5. Processing facility locations for the various alternatives include Endicott MPI, Badami, and Liberty Island.

3.5.2.6 Wetland and Vegetation

The SDI expansion poses the smallest potential impact to wetlands and vegetation (Table 3.5-6). Onshore developments at Pt. Brower and the Kadleroshilik River would require the construction of the gravel pads and roads. This would require a much larger gravel mine than that proposed for the SDI expansion. The placement of gravel fill for the Pt. Brower and Kadleroshilik River alternatives would cover approximately 100 and 150 acres of tundra, respectively. In addition, ice roads would be utilized to construct the necessary roads, pads, and pipelines to tie the Liberty development with the existing Prudhoe Bay infrastructure. Onshore developments would also greatly increase the potential impact to vegetation from oil spills.

The Liberty Island alternative is comparable to SDI expansion regarding the proposed and potential impacts to wetlands and vegetation. The primary difference between the alternatives is the proposed new pipeline construction. Liberty Island would involve 1.5 mi of new onshore pipeline. This would require additional ice road activity as well as increase the impact from potential spills. Using the existing Endicott Causeway for the new pipelines associated with SDI expansion eliminates the need for additional ice roads and greatly reduces the potential impact from spills.

3.5.2.7 Threatened and Endangered Species

Potential impacts to bowhead whales would be greatest for the offshore island alternative compared to the SDI, Pt. Brower, and Kadleroshilik alternatives (Table 3.5-7). The SDI, Pt. Brower, and Kadleroshilik alternatives are primarily land-based options for Liberty development that would result in few potential impacts to bowhead whales. Any potential impacts to bowhead whales would be most likely to occur during the fall migration in August and September. The southern portion of the bowhead migration corridor is located approximately 15 km offshore, and the Liberty land-based alternatives would likely have little effect on bowhead whales. Marine vessel traffic during the sealift of the ***LoSal*™** EOR process plant would have the potential to temporarily displace bowheads along their migratory route. Industrial noise from the offshore island alternative during the fall bowhead migration would have the potential to cause a slight offshore displacement of the southern edge of the migration corridor (McDonald et al., 2006).

Activities associated with ice-road construction and use for the SDI, Pt. Brower, and Kadleroshilik alternatives would have the potential to cause disturbances that may affect polar bears during the initial construction periods. However, annual construction of ice roads would not be planned, and potential impacts would result only during construction of these alternatives. Annual ice-road construction would be planned in support of the offshore island alternative, thus increasing the overall potential of disturbance to polar bears. Denning polar bears could be disturbed by various types of activities during winter or spring when they emerge from dens.

Potential impacts to spectacled and Steller’s eiders would be reduced for the SDI alternative compared to the Pt. Brower and Kadleroshilik alternatives (Table 3.5-8). The construction of gravel roads and pad on tundra habitats would cover approximately 107 and 169 acres for the Pt. Brower and Kadleroshilik alternatives, respectively. This tundra would be lost as potential habitat for spectacled or Steller’s eiders. The SDI option would not require construction of gravel roads or pads that cover tundra habitats, and the only tundra habitat that would be lost during construction would result from gravel mining. Gravel mining would also occur for the Pt. Brower and Kadleroshilik alternatives.

The potential for noise and activity disturbance to affect spectacled and Steller’s eiders would also be reduced for the SDI alternative compared to the Pt. Brower and Kadleroshilik alternatives. Gravel roads would be constructed in areas which have previously been subjected to little disturbance and would cover approximately 7.3 and 15.2 mi for the Pt. Brower and Kadleroshilik alternatives respectively. In contrast, no new roads would be constructed for the SDI alternative. Increased traffic levels along the Endicott Road resulting from construction and operation of the SDI alternative could disturb eiders near the road, although many eiders and other waterfowl would likely be habituated to traffic.

The potential for noise and activity disturbance on pads to affect spectacled or Steller’s eiders would be greater for the Pt. Brower and Kadleroshilik alternatives than for the SDI alternative. The Pt. Brower and Kadleroshilik pads would be surrounded by tundra that could be used by threatened eiders, possibly as nesting habitat. The expanded pad for the SDI alternative would be surrounded by marine waters unsuitable as nesting habitat for spectacled eiders, although eiders could use this area for resting and feeding.

The potential for eider mortality due to collision with structures on pads would likely be greater for the SDI and offshore island alternatives than for the Pt. Brower and Kadleroshilik alternatives. Eider collisions would be most likely to occur during fall migration when flocks of birds are flying at low elevation. Divoky (1984) reported that the primary migration corridor during fall for king and common eiders in the Prudhoe Bay area was offshore between the barrier islands and the 20-m isobath. Day et al. (2005) reported collisions of 36 eiders (all common or king eiders) with facilities at Northstar Island and the Endicott facilities between 2001 and 2004. Little information is available on fall migration corridors for spectacled eiders in the Prudhoe Bay area, but spectacled eiders migrating in offshore areas near the coast would have the potential to collide with structures on the SDI and offshore island pads. Migrating eiders would be most susceptible to collision during periods of poor visibility such as fog or at night. However, due to the low density of spectacled and Steller's eiders in the project area, collisions of threatened eiders with structures would be unlikely for any other alternatives.

3.5.3 Socioeconomic

There are no material differences in the economic, subsistence, sociocultural, and environmental justice impacts associated with the variants among the new alternatives being considered. Effects of all these alternatives are discussed in Sections 3.1.12 (effects associated with the SDI expansion), 3.2.9 (effects associated with onshore construction), and 3.3.12 (effects associated with drilling and oil production).

3.5.4 Oil Spills

The risk of a spill and potential effects of oil spills from the offshore island and other likely alternatives are detailed in the Liberty FEIS (USDOI, MMS, 2002), which concluded:

> "We do not expect significant impacts to result from any of the planned activities such as discharges and disturbances associated with Alternative I (Liberty Development and Production Plan) or any of the other alternatives. Some significant impacts—adverse effects to spectacled eiders, king and common eiders, long-tailed ducks, subsistence-harvest patterns, sociocultural systems, and local water quality—could occur in the unlikely event of a large oil spill. However, the very low chance of such an event occurring…combined with the seasonal nature of the resources inhabiting the area (for example, eiders are present in the Liberty area 1-4 months of the year), makes it highly unlikely that an oil spill would occur and contact the resources. A resource may be present in the area but may not be contacted by oil…None of the component or combination alternatives evaluated [in this] EIS are expected to generate significant impacts from planned activities. If an unlikely oil spill occurred, similar significant effects could occur to spectacled eiders, king and common eiders, long-tailed ducks, subsistence harvests, sociocultural systems, and local water quality for all alternatives."

The onshore Liberty alternatives at Pt. Brower and Kadleroshilik are expected to have the same or lesser impact because they are onshore.

Since publication of the Liberty FEIS, new information has been developed in research reports (see Regehr, Amstrup, and Stirling, 2006), EISs (see USDOI, MMS, 2003, 2006), and a proposed rule to list the polar bear as threatened throughout its range (72 *Federal Register* No. 5, pp. 1064-1099). These documents are incorporated by reference.

Some of the new information relates to changes in estimates of the probability of one or more large crude oil spills occurring for other projects (i.e., Lease Sales 186, 195, and 202), which are not material to this analysis. Other new information relates to possible impacts of an oil spill. As noted in the EIS for Lease Sale 202 (USDOI, MMS, 2006):

> "The summary concludes in Section IV.B that parts of the Beaufort Sea environment have changed substantially since preparation of the multiple-sale EIS. For example, the statistical analysis of long-term data sets indicates substantial reductions in both the extent and thickness of the arctic sea-ice cover during the past 20-40 years. Also, some resources that are dependent on summer and autumn ice cover have declined in abundance. The Sale 195 projected that more polar bears might be forced to stay onshore during summer, leading to increased interaction between polar bears and oil-industry personnel…Recent observations confirm that more polar bears are staying onshore during the autumn…Due primarily to increased concentrations of polar bears on parts of the coast, the relative oil-spill risk to the population has increased since preparation of the multiple-sale EIS. The biological potential for polar bears to recover from any perturbation is low because of their low reproductive rate. The MMS rules can require mitigation that will moderate the spill risk to polar bears (Sec. III.C.2)."

Having said this, the EIS noted: "Our overall finding is that the Proposed Action with the mitigation would lead to no new significant impact that was not already assessed in the Beaufort Sea multiple-sale EIS."

It is clear that a large oil spill from any of the developments might result in significant adverse impacts on various species and, therefore, on the availability of subsistence resources with attendant sociocultural impacts.

Oil production with any of the Liberty alternatives might also result in crude oil or product spills. Small operational spills of crude or product will occur, and as discussed in Section 3.4, large crude spills, although unlikely, might also occur. Depending upon the location, timing, amount, and behavior of the spill(s), significant adverse effects on certain species, subsistence-harvest patterns, and sociocultural systems might result. Section 3.3.12 provides more detail on the impacts of oil spills to subsistence resources and sociocultural systems.

For any alternative, BPXA would implement mitigation measures to minimize the possibility and potential for an oil spill.

3.6 CUMULATIVE EFFECTS

3.6.1 Introduction

As defined by the National Environmental Policy Act [40 CFR 1508.7 and 1508.25 (a) (2)]:

> "Cumulative impact is the impact on the environment which results from the incremental impact of the action when added to the other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.
>
> Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.
>
> To determine the scope of environmental impact statements, agencies shall consider…Cumulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement."

Cumulative impacts were addressed at length in Liberty FEIS (USDOI, MMS, 2002), which is incorporated by reference. The general conclusions reached in this document were:

> "Potential cumulative effects on the bowhead whale, subsistence, sociocultural systems, spectacled eider, Boulder Patch, polar bear, and caribou are of primary concern and warrant continued close attention and effective mitigation practices.
>
> The incremental contribution of the Liberty Project to cumulative effects is likely to be quite small. Construction and operations related to the Liberty Project would be confined to a relatively small geographic area, and oil output would be a small percentage (approximately 1%) of the total estimated North Slope/Beaufort Sea production.
>
> The Liberty Project would contribute a small percentage of spills…to resources in State and Federal waters in the Beaufort Sea from potential offshore oil spills. Any subsequent spills are not expected to contact the same resources or to occur before those resources recover from the first spill.
>
> Potential Environmental Justice effects would focus on the Iñupiat community of Nuiqsut, and possibly of Kaktovik, within the North Slope Borough. If the one large spill assumed in the cumulative case (although not from the Liberty Project) occurred and contaminated essential whaling areas, major effects could occur when impacts from contamination of the shoreline, tainting concerns, cleanup disturbance, and disruption of subsistence practices are factored together. Such impacts would be considered disproportionately high adverse effects on Alaskan Natives."

The proposed action differs from those addressed in the FEIS. The current project eliminates the offshore impacts of island and pipeline construction and significantly mitigates the potential offshore impacts related to the Boulder Patch, marine mammals, and concerns of the North Slope Iñupiat communities related to the bowhead whale and subsistence whaling and made issues related to offshore pipeline design moot. The decision to use the existing infrastructure at Endicott further mitigates impacts by avoiding construction of a pad on the shoreline of Foggy Island Bay and an access road and pipelines crossing the Sagavanirktok River delta.

The Liberty FEIS also offered several comments designed to place possible impacts in perspective. These are shown in Table 3.6-1, which also incorporates the above comment on the revised system design.

The Liberty FEIS focused on oil and gas developments, as these are the main agents of industrial-related change on the North Slope. In particular, the FEIS considered continued operation of the Trans Alaska Pipeline System (and associated marine transportation link) and past, present, and reasonably foreseeable future development/production (within the next 15 to 20 years). The FEIS noted the possibility that if oil prices were to rise substantially, it might be commercially feasible to develop presently stranded gas resources. The FEIS acknowledged this possibility but given the uncertainty associated with construction of a gas transportation system in the foreseeable future, did not include this project in the analysis of possible cumulative effects. In the intervening years, there has been continued interest in such a development, but it is unclear whether or not this project will go forward and what form it might take. Therefore, it is not included in this update.

The Liberty FEIS reached the following conclusion regarding cumulative effects:

> "The MMS does not expect any significant cumulative impacts to result from any of the planned activities associated with the exploration and development of North Slope and Beaufort Sea oil and gas fields…In the event of a large offshore oil spill, some significant adverse impacts could occur to spectacled eiders, long-tailed ducks, common eiders, subsistence resources, sociocultural systems, and local water quality. However, the probability of such an event combined with the seasonal nature of the resources inhabiting the area makes it highly unlikely that an oil spill would occur and contact these resources…"

3.6.2 More Recent Analyses

Since publication of the Liberty FEIS, several additional reports have been published, including EISs for the TAPS Right-of-Way Renewal (USDOI, BLM, 2002); Beaufort Multi-Lease Sale (USDOI, MMS, 2003); Alpine Satellite Development Plan (USDOI, BLM, 2004a); Northwest National Petroleum Reserve-Alaska Final Integrated Activity Plan (USDOI, BLM, 2004b); EA for Lease Sale 195 in the Beaufort Sea Planning Area (USDOI, MMS, 2004); the Northeast National Petroleum Reserve-Alaska Final Integrated Activity Plan (USDOI, BLM, 2005); the EA for Lease Sale 202 in the Beaufort Sea Planning Area (USDOI, MMS, 2006a); and the EA for Lease Sale 193 in the Chukchi Sea Planning Area (USDOI, MMS, 2006b). Additionally, the Committee on Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope of the National Research Council completed a comprehensive study of cumulative environmental effects of oil and gas activities on Alaska's North Slope in 2003 (NRC, 2003). As well, a useful report has been published on Arctic Climate Impact Assessment (ACIA, 2005) that provides pertinent data and information. These are incorporated by reference.

Results of these newer analyses are broadly consistent with the conclusions of the Liberty FEIS regarding possible cumulative effects. If anything, these newer documents suggest that cumulative effects for all past, present, and reasonably foreseeable future projects might be somewhat greater than originally projected in the Liberty FEIS. For example, the NRC offered the following observation on socioeconomic changes on the North Slope:

> "Modern western culture, including oil development and the revenue stream it created, has resulted in major, important, and probably irreversible changes to the way of life in North Slope communities. The changes include improvements in schools, health care, housing, and other community services as well as increased rates of alcoholism, diabetes, and circulatory disease. There have been large changes in culture, diet, and the economic system. Many North Slope residents view many of these changes as positive. However, social and cultural shifts of this magnitude inevitably bear costs in social and individual pathology. These effects accumulate because they arise from several sources, and they interact."

As well, some new impacts (e.g., those from climate change) have assumed increased importance.

The projected production from Liberty is now estimated to be 105 MMbbl — 12.5% smaller than the 120 MMbbl estimated in the Liberty FEIS. Oil prices are volatile and notoriously difficult to forecast; the FEIS used an Alaska Department of Revenue forecast of $16.30/bbl. As this is written, crude oil prices exceed $61/bbl — the *Fall 2006 Revenue Sources Book* (Alaska Department of Revenue, 2006) projects lower crude-oil prices in the future than those at present:

$41.50 per bbl post-fiscal-year 2014.[23] Even so, this revised price estimate is much higher than that assumed in the FEIS. Thus, even though the revised total production estimate from Liberty is smaller than originally assumed, the oil revenues from Liberty are likely to be substantially greater than originally estimated.

Because future oil prices are likely to be substantially greater than assumed in the Liberty FEIS by a factor of approximately 2.5 based on the above priced forecasts, the positive economic impacts from both Liberty and other oil and gas developments included in the FEIS are likely to be substantially greater than estimated originally.

Regarding production, total Liberty output can be placed in context by comparing it to estimated cumulative production from ANS fields through 2011; Liberty accounts for 1/155 of the total cumulative production, which is smaller than projected in the Liberty FEIS. And Liberty's output would account for only a relatively small proportion of production post-2011. Because the expected number of oil spills is believed to be proportional to total output, the likelihood of a spill from Liberty operations is substantially smaller than for all fields as a group.

Therefore, Liberty's output is expected to account for a very small percentage of total ANS output (and smaller than originally estimated), but the revenues from Liberty are likely to be substantially larger than originally estimated. Because of changes to the proposed Liberty design, the probable environmental impacts of Liberty are likely to be more modest than originally estimated. Finally, possible cumulative impacts from all past, present, and reasonably foreseeable developments might be the same or slightly larger than originally estimated. Thus, Liberty offers greater economic benefits than originally estimated and lower impacts in both proportional and absolute terms. More detailed comments are offered below.

3.6.3 Resource-Specific Cumulative Effects

The EIS for Lease Sale 202 in the Beaufort Sea Planning Area (USDOI, MMS, 2006b) offers the most recent authoritative review of possible cumulative effects and is frequently referred to when addressing resource-specific cumulative effects.

3.6.3.1 Warming and Impacts on Arctic Ice and Noise Levels

Some of the key conclusions of the USDOI, MMS (2006a) analysis relate to impacts associated with possible climate warming include (for references see original):

- Available evidence indicates that the total extent of arctic sea ice has declined over the past several decades; these declines are not consistent across the Arctic. Warming trends appear to be affecting the thickness of multiyear ice in the polar basin and perennial sea-ice coverage.
- The presence, thickness, and movement of sea ice contribute significantly to ambient noise levels. The presence of sea ice also affects the timing, nature, and possible locations of human activities such as shipping, research, barging, whale hunting, oil- and gas-related exploration, military activities, and other activities that introduce noise into the marine environment. The presence of ice also impacts which marine species are present. If climate warming continues, it is likely that changes in the acoustic

[23] The forecasting assumptions used by the State of Alaska Department of Revenue are deliberately (and appropriately) conservative. The Energy Information Administration base level crude oil price forecast for 2014 ranges from $44 to $50 per bbl (see http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html). In recent years, official government forecasts have typically underestimated the price of crude oil.

environment also will occur in many parts of the waters off Alaska due to increased human use of the seasonally ice-covered waters.

Global warming has been linked to greenhouse gas emissions, which include those generated on the North Slope and elsewhere. The Liberty FEIS (USDOI, MMS, 2002) provides estimates of future greenhouse-gas emissions for the North Slope in the cumulative case. It also adds the following for perspective:

> "Nationwide and global greenhouse gas emissions can be reduced by energy conservation, improving energy efficiency, and developing alternative energy sources. Regardless of any downward pressure on the growth of oil consumption in the future as a result of measures to reduce greenhouse gas emissions, the need for continued development of domestic new oil and gas resources will still exist. If Alaska energy sources were not to be developed in the future, resources would have to be produced in other areas of the globe. The impacts on greenhouse gas emissions would be very similar, regardless of the location of the energy source."

3.6.3.2 Subsistence-Harvest Patterns

Some of the key conclusions of the multiple-sale EIS (USDOI, MMS, 2003) relative to *subsistence-harvest patterns* included (for references see original):

> "…past, present, and reasonably foreseeable projects on the North Slope [might result in] one or more important subsistence resources becoming unavailable or undesirable for use for 1-2 years, a significant adverse affect. Sources that could affect subsistence resources include potential oil spills, noise and traffic disturbance, and disturbance from construction activities associated with ice roads, production facilities, pipelines, gravel mining, and supply efforts. The communities of Barrow, Nuiqsut, and Kaktovik would potentially be most affected, with Nuiqsut potentially being the most affected community because it is within an expanding area of oil exploration and development both onshore (Alpine, Alpine Satellite, and Northeast and Northwest National petroleum Reserve-Alaska) and offshore (Northstar and Liberty[24])."

Generally similar conclusions were reached in more-recent EISs as summarized by MMS (USDOI, MMS 2006a). For example, the Alpine Satellite Development Plan FEIS (USDOI, BLM, 2004) [see original for contained references] noted that:

> "Development has already caused increased regulation of subsistence hunting, reduced access to hunting and fishing areas, altered habitat, and intensified competition from non-subsistence hunters for fish and wildlife. Additive impacts that could affect subsistence resources include potential oil spills, seismic noise, road and air traffic disturbance, and disturbance from construction activities associated with ice roads, production facilities, pipelines, gravel mining, and supply efforts. Based on potential cumulative, long-term displacement and/or functional loss, habitat available for caribou may be reduced or unavailable for use. Changes in population distribution due to the presence of oilfield facilities or activities may affect [the] availability for subsistence

[24] When this was written, Liberty was believed to be an offshore development. The proposed action for Liberty is now expansion of an existing pad.

> harvest[s] in traditional subsistence use areas…Overall, impacts to subsistence harvest[s] and use[s] may have synergistic impacts with community health, welfare, and social structure. To the extent that subsistence hunting success is reduced in traditional use areas near Nuiqsut because of the presence of oilfield facilities and activities, subsistence hunters will need to travel to more distant areas to harvest sufficient resources in order to meet community needs. Greater reliance on more distant subsistence use areas will result in greater time spent away from the community for some household members and competition for resources with members of other communities. These changes in subsistence patterns may result in stress within households, family groups, and the community."

The Northeast NPR-A Final Amended IAP/EIS (USDOI, BLM, 2005) reached the following conclusions regarding cumulative effects on subsistence:

> "Exploration and development activities on the North Slope have greatly impacted subsistence activities, as noted during public scoping testimony. In the Planning Area, exploration and development could originate from Inigok, Point Lonely, and Umiat vicinity, and could encompass important subsistence harvest areas for moose, fish, caribou, and furbearers, affecting subsistence users in Nuiqsut, Atqasuk, Barrow, and Anaktuvuk Pass. Subsistence hunters traveling in nearly every direction from Nuiqsut would have to pass through some kind of development en route to subsistence harvest areas. Iñupiat hunters are reluctant to use firearms near oil production facilities and pipelines, so subsistence users would be unlikely to harvest subsistence resources in these areas. Aircraft have interfered with hunts by scaring game away from hunters and the increase in air traffic by fixed-wing aircraft and helicopters would make this worse and over a much greater area if development goes forward. This issue has been raised several times by residents of Nuiqsut, who have also noted that oil and gas development is impacting traditional use areas and their ability to pass on knowledge of subsistence resources in these areas, and use of these resources, to their children."

This same EIS also addressed the impacts of climate change on subsistence resources:

> "Climate change and the associated effects of anticipated warming of the climate change regime in the Arctic could significantly affect subsistence harvests and uses if warming trends continue…Every community in the Arctic is potentially affected by the anticipated climactic shift and there is no plan in place for communities to adapt to or mitigate these potential effects. The reduction, regulation, and/or loss of subsistence resources would have severe effects on the subsistence way of life for residents of Nuiqsut, Atqasuk, Barrow, and Anaktuvuk Pass. If the loss of permafrost, and conditions beneficial to the maintenance of permafrost, arise as predicted, there could be synergistic cumulative effects on infrastructure, travel, landforms, sea ice, river navigability, habitat, availability of fresh water, and availability of terrestrial mammals, marine mammals, waterfowl and fish, all of which could necessitate relocating communities or their populations[s], shifting the population[s] to places with better subsistence hunting and causing a loss of dispersal of community."

Similar conclusions were reached in the EA for Lease Sale 202 in the Beaufort Sea Planning Area (USDOI, MMS, 2006a). It is appropriate to note that, however, that the proportional contribution of the Liberty Project to these effects is small. The likelihood of a large oil spill is relatively small — certainly in comparison to the possible contribution of other fields — and the project has been engineered to minimize the additional footprint of facilities.

It is also appropriate to address the possible impact of climate change on the cumulative effects on subsistence in this section. The proposed OCS Lease Sale 202 (USDOI, MMS, 2006) offered the following summary statement on the possible effects of climate change on subsistence-harvest patterns:

> "Because polar marine and terrestrial animal populations would be particularly vulnerable to changes in sea ice, snow cover, and alternations in habitat and food sources brought on by climate change, rapid and long-term impacts on subsistence resources (availability), subsistence-harvest practices (travel modes and conditions, traditional access routes, traditional seasons and harvest locations), and the traditional diet could be expected over the lifetime of Sale 202 development."

3.6.3.3 Sociocultural Systems

Cumulative effects on sociocultural systems could come from changes to subsistence-harvest patterns, social organization and values, and other issues, such as stress on social systems. These effects are noted in the multiple-sale EIS (USDOI, MMS, 2003) and other more-recent analyses such as USDOI, MMS (2006a), which noted:

> "We conclude that potential overall cumulative impacts on subsistence and sociocultural systems from noise, disturbance, large oil spills, and global climate change would be significant, warrant continued close attention, and the development, monitoring, and enforcement of effective mitigation practices. Additionally, the potential effects of the lease sale are assessed within the context of climate change. If any new major effect due to climate changes were to occur, MMS would require changes to exploration or development/production designs and activities."

The Liberty FEIS (USDOI, MMS, 2002) traced other effects, including increases in population growth and employment that might cause long-term disruptions, to (1) the kinship networks that organize the Iñupiat communities' subsistence production and consumption, (2) extended families, and (3) informally derived systems of respect and authority (mainly respect of elders and other leaders in the community). Cumulative effects on social organization could include decreasing importance of the family, cooperation, sharing, and subsistence as a livelihood, and increasing individualism, wage labor, and entrepreneurship. Chronic disruption could affect subsistence-task groups and displace sharing networks, but it would not displace subsistence as a cultural value. Impacts to sociocultural systems have occurred, but there are many contributing factors (e.g., greater social mobility, access to media, particularly television and the media), and the relative importance of oil and gas activities is unclear.

In assessing changes to sociocultural systems, it is also important to consider the possible impacts associated with decreasing throughput and revenues — which will occur in any event, but would have greater impact if development of new fields does not occur. As noted in the Northeast NPR-A Final Amended IAP/EIS:

> "Because of impacts from climate change on long-standing traditional hunting and gathering practices that promote health and cultural identify, and, considering the limited capacities and choices for adaption and the ongoing cultural challenges of globalization to indigenous communities, North Slope peoples would experience cultural stresses, as well as impacts to population, employment, and local infrastructure. The termination of oil activity could result in the outmigration of non-Iñupiat people from the North Slope, along with some Iñupiat who may depend on higher levels of medical support or other infrastructure and services that may [not] be available in a fiscally constrained, post-oil production circumstance."

Because of its possible impacts on subsistence, climate change could also have significant sociocultural consequences. This point is made in the proposed OCS Lease Sale 202 EA (USDOI, MMS, 2006) as follows:

> "Because of rapid and long-term impacts from climate change on long-standing traditional hunting and gathering practices that promote health and cultural identity, and considering the limited capacities and choices for adaptation and the ongoing cultural challenges of globalization to indigenous communities, we conclude that communities in the Arctic would experience significant cultural stresses, as well as major impacts on population, employment, and local infrastructure. If subsistence livelihoods are disrupted, communities in the Arctic could face increased poverty, drug and alcohol abuse, and other social problems."

It should be noted, however, that decisions on Liberty and other ANS projects are unlikely to affect climate change in any material way.

3.6.3.4 Marine and Coastal Birds

Possible cumulative impacts on marine and coastal birds have been reviewed in all the EISs incorporated by reference. All point to the potential for impacts. The most recent analysis (USDOI, MMS, 2006a) concluded:

> "Specific potential effects of cumulative factors may include the loss of small numbers of spectacled eiders and other sea ducks or aquatic bird species as cumulative projects are developed. Minor declines in fitness, survival, or production of young resulting from exposure of these species to disturbance factors, or mortality from collision with structures, warrants continued close attention and effective mitigation practices. Mortality from a large oil spill, an unlikely event, could be relatively substantial and represent a significant effect for any of several marine or coastal bird species, recovery of these species from such mortality is not expected to occur if their population is exhibiting a declining trend. In the context of new information that has become available since publication of the multiple-sale EIS, these conclusions remain consistent: thus, the updated level of effect on marine and coastal bird populations is expected to be the same as stated in that document."

3.6.3.5 Local Water and Air Quality

The MMS cumulative analysis contained in the multiple-sale EIS (USDOI, MMS, 2003) concluded:

> "A spill could affect water quality for 10 or more days in a local area. The effects of discharges and offshore construction activities are expected to be short term, lasting as long as the individual activity and to have the greatest impact in the immediate vicinity of the activity."

This conclusion was supported in the most recent analysis (USDOI, MMS, 2006a).

Regarding air quality, the Liberty FEIS concluded that the cumulative effects of all projects affecting the North Slope in the past and occurring now have caused generally little deterioration in air quality, which remains better than required by national standards. Moreover, the Liberty FEIS concluded that reasonably foreseeable future developments would not change this situation.

3.6.3.6 Bowhead Whales

Bowhead whales are a key subsistence resource and important to the sociocultural identity of several ANS communities (see Section 2.15). For this reason, Alaskan Natives have continued to express concerns regarding the possibility of any adverse effects on this key resource. And for this reason, EISs (particularly those dealing with offshore developments) have devoted considerable attention to possible impacts on this resource. Key potential impacts of oil and gas activities in the cumulative case could include those resulting from noise (avoidance) and oil spills (temporary nonlethal effects).

The Liberty FEIS (USDOI, MMS, 2002) concluded that potential cumulative effects would be important, but were unlikely. Because of the changes to the recommended alternative, adverse impacts are even less likely with the new project design. The most recent MMS analysis of cumulative effects (USDOI, MMS, 2006a) notes:

> "Overall, we conclude…that the cumulative effects on bowhead whales would not be significant. However, we also conclude, as we did in the multiple-sale EIS (USDOI, MMS, 2003), that cumulative effects on bowhead whales are of primary concern and, thus, warrant continued close attention and effective mitigation practices."

3.6.3.7 Polar Bears

The most recent analysis (USDOI, MMS, 2006a) of possible cumulative impacts of oil and gas activities on polar bears stated:

> "Despite the fact that the amount of proposed seismic activity has approximately doubled since the multi-sale EIS was written, the main effects of concern to polar bears are climate change, overharvest, and oil and fuel spills."

This same document referred to a Sale 195 EA, which concluded:

> "…partly because of climate changes, we still conclude that potential effects on polar bears…would be a primary concern. We identify ringed seals and other ice-dependent pinnipeds as additional resources of primary concern. Therefore, we conclude that the potential cumulative effects on polar bears, seals, and other ice-dependent pinnipeds would be of primary concern and would warrant close attention and effective mitigation practices."

Several analyses, particularly USDOI, MMS (2006a), have concluded that climate change is the principal impact of concern, but continue to note that large oil spills are also problematic. On balance, however, this analysis concluded:

> "The potential impacts of a large oil spill are [of concern]….Due primarily to increased concentration of bears on parts of the coast, the relative oil-spill risk to the population has increased since preparation of the multiple-sale EIS. Further, based on the observed and predicted impacts that global climate change can have on polar bears, their distribution and population trends still warrant close attention and effective mitigation measures. The existing MMS operating regulations, the standard mitigation measures…would moderate the spill risk to polar bears. Thus, there would be no new significant cumulative effect."

3.6.3.8 Other Marine Mammals

Recent analyses (USDOI, MMS, 2006a) of possible cumulative effects on other marine mammals conclude:

> "Due to the ongoing effects of climate change in the Arctic, continued close attention and effective mitigation practices with respect to non-endangered marine mammal populations and distributions are warranted, particularly with respect to ringed seals, which likely would be among the first marine mammals to show the negative effects of climatic warming."

As noted with respect to many other sections of this document dealing with climate change, the possible contribution of the Liberty Project to global warming is de minimis.

3.6.3.9 Fishes and Essential Fish Habitat

Cumulative effects of Alaska North Slope oil and gas activities include those related to possible oil spills and climate changes. Recent analyses (see e.g., USDOI, MMS, 2006a) of climate change effects conclude:

> "The climate of the Arctic is changing and affecting fish distributions. Evidence of such change is discussed in the Arctic Climate Impact Assessment report (ACIA, 2005).[25] Trends in instrumental records over the past 50 years indicate a reasonably coherent picture of recent environmental change in northern high latitude (ACIA, 2005). It is probable that the past decade was warmer than any other in the period of the instrumental record…Climate change can affect fish production (e.g., individuals and/or populations) through a variety of means…Direct effects of temperature on the metabolism, growth, and distribution of fishes occur. Food-web effects also occur through changes in lower trophic-level production or in the abundance of predators, but such effects are difficult to predict. Fish-recruitment patterns are strongly influenced by oceanographic processes such as local wind patterns and mixing and by prey availability during early lifestages. Recruitment success sometimes is affected by changes in the time of spawning, fecundity rates, survival rate of larvae, and food availability."

[25] The chapter on fisheries is available electronically at: http://www.acia.uaf.edu/PDFs/ACIA_Science_Chapters_Final/ACIA_Ch13_Final.pdf.

Regarding possible impacts from oil spills, the Liberty FEIS (USDOI, MMS, 2002) noted:

> "While small numbers of fish in the immediate area of an offshore or onshore oil spill may be killed or harmed, an oil spill assumed for this analysis is not expected to have a measurable effect on fish populations. Subsistence and commercial fishing are likely to have a measurable cumulative effect on freshwater and migratory fish populations. However, due to a lack of survey information, the cumulative effect of these activities, and the amount of time required for each population to recover, is unknown."

This conclusion has not changed.

3.6.3.10 Terrestrial Mammals

The Liberty FEIS (USDOI, MMS, 2002) considered possible cumulative impacts on terrestrial mammals including caribou, muskoxen, grizzly bears, and arctic foxes. Impacts could result from encroaching oil development, activities such as gravel mining, the construction of roads and gravel pads, and possible oil spills. Although the FEIS illustrated various possible effects, the overall FEIS conclusion was that these effects would not be significant.

3.6.3.11 Archeological Resources

The Liberty FEIS (USDOI, MMS, 2002) concluded that the cumulative effects of proposed projects would likely disturb the seafloor more often, but remote-sensing surveys made before approval of any Federal or State lease actions should keep these effects low. Federal laws would preclude effects to most archeological resources from these planned activities. The most recent report (USDOI, MMS, 2006a) restates this conclusion.

3.6.3.12 Environmental Justice

As noted in other sections of this document that address environmental justice, Alaskan Iñupiat Natives, a recognized minority, are the predominant residents of the North Slope Borough, the area potentially most affected by cumulative oil and gas developments. Effects on Iñupiat Natives could occur because of their reliance on subsistence foods, and cumulative effects might affect subsistence resources and harvest practices. Potential effects from noise, disturbance, and oil spills on subsistence resources and practices and sociocultural patterns could affect many NSB communities. The Liberty FEIS (USDOI, MMS, 2002) concluded:

> "Potential effects would focus on the Iñupiat community of Nuiqsut, and possible of Kaktovik, within the North Slope Borough. However, effects are not expected from routine activities and operations. If the one large spill assumed in the cumulative case (although not from the Liberty Project) occurred and contaminated essential whaling areas, major effects could occur when impacts from contamination of the shoreline, tainting concerns, cleanup disturbance, and disruption of subsistence practices are factored together. Such impacts would be considered disproportionately high adverse effects on Alaskan Natives. Oil-spill contamination of subsistence foods is the main concern regarding potential effects on Native health. The MMS believes that serious mitigation for such impacts begins with a commitment to preventing them by employing the highest standards of pipeline technology that include extra-thick-walled pipelines,

> pipeline burial depths more than twice the maximum 100-year ice gouging event, and advanced leak detection systems."

The current Liberty Project eliminates the potential for impacts from offshore pipelines. More recent reports (see e.g., USDOI, MMS, 2006a) also conclude that oil and gas developments have the potential to cause disproportionate impacts on Alaska Natives. Here is an illustrative summary statement (USDOI, MMS, 2006a):

> "Potential significant impacts to subsistence resources and harvests and consequent significant impacts to sociocultural systems would indicate significant cumulative environmental justice impacts—disproportionate, high adverse environmental and health effects on low-income, minority populations in the region. We still conclude that potential environmental justice effects would focus on the Iñupiat communities of Barrow, Atqasuk, Nuiqsut, and Kaktovik within the NSB; such cumulative effects would be considered disproportionately high adverse effects on Alaska Natives. Any potential effects are expected to be mitigated substantially, although not eliminated."

As noted above, climate change could have cumulative impacts on subsistence resources, subsistence-harvest patterns, and (in consequence) sociocultural impacts. This would have implications for environmental justice. The EA for Proposed OCS Lease Sale 202 (USDOI, MMS, 2006) offered the following summary:

> "We conclude that potential overall cumulative impacts on subsistence and sociocultural systems from noise, disturbance, large oil-spills, and global climate change would be significant, warrant continued close attention, and the development, monitoring, and enforcement of effective mitigation practices. Additionally, the potential effects of the lease sale are assessed within the context of climate change. If any new major effect due to climate change were to occur, MMS would require changes to exploration or development/production designs and activities."

As with other cumulative impacts, those associated with Liberty must be placed in perspective:

- Liberty's total production is a very small component of the past, present, and future output from the North Slope;
- The oil spill analysis conducted for Liberty indicates that although small spills are likely to occur, the probability of one or more large spills is quite low;
- The revised Liberty Project design is likely to have smaller environmental impacts than any of the original alternatives considered; and
- Climate change is a global, not a local issue. Climate changes are not materially dependent upon decisions regarding Liberty or other ANS development options.

4. MITIGATION MEASURES

This section describes the mitigation measures considered in the design of the proposed Liberty Development Project. A consistent goal of BPXA has been to minimize overall project impacts through careful design and planning of the project. Tables 4-1 and 4-2 summarize mitigation actions and expected benefits at the design, construction, and operation levels. In 2005, BPXA made the decision to move the Liberty Project onshore to be developed using uERD from a newly constructed pad on the shore of Foggy Island Bay. This significantly mitigated potential offshore environmental impacts related the Boulder Patch, marine mammals, and concerns of Inupiat residents of the North Slope related to the bowhead whale and subsistence whaling. In August 2006, BPXA decided to develop the project at the Endicott Satellite Drilling Island (SDI). This decision further mitigated potential impacts by taking advantage of existing infrastructure at the SDI and on the Endicott Main Production Island (MPI). Because this option eliminates the need for construction of a new pad on the shore of Foggy Island Bay and associated roads and pipelines through undeveloped lands, impacts to wetlands have been significantly reduced as well as shoreline and tundra habitats for birds and caribou along the coast of the Sagavanirktok River delta and Foggy Island Bay.

4.1 MITIGATION OF CONSTRUCTION IMPACTS

To minimize environmental impacts, all major construction involving offshore and on-tundra activities will take place during winter, including construction of the SDI expansion and development of the gravel source adjacent to the existing Duck Island mine site. Disturbance of wildlife should be minimal, and impacts to tundra habitats will be minimized or eliminated.

4.1.1 Gravel Mining

Gravel for the project will be obtained from a new site in the Sagavanirktok River floodplain. BPXA has selected a gravel mine site location adjacent to the existing Duck Island mine site. Preliminary vegetation and habitat analysis (which will be followed up by field surveys in the summer of 2007) indicates that no special habitat will be impacted. BPXA's mining and rehabilitation plan is attached under separate cover as Attachment D to the *Liberty Development Project Development and Production Plan (April 2007)*.

Prior to any gravel mining activities on previously un-surveyed locations, BPXA will conduct archeological and cultural resource surveys to assure that any sites are avoided and/or resources protected. A contract archeologist meeting the Secretary of the Interior's professional standards will be employed to perform these archaeological and cultural resource surveys. If cultural resources not identified during archeological surveys are discovered during construction, work will be halted and the State Historic Preservation Officer will be contacted. In addition, MMS cultural resource personnel and the North Slope Borough Inupiaq History, Language, and

Culture Commission will be consulted. A decision will be made, following these discussions, to avoid, protect, or remove the resource, using appropriate scientific and culturally-sensitive techniques.

4.1.2 Ice Roads

Ice roads will be used for temporary gravel haul from the mine site to the SDI and inter-island (MPI to SDI) pipeline construction. Ice roads will be located within the nearshore areas and offshore to the island. Onshore ice roads for pipeline construction can be breached at river and stream crossings if necessary prior to breakup, and all ice roads will melt during breakup.

4.1.3 Boulder Patch Communities

The only potential impacts to Boulder Patch communities would come from excessive propeller downwash from barge and tug traffic that could disturb epilithic fauna and kelp of the Boulder Patch (see Section 3.1.5). BPXA currently plans a sealift of the ***LoSal***™ modules directly to the Endicott MPI and will route any barge traffic to avoid the Boulder Patch community, thus eliminating the potential for physical damage.

4.1.4 Fish and Essential Fish Habitat

4.1.4.1 Gravel Mining

Once mining operations are completed, the mine site will be rehabilitated according to the agency-approved mining and rehabilitation plan (attachment D to the DPP).

4.1.4.2 Ice Roads

A 3-mi-long ice road that would run parallel to the lagoon side of the inter-island causeway may be located near potential fish overwintering habitat (see Section 3.2.3). However, it is expected that the ice road would be limited for the most part to the grounded-ice area along the southwest shore of the causeway and as close to the gravel beach. As a result, possible damage to any potential fish overwintering habitat should be avoided.

4.1.4.3 West Sagavanirktok River Bridge Work

At least two deep-water holes are located at the existing West Sagavanirktok River Bridge and pipeline crossing (see Section 3.2.3). These areas appear to be overwintering sites for a number of freshwater species and may be a spawning area for broad whitefish. The project will make all attempts to minimize impacts to these areas during bridge construction.

Information defining the overwintering holes is from the late 1990s. The river is a dynamic system and some of the holes may have changed location. BPXA will conduct open-water surveys during the summer of 2007 and refine the bathymetry of the bridge area. Particular attention will be given to deep holes that could provide overwintering habitat for fish.

4.1.5 Marine Mammals

The overall impact on marine mammals from the SDI option for Liberty Project construction activities during winter is unlikely to be significant. Conducting construction activities during the winter when beluga whales (and possibly Pacific walruses) are not present will eliminate potential disturbances from those activities.

Marine mammals are unlikely to be seriously impacted by summer erosion because BPXA plans to install sheetpile slope protection on the north and east sides of the SDI which are the side most prone to erosion. Installation of the sheet pile wall is planned to be concurrent with the winter gravel placement thus minimizing erosion.

4.1.6 Marine and Coastal Birds

Winter construction will assist in reducing disturbance to nesting birds and brood-rearing birds.

Compliance with regulations governing waste management and feeding of wildlife will assist with preventing skewed distributions of predator species such as arctic fox, red fox, grizzly bear, polar bear, glaucous gull, and common raven, which can significantly decrease nesting-bird production. Segregation of food waste and disposal in animal-proof containers will reduce access of food wastes to predator species

Obstruction of brood movements due to increased traffic on roadways will be mitigated by reducing traffic speeds along the Endicott Road during brood rearing, as is the current policy, and by staggering traffic levels to allow some quiet periods. These actions will enhance road crossing.

BPXA plans, to the extent feasible as dictated by river hydrology, to route the ice road from the mine site to the SDI via a channel of the Sag River. As a result, ice road damage to foraging and nesting habitats would be minimized. Part of the ice road route would cross coastal mudflats that do not contain habitats for overwintering fish.

4.1.7 Terrestrial Mammals

Identification of active grizzly bear dens and arctic-fox den structures prior to winter construction activities will allow avoidance of these structures and will minimize injury or disturbance to hibernating grizzly bears and destruction of fox den sites.

Construction during winter will reduce disturbance to caribou and muskoxen, which generally are not on the Arctic Coastal Plain in the project vicinity during winter. However, while most major gravel placement occurs during winter, summer activities associated with smoothing, grading, and installation of other facilities on the expanded SDI have the potential to disturb terrestrial mammals.

Compliance with regulations governing waste management and feeding of wildlife will assist in preventing skewed distributions of predator species such as arctic fox, red fox, and grizzly bear. To reduce attraction, food waste will be segregated and disposed of in animal-proof containers.

Obstruction of caribou movements and collision mortality due to increased traffic on the Endicott Road will be mitigated by reducing traffic speeds along the road during summer insect season when the caribou may be present in large numbers. These actions would also enhance road-crossing success by the animals.

Damage to coastal foraging habitats due to ice road construction will be minimized by constructing the roads along river channels and coastal mudflats that do not contain habitats for overwintering fish.

4.1.8 Wetlands and Vegetation

The selected mine site is in a non-active portion of the Sagavanirktok River floodplain and impacts the least amount of vegetation and wetlands compared to the other onshore alternatives. After mine site closure, the mine will be rehabilitated according the mine site rehabilitation plan (Appendix D of the DPP).

An ice road will be used to transport gravel from the mine site to the SDI. As discussed in Section 3.2.7, tussock-type tundra and areas with elevated microsites or irregular topography are more susceptible to damage from ice roads than are wetter meadow-type communities. To the extent possible, surveying the ice-road route to avoid potentially higher risk areas and routing along the Sagavanirktok River channel to the maximum extent feasible will minimize the impact from construction activities.

Increased traffic along the Endicott Road to support construction activities will generate additional road dust. A reduced speed limit along the Endicott Road during development of the Endicott project lessened the disturbance to molting snow geese in the area. Slower traffic also helps reduce the amount of dust generated. This, in addition to the current road-watering program, should provide some relief to adjacent vegetation from the effects of dust fallout.

4.1.9 Threatened and Endangered Species

Construction activities are unlikely to have any significant effect on bowhead whales. The construction activity with the greatest potential to impact bowhead whales is the proposed sealift of Liberty ***LoSal*™** EOR plant to the Endicott MPI. Scheduling of the sealift to be completed prior to August 31 should mitigate possible deflection of the bowhead whale migration. Most whales migrate offshore of the SDI and outside of the barrier islands passing by during September.

In general, very few of the construction activities related to the Liberty Project at the SDI are likely to negatively impact threatened eiders. The activities with the greatest potential to impact eiders relate to disturbance from increased road traffic, potential temporary habitat loss at water source lakes and at ice road locations, and potential habitat loss at the mine site. Mitigation for spectacled and/or Steller’s eiders include:

- Reduced speed limits on the Endicott Road during the pre-nesting, nesting, and brood-rearing periods to decrease the potential for disturbance to eiders near the road, eider collisions with vehicles, and dust deposition on tundra adjacent to roads.
- Surveys in the vicinity of the mine site and of water source lakes to determine their suitability as eider habitat.

Potential impacts from ice roads on denning polar bears will be by determining historical and recent den locations and routing ice roads to avoid the dens. Pre-construction surveys (FLIR surveys) should determine den sites near the ice-road corridor.

Current North Slope waste-management practices incorporate methods to minimize attraction of wildlife to development. Continued implementation of these practices will help prevent interactions with polar bears that could potentially result in hazing or destruction of bears, or in injury to oil field workers.

4.1.10 Personnel Training

BPXA has developed health, safety, and environmental (HSE) and technical training programs that should address the requirements of 30 CFR Subpart B, Stipulation No. 3

(Orientation Program of Lease Sale 144), and Stipulation No. 2 (Protection of Biological Resources) of Lease Sale 124. Those stipulations are focused on projects located in the OCS. BPXA will evaluate its existing training programs with respect to these MMS requirements and the specific circumstances of an Endicott-based development prior to initiating construction and drilling operations, and consult with the MMS to assure the programs comply with MMS requirements.

General topical areas in BPXA's HSE and technical training programs that Liberty personnel will have to take as applicable to their job include the following:

- uERD drilling
- Well control
- Permit and regulatory compliance
- Pollution prevention and spill reporting
- Biological resource protection and wildlife interaction (e.g., polar and grizzly bears)
- Safety and health

4.1.11 Cultural Resources and Subsistence

Prior to construction activities, BPXA will conduct archeological and cultural resource surveys of areas to be disturbed (including the gravel mine site) in order to assure that any sites are avoided and/or resources protected. A contract archeologist meeting the Secretary of the Interior's professional standards will be employed to perform these archaeological and cultural resource surveys. If cultural resources not identified during archeological surveys are discovered during construction, work will be halted and the State Historic Preservation Officer will be contacted. In addition, MMS cultural resource personnel and the North Slope Borough Inupiaq History, Language, and Culture Commission will be consulted. A decision will be made, following these discussions, to avoid, protect, or remove the resource, using appropriate scientific and culturally-sensitive techniques.

The Liberty Project area is not an area of high subsistence activities. Fall bowhead whaling is conducted by Nuiqsut whalers from Cross Island located about 10 mi northwest of Endicott. The Liberty project currently includes a single sealift in the 2012 open-water season of the ***LoSal*™** plant and other equipment. As is typical for most sealifts to the central Beaufort Sea, this sealift is scheduled to be completed early in August prior to the main migration of the Bowhead whale and fall subsistence whaling depending upon weather and ice conditions. Should the sealift be delayed into September for any reason, then BPXA will coordinate this activity with the Alaska Eskimo Whaling Commission (AEWC) and Barrow and Nuiqsut Whaling Captains' Associations through a Conflict Avoidance Agreement (CAA) or other communication mechanisms. Consistent with safe navigation and ice conditions, the sealift may be routed inshore to avoid migrating bowhead whales and subsistence whaling.

4.1.12 Water Quality

Turbidity will be minimized by conducting gravel-fill operations in the winter when nearshore circulation is more muted compared to the open-water season. Turbidity should be further reduced through the installation of the sheet pile wall on the north and east sides of the expanded SDI. Installation will be done concurrent with winter gravel placement. The potential for small equipment spills (oil, diesel fuel, and hydraulic fluid) will be mitigated though proper training and awareness of personnel. Best management practices will be followed for fuel handling, storage, and dispensing. The amendment to the *Endicott and Badami Oil Discharge Prevention and Contingency Plan* for the Liberty Project will detail measures to be taken to reduce the possibilities of a spill reaching marine waters. Also, the drainage plan for the expanded SDI provides for internal drainage of stormwater and low points to reduce the possibility of spills entering marine waters.

4.2 MITIGATION OF OPERATION IMPACTS

4.2.1 Wildlife Protection

4.2.1.1 Benthic and Boulder Patch Communities

The Boulder Patch will be largely isolated from the normal operational activities of the Liberty Project. Leak detection systems and routine pipeline inspections (including pigging of the Endicott sales oil line) will reduce the likelihood of a significant oil spill from existing pipelines that could reach nearshore benthic communities. Continuous and rigorous training of oil spill response teams increases the probability that that any spill, should it occur, will be contained and damage to the coastal benthos minimized. Approved discharges (principally the brine reject from the ***LoSal*™** EOR plant) into surrounding waters stemming from production activities will be monitored according to the requirements of the NPDES permit to ensure compliance with regulatory guidelines.

4.2.1.2 Fish and Essential Fish Habitat

Fish protection measures are essentially the same as for benthic communities above; routine pipeline inspections will reduce the chance of a significant oil spill from new or existing pipelines that could reach coastal or freshwater fish habitat. Continuous training by oil spill response teams increases the likelihood that any spills will be contained and potential damage to the fish habitat is minimized. Approved discharges (principally the brine reject from the ***LoSal*™** EOR plant) into surrounding waters stemming from production activities will be monitored according to the requirements of the NPDES permit to ensure compliance with regulatory guidelines.

4.2.1.3 Marine Mammals

The greatest potential impact on marine mammals from operations at Liberty facilities would be the effects of a large oil spill. Preventative maintenance and monitoring of all operational aspects will be given the highest of priority. Oil spill prevention is the greatest single measure that can be taken to prevent significant consequences for all marine mammals in the area. BPXA's amendment to the *Endicott and Badami Oil Discharge Prevention and Contingency Plan* for the Liberty Project to be submitted to ADEC will discuss methods to prevent and clean up oil spills.

4.2.1.4 Marine and Coastal Birds

Use of existing infrastructure, such as the Endicott SDI, MPI, and the Endicott Road, mitigates habitat loss from the construction of new facilities, such as production pads, access roads, and pipelines. Leak-detection systems and routine pipeline inspections reduce the likelihood of a significant oil spill from new or existing pipelines. Compliance with regulations governing waste management and feeding of wildlife will assist with preventing skewed distributions of predator species such as arctic fox, red fox, grizzly bear, polar bear, glaucous gull, and common raven, which can significantly decrease nesting-bird production. Food waste will be segregated and disposed of in animal proof containers.

Technical training programs, such as the biological resource protection and wildlife interaction plans, inform project personnel on the importance of protection of wildlife resources, reduce potential for harassment of wildlife, and illustrate how personnel actions have a potential to negatively affect coastal and marine bird resources. Restriction of on-tundra activities during spring and summer reduces disturbance to nesting birds.

The creation of artificial nesting structures for ravens and snow buntings can be mitigated when practicable by designing structures with smooth exteriors or installing wire fencing or similar enclosures and prevent access to areas potentially used by nesting birds.

Environmental and safety training programs assist in preventing fuel spills, vehicle collision mortalities, and other avoidable effects to coastal and marine birds and their habitats, and ensure compliance with permit requirements.

4.2.1.5 Terrestrial Mammals

Use of existing infrastructure, such as the Endicott SDI, MPI, and the Endicott Road, mitigates habitat loss from the construction of new facilities, such as production pads, access roads, and pipelines. Should culverts be required for the Liberty Project (e.g., for the mine site access road), foxes creating dens in culverts and other structures will be discouraged by inspection and removal of the dens. In addition, the structures and culverts will be designed to discourage these activities (i.e., use of screens, fences, or construction materials that are unattractive to the animals). Leak-detection systems and routine pipeline inspections reduce the likelihood of a significant oil spill from pipelines.

Compliance with regulations governing waste management and feeding of wildlife will assist with preventing skewed distributions of predator species such as arctic fox, red fox, and grizzly bears. To reduce attraction, food waste will be segregated and disposed of in animal-proof containers.

Biological resource protection and wildlife interaction plans inform project personnel of the importance of wildlife and resource protection, reduce potential for harassment of wildlife, and illustrate how personnel actions have a potential to negatively affect terrestrial mammal resources. Restriction of on-tundra activities during spring and summer reduces the potential disturbance to terrestrial mammals.

Environmental and safety training programs assist in preventing fuel spills, vehicle collision mortalities, and other avoidable effects to terrestrial mammals and their habitats, and ensure compliance with permit requirements.

4.2.1.6 Wetlands and Vegetation

Operational impacts associated with the SDI expansion would have minimal direct impact to wetlands and vegetation. The primary risk would be associated with a large oil spill. Prevention, responsible monitoring, and a reliable response plan are all critical to mitigating damage to wetlands and vegetation.

4.2.1.7 Threatened and Endangered Species

The greatest potential impact on bowhead whales and threatened eiders from operations at Liberty facilities is from a large oil spill. Preventive maintenance and monitoring of all operational aspects will be given the highest of priority to minimize the chance of an oil spill. Oil spill prevention is the greatest single measure that can be taken to prevent significant consequences for bowhead whales.

Adequate preparation for oil spill response on terrestrial, delta, and offshore habitats requires that a variety of properly maintained equipment and supplies be available and accessible, and that response personnel have proper training. Implementation of the response strategies detailed in the *Endicott and Badami Oil Discharge Prevention and Contingency Plan* (to be amended to cover the Liberty Project) (see Appendix B) should mitigate the impact of both small and large spills should they occur.

There is the possibility that predators might be attracted to Liberty Project facilities by food or structures suitable for denning/nesting, and more predators would have the possibility to elevate natural predation rates on adult eiders and their young/eggs. Continuation of standard North Slope practices designed to reduce or eliminate the attraction of predators to anthropogenic sources of food and nesting or denning sites will help to mitigate the potential for increase predation pressure on threatened eiders resulting from Liberty.

Polar bears are known to investigate human activities, especially when certain attractants such as food are present. Continuation of current North Slope practices on food handling and disposal will help reduce the potential for human/bear interactions. Reducing these encounters will play an important role in reducing the impacts of the Liberty Project on polar bears.

4.2.2 Cultural Resources and Subsistence

Any archeological or cultural resources will have been identified prior to or during construction and appropriate protection measure implemented as required by regulations.

4.2.3 Air and Water Quality

4.2.3.1 Air

Air quality impacts of operation activities and mitigation are described in the air quality control permit application submitted to ADEC (April 2007). Potential impacts of operations to air quality will be mitigated principally through selection of the most efficient equipment, implementation of best available control technology (BACT) where applicable, and use of natural gas instead of diesel fuel to power the drilling rig.

4.2.3.2 Water

The potential for small equipment spills (oil, diesel fuel, and hydraulic fluid) will be mitigated though proper personnel training and adherence to best management practices for handling, storage, and dispensing of fuel. The expanded SDI has been designed to confine surface-water drainage to the work surface and will also reduce the risk of any incidental equipment spills reaching marine waters. The project will have zero surface discharges of drilling wastes. Operational discharges will conform to the stipulations of the existing or renewed Endicott NPDES permit.

4.2.4 Large Oil Spills

The proposed action will mitigate the effects of oil spills during the operation of the Liberty Project. For example, the offshore pipeline has been eliminated and use of the present infrastructure is maximized.

No new oil or three-phase flow pipelines are required for the Liberty project. Two new pipelines will be constructed to support the Liberty project: a 10-inch diameter ***LoSal*™** water injection pipeline and 6-inch gas pipeline routed along the inter-island causeway from the MPI to the SDI. These pipelines will be on new vertical support members on the lagoon side of the causeway. Production from the Liberty wells will be transported form the SDI to the MPI for processing via the existing 28-inch flowline which is constructed of corrosion resistant alloy (CRA). The existing 16-inch-diameter Endicott sales oil line will be used to export Liberty oil to Pump Station 1 of TAPS. This line has isolation valves installed at both sides of the causeway bridges. The pipeline is monitored for leaks using the industry-standard mass-balance line-pack compensation system and is pigged according to DOT requirements. .

The proposed project will incorporate other design measures to assure that the potential for spills and leaks has been minimized to the extent practicable. These features include lined, bermed areas for storage tanks, discharge detection technology, tank overfill-protection technology, well control design, and pad design and grading. Significant quantities of diesel fuel are not anticipated to be stored on the SDI because the drilling rig will be fueled by natural gas.

Implementation of an approved oil spill response plan will mitigate the potential for adverse impacts to wildlife and habitats as a result of an oil spill. Liberty Project planning includes oil spill prevention measures, as well as spill response preparedness. BPXA will submit an application to the Alaska Department of Environmental Conservation to amend the E*ndicott and Badami Oil Discharge Prevention and Contingency Plan* to cover the operations of the Liberty Project at the Endicott facility. Following State approval, the amended plan will be submitted to MMS for its approval. MMS spill response planning regulations (30 CFR 254.53) provide for submitting a response plan developed under State requirements for facilities within 3 mi of the natural shoreline.

A more detailed discussion of the oil spill response plan may be found in Section 10.1.2 of the Liberty DPP.

4.3 COMPLIANCE WITH LEASE SALE STIPULATIONS

4.3.1 Stipulation No. 1, Protection of Biological Resources

Stipulation Summary: The Regional Supervisor, Field Operations (RS/FO) may require the lessee to conduct biological surveys needed to determine the extent and composition of biological populations and habitats requiring additional protection. As a result of these surveys, the RS/FO may require the lessee to relocate the site of operations, modify the operation and/or establish that operations will not have adverse effects, or ensure that special biological resources do not exist. In addition, the lessee is required to report any area of biological significance discovered during the conduct of any operations on the lease, and make every effort to preserve and protect the biological resource from damage until the RS/FO provides direction with respect to resource protection.

Planned BPXA Compliance: The proposed project is located near the Stefansson Sound Boulder Patch, a special biological resource. Selection of the SDI pad location rather than an offshore island in Foggy Island Bay avoids impacts to Boulder Patch habitats.

4.3.2 Stipulation No. 2, Orientation Program

Stipulation Summary: The lessee must develop a proposed orientation program for all personnel involved in the Liberty Project. The program must address environmental, social, and cultural concerns that relate to the area, including the importance of not disturbing archaeological and biological resources and habitats. The program will include distribution of information cards on endangered and/or threatened species in the sale area. The program shall be designed to increase the sensitivity and understanding of the personnel to community values, customs, and lifestyles in areas in which such personnel will be operating. The orientation program also shall include information concerning avoidance of conflicts with subsistence, commercial fishing activities, and pertinent mitigation. The program shall be attended at least once a year by all personnel involved in onsite exploration or development and production activities. The lessee shall maintain a record of all personnel who attend the program onsite for so long as the site is active, not to exceed 5 years.

Planned BPXA Compliance: BPXA requires all North Slope field contractors complete an 8-hour “unescorted” training program provided by the North Slope Training Cooperative. All attendees receive a Field Environmental Handbook, an Alaska Safety Handbook, and a North Slope Visitor’s Guide. The unescorted training includes review of the Alaska Safety Handbook, personal protective equipment, camps and safety orientation, hazard communications, HAZWOPER Level 1, Environmental Excellence, and cultural awareness modules.

The program includes an explanation of the applicable laws protecting cultural and historic resources, and stresses the importance of not disturbing archeological, cultural and historic resources, and biological resources and habitats while providing guidance on how to avoid disturbance.

Federal Occupational Safety and Health Administration (OSHA) regulations and guidance provide training standards for individual positions. Training for individual positions vary with the activities performed. Individual training may include an electrical safety program; emergency preparedness and action plans; hazards communication program; HAZWOPER (Levels 3-5); lockout/tagout procedures for control of hazardous energy; emergency shut down systems; cranes, chain hose, and sling/rope inspection program; drilling and workover operations; machinery guarding; tank/vessel cleaning procedures; confined space entry program; first aid material and training; eye and face protection; hearing conservation program; personnel protective equipment; respiratory protection program; safety and environmental meetings.

As discussed in Section 4.1.10, BPXA will evaluate its existing training programs with respect to MMS requirements and the specific circumstances of an Endicott-based development.

4.3.3 Stipulation No. 3, Transportation of Hydrocarbons

Stipulation Summary: Pipelines are the preferred transportation mode for production.

Planned BPXA Compliance: BPXA plans to use existing Endicott flowlines and the existing Endicott sales oil pipeline to transport Liberty production.

4.3.4 Stipulation No. 4, Industry Site-Specific Bowhead Whale Monitoring Program

Stipulation Summary: A monitoring program is required for exploratory operations conducted during the bowhead whale migration.

Planned BPXA Compliance: Not applicable to this proposed development and production project.

4.3.5 Stipulation No. 5, Subsistence Whaling and Other Subsistence Activities

Stipulation Summary: The lessee must conduct operations in a manner that prevents unreasonable conflicts between industry activities and subsistence activities. Prior to submitting a DPP, the lessee shall consult with the potentially-affected communities and the Alaska Eskimo Whaling Commission to discuss potential conflicts with the siting, timing, and methods of proposed operations and safeguards or mitigation measures which could be implemented to prevent unreasonable conflicts. The lessee shall make every reasonable effort to assure that development and production activities are compatible with whaling and other subsistence hunting activities and will not result in unreasonable interference with subsistence harvests.

A discussion of resolutions reached during this consultation process and any unresolved conflicts shall be included in the DPP. In particular, the lessee shall show in the plan how mobilization of the drilling unit and crew and supply boat routes will be scheduled and located to minimize conflict with subsistence activities. Those involved in the consultation shall be identified in the plan. The lessee shall notify the RS/FO of all concerns expressed by subsistence hunters during the operations and of steps taken to address such concerns.

Planned BPXA Compliance: Fall bowhead whaling is conducted by Nuiqsut whalers from Cross Island located about 10 mi northwest of Endicott. As discussed elsewhere, significant marine support activities are not envisaged for Liberty at this time. Currently, there will be one sealift for the ***LoSal***™ plant to the Endicott MPI (BPXA is also considering the option of sealifting the drill rig to the SDI, but the base case involves road transport of modules from southern Alaska). Typically sealifts occur prior to September and fall subsistence whaling depending upon ice and weather conditions. Should the sealift be delayed into the subsistence whaling season, then that activity would be coordinated with the AEWC and with Barrow and Nuiqsut Whalers' Associations through a Conflict Avoidance Agreement or other communications mechanisms. BPXA has also consulted with a number of North Slope organizations including the AEWC about the project during the pre-application phase process. These consultations will continue through other phases of the project.

4.3.6 Stipulation No. 6, Agreement Between the United States of America and the State of Alaska

Stipulation Summary: An advisory regarding the terms of the subject agreement.

Planned BPXA Compliance: No compliance activity required.

4.3.7 Stipulation No. 7, Agreement Regarding Unitization

Stipulation Summary: An advisory regarding the terms of an agreement between the United States of America and the State of Alaska.

Planned BPXA Compliance: No compliance activity required.

5. CONSULTATION AND COORDINATION

BPXA has had extensive consultations with regulatory agencies and other stakeholders prior to and subsequent to the decision to develop from onshore using uERD (August 2005) and more recently, to develop Liberty from Endicott (August 2006). These consultations have including informal meetings and briefings and formal pre-application meetings (January-March 2007). The purpose of these consultations has been to obtain comments and input on potential development alternatives, provide project progress updates, and clarify regulatory requirements. BPXA has consulted and coordinate with following agencies and organizations since August 2005:

- Federal Agencies
- Minerals Management Service (Anchorage and Washington, D.C. offices)
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency (Anchorage and Seattle offices)
- National Marine Fisheries Service
- U.S. Fish and Wildlife Service
- State Agencies
- Alaska Department of Natural Resources, Office of Project Management and Permitting (Anchorage and Juneau)
- Alaska Department of Natural Resources, Office of Habitat Management and Permitting (Anchorage and Fairbanks)
- Alaska Department of Natural Resources, Division of Oil and Gas (Anchorage)
- Alaska Department of Environmental Conservation, Division of Spill Prevention and Response (Anchorage)
- Alaska Department of Environmental Conservation, Division of Air Quality (Juneau)
- Alaska Department of Natural Resources, Division of Mining, Land and Water (Anchorage and Fairbanks)
- Alaska Oil and Gas Conservation Commission
- North Slope Borough (Local) Agencies and Organizations
- North Slope Borough Planning and Community Affairs Department
- North Slope Borough Wildlife Department
- North Slope Borough Planning Commission
- North Slope Borough Mayor’s Office
- City of Barrow
- Inupiat Community of the Arctic Slope
- Native Village of Barrow
- Arctic Slope Regional Corporation
- Kuukpik Corporation

- Alaska Eskimo Whaling Commission

In addition to these consultation, BPXA entered into two memoranda of understanding (MOU) with regulatory agencies to detail applicant-agency consultation processes, roles and responsibilities and the permitting processes. One MOU was executed by BPXA with the MMS, U.S. Army Corps of Engineers and State of Alaska, and the other with the State of Alaska, Department of Natural Resources.

6. LIST OF PREPARERS

Table 6-1 provides a list of the preparers of this EIA, along with their affiliations.

Table 6-1
List of Preparers

EIA SECTION		Authors	Affiliation
1.	**PROJECT SUMMARY**	Jim Lukin	Lukin Publications Management
2.	**AFFECTED ENVIRONMENT**		
2.1	**Air Environment**		
2.1.1	Climate and Meteorology	Martha Shulski, Brian Hartmann & Gerd Wendler	UAF Climate Research Center
2.1.2	Air Quality	Al Trbovich	Hoefler Consulting Group
2.2	**Reservoir Geology**	BPXA	BPXA
2.3	**Geomorphology**		
2.3.1	Marine Geology	Greg Hearon	Coastal Frontiers Corporation
2.3.2	Bathymetry	Greg Hearon	Coastal Frontiers Corporation
2.3.3	Coastal Sediment Processes	Greg Hearon, Peter Gadd	Coastal Frontiers Corporation
2.4	**Oceanography**		
2.4.1	Seasonal Generalities	Greg Hearon	Coastal Frontiers Corporation
2.4.2	Circulation	Greg Hearon	Coastal Frontiers Corporation
2.4.3	Currents	Greg Hearon	Coastal Frontiers Corporation
2.4.4	Water Levels	Greg Hearon, Craig Leidersdorf	Coastal Frontiers Corporation
2.4.5	Waves	Greg Hearon, Craig Leidersdorf	Coastal Frontiers Corporation
2.4.6	River Discharge	Greg Hearon	Coastal Frontiers Corporation
2.4.7	Sea Ice	Kennon D. Vaudrey	Vaudrey and Associates
2.5	**Marine Water Quality**		
2.5.1	Salinity and Temperature	Greg Hearon	Coastal Frontiers Corporation
2.5.2	Dissolved Oxygen	Greg Hearon	Coastal Frontiers Corporation
2.5.3	Turbidity	John H. Trefry	Florida Institute of Technology
2.5.4	Hydrogen Ion Concentration (pH)/Acidity/Alkalinity	Greg Hearon	Coastal Frontiers Corporation
2.5.5	Trace Metals	John H. Trefry	Florida Institute of Technology
2.5.6	Hydrocarbons	John H. Trefry	Florida Institute of Technology
2.6	**Fresh Water Environment**		
2.6.1	Sagavanirktok River	John Pickering	PN&D Engineers
2.6.2	Lakes	John Pickering	PN&D Engineers
2.6.3	Surface Water Quality	John Pickering	PN&D Engineers
2.6.4	Groundwater	John Pickering	PN&D Engineers
2.7	**Benthic and Boulder Patch Communities**	Kenny Dunton, Susan Schoenberg	Marine Science Institute, University of Austin, Texas
2.8	**Fish**	Benny Gallaway Robert G. Fechhelm Larry Moulton	LGL Ecological Research Assoc. LGL Ecological Research Assoc. MJM Research
2.9	**Marine Mammals**	Mike Williams Robert Rodrigues Charles Greene	LGL Alaska Research Assoc. LGL Alaska Research Assoc. Greeneridge Sciences
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2.11	**Terrestrial Mammals**	Lynn Noel	ENTRIX, Inc.

Table 6-1 (Cont'd)
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2.12	**Vegetation and Wetlands**	Jay McKendrick Lynn Noel Dale Funk	Lazy Mountain Research Co. ENTRIX, Inc. LGL Alaska Research Assoc.
2.13	**Threatened and Endangered Species**	Declan Troy Bob Richie Lynn Noel Janet Kidd Robert Rodrigues	Troy Ecological Research Assoc. ABR, Inc. ENTRIX, Inc. ABR, Inc. LGL Alaska Research Assoc.
2.14	**Cultural Resources**	Dan Maxim, Ron Niebo	Everest Consulting Associates
2.15	**Socioeconomics**	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.	**ENVIRONMENTAL CONSEQUENCES**		
3.1	**SDI Expansion**		
3.1.1	Air Quality	Al Trbovich	Hoefler Consulting Group
3.1.2	Sediment Suspension and Transport	Greg Hearon, Peter Gadd	Coastal Frontiers Corporation
3.1.3	Oceanography	Greg Hearon	Coastal Frontiers Corporation
3.1.4	Marine Water Quality	Greg Hearon	Coastal Frontiers Corporation
3.1.5	Benthic and Boulder Patch Communities	Benny Gallaway, Robert Fechhelm	LGL Ecological Research Assoc.
3.1.6	Fish and Essential Fish Habitat	Benny Gallaway, Robert Fechhelm	LGL Ecological Research Assoc.
3.1.7	Marine Mammals	Robert Rodrigues	LGL Alaska Research Assoc.
3.1.8	Marine and Coastal Birds	Lynn Noel	ENTRIX, Inc.
3.1.9	Terrestrial Mammals	Lynn Noel	ENTRIX, Inc.
3.1.10	Wetlands and Vegetation	Steve McKendrick, Dale Funk	LGL Alaska Research Assoc.
3.1.11	Threatened and Endangered Species	Robert Rodrigues	LGL Alaska Research Assoc.
3.1.12	Socioeconomics	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.1.13	Waste Management	Jim Lukin	Lukin Publications Management
3.2	**Onshore Construction**		
3.2.1	Air Quality	Al Trbovich	Hoefler Consulting Group
3.2.2	Hydrology	John Pickering	PN&D Engineers
3.2.3	Fish and Essential Fish Habitat	Benny Gallaway, Robert Fechhelm	LGL Ecological Research Assoc.
3.2.4	Marine Mammals	Robert Rodrigues	LGL Alaska Research Assoc.
3.2.5	Marine and Coastal Birds	Lynn Noel	ENTRIX, Inc.
3.2.6	Terrestrial Mammals	Lynn Noel	ENTRIX, Inc.
3.2.7	Wetlands and Vegetation	Steve McKendrick, Dale Funk	LGL Alaska Research Assoc.
3.2.8	Threatened and Endangered Species	Robert Rodrigues	LGL Alaska Research Assoc.
3.2.9	Socioeconomics	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.2.10	Waste Management	Jim Lukin	Lukin Publications Management
3.3	**Drilling and Oil Production**		
3.3.1	Air Quality	Al Trbovich	Hoefler Consulting Group
3.3.2	Sediment Suspension and Transport	Greg Hearon, Peter Gadd	Coastal Frontiers Corporation
3.3.3	Oceanography	Greg Hearon	Coastal Frontiers Corporation

Table 6-1 (Cont'd)
List of Preparers

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3.3.4	Marine Water Quality	Greg Hearon	Coastal Frontiers Corporation
3.3.5	Benthic and Boulder Patch Communities	Benny Gallaway, Robert Fechhelm	LGL Ecological Research Assoc.
3.3.6	Fish and Essential Fish Habitat	Benny Gallaway, Robert Fechhelm	LGL Ecological Research Assoc.
3.3.7	Marine Mammals	Robert Rodrigues	LGL Alaska Research Assoc.
3.3.8	Marine and Coastal Birds	Lynn Noel	ENTRIX, Inc.
3.3.9	Terrestrial Mammals	Lynn Noel	ENTRIX, Inc.
3.3.10	Wetlands and Vegetation	Steve McKendrick, Dale Funk	LGL Alaska Research Assoc.
3.3.11	Threatened and Endangered Species	Robert Rodrigues	LGL Alaska Research Assoc.
3.3.12	Socioeconomics	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.3.13	Waste Management	Jim Lukin	Lukin Publications Management
3.4	**Fate and Effect of Oil Spills**		
3.4.1	Risk of an Oil Spill	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.4.2	Behavior of Spilled Oil	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.4.3	Oil Spill Trajectory Analysis	Tina Barber	SLR Alaska
3.4.4	Effects of Oil Spills	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.5	**Effects of Alternatives**		
3.5.1	Physical	Greg Hearon	Coastal Frontiers Corporation
3.5.2	Biological	Robert Fechhelm	LGL Ecological Research Assoc.
3.5.3	Socioeconomics	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.5.4	Oil Spills	Dan Maxim, Ron Niebo	Everest Consulting Associates
3.6	**Cumulative Effects**	Dan Maxim, Ron Niebo	Everest Consulting Associates
4.	**MITIGATION MEASURES**		
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ATTACHMENT A
ENVIRONMENTAL IMPACT ANALYSIS

APPENDIX B

Section 2, Prevention Plan from Endicott and Badami Oil Discharge Prevention and Contingency Plan

Appendix A. Analysis of Industry Crude and Product Oil Spills on the Alaska North Slope and Estimates of Potential Spills for the Liberty Development Project

July 2, 2007

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Appendix A. Analysis of Industry Crude and Product Oil Spills on the Alaska North Slope and Estimates of Potential Spills for the Liberty Development Project

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Appendix A. Analysis of Industry Crude and Product Oil Spills on the Alaska North Slope and Estimates of Potential Spills for the Liberty Development Project

Summary

This appendix explains the data, methods, and results of an analysis of historical crude oil and refined product[1] ("product") spills for Alaska North Slope (ANS) facilities, including wells, facilities and other pipelines up to (but not including) Pump Station 1 (PS-1), which marks the beginning of the Trans Alaska Pipeline System (TAPS). The purpose of this analysis is to estimate the potential direct and indirect environmental impacts of the Liberty Development Project from potential crude oil and product spills. The projection method is based on statistical models used by the Minerals Management Service (MMS) for ANS and other oilfields. The data used for this analysis include historical ANS crude and product spills for the period 1985 – 2006; a time period believed most appropriate for this purpose.[2] The basic assumption is that the likelihood of future crude and product spills associated with the Liberty Development Project can be accurately estimated from prior ANS experience, i.e., that spill rates (per billion barrels produced) for this project will be similar to those at other ANS facilities. This basic assumption may overstate potential spills from the Liberty Development Project because this project makes efficient use of existing facilities and features few incremental facilities. The Liberty Development Project design and scope have evolved from an offshore stand-alone development in the outer continental shelf (OCS) (production/ drilling island and subsea pipeline) – as described in the 2002 Liberty Development and Production Plan Final Environmental Impact Statement – to make maximum use of the existing infrastructure involving an expansion of the Endicott Satellite Drilling Island (SDI). As a result, development of Liberty from Endicott significantly reduces potential environmental impacts, project footprint and does not require construction of new processing and transportation facilities.

Liberty will be developed with very few wells; up to six wells will be drilled from the expanded SDI using a purpose built drilling rig to reach the offshore Liberty reservoir located on the OCS. The drilling rig will be powered by natural gas so no handling and

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[1] Two types of spills are considered in this analysis (1) spills of crude oil and (2) spills of refined products (e.g., aviation fuel, gasoline, diesel fuel, turbine fuel, motor oil, hydraulic oil, transformer oil, transmission oil, and engine lube oil, etc.). Produced water spills are not considered in this analysis. In cases where a "mixed spill" occurs the respective volumes of crude oil and product are calculated by multiplying the total spill volume by the respective percentages of crude or product. For simplicity, these are referred to as crude and product spills in the remainder of this appendix.

[2] It is believed that use of this spill reporting period is more accurate. First, the accuracy of oil spill data may have increased after 1985 and 1999 due to increased public awareness after certain large spills such as the Exxon Valdez, changes in the underlying reporting requirements in state and federal law, and a change from a paper format to an electronic format for records retention. Second, the reporting threshold for spills has substantially decreased since the early days of North Slope operations. This is supported by the finding that the average reported volumetric spill rate (see main text for definitions) from 1985 onwards was approximately 3 times greater than for the period 1977 – 1984. To avoid the possibility of under-estimating the number of spills the period from 1985 onwards was selected in this analysis.

storage of large quantities of diesel fuel is required for the project. Production from the Liberty wells will be tied into the existing Endicott flow line system with production sent from the SDI via the existing 28-inch CRA (Corrosion Resistant Alloy) three phase flow line to the Endicott Main Production Island (MPI) for processing. The Endicott plant internals are constructed of duplex stainless steel for production. After processing at the MPI facilities, Liberty oil will be transported through the existing 16-inch Endicott Sales oil pipeline (which is a DOT regulated pipeline) to Pump Station No. 1 of TAPS. This pipeline is internally inspected on a cycle of not less than once every five years (the last inspection was 2005) using a magnetic flux pig. The Liberty Project will be utilizing the Endicott facilities through a Facility Sharing Agreement (FSA) with the Duck Island Unit Owners which is currently being negotiated. No buried subsea pipelines (included in the alternatives considered in the original FEIS) are required.

As noted above, Liberty will maximize use of existing infrastructure; the analysis presented here conservatively assumes that the direct and indirect impacts of the Liberty Development Project can be estimated based on a statistical analysis of the historical crude and refined product oil spills that occurred on the North Slope.

Crude oil spills included in this analysis are subdivided into large spills (those greater than or equal [≧ to 200 barrels [bbls]) and small spills.[3] For large crude oil spills:

- The expected[4] number of large crude oil spills for the operating life of the Liberty Development Project is 0.09 based on the estimated production of 105 million bbls and the ANS experience that nine large crude oil spills occurred during the production of nearly 11 billion bbls of crude oil produced over the period from 1985 to 2006. We have high (95%) confidence that the expected number of future large crude oil spills associated with the Liberty Development Project ranges will be between 0.039 and 0.163.[5]

[3] MMS traditionally uses 1,000 bbls as the threshold for a large OCS oil spill. However, only one ANS spill > 1,000 bbls has occurred over the period from 1977 to the present. The original EIS for Liberty used 500 bbls as a threshold and more recent studies (Eschenbach and Harper, 2006) have considered thresholds as small as 50 bbls. The choice of 200 bbls provides an adequate sample of large spills for statistical purposes and lowers the likelihood that the estimates will be biased if the volume distribution of small spills differs from that for large spills.

[4] This is a statistical term of art and denotes the sum of the probabilities of 0, 1, 2, 3...spills times the number of spills, summed over all possible numbers of spills. Another word that might be chosen is the *estimated* number of spills. In this instance the expected or estimated number of large spills is 0.09—an impossibility because the number of large spills must be an integer (0, 1, 2, 3, etc). What this estimate tells us is that it is very likely that zero large spills will occur, a point amplified in the following paragraph.

[5] Technically this is known as a *confidence interval*. In statistics, a confidence interval (CI) for a population parameter (the large crude oil spill rate in this example) is an interval with an associated probability (95% in this instance) that is generated from a random sample of an underlying population such that if the sampling was repeated numerous times and the confidence interval recalculated from each sample according to the same method, a percentage (95%) of the confidence intervals would contain the true value of the population parameter in question. The use of confidence intervals was one of the specific recommendations of the NSBSAC. For additional information on confidence intervals, see http://www.cas.lancs.ac.uk/glossary_v1.1/confint.html.

- The estimated probability (in percentage terms) that no large crude oil spill will occur from the Liberty Development Project is approximately 92%[6] if the future is like the past and the assumed model is correct.[7] We have high (95%) confidence that the actual probability that no large crude oil spill will occur during the operation of Liberty lies between 85% and 96%. That is, large crude oil spills associated with the Liberty Development Project are unlikely.

- The estimated probabilities (expressed in percentage terms) that there will be 1, 2, or 3 large spills are approximately 7.8%, 0.3%, and < 0.01%, respectively.

- The odds against one or more large spills occurring are approximately 11:1. The odds against two or more large spills occurring are nearly 285:1.

- If a single large crude oil spill were to occur, then a reasonable estimate of the probable spill volume (using actual data directly as well as fitting statistical models) is 1,000 bbls. Allowing for the possibility of multiple large spills, the estimated spill volume is only slightly larger than 1,000 bbls. However, because large spills are infrequent, the weighted-average large spill volume is estimated to be 85 bbls[8].

- Because there is a distribution of large spill volumes, it is possible that the cumulative large spill volume—given the unlikely event that one occurs—would be greater than 1,000 bbls. Monte Carlo simulations, explained in the text, indicate that the 95% confidence interval on the volume of large spills (given that one occurs) is from 225 to 4,786 bbls.

It is important to note that, because the throughput of the Liberty Development Project is only a small fraction of the total ANS crude oil throughput, it is more likely that any future large crude oil spill will come from one of the other producing fields than from Liberty.

The Liberty Final EIS (USDOI, MMS, 2002) concluded on the basis of engineering judgment that the original designs would produce a "minimal chance of a significant oil spill reaching the water." This conclusion was based on the results gathered from several spill analyses done for Liberty that applied trend analysis and looked at causal factors. All showed a low likelihood of a spill, on the order of a 1 – 6% chance or less over the estimated 15 – 20 year life of the field.

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[6] Note that this statement applies only to large crude oil spills. Many small spills (addressed later in this appendix) are likely to occur. Note also that probabilities can be expressed in two equivalent ways, as fractions between zero and one and as percentages. Thus, for example, a probability of 0.5 is exactly equivalent to a probability expressed in percentage terms of 50%--as likely as not in this case. For many readers it is more intuitive to think of probabilities as percentages. To avoid confusion, we insert the percentage symbol (%) to denote a probability expressed in percentage terms.

[7] This model is conceptually plausible and has been validated by historical experience in the Gulf of Mexico and ANS areas.

[8] As noted, if a large spill occurs, the volume estimate is approximately 1,000 bbls. But because the probability of a large spill occurring is so low, the weighted average volume of a large spill is much lower.

Small spills of either crude oil or refined product are more numerous than large spills. However, the average size of a small spill is very much smaller than the average size of a large spill, with the result that the aggregate volume of small spills is only about 28% of the total volume spilled (for crude). This analysis also develops estimates of the volume of small spills associated with Liberty. For small crude oil spills:

- The estimated total volume (throughout the operating lifetime of the Liberty Project) based on the observed ratio of the volume of small spills to ANS production is approximately 34 bbls. The Liberty Project Description (BPXA, 2006) does not specify the economic life of the project. Assuming a 20-year project lifetime, the average small crude-oil volume spilled per year would be approximately 1.75 bbl/year.

- The 95% confidence interval on the total volume of small crude oil spills ranges from 6 to 100 bbls.

Refined product spills, though numerous, are very small on average. Using the same method as that employed to project small crude oil spills, the following estimates are derived for the expected and 95% confidence limits on the volume of refined product spills yields the following estimates:

- The estimated total volume (throughout the operating lifetime of the Liberty Development Project) based on the observed ratio of the volume of small spills to ANS production is approximately 42 bbls, equivalent to approximately 2 bbl/year over a 20-year project lifetime.

- The 95% confidence interval on the total volume of small crude oil spills ranges from 10 to 125 bbls.

Introduction

This appendix provides an analysis of historical crude oil and refined product ("product") spills occurring on the Alaska North Slope (ANS) and develops projections of future spills associated with the operation of the Liberty Development Project using models originally developed by the Minerals Management Service (MMS) of the US Department of the Interior. Other sections of this Environmental Impact Analysis address a trajectory scenario and fate and effects of crude oil and product spills. As noted above, we believe that the estimates provided in this analysis are conservative in the sense that these are (if anything) likely to overstate spills originating from the Liberty Development Project because this facility will take maximum advantage of existing infrastructure.

Crude oil spills are among the most visible of the environmental impacts associated with industry exploration and production (E&P) activities and, as such, merit careful attention in any study of the environmental consequences of proposed ANS oil development.

This analysis begins with a characterization and analysis of historical crude and product spills. Crude oil is produced via deep wells, the oil/water/gas mixture is transported via flow lines to the production facilities, the three-phase mixture is processed (to remove water, solids, and gas), and then transported off the North Slope to refineries located in Alaska and elsewhere. Refined oil products, including aviation fuel, gasoline, diesel fuel, turbine fuel, motor oil, hydraulic oil, transformer oil, transmission oil, and engine lube oil, are used during E&P operations (MMS, 2002; BLM, 1998). Spills associated with operation of ANS facilities include both crude oil and product spills.

A brief description of Typical ANS Oil and Gas facilities

It is useful to provide a brief description of the ANS oilfields in order to understand possible sources of crude oil and product spills. This description is abstracted from discussions found in several *environmental impact statements* [EISs] (e.g., NPR-A, BLM, 1998). Oil is produced from wells (typically located on gravel *production pads*) and flows from wellhead manifolds to production facilities (PF) [termed flowstations, gathering centers, or central processing facilities depending upon the particular field and nomenclature of the operators]. Offshore wells are located on islands. Produced oil is transported as a multiphase slurry (or three phase oil containing oil, gas, and water) by *facility oil pipelines* and the *flowlines* from the wellhead manifold to the PFs. A PF is the operational center of production activities in an oilfield. The PF typically includes production equipment, offices, maintenance facilities, storage tanks for fuel and water, power generators, and a communications facility. The oil production equipment includes three-phase separators (oil, gas, and water are produced in varying proportions from each well), gas conditioning equipment (to remove natural gas liquids from produced gas), pipeline manifold and pressure-regulation systems, and well monitoring and control systems. Oil from production wells is filtered (to remove sand and other solids) and processed (removing water and gas). After processing, crude oil (termed *sales oil*) is routed either via non-common carrier oil transit pipelines if the lines are still inside the oil and gas field or are routed through a sales meter and transportation on one or more common carrier *crude oil transmission pipelines*, (also termed *sales-oil pipelines*) for delivery to a larger-diameter mainline at *Pump Station 1* (PS-1) of the *Trans Alaska Pipeline System* (TAPS) for shipment to Fairbanks or Valdez and ultimate loading onto tankers. System pipelines are many and vary in what they are designed to carry (three-phase fluids, produced water, fresh water, salt water, gas, crude oil, diesel or other products such as methanol) and vary in diameter, depending upon function and necessary capacity, and are normally laid out in straight-line segments and installed above ground on *vertical support members* (VSMs). Above ground pipelines are less disruptive to the environment and easier to monitor, repair, and (when necessary) reconfigure than are buried pipelines. Only one offshore field (Northstar) is connected into the system via a buried *(subsea)* pipeline.

Thus, the production-processing-distribution system on the North Slope consists of wells, facility oil piping, flowlines, PFs, transmission pipelines, and various associated equipment (e.g., pumps, valves of various kinds, and separators). Tanks are used to store water, refined products, and certain other fluids.

In principle, crude oil or product spills can occur at any of the types of facilities described above. Crude oil spills result when the integrity of the production-processing-transport system is breached. Product spills can result from a variety of other causes.

The Liberty Development Project design and scope have evolved from an offshore stand-alone development field in the OCS (production/drilling island and subsea pipeline as described in the original *Final EIS* [FEIS], [MMS, 2002]) to use existing infrastructure involving an expansion of the Endicott *Satellite Drilling Island* (SDI)[9]. The present plan uses *ultra-extended-reach drilling* (uERD) from the SDI.[10] BPXA estimates (see main text) that the Liberty Development Project could recover approximately 105 million bbls of hydrocarbons by waterflooding and using the *LoSal*™ *enhanced oil recovery* (EOR) process.

Thus, the Liberty Development Project is properly viewed as an onshore facility that takes maximum advantage of existing infrastructure. Spill rates are assumed to be similar to those experienced historically on the ANS.

Types of spills

This section provides information on the various types of E&P crude oil and product spills that have occurred over the operating history of the ANS fields, including information on causes, effects, and corrective actions/countermeasures. Because of the importance of large spills to spill totals (see above) it is appropriate to focus on these spills. (This analysis includes both large and small spills, however.)

Table 1 provides a list of the crude oil spills greater than or equal to 200 bbls that have occurred on the North Slope since 1985.[11] These spills range in volume from 225 bbls to 4,786 bbls. The spills shown in Table 1 list the volume of crude oil released in the event, even though other liquids may have also been released (e.g., produced water in the case of spills from some pipelines).

Causes of ANS E&P spills reported in various environmental assessments and EISs (e.g., Parametrix, 1997; BLM, 1998; MMS, 2002) include leaks from or damage to storage tanks, faulty valves/gauges, faulty connections, vent discharges, ruptured lines, seal failures, various human errors (e.g., tank overfill, tank damage, and failure to ensure connections), and explosions. Several of these causes are reflected in the brief spill descriptions given in Table 1. Many of the spills were also contained and not released into the environment, but the volume given is the total amount that was released even if to secondary containment.

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[9] The SDI is not an onshore location. It is an existing gravel island attached to land via a causeway and is similar in construction to an onshore gravel pad facility. SDI facilities are also similar to onshore facilities (i.e., pipelines are aboveground and there is no need for an undersea buried pipeline). The SDI, while not an onshore facility more closely resembles an onshore facility than the offshore gravel island identified as the proposed action in the Liberty FEIS.

[10] BP has extensive experience with the use of extended reach drilling in overseas locations.

[11] Justification for use of the period from 1985 to 2006 is provided in a later section. The dates included are from 1 January 1985 until 31 December 2006.

Table 1. ANS crude oil spills greater than or equal to 200 bbls (1985-2006) – spill event description.

Rank	*Date*	*Volume (bbls)*	*Description of Spill Event*
1	2 Mar 06	4,786	Crude oil spill caused by corrosion and failure of a buried section of the pipe from GC-1 to GC-2.
2	28 Jul 89	925	The oil reserve tank overflowed because the high-level tank alarm system failed. The crude oil overflowed into a reserve pit.
3	21 Aug 00	715	Communication systems experienced a glitch which tripped some, but not all, shut down procedures. As a result, a tank continued to fill and overflowed.
4	17 Aug 93	675	A hole caused by external corrosion in a divert tank released a mixture of crude oil and produced water. Spill volume is crude oil only.
5	26 Sep 93	650	A Sulzer pump failure caused an overflow of Tank 7003. To alleviate rising tank levels, the inlet valve was closed and the outlet valve was opened, allowing material to spill into a containment dike. High winds carried some light oil mist to snow outside of the containment dike.
6	25 Aug 89	510	A 16 inch pipeline valve failed, allowing crude oil to leak from a piping system.
7	30 Dec 93	375	Wind-induced vibration caused a flowline leading from the well house to the manifold building to crack. Crude oil sprayed out of the crack. High winds carried some of the crude oil away from the pad towards Spine Road. At the time, the low-pressure safety system was disabled.
8	10 Jun 93	300	During a shutdown, a high-level alarm on a knockout drum failed.
9	20 Feb 01	225	During maintenance of a pipeline for thawing and displacement, pipeline ruptured, releasing the 'dead' crude mixture in the pipe.

Table 2 provides information similar to that given in Table 1 for ANS ***product spills.*** Table 2 provides information on spills greater than or equal to 50 bbls (rather than greater than or equal to 200 bbls). Spill volumes for the eleven largest product spills range from 50 bbls to 262 bbls – very much smaller on average than for crude oil spills. The largest product spills released diesel fuel, drilling oil, and drag reducing agent. As one would expect, the largest product spills involve materials kept on site in large quantities. However, the database also includes information on numerous small product spills for materials such as aviation fuel, brake fluid, chain saw oil, crankcase oil, cutting oil, engine lube oil, fuel oil, gasoline, gear oil, grease, hydraulic fluid, hydraulic oil, jet fuel, lube oil, motor oil, natural gas liquids, oil phase mud, slop oil, transformer oil, transmission fluid, turbine oil, used oil and waste oil as well as unknown products listed as 'other'. Causes for many of these spills include vehicle accidents, corrosion, faulty valves, broken fuel lines, and human errors (e.g., accidental overfill).

The spill database

The statistical analyses presented here are based upon data collected in a database developed over several years and used in several earlier spill studies. Initially, the database was developed for use in the *Trans Alaska Pipeline System Environmental Report* (TAPS ER) in support of an application for renewal of the TAPS pipeline *right-of-way* (ROW). The TAPS ER was prepared by an internal task force assisted by a team

Table 2. ANS refined product spills greater than or equal to 50 bbls (1985-2006) – spill event description.

Number	*Date*	*Volume (bbls)*	*Description of Spill Event*
1	17 Nov 03	262	Human error allowed a tanker truck to overfill at the MCC fuel dock. A seam failed and released diesel to secondary containment.
2	19 May 97	180	A needle valve on the fill line of a diesel storage tank broke, causing the diesel to drain into a lined containment area.
3	2 Mar 00	143	A release of drag reducing agent. All material was recovered.
4	16 Oct 86	100	Broken fuel line.
5	22 May 85	95	A faulty connection on a diesel tank truck caused this spill. A camlock fitting failed, allowing diesel to spill next to the truck.
6	28 Feb 03	85	A filter on a diesel spill at the MCC fuel dock failed and released diesel. Majority of spill was to secondary confinement.
7	31 Jul 91	75	Diesel released from a hole in annulus.
8	22 Jan 01	68	A diesel spill at a well pad.
9	5 Oct 95	50	Drilling oils released and contained on pad.
10	25 Nov 89	50	A maintenance issue allowed a valve to vibrate open and release diesel.
11	25 May 85	50	Heavy vehicle accident released diesel.

of external experts retained by the TAPS Owners (TAPS Owners, 2001) to characterize oil spills from 1977, when the first barrels of ANS oil flowed through the TAPS system, until August 1999. Details on data sources, compilation methods, and consistency checks are discussed in the TAPS ER and related documents (TAPS Owners, 2001). Prior to the release of the ROW documents, TAPS Owners performed extensive data audits and validation checks and appropriate corrections and adjustments were made (Niebo, 2001a,b and Maxim, 2001; Maxim and Niebo, 2001).

In 2002, this database was updated to provide information for a study commissioned by the *National Research Council* (NRC). The NRC study documented and evaluated information on the cumulative environmental effects of ANS oil and gas activities (NRC, 2003). As part of the study, the oil spill database was updated with government and industry records for crude oil and refined product spilled through 31 December 2001.

The current version of the oil spill database includes ANS crude oil and refined product spills from 1977 to 31 December 2006. In total, the ANS oil spill database provides information on nearly 8,000 spill events totaling approximately 20,300 barrels of material (including both crude oil and refined product) spilled over the 30-year period.

-Updating the oil spill database for the Liberty Development Project

The oil spill database needed to be updated for the Liberty Development Project. The original database was compiled from spill records maintained by both the Alaskan oil industry and state and federal agencies.

To update the oil spill database for the Liberty Development Project, electronic spill records were collected from *Alaska Department of Environmental Conservation* (ADEC) spill database and those maintained by BP Exploration (Alaska) [BPXA] and ConocoPhillips. Records were requested for the period from 1 January 2001 to 31 December 2006[12]. Once received, spill records were sorted based on the type of material spilled and segregated into two lists; a list of crude oil spills and a list of refined products spills. The lists were examined for duplicate spill records and duplicate records were removed and kept for reference. Duplicate spills were identified by comparing the date of each spill, identity of the spilled material, reported spill volume, and spill location.

There are differences between the industry and ADEC spills databases. Current spill reporting regulations are described in 18 AAC 75.300 and summarized on the ADEC website at http://www.dec.state.ak.us/spar/spillreport.htm#requirements. Differences between the industry and ADEC databases include:

- By regulation, some small spills are not reportable to ADEC, but industry has generally kept records of these small spills. Thus, there are some spills included in the industry databases that are not included in the ADEC database.

- The ADEC database also includes some spills that are not listed in the industry databases. As might be expected, some spills on the North Slope are not directly attributable to the oil industry and some may be related to government or military installations. These spills are not frequent and are typically related to spills of refined products. By combining relevant spill data from both industry and ADEC datasets, the resulting ANS oil spill database proves a more accurate picture of the spill history on the North Slope.

- Some spills are included in both databases, but a different spill volume is listed in each. These discrepancies occur for several reasons. In some cases a spill volume is used in the ADEC data base, that is subsequently revised (either upwards or downwards) and the revised data may not be listed (i.e. the spill record may not have been updated). In other cases, for example, the large crude oil spill discovered in March 2006, ADEC includes a margin of error (+33%) to allow for possible errors of estimation, whereas the oil industry data report uses an estimated value.

[12] Requesting data from Jan. 1, 2001 provided a useful check against the 2001 data already in the database. Some of the 2001 spill records in the existing database required changes to account for information that was entered at a later date. For example, an initial spill volume in an August 2001 spill record may have been updated with a final volume during 2002.

For most spills, the ADEC and industry oil data match very well. When the records matched (e.g., had same volume, spilled material, date and location) the record with the most supplemental information was retained for the database. That is, if the industry record had information on the circumstances of the spill or clean up that were not provided with the ADEC record, the industry record was kept for the final database. If the ADEC record contained more information than the industry record, the ADEC record was retained.

In some cases, the ADEC database and industry database do not agree on spill volumes even though they report the same spill. There are three reasons for disagreement. First, the ADEC spill database sometimes provides information on the total amount of liquid spilled during a spill event. A single spill event may release numerous types of liquids (such as produced water and crude oil from a pipeline leak, or diesel fuel, motor oil and hydraulic fluid in the case of a vehicle accident). The industry records generally identify the volume of specific types of liquid spilled. In instances where it was clear by that the ADEC data record had not disaggregated the spilled materials, the industry data records were used.

Second, conversations with ADEC personnel[13] indicated that the ADEC oil spill database had gone through revisions and a software upgrade recently. As a result, some of the smaller spills (reported to the agency as less than one gallon or in fractional gallons) had been rounded up. For example, the ADEC data may list a spill of two gallons while the industry database lists it as 1.5 gallons. In these cases, the industry record was used because of the precision of the volume. In general, the rounding appears to primarily have occurred with small spill of less than 2 gallons.

Third, for more recent spills, records in the ADEC database have not been "closed." That is, some of the spill response activities are still ongoing and the spill volume listed may be preliminary. In those instances, the industry records were used. This issue is only relevant for spills occurring during 2006.

To update the database, North Slope spills were added to the database. Specifically, spills were added from the ANS E&P facilities and pipelines and from records tagged by ADEC as occurring on the North Slope. All TAPS facilities were excluded from the database. Thus, there are no spills attributed to the TAPS pipeline or associated pump stations on the North Slope. Spills occurring from facilities in the town of Deadhorse were included in the update because those spills might be related to oil and gas activities on the North Slope. Spills from the neighboring towns and villages were not included. Typically, spills from these villages are usually small volumes of refined products.

[13] Personal Comm. with Camille Stephens, ADEC Environmental programs Spec III (907) 465-5242, January 19, 2007.

-Period of analysis

The ANS oil spill database contains records back to the beginning of oil production on the ANS in 1977. However, there are fewer spill records during the years from 1977 to 1985 (see Fig. 1) and the completeness and accuracy of the older records has been questioned. In fact, several observers believe that the accuracy of oil spill data on the North Slope is naturally greater for the period after 1985 (MMS, 2002) or 1989 (BLM, 1998) than for the earlier years.

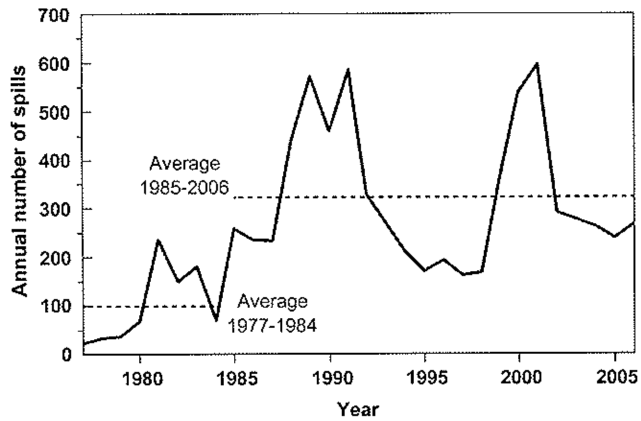

Fig. 1. Annual number of crude and product spills listed in ANS oil spill database, 1977 to 2006.

It has been suggested that spills may have been under-reported in the earlier years.[14] One report (AGRA, 2000) claims that prior to the 1990s only 10% of spills on tundra were reported to the ADEC and included in the State's files. We know of no reliable basis for estimating the extent (if any) of under-reporting prior to 1985.

Another issue that confounds accurate assessment of the spill record prior to 1985 is that prior to 1985, the ADEC spill records, the only source that may have been available for public scrutiny, were kept as paper files. After 1985, the system was converted to an electronic database. The written records for many spills prior to 1985 are now missing or incomplete; a search of the paper records by MMS contractor Hart Crowser in 1999 revealed that very little of the paper record existed publicly through ADEC.

Analysis of the updated spills database indicates that there are fewer spill records per year in the early years of ANS production. Figure 1 plots the annual number of crude oil and refined product spills in the database from 1977 through 2006. The average number of spills reported from 1977 to 1984 was 100 per year. The average number of spills reported from 1985 to 2006 was 324 spills per year—greater by a factor of three.

Currently, we have no definite explanation why fewer annual spills were reported in the early years. However, to avoid any possible under-estimation of future spill quantity projections, and to acknowledge that the data prior to 1985 can not be easily validated through a public source, we restricted our analysis to spills that occurred from

[14] It is difficult to assess the validity of this claim. On the one hand, reporting thresholds for spills have decreased over time, which would be consistent with this hypothesis. As well, spill awareness has also increased. However, on the other hand, large spills account for the bulk of the total volume and changes in the reporting threshold or spill awareness would probably not affect the likelihood of reporting large spills.

1 January 1985 to 31 December 2006—an assumption supported by MMS personnel. *The database used for this analysis includes 22 years of ANS spill history and thousands of spill records for statistical analysis.*

Spill data and spill rates

As the term is used here, "oil spills" are unintentional accidental releases of crude oil or product. Accidents are fundamentally probabilistic, rather than deterministic, events. Accordingly, it is appropriate to analyze spill data in statistical terms.

-Size distribution of ANS spills

As noted above, the reporting threshold by regulation is quite low, and the oil industry maintains records of spills below the reporting threshold. For this reason, ANS spill records in the database range more than six orders of magnitude in volume, from 0.01 *gallons* (7.5 teaspoons) to 4,786 *barrels*[15]. That is, relatively small spills are quite frequent, but there is a long "tail" to the distribution—the total volume is dominated by relatively few large spills. This characteristic (see below) has important implications for the appropriate choice of a spill metric—it is *the total volume, not the total number of spills* that is relevant.

A key conclusion of this analysis is that smaller spills, although more numerous, account for only a small proportion of the total spill volume. This is best illustrated by a *Lorenz diagram*, which plots the fraction of the spill volume (on the vertical axis) versus the fraction of the number of spills (on the horizontal axis). It is constructed as follows. First, the spill data are sorted in ascending order of spill volume. Next the cumulative fraction of the total volume spilled (y-axis) is plotted as a function of the cumulative fraction of the total number of spills (x-axis). Figure 2 provides a hypothetical illustration of a Lorenz plot. If all spills were exactly the same size, the fraction of the spill volume would correspond exactly to the fraction of the number of spills. The 45° line "AB" in Fig. 2 depicts this situation. However, if some spills were larger than others, then the fraction of the spilled volume would be less than the fraction of the number of spills, as shown by the curve "AB" beneath the 45° line in Fig. 2. The area between the curve

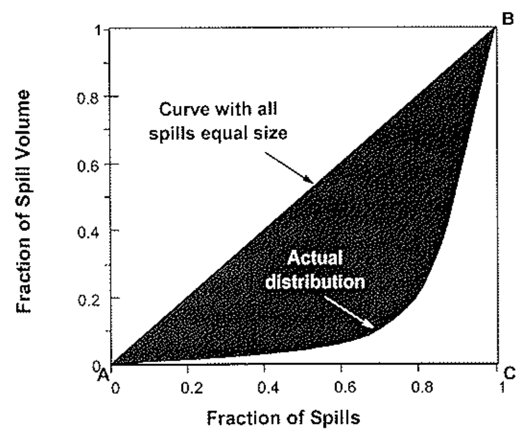

Fig. 2. A hypothetical Lorenz diagram: the size of the area between the line of constant spill volume and the actual Lorenz curve as a fraction of the bounding triangle ABC is used as a measure of inequality.

[15] One barrel is equal to 42 gallons.

and the straight line (the shaded area in Fig. 2) provides an indication of the degree of inequality in spill size distribution. Dividing the shaded area by the area of the triangle ("ABC" in Fig. 2) yields a normalized index or coefficient, denoted L, of the variability of spill volumes. L ranges from 0 (all spills the same size) to 1.

The diagram shown in Fig. 2 is hypothetical, included solely to illustrate the concept. The actual curves for ANS spills are more extreme. Figure 3 shows Lorenz plots for ANS crude (shown in red) and product spills (shown in blue) over the period from 1985 to 2006. As can be seen, there is substantial curvature in these plots (the computed Lorenz coefficients are 0.96 and 0.87 for crude and product ANS spills, respectively).

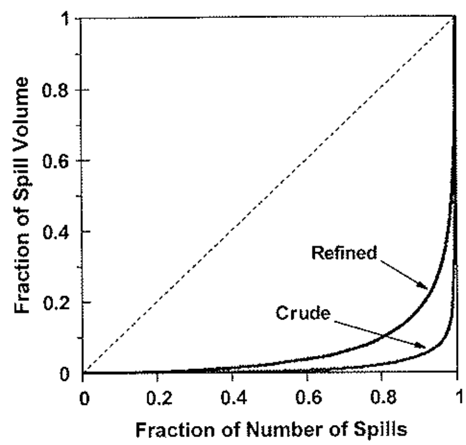

Fig. 3. Actual Lorenz curve for ANS crude and product spills (1985-2006).

The Lorenz plots provide a useful characterization of ANS spills. The clear message is that a few relatively large spills account for a majority of the total spill volume. This conclusion is suggested by numerous spill studies (Smith *et al.*, 1982; BLM, 1998, 2004, 2005; MMS, 2002, NRC, 2003; and Taps Owners, 2001). Most spills are relatively small:

- Fifty percent (the median) of ANS crude oil spills were less than or equal to 0.119 bbls (5 gallons). Fifty percent of product spills were less than or equal to 0.095 bbls (slightly less than 5 gallons).

- The smallest 90% of crude oil spills accounted for only approximately 4.4% of the total volume spilled and the smallest 95% of the spills accounted for only 7.4% of the spilled volume. The corresponding percentages for product spills were 17.6% and 26.6%, respectively.

- Another perspective on ANS spill volumes is evident from the *cumulative distribution function* (CDF). Figure 4 shows the CDF for ANS spills (crude and product) over the period from 1985 to 2006. The CDF plots the fraction of spills with a volume less than or equal to a specified amount x (on the y-axis) against the value of x (on the x-axis); crude oil spills are shown in red, product spills in blue. Because of the large variability in spill volumes, only a portion of the CDF is plotted in Fig. 4;

that for spills less than or equal to 5 bbls. This diagram clearly shows that most spills are relatively small. For ANS spills, 87.3% of crude oil spills and 94.7% of product spills are less than 2 bbls. A few specific spills are discussed below, but small spills are quite diverse (fueling vehicles, leaking drums, and splashes).

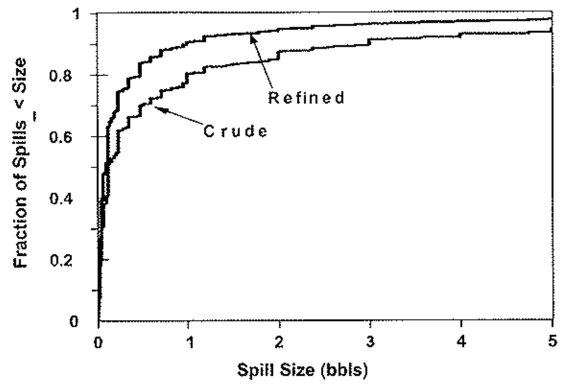

Fig. 4. Cumulative distribution function for ANS E&P spills less than 5 bbls (1985-2006).

Small spills are inherently of less concern than larger spills for the following reasons (TAPS Owners, 2001; McKendrick 2000 and references therein; NRC, 2003; BLM, 1998, 2005):

- Small spills are more likely to be contained on site,
- Small spills are also more likely to be fully recovered,
- Small spills have a lower potential to produce significant adverse environmental impacts, and
- Small spills collectively account for only a small proportion of the total volume spilled.

The above findings argue for an analytic focus on the *volume spilled*, rather than the *number of spills* and a corresponding emphasis upon the causes, effects, and consequences of larger spills.[16] Most EISs distinguish between small and large spills and, indeed, use separate methodologies for projection of future spills of each type.

In what follows, we first address large crude oil spills and develop methods for projection of future large spills associated with the Liberty Development Project. Next we develop projections for small crude oil and product spills for this project.

"Large" spill definition and projections

MMS and its contractors have developed useful methods for predicting "large spills" (Smith *et al.,* 1982; LaBelle and Anderson, 1985; Anderson and LaBelle, 1990, 1994; Amstutz and Samuels, 1984; MMS, 1987, 1990a,b, 1996, 1998, 2002; Eschenbach and Harper, 2006). (Historically, MMS has typically used 1,000 bbls as the threshold for a large OCS spill. We modify this definition below.)

[16] This is not meant to imply that North Slope operators disregard small spills. Many small spills (e.g., vehicle leaks) are easily prevented (e.g., periodic maintenance) or contained (e.g., use of drip pans) by simple devices and/or changes in operating procedures. Such measures (including simple housekeeping) are readily implemented and cost-effective. Each of the North Slope operators has developed *standard operating procedures* (SOPs) that are designed to combat both large and small spills.

This method examines the frequency of large crude oil spills in comparison to the volume of oil produced by calculating a spill rate expressed as the number of large spills per billion bbls produced.[17] Large spills are assumed to occur as a Poisson process and the Poisson distribution is used to estimate the future number of large spills for the forecast throughput over the planning horizon.[18] That is, if μ is the expected number of spills associated with a particular production volume, then the probability[19] of $x = 0, 1, 2, 3,\ldots k$ future spills is given by,

$$P\{x = k\} = \exp(-\mu)\,(\mu)^k/k!. \qquad (1)$$

Defining j as the observed number of large crude oil spills in the past associated with the production of y billion bbls (Bbbls), the observed (historical) large crude oil spill rate for pooled ANS facilities is calculated from the ratio j/y. If an additional z Bbbls are to be produced over some future time horizon, then the expected number of large spills over this horizon is calculated as $\mu = z\,(j/y)$.[20] The MMS methodology has been challenged by some,[21] but more recent analyses (e.g., Eschenbach and Harper, 2006) indicate that this basic model is appropriate[22]. For estimation of spill rates we use only data from ANS operations. We make no assumption that spill rates from other areas, such as the *Gulf of Mexico* (GOM), apply to the ANS.[23]

In principle, the threshold for definition of a large spill is (to a large extent) arbitrary, but prior analyses (chiefly those of spills in the GOM) have typically chosen a threshold of 1,000 bbls. However, in preparing the spill projections for the Liberty field (MMS, 2002), MMS used a lower large spill threshold of 500 bbls (MMS, 2002). There were both policy[24] and practical reasons for this choice; when this analysis was originally

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[17] Other exposure measures have been proposed and analyzed, such as time, pipeline km for pipeline spills, and platform years for oil platforms. Eschenbach and Harper (2006) show that these candidate exposure measures are generally correlated. In this analysis, we use production as the exposure metric. This is easy to understand, consistent with many earlier analyses, and does not require that pipeline and platform spills be disaggregated.

[18] Because of the limited number of large spills that have occurred it is not possible to distinguish between pad (platform) and pipeline spills. Instead, large spills are pooled for all *facilities*.

[19] The probability calculated using this question is expressed as a fraction, not in percentage terms.

[20] MMS has now developed a different model to describe offshore facilities that accounts for possible additional failure modes and mechanisms for undersea pipelines. As Liberty is properly viewed as an onshore development use of this new methodology was not considered necessary.

[21] For example, the *North Slope Borough Science Advisory Committee* (NSBSAC) made several trenchant comments on this methodology—or at least how this methodology was applied in recent EISs (NSBSAC, 2003). We believe that we have addressed their concerns in this analysis.

[22] Eschenbach and Harper (2006), in a study funded by MMS, have shown that the Poisson model provides an adequate representation. Specifically, they concluded:

> "The Poisson distribution for pipeline and platform spill rates is satisfactory. Other distributions could be chosen, but the Poisson
> 1. Fits with historical practice
> 2. Has a theoretical foundation – it is not just an empirical curve fit
> 3. Is "not rejected" at reasonable levels of statistical confidence
> 4. Even though the fit of any distribution may be imperfect, the key question when estimating rates, is 'how much do these imperfections change the estimated rate? Generally, the answer is very little.'"

[23] This was one of the concerns of the NSBSAC (NSBSAC, 2003) in reviewing MMS methodology—the possible lack of similarity between ANS and GOM operations.

[24] MMS typically uses a large spill volume of greater than or equal to 500 bbl for Alaska North Slope EIS documents.

undertaken, no spills greater than 1,000 bbls had ever occurred on the North Slope. More recently (Eschenbach and Harper, 2006) MMS has examined various thresholds for the definition of an OCS large spill as low as 50 bbls.

As noted above, the threshold for definition of a large spill is (to a large extent) arbitrary. Nonetheless, there are some practical reasons for choosing one threshold compared to another:

- The volume threshold must be sufficiently high to include a reasonable number of "large" spills in the data set for analysis. As described above, upper and lower confidence limits are calculated based on the available data—the width of the confidence interval depends upon the number of data points included. If there are only a few data points included, then the results will not be precise. This criterion argues for relatively lower volume threshold to increase the available sample size.

- It is possible that the statistical characteristics of "large" spills differ from that for "small" spills. If the threshold for a large spill is set too low, then the population of "large" spills would also include an appreciable proportion of small spills, which might bias the analysis. This possibility argues for a higher volume threshold.

In the end, it is a matter of judgment as to the appropriate threshold. In this analysis we have chosen 200 bbls as a practical compromise. Reference to Table 1 shows that using a threshold of ≥200 bbls implies that a total of nine large spills occurred over the period from 1985 to 2006.[25]

Probability calculations for future large spills from the Liberty Development Project

This section provides probability calculations for number of large crude oil spills associated with the development and production of the Liberty Development Project. For the *base case* we use a threshold of 200 bbls for the definition of a large spill. Over the period from 1985 through the end of 2006 nine large spills occurred, accounting for approximately 72% of the total volume of crude oil spilled. A total of 10.976 billion barrels (Bbbls) of crude oil was produced over this period.

The estimated mean spill rate μ (given these assumptions) is 9 spills/10.976 Bbbls = 0.82 large spills/Bbbls produced. This and other calculations are shown in Table 3.

-Estimate of future large spills from the Liberty Development Project

As noted above, the estimated total production from the Liberty Development Project is 105 million bbls (0.105 Bbbls). Thus the estimate of the expected number of large crude oil spills associated with this production volume (assuming that spill rates in the future are the same as those observed historically) is 0.82 large spills/Bbbls x 0.105 Bbbls = 0.086 large spills (see Table 3). Using this spill rate and the Poisson model (equation [1]) it is possible to estimate the probability of 0, 1, 2, 3…large spills

[25] If the threshold were set at 100 bbls, 17 large spills would have occurred. If the threshold were set at 500 bbls, then six large spills would have occurred.

associated with the development of the Liberty Project. As shown in Table 3[26], the best estimate of the probability of 0 large spills is approximately 0.9175 (nearly 92%), of exactly 1 large spill is 0.0789 (nearly 8%), of exactly 2 large spills is 0.0034 (0.3%) etc. The probability of 1 or more large spills from this facility is 1 – P(0) = 1 – 0.9175 = 0.0824 (approximately 8%).

Table 3. Calculation of large spill probabilities and confidence intervals for Liberty field.

Inputs:

Quantity	*Units*	*Value*	*Source/remarks*
Confidence level, p	NA	0.05	Conventional statistical assumption
Large spill threshold	Bbls	200	Assumption
# large spills in baseline period	NA	9	ANS data from 1985 through 2006 for all facilities
Throughput in baseline period	Bbbls	10.976	ANS data from 1985 through 2006
Large spill rate	spills/Bbbls	0.8200	ANS estimate of mean large spill rate
Exact LCL on spill rate	spills/Bbbls	0.3749	Computed exact lower confidence limit
Exact UCL on spill rate	spills/Bbbls	1.5566	Computed exact upper confidence limit
Throughput for Liberty Project	Bbbls	0.105	Estimated future production of Liberty field from Liberty Project description December 2006 (BPXA, 2006)

Future estimates:

	Lower confidence limit			*Best estimate*			*Upper confidence limit*		
Expected number of large spills over life of Liberty field	0.0394			0.0861			0.1634		
Number of large spills, x	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* X	*Probability* <= x	*Probability* x| x>=1
0	0.96139589	0.96139589		0.91750529	0.91750529		0.84921846	0.84921846	
1	0.0378492	0.99924508	0.98044466	0.0789944	0.99649968	0.95756918	0.13879525	0.98801372	0.92050563
2	0.00074504	0.99999013	0.01929956	0.00340059	0.99990027	0.04122189	0.01134227	0.99935598	0.07522317
3	0.00000978	0.9999999	0.00025327	0.00009759	0.99999786	0.00118303	0.00061792	0.9999739	0.00409813
4	0.0000001	1	0.00000249	0.0000021	0.99999996	0.00002546	0.00002525	0.99999915	0.00016745
5	7.58E-10	1	0.00000002	0.00000004	1	0.00000044	0.00000083	0.99999998	0.00000547
6	4.97E-12	1	1.29E-10	5.19E-10	1	6.29E-09	0.00000002	1	0.00000015
7	2.80E-14	1	7.24E-13	6.38E-12	1	7.74E-11	5.25E-10	1	0.00000003
8	1.38E-16	1	3.56E-15	6.87E-14	1	8.33E-13	1.07E-11	1	7.11E-11

Number of large spills, x	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*
1	0.03860411	24.9	0.08249471	11.1	0.15078154	5.6
2	0.00075492	1,323.60	0.00350032	284.7	0.01198628	82.4
3	0.00000987	101,273.20	0.00009973	10,026.00	0.00064402	1,551.80
4	0.0000001	10,310,096.50	0.00000214	467,874.60	0.0000261	38,318.40

[26] Several decimal places are shown in these calculations to assist the reader interested in replicating these calculations, not because of any assumed accuracy. These estimates have been rounded in summary statements. Probabilities shown in this and other tables are expressed as fractions; multiply by 100 to convert these to percentage terms. Note also that this calculation applies only to large spills. Many small spills (addressed later in this appendix) are likely to occur.

In plain language, if the frequency of future large (≥200 bbls) crude oil spills is similar to those observed historically, then the following statements can be made with respect to large spills associated with the development of the Liberty Project:

- The estimated number of large crude oil spills is approximately 0.09,[27]
- The probability that there would be no large crude oil spill (expressed in percentage terms) is approximately 92%, and
- The odds against one or more large spills are approximately 11:1. The odds against two or more large spills occurring are nearly 285:1.

Formulas to calculate a (1 – p)% confidence interval on this rate are given in various sources (see e.g., Eschenbach and Harper (2006) and references contained therein).[28] If μ_L and μ_U denote the lower and upper confidence limits on μ based on a total of x spills, these are given by the following formulas:

$$\mu_L = 0.5\,\chi^2\,(2x, p/2)/\text{ exposure variable} \qquad (2)$$

$$\mu_U = 0.5\,\chi^2\,(2(x+1), 1- p/2)/\text{ exposure variable} \qquad (3)$$

where χ^2 is the value of the Chi-square distribution. In this example, the 0.025 and 0.975 confidence limits on the mean rate calculated from equations (2) and (3) are approximately 0.37 and 1.56 large crude oil spills/Bbbls, respectively (as shown in Table 3). And, therefore, the 95% confidence interval on the estimated number of large crude oil spills associated with the Liberty Development ranges from 0.37 spills/Bbbls x 0.105 Bbbls = 0.039 spills to 1.56 spills/Bbbls x 0.105 Bbbls = 0.163 spills.

Associated with each of these spill rates are probabilities similar to those cited above. Thus, for example:

- We have high confidence (95%) that the chance that there would be no large crude oil spill associated with the development of the Liberty Project is between 85% and 96%.
- If a large crude oil spill should occur, then the probability that there is exactly one large spill ranges from 0.92 (92%) to 0.99+ (> 99%). That is, it is very likely that no more than one large spill would occur, even if one spill did occur.

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[27] As noted elsewhere the number of large spills must be an integer, that is 0, 1, 2, 3, etc. The estimated number of spills is calculated by multiplying the number of spills (an integer) by the probability that this many spills would occur and summing over all possibilities. The significance of a very small number (0.09 in this instance) is that it is very likely that no large spills will occur.

[28] One of the NSBSAC criticisms of earlier MMS analyses was the omission of any calculation of confidence limits on projected quantities. Confidence limits are used extensively in this analysis. Other sources for equations to calculate confidence limits on the mean of a Poisson distribution are available electronically at http://hyperphysics.phy-astr.gsu.edu/hbase/math/poifcn.html#c2, http://www.math.mcmaster.ca/peter/s743/poissonalpha.html, and http://www.hep.fsu.edu/~harry/Public/Morelia2002-1.pdf.

- The odds against one or more large spills associated with development of the Liberty Project range from 5.6:1 to 24.9:1.

As noted above, we believe that 200 bbls strikes a reasonable balance among competing objectives in setting a threshold. To illustrate the sensitivity of this assumption, Tables 4 and 5 show replicate computations if the large-spill threshold were set at 500 bbls (65% of total spilled) or 100 bbls (82.3% of total spilled).

Table 4. Calculation of large spill probabilities and confidence intervals for Liberty field assuming a large spill threshold of 500 bbls.

Inputs:

Quantity	*Units*	*Value*	*Source/remarks*
Confidence level, p	NA	0.05	Conventional statistical assumption
Large spill threshold	Bbls	500	Assumption
# large spills in baseline period	NA	6	ANS data from 1985 through 2006 for all facilities
Throughput in baseline period	Bbbls	10.976	ANS data from 1985 through 2006
Large spill rate	spills/Bbbls	0.5466	ANS estimate of mean large spill rate
Exact LCL on spill rate	spills/Bbbls	0.2006	Computed exact lower confidence limit
Exact UCL on spill rate	spills/Bbbls	1.1898	Computed exact upper confidence limit
Throughput for Liberty Project	Bbbls	0.105	Estimated future production of Liberty field from Liberty Project description December 2006 (BPXA, 2006)

Future estimates:

	Lower confidence limit			*Best estimate*			*Upper confidence limit*		
Expected number of large spills over life of Liberty field	0.0211			0.0574			0.1249		
Number of large spills, x	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* X	*Probability* <= x	*Probability* x| x>=1
0	0.979156	0.97915626		0.944218	0.94421823		0.882558	0.88255763	
1	0.020625	0.99978124	0.989505	0.054196	0.99841443	0.971576	0.110259	0.9928166	0.938835
2	0.000217	0.99999847	0.010421	0.001555	0.99996981	0.027883	0.006887	0.999704	0.058645
3	1.53E-06	0.99999999	7.32E-05	2.98E-05	0.99999957	0.000533	0.000287	0.99999081	0.002442
4	1E-08	1	3.9E-07	4.3E-07	1	7.66E-06	8.96E-06	0.99999977	7.63E-05
5	3.38E-11	1	1.62E-09	0	1	9E-08	2.2E-07	1	1.91E-06
6	1.19E-13	1	5.70E-12	4.69E-11	1	8.41E-10	0	1	4E-08
7	3.57E-16	1	1.71E-14	3.85E-13	1	6.89E-12	8.32E-11	1	7.08E-10
8	9.41E-19	1	4.52E-17	2.76E-15	1	4.95E-14	1.30E-12	1	1.11E-11

Number of large spills, x	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*
1	0.020844	47	0.055782	16.9	0.117442	7.5
2	0.000219	4,570.30	0.001586	629.7	0.007183	138.2
3	1.53E-06	652,203.30	3.02E-05	33,122.10	0.000296	3,377.30
4	1E-08	123,982,510.20	4.3E-07	2,314,985.10	9.19E-06	108,852.50

Table 5. Calculation of large spill probabilities and confidence intervals for Liberty field assuming a large spill threshold of 100 bbls.

Inputs:

Quantity	*Units*	*Value*	*Source/remarks*
Confidence level, p	NA	0.05	Conventional statistical assumption
Large spill threshold	Bbls	100	Assumption
# large spills in baseline period	NA	17	ANS data from 1985 through 2006 for all facilities
Throughput in baseline period	Bbbls	10.976	ANS data from 1985 through 2006
Large spill rate	spills/Bbbls	1.5488	ANS estimate of mean large spill rate
Exact LCL on spill rate	spills/Bbbls	0.9023	Computed exact lower confidence limit
Exact UCL on spill rate	spills/Bbbls	2.4798	Computed exact upper confidence limit
Throughput for Liberty Project	Bbbls	0.105	Estimated future production of Liberty field from Liberty Project description December 2006 (BPXA, 2006)

Future estimates:

	Lower confidence limit			*Best estimate*			*Upper confidence limit*		
Expected number of large spills over life of Liberty field	0.0947			0.1626			0.2604		
Number of large spills, x	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* x	*Probability* <= x	*Probability* x| x>=1	*Probability* X	*Probability* <= x	*Probability* x| x>=1
0	0.90961255	0.90961255		0.84990768	0.84990768		0.77075674	0.77075674	
1	0.08617355	0.99578609	0.95337953	0.1382184	0.98812608	0.92088923	0.20069154	0.97144828	0.87545231
2	0.00408189	0.99986799	0.04515994	0.01123906	0.99936514	0.07488098	0.02612828	0.99757656	0.11397621
3	0.0001289	0.99999689	0.0014261	0.00060926	0.9999744	0.00405924	0.00226778	0.99984434	0.00989247
4	0.00000305	0.99999994	0.00003378	0.00002477	0.99999917	0.00016504	0.00014762	0.99999197	0.00064396
5	5.78E-08	0.999999999	0.00000064	0.00000081	0.99999998	0.00000537	0.00000769	0.99999965	0.00003353
6	9.13E-10	1	0.00000001	0.00000002	0.999999999	0.00000015	0.00000033	0.99999999	0.00000146
7	1.24E-11	1	1.37E-10	5.07E-10	1	3.38E-09	1.24E-08	1	0.000000054
8	1.46E-13	1	1.62E-12	1.03E-11	1	6.87E-11	4.04E-10	1	0.000000002

Number of large spills, x	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*	*Probability x or more large spills*	*Odds 1: y*
1	0.09038745	10.1	0.15009232	5.7	0.22924326	3.4
2	0.00421391	236.3	0.01187392	83.2	0.02855172	34
3	0.00013201	7,574.00	0.00063486	1,574.20	0.00242344	411.6
4	0.00000311	321,367.80	0.0000256	39,063.50	0.00015566	6,423.40

Empirical cumulative distribution function (CDF) of ANS large spill volumes

The above sections develop estimates (and associated 95% confidence limits) of the probability of 1, 2, 3… large crude oil spills associated with production from the Liberty Development Project. This and following sections develop an estimate of the probable *volume of a large spill* (if one occurs) and the cumulative number of large spills (if more than one occur).

The available data for estimation of the volume of a large spill consist of the observed historical (over the period of interest) ANS large spill volumes x_i ($i = 1, n$), in ascending order so that $x_1 \leq x_2 \leq x_3 \ldots \leq x_n$. If μ denotes the cutoff volume used to define a large spill, then $\mu \leq x_i$ for all i, by definition. As noted above, for example, if ≥200 bbls is defined as the cutoff volume for definition of a large spill, based on the ANS spill data, then there are nine large spills (n = 9). As shown in Table 1, these volumes are (rounded) as follows; 225, 300, 375, 510, 650, 675, 715, 925, and 4,786 bbls.[29]

The CDF is a plot of the fraction (or percentage) of the observed large spill volumes less than or equal to a specific volume x, denoted F(x), versus the spill volume x. Because the observed number of large spills is finite, the CDF can be directly[30] estimated only at each of the individual data points, $F(x_i)$. The conventional estimator of $F(x_r) = r/n$, where x_r is the volume corresponding to the r^{th} data point in the ordered list.[31] Thus, for example, F(225) = 1/9, F(300) = 2/9 etc.

Other estimators of $F(x_r)$ suggested in the literature include; $(r - 0.3)/(n + 0.4)$, Gross (1996);[32] $(r - ½)/n$, Guttman *et al.*, (1982) or Gilbert (1987); $(3r - 1)/(3n + 1)$, Koch and Link, (1971); and $r/(n + 1)$, Mosteller and Rourke (1973) or Uusitalo (2004).[33] When n is large, these different estimators do not differ materially, but when n is small (as it is in this case) the differences are more appreciable. Unless otherwise noted, we use the convention $F(x_r) = (r - 1/2)/n$. Given this plotting convention, Fig. 5 shows the empirical CDF of large ANS spills (assuming γ = 200 bbls). As can be seen, the empirical CDF

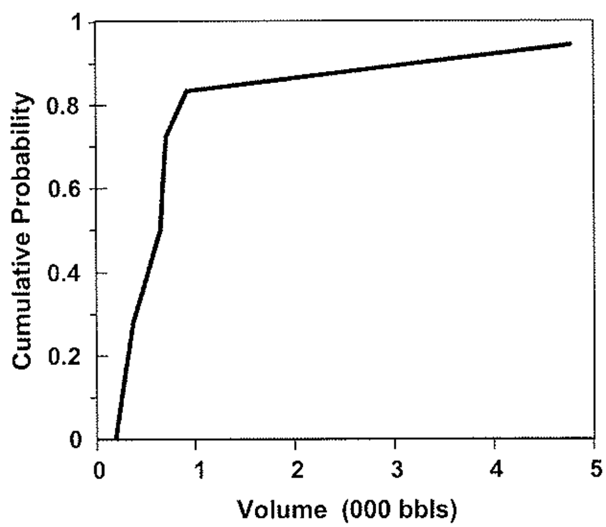

Fig. 5. Empirical CDF of ANS large (≥200 bbls) spills 1985-2006.

[29] As noted above, the largest spill volume is given as 4,786 bbls, which is the calculated estimate of the spill volume for the spill detected on 2 March 2006. The source of the spill was an above-ground 34 inch diameter crude oil transit line between Gathering Center 2 (GC-2) and GC 1, Western Operating Unit, Prudhoe Bay. ADEC lists this volume in their database as 6,357 bbls, the upper confidence limit of a range of approximately +/- 33%. Additional studies are underway to estimate this spill volume. Lacking more precise estimate of this spill volume, we use the calculated estimate of 4,786 bbls in this analysis.

[30] Other percentiles of the CDF can also be estimated by fitting distributions (see e.g., Gilbert, 1987).

[31] See, e.g., the probability-probability plots entry within an online glossary of statistical terms at http://sunsite.univie.ac.at/textbooks/statistics/glosp.html.

[32] This was suggested specifically for the three-parameter Weibull, see Gross, B., (1996). Least Squares Best Fit Method for the Three Parameter Weibull Distribution: Analysis of Tensile and Bend Specimens With Volume or Surface Flaw Failure, NASA Technical Memorandum 4721, NASA Lewis Research Center, Cleveland, OH, available electronically at http://gltrs.grc.nasa.gov/reports/1996/TM-4721.pdf.

[33] See, Uusitalo, K., (2004). The empirical cumulative distribution function, its inaccuracy and probability plotting, Helsinki, Finland, available electronically at http://www.helsinki.fi/~kuusital/doc/ecdf-inaccuracy-and-probability-plotting.pdf.

shows that most of the large spills (if fact 8 out of 9) were less than 1,000 bbls.[34] The empirical CDF appears irregular because the number of large ANS spills over the period from 1985 to 2006 is relatively small.

There are two basic approaches for handling the large spill data in order to make an estimate of the likely volume of any future large spills associated with the Liberty Development Project; (1) fitting the empirical data to a defined statistical distribution and (2) analyzing the empirical data directly. Both approaches are explored in this analysis.

-Fitting the large spill data to a probability distribution

Prior analyses of large spill volume data by MMS and others (see, e.g., Anderson and Labelle, 1990, 1994, 2000; Eschenbach and Harper, 2006; Hart Crowser, Inc., 2000; Lanfear and Amstutz, 1983; MMS, 2002; Smith *et al.*, 1982; Stewart, 1976; Stewart and Kennedy, 1978; and TAPS Owners, 2001) suggest that these spill volumes appear to conform to, or at least can be satisfactorily described by, a statistical probability distribution. Several candidate distributions have been suggested in the literature, including the Weibull, Gamma, and lognormal models. The three-parameter Weibull distribution (favored by several authors), for example, has the following density and cumulative distribution functions:

$$f(x) = (\alpha/\beta)((x-\gamma)/\beta)^{(\alpha-1)} \exp(-((x-\gamma)/\beta)^{\alpha}) \qquad (4)$$

$$F(x) = 1 - \exp(-((x-\gamma)/\beta)^{\alpha}) \qquad (5)$$

where:

α = continuous *shape* parameter ($\alpha > 0$)

β = continuous *scale* parameter ($\beta > 0$), and

γ = continuous *location* parameter (γ = minimum spill volume).

The three-parameter Weibull distribution has found wide applicability for such diverse applications as modeling spill volumes, environmental pollution, reliability theory, weather forecasting, and the breaking strengths of materials. Apart from any theoretical justification, this model is quite flexible and capable of mimicking many other continuous distributions.[35]

The parameters of the Weibull distribution (α, β, and γ[36]) can be fitted using several statistical approaches, including (1) matching the observed CDF with the empirical CDF, (2) maximum likelihood, and (3) the method of moments. By matching CDFs (squared error criterion, using (r – ½)/n as the basis for the empirical CDF) we developed the following best-fit estimates; γ = 200 bbls (definition) α = 1.213 and β =

[34] Using Table A-22 in Natrella (1963) the 95% confidence bounds on the proportion of samples that would be expected to be less than 1,000 bbls range from 0.557 to 0.994. Thus, there is high confidence that the median spill volume is less than 1,000 bbls for this data set.

[35] See e.g., Eschenbach and Harper, (2006); Gilbert, (1987); and Johnson and Kotz, (1970). Some readily available electronic references include: http://en.wikipedia.org/wiki/ Weibull_distribution and http://www.itl.nist.gov/div898/handbook/ apr/section1/apr162.htm.

[36] In this case it is not necessary to fit γ as this is specified in the definition of the large spill threshold.

493.54.[37] Figure 6 shows the best-fit three-parameter Weibull CDF (the solid line) and the empirical CDF (the points) using the above parameter estimates. The fit appears quite good. Another way of examining the quality of the fit is to show a P – P diagram; this diagram (shown in Fig. 7) plots the fitted CDF versus the empirical CDF. As illustrated in Fig. 6, this plot shows that the quality of the fit is quite good.

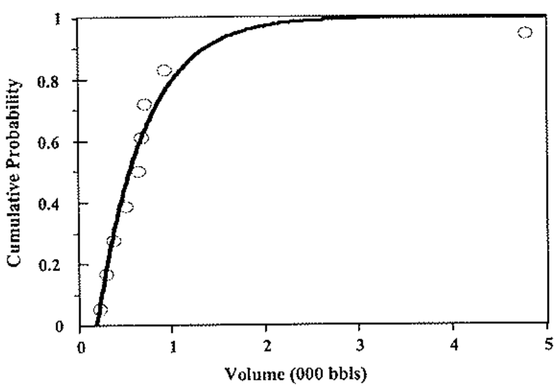

Fig. 6. A comparison between the observed (plotted points) and best-fit three-parameter Weibull distribution to ANS large (≥200 bbls) spill data.

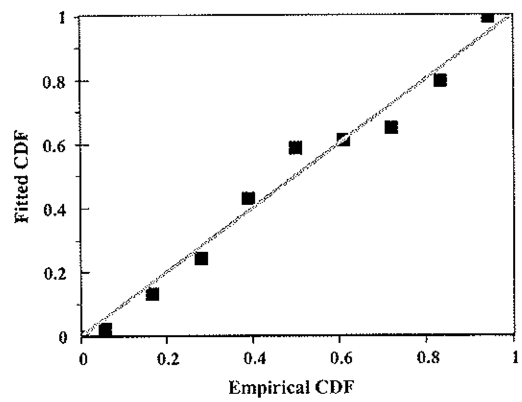

Fig. 7. A "P-P" plot showing the comparison between observed and fitted ANS large (≥200 bbls) spill CDFs.

The choice of fitting technique affects the resulting parameter estimates. For example, the best-fit parameter values determined using a commercially available computer program are; γ = 200 bbls (definition) $\alpha = 0.84$ and β = 426.88,[38] which has a very similar CDF to that estimated by matching CDFs. Figure 8 shows a comparison of the fits made by matching the CDFs (the blue line) and maximum likelihood (the green line). Table 6 shows the Kolmogorov-Smirnov and Anderson-Darling statistical tests on this fit. These tests indicate that the three parameter Weibull distribution provides an adequate fit to the observed data.

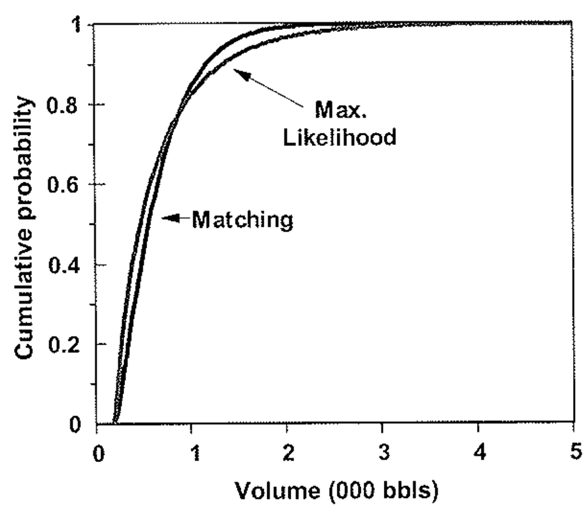

Fig. 8. Best-fit three-parameter Weibull distributions using two fitting criteria.

[37] These estimates were derived using as a criterion function the sum of squared differences between the empirical CDF values (nine points) and the predicted CDFs. The criterion function was minimized using the *Solver*™ routine in the spreadsheet program *Excel*™.

[38] Fitted using EasyFit™ software from Mathwave Technologies, see http://www.mathwave.com/products/easyfit.html.

Table 6. Statistical tests of adequacy of fit for the three-parameter Weibull model.

Goodness of Fit – Details
Three-parameter Weibull

Kolmogorov-Smirnov

Sample Size	9				
Statistic	0.09934				
P	0.2	0.15	0.1	0.05	0.01
Critical Value	0.339	0.36	0.388	0.432	0.514
Reject?	No	No	No	No	No

Anderson-Darling

Sample Size	9				
Statistic	0.7809				
P	0.2	0.15	0.1	0.05	0.01
Critical Value	1.3749	1.6024	1.9286	2.5018	3.9074
Reject?	No	No	No	No	No

Direct maximization of the likelihood function in *Excel*™ using the *Solver*™ subroutine results in slightly different parameter estimates; $\gamma = 200$ bbls (definition) $\alpha = 0.744467$ and $\beta = 654.8$.

Once an adequate statistical representation is found, the best-fit model can be used to estimate the mean or any percentile of the spill volume distribution, given that a large spill occurs.[39] For the three-parameter Weibull distribution, the equations for the mean and $1 - p^{th}$ percentile volumes of the large spill size distribution are:

$$\text{Mean} = \gamma + \beta\,\Gamma(1 + 1/\beta) \quad (6)$$

$$x_{(1-p)} = \gamma + \beta\,[-\ln(p)]^{(1/\alpha)} \quad (7)$$

where

Γ = Incomplete gamma function and

$x_{(1-p)}$ = The volume of the $(1\text{-}p^{th})$ percentile of this distribution (bbls).

Thus, for example, if the CDF is approximated by $(r - ½)/n$, and the "matching CDFs" fitting criterion is used, the best-fit parameters are $\gamma = 200$ bbls (definition) $\alpha = 1.213$ and $\beta = 493.54$. Using equations (3) and (4) the estimated median ($p = 0.5$), mean, and 95% percentile ($p = 0.05$) of the large crude oil spill volume distribution are approximately 565 bbls, 663 bbls and 1,419 bbls, respectively.

[39] This provides a conceptual advantage over the use of the data directly for small sample sizes where estimation of extreme quantiles may be difficult, as it is in this case.

As shown in Table 7, these estimates are a function of the fitting technique and the convention used to estimate the CDF. This said, the estimates do not differ by much for the median and mean values. Depending upon the conventions used, the estimated median large spill volumes range from approximately 480 to 600 bbls and the estimated mean large spill volumes range from approximately 620 – 984 bbls. The differences are larger for the estimated 95% upper confidence limit on size; these range by a factor of approximately two from 1,400 to 3,060 bbls. The reason for the greater discrepancy of the 95% percentile values is the differential "leverage" of the largest spill in the data on the parameter estimation techniques.

Table 7. Summary of results for fitting a three-parameter Weibull distribution to the ANS large spill data (≥200 bbls threshold).

Fit criterion	*Matching CDFs Empirical CDF estimated as:*				*Maximum likelihood*	*EasyFit™*
Quantity	r/n	(r - 1/2)/n	(3r-1)/(n+1)	r/(n+1)	N/A	N/A
Parameters:						
γ	200	200	200	200	200	200
β	429.39	493.58	499.56	513.20	654.81	426.88
α	1.0698	1.2135	1.1400	1.0105	0.7445	0.8378
Spill sizes (bbls):						
Median	505	565	562	557	600	476
Mean	618	663	677	711	984	669
95% percentile	1,397	1,419	1,508	1,720	3,058	1,782

The estimates shown in Table 7 all assume that the three-parameter Weibull model provides an adequate fit to the data—as, indeed, it does (see Table 6). Fitting the data to a different model would produce slightly different estimates. However, these differences are relatively small. For example, fitting a three-parameter lognormal model to the data results in median and mean large spill volumes of approximately 530 and 1,029 bbls, respectively. Both the Gamma and generalized extreme value (see e.g., Castillo *et al.*, 2005 or Evans *et al., 2000*) models estimate comparable median and mean spill sizes. Thus, use of a variety of plausible statistical distributions (which have generally comparable fits) leads to similar estimates for typical spill volumes.

-Using the raw data directly (nonparametric methods)

The second approach for estimating a typical size of a large spill is to use the raw data without assuming a particular model for fitting this distribution. The median large spill volume from these data is 650 bbls. (The median value is that value which divides the data in half, i.e., 50% of the values are greater than the median and 50% of the values are less than the median.) The arithmetic mean large crude oil spill volume is 1,018 bbls. (The median of a data set is often preferred to the mean as a measure of central tendency if outliers might be present in the data.)

Summary: likely large crude oil spill volume

Use of the data directly or fitting a three-parameter Weibull model to the large spill volume data produce estimates of the mean spill volume that are equal to or less than 1,000 bbls. This figure is used as an average or expected large spill volume—or point of departure—for estimation of possible environmental impacts of future large crude oil spills.

Future cumulative spill volumes

As noted above, 1,000 bbls is taken as a nominal large spill volume, given that one large spill occurs. Use of the Poisson model based on the actual number of large spills that have occurred over the period from 1985 to 2006 indicates it is highly likely that number of large spills associated with development of the Liberty Project would be zero, but it is also possible (though highly unlikely) that 1, 2, 3 or more large spills would occur. This section estimates the expected total large spill volume.

Table 8 (see also Table 3) shows these calculations for the most likely large spill rate (0.82 spills per Bbbls) assuming that a large spill is at least 200 bbls and an average large spill has a volume of 1,000 bbls. Two sets of calculations are made; (1) based on the estimated probabilities that 0, 1, 2, 3, large spills would occur throughout the life of the Liberty Project and (2) based on the assumption that at least one large spill occurs. The total expected spill volumes corresponding to these two cases are approximately 86 and 1,043 bbls, respectively.

If the nominal volume of a large crude oil spill is 1,000 bbls, why is it that the expected large crude oil spill volume is only 86 bbls? The answer is that there is a very high probability (approximately 92%, see Tables 3 or 8) that there would be no large crude oil spills over the lifetime of the Liberty Project. The 86-bbls figure weighs each of the possible spill volumes; zero if there are no large spills, 1,000 bbls if there is exactly 1 large spill; 2,000 bbls if there is exactly 2 large spills, etc, by the estimated probability of 0, 1, 2, ... spills.

The second calculation shown in Table 8 estimates the average total large spill volume *given that at least one large spill occurs* (itself an unlikely event). This quantity is 1,043 bbls. Why 1,043 bbls when the possibilities are 1,000 bbls, 2,000 bbls, etc? The result, 1,043 bbls, weights these values by the probabilities of 1, 2, 3, 4, ...spills given that at least one occurs. In this instance, the total volume is slightly larger than the volume of 1 large spill because, even assuming that at least one spill has occurred, it is unlikely that 2 or more have occurred. *Thus, our best estimate of the total large crude oil spill volume is low—86 bbls because it is unlikely that any large spills would occur. However, if at least one large crude oil spill occurs, then the expected large spill volume would be approximately 1,043 bbls—only marginally higher than the nominal large spill volume because the estimated probability of 2 or more large spills is so small.*

Table 8. Calculation of aggregate large spill volume for Liberty field.

Inputs:

Quantity	*Units*	*Value*	*Source/remarks*
Confidence level, p	NA	0.05	Conventional statistical assumption
Large spill threshold	bbls	200	Assumption
# large spills in baseline period	NA	9	ANS data from 1985 through 2006 for all facilities
Throughput in baseline period	Bbbls	10.976	ANS data from 1985 through 2006
Large spill rate	spills/Bbbls	0.8200	ANS estimate of mean large spill rate
Exact LCL on spill rate	spills/Bbbls	0.3749	Computed exact lower confidence limit
Exact UCL on spill rate	spills/Bbbls	1.5566	Computed exact upper confidence limit
Throughput for Liberty Project	Bbbls	0.105	Estimated future production of Liberty field from Liberty Project description December 2006 (BPXA, 2006)

Future estimates:

	Best estimate
Expected number of large spills over life of Liberty field	0.0861
Expected volume of large spill (bbls)	1,000.00

Number of large spills,	*Probability*	*Extension*	*Probability*	*Extension*
X	x		x| x>=1	
0	0.91750529	0.0000		
1	0.07899440	78.9944	0.95756918	957.5692
2	0.00340059	6.8012	0.04122189	82.4438
3	0.00009759	0.2928	0.00118303	3.5491
4	0.00000210	0.0084	0.00002546	0.1019
5	0.00000004	0.0002	0.00000044	0.0022
6	5.19E-010	0.0000	6.292E-009	0.0000
7	6.384E-012	0.0000	7.739E-011	0.0000
8	6.871E-014	0.0000	8.3283E-013	0.0000
Expected total spill volume		86.10		1,043.67

-Confidence intervals

The above estimates are based on expected values, including the expected number of large crude oil spills and the expected volume of a large crude oil spill or total volume given that a spill occurs. It is useful to estimate lower and upper confidence limits for these quantities. To do this we conservatively assume that the large spill distribution matches the empirical large spill distribution—that is, it includes the 4,786 bbls spill discovered in March 2006. Accordingly, Table 9 shows the results of 50,000 Monte Carlo simulations calculating the total large crude oil spill volume over the lifetime of the Liberty Project. Two cases are included (1) using the expected large spill rate and (2) using a 95% upper confidence limit on this rate. The mean total spill volumes are quite close to those calculated above. However, the upper 95% confidence limit (95th percentile) total spill volume is 4,786 bbls.

Table 9. Results of large crude oil spill simulations.

	Expected spill rate		
Quantity	*Best estimate*	*Upper 95% confidence limit*	*Units*
Number of trials	50,000	50,000	trials
Average total spill volume	1,055	1,108	bbls
Minimum total spill volume	225	225	bbls
Median total spill volume	650	650	bbls
75th percentile spill volume	925	945	bbls
95th percentile spill volume	4,786	4,786	bbls

Large crude oil spill estimates in this analysis compared to FEIS estimates

The Liberty Final EIS (USDOI, MMS, 2002) offered the following comments on the chance of a large oil spill occurring:

> "The analysis of historical oil-spill rates and failure rates and their application to the Liberty Project provides insights, but not definitive answers, about whether oil may be spilled from a site-specific project. Engineering risk abatement and careful professional judgment are key factors in confirming whether a project would be safe.
>
> We conclude that the designs for the Liberty Project would produce minimal chance of a significant oil spill reaching the water. If an estimate of change must be given for the offshore production island and the buried pipeline, our best professional judgment is that the chance of an oil spill greater than or equal to 500 bbls occurring from the Liberty Project and entering the offshore waters is on the order of 1% over the life of the field...
>
> We base our conclusion on the results gathered from several spill analyses done for Liberty that applied trend analysis and looked at causal factors. All showed a low likelihood of a spill, on the order of a 1 – 6% chance or less over the estimated 15 – 20 year life of the field."

While not identical, the projections made in this report are broadly consistent with the results of the final Liberty EIS; both estimates indicate that it is unlikely that a large crude oil spill would occur. As to differences:

- The original analysis defined a large spill as one 500 bbls or greater, whereas this analysis uses ≥200 bbls as the threshold of a large spill.[40] As shown below, the probability that no large spill would occur (assuming a 500 bbl threshold) is 94.4%--numerically closer[41] to that estimated in the final EIS. (The 95% confidence interval on the probability that no large crude oil spill would occur assuming a 500 bbl threshold is from 88.3% to 97.9%. This confidence interval overlaps the 94% - 99% range specified in the final Liberty EIS.)

[40] This choice of 200 bbls as the threshold was made on statistical grounds.
[41] This estimate is within the range of plausible estimates given in the final EIS.

- The original spill estimates were based on the definition of a large crude oil spill from the offshore production island and buried pipeline reaching the water. This analysis addresses the occurrence of a large crude oil anywhere in the facility and makes no assumption regarding whether or not the spill reaches the water.

- The estimate developed in this document is based solely on the assumed production volume of Liberty and actual spill statistics from ANS operations updated through 2006. That presented in the final EIS used data from several sources and ultimately was based on engineering judgment.

Small spills

As noted above, spills have been divided into large and small spills. For crude oil, the base case large spill threshold was assumed to be ≥200 bbls. What can be said of the small spills?

-Small crude oil spills

Experience at ANS and elsewhere shows that typically there are many more small crude oil spills than large spills. Using ANS data, for example, over the period from 1985 to 2006, a total of 1,662 small (< 200 bbls) crude oil spills were reported—compared to only nine large spills. Thus, small spills accounted for 99.46% of the total *number* of spills. However, the average spill size of small spills is very much smaller than that of large spills. For the same period, the average volume of a small spill was approximately 2.14 bbls. (The median small crude oil spill volume, approximately 0.12 bbls, is even smaller.) Figure 9 shows the empirical CDF (x-axis plotted as the natural logarithm of the spill volume) of all small ANS crude oil spills for the period from 1985 to 2006. The irregularities in the CDF reflect rounding of spill volumes in the reporting process.

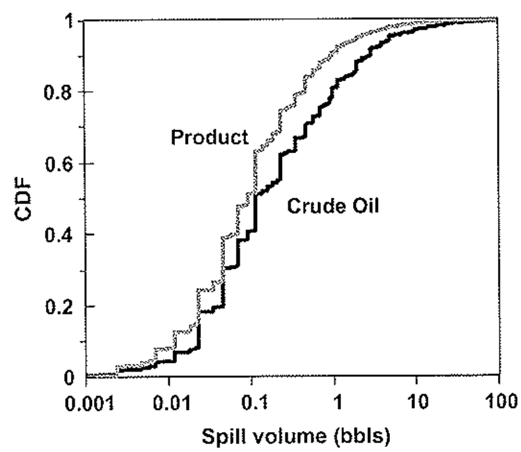

Fig. 9. Empirical CDFs of 1,662 small crude oil spills and 5,456 produced spills for ANS 1985-2006. Note that x-axis shows natural logarithm of spill size.

Figure 9 also shows the empirical distribution of refined product spills (n = 5,456) that occurred over the same time period. (Product spill data are discussed below.)

In aggregate small crude oil spills accounted for slightly less than 28% of the total volume spills over the period from 1985 to 2006, even though these occurred much more frequently.

The analytical method used in this analysis (and many others, see, e.g., TAPS Owners, 2001) to estimate future small spill volumes is to calculate a *volumetric spill rate* (VSR) defined as the ratio of the aggregate small spill volume (bbls) to the ANS production (Bbbls). Next, we multiply the appropriate VSR by the estimated total production of the Liberty Development Project (0.105 Bbbls) to estimate the total small spill volume that would result from operation of Liberty. This procedure assumes that the observed VSR for Liberty will be the same as that experienced historically for the North Slope as a whole.[42] Before accepting this assumption uncritically, however, it is appropriate to see if there are any time trends in the observed small spill VSRs. If, for example, VSRs tended to decrease (increase) with time, then use of an average VSR would overstate (understate) future spill volumes.

Table 10 provides relevant data and computed small ANS crude spill VSRs for the period from 1985 to 2006. Figure 10 shows a time series of the observed VSRs (solid line) and the average VSR (dashed line) of 324 bbls spilled per Bbbls production. Earlier analyses (see e.g., TAPS Owners, 2001[43]) found no statistically significant trend in these data although visually there appeared to be a slight downward trend. Linear regression of the data plotted in Fig. 10 indicates that there is a slight, but not statistically significant ($p = 0.58$), downward trend. The VSR for 2006 has a studentized residual of 2.945, which indicates that this point might be an outlier. And, indeed, if this point is deleted, the downward time trend in VSR is statistically significant ($p = 0.03$).

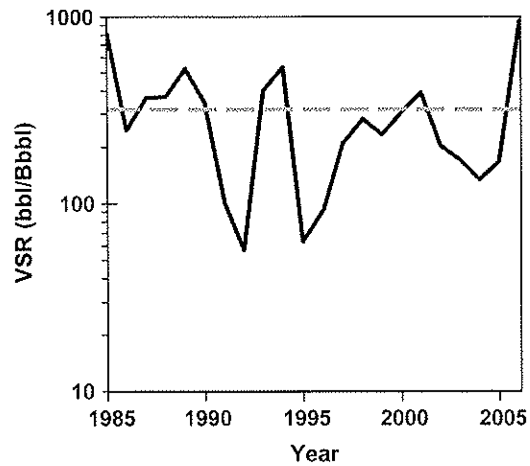

Fig. 10. Volumetric spill rates (VSRs) for ANS small crude oil spills, 1985-2006.

However, to avoid possible understatement of spill volumes, we have not made any allowance for a possible time trend in the data.

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[42] It is probably appropriate to see if there is any statistically significant relation between the annual small spill volume and the production in any year. Analysis shows that there is a weak ($R^2 = .24$), but statistically significant ($p = 0.021$) relation.

[43] The estimated VSR for ANS obtained in this source was 860 bbls/Bbbls. This VSR included both large and small crude oil spills as well as product spills and applied to a different time period (1977 – 1999). If we add the estimated VSR for product spills (400 bbls/Bbbls see Table 11) a total of 724 bbls/Bbbls results. This estimate is consistent with the earlier TAPS ANS analysis, which includes the contribution of spills > 200 bbls.

Table 10. Small crude oil spill characteristics, 1985-2006.

Years since 1985	*Year*	*Production volume (Bbbls)*	*Number of spills*	*Total volume (bbls)*	**Volumetric spill rate** *(VSR) (bbls spilled / Bbbls produced)*	*Average Spill volume (bbls)*
0	1985	0.649	91	535.429	824.641	5.884
1	1986	0.664	91	164.667	248.091	1.810
2	1987	0.700	97	256.643	366.734	2.646
3	1988	0.722	129	270.702	374.702	2.098
4	1989	0.669	161	355.048	531.022	2.205
5	1990	0.636	101	223.264	350.953	2.211
6	1991	0.641	140	65.562	102.280	0.468
7	1992	0.612	70	34.800	56.852	0.497
8	1993	0.564	57	230.534	409.005	4.044
9	1994	0.553	51	298.758	539.852	5.858
10	1995	0.526	39	33.333	63.355	0.855
11	1996	0.495	52	46.260	93.375	0.890
12	1997	0.461	39	97.888	212.470	2.510
13	1998	0.417	44	118.494	284.124	2.693
14	1999	0.372	50	87.025	233.762	1.741
15	2000	0.345	94	106.802	309.926	1.136
16	2001	0.340	90	134.917	396.915	1.499
17	2002	0.348	52	70.778	203.364	1.361
18	2003	0.346	60	59.965	173.547	0.999
19	2004	0.324	62	44.210	136.350	0.713
20	2005	0.308	42	52.062	168.863	1.240
21	2006	0.284	50	271.647	957.938	5.433
Totals		**10.976**	**1,662**	**3,558.786**	**324.232**	**2.141**

Note: Production volume data taken from US Dept. of Energy, Energy Information Administration, data for crude oil production on Alaska's North Slope as presented in January, 2007. Only partial data for year 2006 was available. To calculate an annual figure, the monthly 2006 production values were averaged and added to the partial year total. Current data area available at ttp://tonto.eia.doe.gov/ dnav/pet/hist/manfpak1M.htm

The estimated total volume of small crude oil spills associated with the operation of the Liberty Project is, therefore, 324 bbls/Bbbls x 0.105 Bbbls = 34 bbls in total.[44] This estimate is much smaller than the expected total large spill volume (86 bbls) or the expected volume (~1,000 bbls) given that a large spill were to occur. Taking the empirical VSRs over the period from 1985 to 2006, the approximately 95% confidence limits on the total spill volume range from approximately 6 to 100 bbls.

[44] If the average small size for Liberty matches that observed for ANS historically, then this means that there would be approximately 34/2.14 ~ 16 small crude oil spills.

-Product spills

As noted above, spills are not limited to crude oil. Refined product spills also occur—indeed, product spills have historically been more numerous than crude oil spills. Over the period from 1985 to 2006 a total of 5,456 product spills have been reported on the North Slope. Most of these are quite small—smaller on average than small crude oil spills, although as shown in Table 2 a few larger product spills have resulted.[45] Product spills sizes range from approximately 8 teaspoons (0.01 gallons) to 262 bbls (approximately 11,000 gallons) in size.

Figure 9 also shows the empirical CDF of ANS product spills. Compared even to small crude oil spills, product spills are typically smaller. For example, the median and mean product spills over the period from 1985 to 2006 were 0.095 and 0.8 bbls, respectively. 90% of product spills were less than 1 bbls. For purposes of this analysis we treat all product spills as being small spills. That is, we do not use the MMS methodology for large crude oil spills to represent data on product spills. Instead we use the volumetric spill rate method described earlier for use on small crude oil spills.

Figure 11 shows the time trend in VSR for product spills (compare to Fig. 10 for crude oil spills.) and Table 11 shows the data. There is no statistically significant time trend in the data ($p = 0.257$). As with the small crude oil spills, we use the average VSR for the entire time period, 400 bbls/Bbbls of production. *Based on this average, the estimated product spill volume for the Liberty Project is 400 (0.105) = 42 bbls. The 95% confidence interval on this estimate is [10, 125 bbls].*

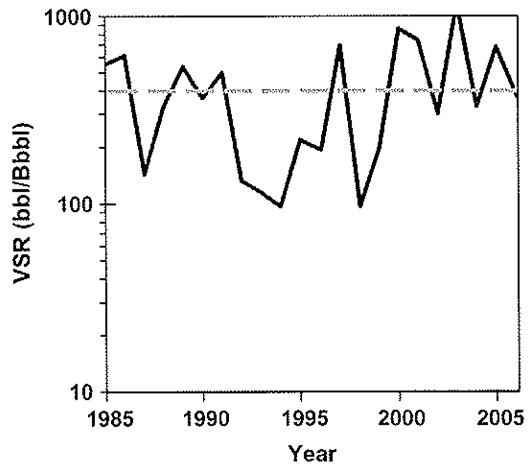

Fig. 11. Volumetric spill rates (VSRs) for ANS product spills, 1985-2006.

Summary of small spill projections

To summarize briefly, this analysis considers small spills for both crude oil and product spills associated with the development of the Liberty Project. For small crude oil spills, it is estimated that 34 bbls will be spilled (expected value) over the life of the project; the 95% confidence interval on this estimate ranges from 6 to 100 bbls. For product spills, it is estimated that 42 bbls will be spilled (expected value); the 95% confidence interval on this estimate ranges from 10 to 125 bbls.

[45] Because of the very small number of "large" refined product spills it is unrealistic to model these separately. Instead, we use the same VSR spill rate approach used for small crude oil spills.

Table 11. Small product spill characteristics, 1985-2006.

Years since 1985	*Year*	*Production volume (Bbbls)*	*Number of spills*	*Total volume (bbls)*	*Volumetric spill rate (VSR) (bbls spilled / Bbbls produced)*	*Average Spill volume (bbls)*
0	1985	0.649	168	363.167	559.331	2.162
1	1986	0.664	145	410.405	618.325	2.830
2	1987	0.700	137	102.101	145.899	0.745
3	1988	0.722	312	240.940	333.506	0.772
4	1989	0.669	408	364.638	545.365	0.894
5	1990	0.636	359	234.846	369.159	0.654
6	1991	0.641	445	324.861	506.797	0.730
7	1992	0.612	259	81.796	133.629	0.316
8	1993	0.564	209	65.213	115.699	0.312
9	1994	0.553	159	54.226	97.986	0.341
10	1995	0.526	132	115.865	220.219	0.878
11	1996	0.495	141	97.307	196.415	0.690
12	1997	0.461	123	321.655	698.164	2.615
13	1998	0.417	124	40.562	97.259	0.327
14	1999	0.372	311	74.117	199.088	0.238
15	2000	0.345	444	297.554	863.465	0.670
16	2001	0.340	505	253.905	746.969	0.503
17	2002	0.348	241	107.111	307.761	0.444
18	2003	0.346	218	410.586	1188.296	1.883
19	2004	0.324	200	107.316	330.976	0.537
20	2005	0.308	199	213.568	692.708	1.073
21	2006	0.284	217	106.087	374.107	0.489
Totals		**10.976**	**5456**	**4,387.827**	**399.764**	**0.804**

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2 PREVENTION PLAN [18 AAC 75.425(e)(2)]

2.1 PREVENTION, INSPECTION AND MAINTENANCE PROGRAMS [18 AAC 75.425(e)(2)(A)]

2.1.1 Prevention Training Programs [18 AAC 75.007(d)]

BP Exploration (Alaska), Inc. (BPXA) and contractor personnel are trained in company and state pollution prevention measures applicable to their duties affected by 18 Alaska Administrative Code (AAC) 75 Article 1 as required by 18 AAC 75.007(d). Trained personnel sign a training roster. BPXA's training courses are assigned a number and have course specifications e.g., objectives, material, and trainer qualifications. BPXA makes a computerized record to document the training.

BPXA and contractor oil-handling personnel receive training on the operation and maintenance of oil equipment, oil spill protocols, general facility operations, and contents of the Spill Prevention, Control, and Countermeasures (SPCC) Plan. Oil spill prevention training and oil spill prevention briefings for oil-handling personnel are held annually and meet U.S. Environmental Protection Agency SPCC training requirements in 40 CFR 112.7(f)(1) and (3).

Unescorted workers on BPXA leases receive spill prevention training through the North Slope Training Cooperative program. The one-day training seminar, mandatory for workers on the North Slope, covers the following topics:

- *North Slope Environmental Handbook*,
- *Alaska Safety Handbook*,
- Camps and Facilities Safety Orientation,
- Environmental Excellence,
- Hazard Communication (HAZCOM),
- Hazardous Waste Operations and Emergency Response (HAZWOPER) Awareness,
- Personal Protective Equipment (PPE), and
- Hydrogen Sulfide.

BPXA employees and contractor personnel working on the North Slope receive copies of the *North Slope Environmental Field Handbook* and *Alaska Safety Handbook*. The *North Slope Environmental Field Handbook* provides an overview of state and federal spill prevention regulations and programs applicable to the North Slope oil fields and summarizes procedures to comply with those regulations. In particular, the handbook explains fluid transfer procedures, drip liner usage, secondary containment and spill reporting.

The *Alaska Safety Handbook* provides standardized safety instructions for BPXA and contractor personnel. The handbook covers employee safety, including PPE, equipment safety, chemical handling, transportation safety, work permitting, and incident reporting.

Facility and response personnel are provided a mandatory site orientation that includes familiarization with facility Emergency Response Plans.

Facility personnel also receive training on the BPXA Environmental Management System Awareness & Hotline. BPXA's Environmental Management System promotes continual improvement in environmental performance. The system uses direct input from technical specialists and field personnel and information developed through routine loss control and incident investigations to minimize the potential recurrence of events. Safety and environmental communications and bulletins are regularly distributed to ensure specific safety and environmental issues are communicated. Most supervisors discuss safety and environmental communications and bulletins with their crews during daily and weekly toolbox safety meetings.

Waste management training using the *Alaska Waste Disposal and Reuse Guide*, also known as the "Red Book," is designed to familiarize North Slope personnel with the regulatory classification and disposal requirements for industrial wastes. The training covers waste classification, transportation requirements, and a description of waste disposal facilities on the North Slope. BPXA and ConocoPhillips Alaska, Inc. track waste by manifesting waste destined for a disposal facility. The course is mandatory for waste generators, transporters, and receivers.

BPXA maintains records of its employees' oil spill prevention training required by 18 AAC 75 Article 1. Records are kept for at least five years. They are provided to the Alaska Department of Environmental Conservation upon request.

The BPXA Learning and Organizational Development Group maintains a database with records of courses completed by BPXA employees. Access to the database is through the BPXA intranet. Individual training records are available through an employee's immediate supervisor or by contacting the Training Coordinators. Contractors maintain their own training records.

In summary, personnel who handle oil equipment receive training in general North Slope work procedures, spill prevention, environmental protection awareness, safety, and site-specific orientation. Personnel receive training in oil spill notification protocols, oil spill source control, and HAZWOPER safety. The *Alaska Safety Handbook* and the *North Slope Environmental Field Handbook* supplement spill prevention training.

2.1.2 Substance Abuse Programs [18 AAC 75.007(e)]

BPXA policy provides guidance for an environment free of substance abuse, related accidents, and emergencies. This environment is maintained through adherence to strict alcohol and drug abuse policies and professionally recognized rehabilitation programs. The company has jurisdiction to intervene and impose disciplinary measures when problems are identified.

The BPXA drug policy promotes the safety of employees, contractors, and non-employees, and provides a safe working environment. The company prohibits the following in the workplace or on the job:

- Possession of illicit drugs,
- Possession of controlled substances without a physician assistant's knowledge,
- Use of drug or alcoholic substances, and
- Distribution or sale of drugs or alcohol.

BPXA complies with regulations promulgated by the U.S. Department of Transportation (DOT) at 49 CFR 40, which mandates biological testing and supervisory training programs. BPXA employees involved in safety-sensitive positions within natural gas, liquefied natural gas, and hazardous liquid pipeline operations are required to undergo pre-employment biological testing and testing for reasonable cause following reportable accidents, alcohol or drug rehabilitation, and on a random basis in accordance with this regulation. Other BPXA employees fall under the company's drug testing program. Each of these groups is randomly tested at a rate of a minimum of 25 percent per year. Contract personnel maintain their own drug testing records. The testing must meet the minimum standards set by BPXA.

BPXA employees and contract personnel must be free from the influence of drugs or alcohol on company premises. Implementation of the BPXA Substance Abuse Program is divided into three parts as follows:

- **Education.** Training is available to both employees and supervisors to teach them to detect signs of abuse in themselves and the people with whom they work. Information is provided on the available rehabilitation programs.
- **Intervention.** The company has jurisdiction to perform a drug test on employees when there is legitimate cause, such as medical surveillance following rehabilitation, or as periodic drug screening. The company makes every effort to support its employees and strongly encourages medical rehabilitation.
- **Discipline.** Upon the discovery of illicit drug use, controlled substance abuse, or alcoholic beverage possession, an employee will be suspended.

The BPXA Work Life and Employee Assistance Program (EAP) is an elemental part of rehabilitation. EAP is a confidential counseling and referral service provided free-of-charge to employees and their families. BPXA also supports medical rehabilitation programs outside of the EAP program, which are covered by the BPXA medical plan.

2.1.3 Medical Monitoring [18 AAC 75.007(e)]

New BPXA employees receive an entrance physical to establish baseline health conditions. Under federal Occupational Safety and Health Administration (OSHA) and Alaska Department of Occupational Safety and Health requirements, medical monitoring is conducted as required by the type of work performed. Emergency response personnel have annual medical examinations, which include a physical exam, audiogram, respiratory exam, electrocardiogram, x-rays, and blood work. All other BPXA employees who are field workers receive annual respiratory exams and audiograms.

2.1.4 Security Programs [18 AAC 75.007(f) and 40 CFR 112.20(h)(10)]

Access to BPXA's North Slope operations is controlled through BPXA security checkpoints and with Security personnel and records in the operating areas. Each BPXA employee and contractor is issued an identification badge with the employee's or contractor's name and badge number. The security badge system provides a method for monitoring personnel moving on and off BPXA leases.

2.1.5 Fuel Transfer Procedures [18 AAC 75.025]

Measures are taken to prevent spills or overfilling during a transfer of oil into Alaska Department of Environmental Conservation (ADEC)-regulated storage tanks, as required by 18 AAC 75.025(a). Loading rates are reduced at the beginning and end of a transfer, as required by 18 AAC 75.025(a).

Each person involved in a transfer of oily fluids into an ADEC-regulated tank is capable of clearly communicating orders to stop a transfer at any time during the transfer, as required by 18 AAC 75.025(d).

A positive means is provided to stop a transfer of oily fluid into an ADEC-regulated tank in the shortest possible time, as required by 18 AAC 75.025(e).

Before beginning a transfer to or from an ADEC-regulated tank at an area not protected by secondary containment, the valves in the transfer system are checked to make sure they are in the correct position, as required by 18 AAC 75.025(f). Manifolds not in use are blank flanged or capped. Transfer piping and hoses used in the transfer are checked for damage or defects before the transfer and during the transfer. The lowermost drain and the outlets of a truck oily fluid tank are examined for leaks before the truck's tank is filled and again before the truck departs, as required by 18 AAC 75.025(g). The truck's manifold is blank flanged or capped and valves are secured before it leaves the transfer area. Surface liners at inlet and outlet points are the primary prevention mechanisms against discharge to the ground during the transfer of liquids.

Effective communication and planning are key factors in preventing spills. Trucks are continuously staffed during fluid transfers and transfer personnel have radios. For transfers from trucks to ADEC-regulated tanks, manual shutoff valves are available to the truck operator to stop transfers.

The Endicott fuel transfer area, Skid 610, is located approximately 40 feet north of the gasoline and diesel storage tanks. Mobile equipment such as trucks and forklifts park on a lined containment area during fueling. The diesel and gas lines are buried, coated with a protective wrapping, and are cathodically protected.

Badami's fueling system consists of one storage tank (TK-0004), two transfer pumps and one vehicular diesel pump. Two emergency shutdown valves (ESDV-1209 and 1210) provide isolation of the storage tank within the dike. The transfer pumps can be stopped and started manually from the local panel, or they can be stopped remotely. Valve ESDV 1210 opens when either of the pump motors is started and is closed whenever both motors are off. A low-pressure trip is provided on the common pump discharge header in case of pressure loss due to a leak. Alarms are triggered when the transfer pumps are stopped.

The dispenser operation requires that one of the diesel transfer pumps be started from the motor starter panel. Valve ESDV-1210 will then open. The hose is removed from the fuel dispenser, and the dispenser on switch is activated. The vehicular diesel pump on the fuel dispenser will start and fuel is pumped at a regulated pressure. Once the dispenser switch is turned off, the vehicular diesel pump stops.

2.1.6 Operating Requirements for Exploration and Production Facilities [18 AAC 75.045]

Produced oil from flow tests and other drilling operations is handled to prevent spills (18 AAC 75.045(a)). Oil produced from flow tests may be flowed directly to the plant or stored in mobile tanks. Facilities are staffed 24 hours a day. At each shift change, personnel inspect oil tank levels and tankage, sumps, drains, piping, valves, glands, wellheads, pumps, and other machinery for indications of oil leaks.

The requirements for platform integrity inspections and isolation valves for pipelines leaving platforms do not apply (18 AAC 75.045(b) and (c)).

Catch tank requirements do not apply (18 AAC 75.045(e)).

Information pertaining to oil storage tanks and facility oil piping is found later in Part 2 and in Part 3. Impermeable well cellars at Endicott fulfill the requirements for drip pans or curbing at offshore facilities and well head sumps for onshore facilities (18 AAC 75.045(d)). Well cellars with concrete floors at Badami fulfill the requirement for well head sumps for onshore drilling (18 AAC 75.045(d)).

2.1.7 Leak Detection, Monitoring, and Operating Requirements for Crude Oil Transmission Pipelines [18 AAC 75.055]

The crude oil transmission pipeline is equipped with a system capable of detecting a leak with a daily rate equal to one percent of daily throughput, as required by 18 AAC 75.055(a)(1). Flow is verified at least once every 24 hours, as required by 18 AAC 75.055(a)(2). The flow of incoming oil can be stopped within one hour after detection of spill, as required by 18 AAC 75.055(b). The control board operator proceeds through a series of steps to determine the cause of the alarm. Ground-based surveillance may be requested. Verification of a leak would facilitate pipeline shut in. See also Section 2.5.6.

ADEC is notified in writing within 24 hours if a significant change occurs in or is made to the leak detection system and if as a result of the change the system does not meet the “equal to not more than one percent of daily throughput” criterion [18 AAC 75.475(d)(1)].

2.1.8 Oil Storage Tanks [18 AAC 75.065 and 0.066]

This section describes the management of ADEC-regulated tanks, i.e., oil tanks greater than 10,000-gallon capacity whether stationary or portable and that are “in service.” In this plan the term “in service” describes oil tanks that remain in regular inspection and maintenance programs whether the tank holds oil or not, unless noted otherwise, a usage consistent with 18 AAC 75 Article 1. The meaning differs from that in API 653. Part 3 provides information for stationary and portable oil storage tanks greater than 10,000 gallons as required by 18 AAC 75.425(e)(3)(A). Containers are constructed of materials compatible with the stored products. Tanks for processing muds and cuttings on drill rigs are not oil storage tanks.

Inspections

Stationary oil storage tanks greater than 10,000 gallons and in service on BPXA leases are maintained and inspected consistent with API Standard 653, third edition 2001, and Addendum 1, September 2003, or API Recommended Practice 12R1, fifth edition 1997, as required by 18 AAC 75.065(a). Inspection intervals for field-constructed tanks are not based on similar service as outlined in API 653. Furthermore, a tank’s inspection interval may not be risk-based as outlined in API 653 unless ADEC approves.

As required by API Standard 653, Section 6.3.1, monthly visual inspections are conducted on tanks that are “in service” as the term is used by API 653. API 653 uses the term “in service” to mean in operation, e.g., storing product. Consequently, tanks not in operation are not required to receive monthly in-service inspections.

Shop-fabricated oil tanks are not precluded from the similar service and risk-based inspection interval procedures outlined in API 653.

Inspection results and corrective action descriptions of oil storage tanks greater than 10,000 gallons are kept for the service life of the tanks. They are provided to ADEC for inspection and copying upon request, as required by 18 AAC 75.065(d).

Notifications and Service Status

BPXA’s CIC group follows its written procedure to notify ADEC before a BPXA-owned field-constructed oil storage tank greater than 10,000 gallons and on a BPXA lease undergoes “major repair” or “major alteration” as defined in API 653, Section 12.3.1.2 and again before the tank is filled [18 AAC 75.065(e)]..

A field-constructed oil tank greater than 10,000 gallons capacity that has been removed from a maintenance and inspection program required by 18 AAC 75.065 for more than one year is made free of accumulated oil, marked with the words “Out of Service” and the date taken out of service, secured to prevent unauthorized use, and blank flanged or disconnected from facility piping. BPXA notifies ADEC when those tasks are complete and when the tank has been out of service for up to one year. Shop-constructed tanks have no service status notification and placarding requirement.

Construction

Internal steam heating coils are designed to control leakage through defects, as required by 18 AAC 75.065(f).

If an oil storage tank greater than 10,000 gallons has an internal lining system, it is installed in accordance with API 652, as required by 18 AAC 75.065(g).

As required by 18 AAC 75.065(i), field-constructed oil storage tanks greater than 10,000 gallons and installed after May 14, 1992, meet the following construction standards unless they have an ADEC waiver:

- Constructed and installed in compliance with API 650, 1988 edition, or API 12, D, ninth edition 1989, F tenth edition 1989, and P first edition 1986, or another standard approved by ADEC, and
- Not of riveted or bolted construction, and
- With cathodic protection or another ADEC-approved corrosion control system to protect the tank bottom from external corrosion if local soil conditions warrant, and
- Having a leak detection system that an observer from outside the tank can use to detect leaks in the tank bottom, such as secondary catchment under the tank with a leak detection sump, or a sensitive gauging system or another leak detection system approved by ADEC.

As required by 18 AAC 75.065(h), field-constructed oil storage tanks greater than 10,000 gallons and installed before May 14, 1992, meet the following standards unless they have an ADEC waiver:

- Having a leak detection system that an observer from outside the tank can use to detect leaks in the tank bottom, such as secondary catchment under the tank with a leak detection sump, or a sensitive gauging system or another leak detection system approved by ADEC, or
- Cathodic protection in accordance with API 651, first edition 1991, or
- A thick film liner in accordance with API 652, first edition 1991, or
- Another leak detection or spill prevention system approved by ADEC.

Shop-fabricated, ADEC-regulated oil tanks first placed in service before December 30, 2008, are not subject to an ADEC-requirement for construction standards.

As required by 18 AAC 75.065(k) and .066(g), stationary and portable oil storage tanks greater than 10,000 gallons have one or more of the following overfill protection means:

- High liquid level alarm with signals that sound and display, or
- High liquid level automatic pump shutoff device, or
- A means to immediately determine the tank’s liquid level, including close monitoring of the liquid level during a transfer to the tank, or

- Another system approved by ADEC which notifies the operator of high liquid level.

Overfill Protection Device Inspections

Overfill protection devices on ADEC-regulated tanks are tested before each transfer to them or monthly, whichever is less frequent. However, if the monthly test would interrupt the operation of a continuous flow system, then the device is inspected monthly and tested annually, as required by 18 AAC 75.065(l).

Overfill protection devices on ADEC-regulated tanks that are part of continuous flow systems, such as process tanks, and that can be tested without interrupting operations are tested monthly as required by 18 AAC 75.065(k). Overfill protection devices on ADEC-regulated tanks not part of continuous flow systems are tested monthly or just before filling, whichever is less frequent. See the tank tables in Part 3.

A test of the overfill protection device is a manipulation of part of the system for the purpose of eliciting a response. Devices are tested in a variety of ways depending on how they are used and frequency of use. Overfill protection devices are tested by level transmitter calibration, level transmitter calibration with annunciation of the alarm, level transmitter calibration with annunciation of the alarm and strapping, testing the level indicators and alarms by lowering the high liquid level alarm set point to below the actual liquid level to force a false alarm, checking the circuit continuity, changing the level in the tank to verify the level transmitter or alarm enunciator, strapping to calibrate the continuous level indicator in the control room and comparing sight glasses to a measured volume. Some methods are part of regular preventative maintenance procedures.

Inspections for each type of overfill protection device on continuous flow oil storage tanks over 10,000 gallons whose operation would be interrupted by a test are visual observations of one or more parts of the device's system that are visible from the outside of the tank. An example is daily reading sheets which show recordings of the tank liquid level heights reported by the level sensor from the control room readout.

2.1.9 Secondary Containment for ADEC Oil Storage Tanks [18 AAC 75.075]

Stationary and Portable Oil Storage Tanks

Single-wall oil storage tanks greater than 10,000 gallons are located within secondary containment with the capacity to hold the volume of the largest tank plus precipitation within the containment, unless there is a waiver of this requirement by ADEC. Secondary containment areas are constructed of bermed/diked/retaining walls. The containment areas are lined with materials resistant to damage and are impermeable as required by 18 AAC 75.075. Oil storage tanks are listed in Part 3.

Portable, shop-built aboveground oil storage tanks of a vaulted, self-diked, or double-walled design are not required to be placed within bermed, lined, secondary containment areas if they are equipped with catchments that positively hold overflow due to tank overfill or divert it into an integral secondary containment area [18 AAC 75.075(h)].

Secondary containment systems are maintained free of debris, vegetation, and other materials or conditions, including excessive accumulated water that might interfere with the effectiveness of the system as required by 18 AAC 75.075. Debris and vegetation that might interfere with the secondary containment effectiveness is that which threatens the containment integrity or reduces its capacity to less than 110 percent. Some fabric liner bottoms are held in place with a gravel layer.

Facility personnel visually check for the presence of oil leaks or spills within ADEC tank secondary containment daily, and conduct documented inspections of secondary containment areas. The containment areas are visually inspected for holes weekly. The records of the daily and weekly inspections are entered weekly as noted in Table 2-7.

Snowmelt runoff, debris, and accumulated rainwater are vacuumed out, or dewatered, and disposed of through the waste handling procedure. See Table 2-7 for visual inspection for sheens on discharge water.

BPXA notifies ADEC in writing within 24 hours if a significant change occurs in or is made to an ADEC-regulated tanks secondary containment system and if as a result of the change the system no longer meets the ADEC performance requirement [18 AAC 75.475(d)]. Vegetation, debris and accumulated water that does not interfere with the impermeability of the system or reduce its capacity below 110 percent of the largest tank capacity are not significant changes.

Tank Truck Loading and Unloading Areas

Endicott has two permanent tank truck unloading areas, one at the 305 Module ADEC-regulated tanks and another at the diesel and gasoline fuel tanks. Badami has a single permanent tanker truck loading area at the 15,000-barrel (bbl) diesel tank TK-0004.

The tank truck loading areas are maintained free of debris that might interfere with the effectiveness of the system. The areas have warning signs to prevent premature vehicular movement as required by 18 AAC 75.075(g)(4).

The tank truck loading and permanent unloading areas are visually inspected before transfers or at least monthly (see Table 2-7).

2.1.10 Facility Oil Piping and Flow Lines

Corrosion Management Program

Facility oil piping is in a corrosion control program as required by 18 AAC 75.080(b). The Corrosion Management Program meets the commitment made by BPXA to the State of Alaska in the "Charter for Development of the Alaskan North Slope" by providing the ADEC an annual report *Commitment to Corrosion Monitoring* on BPXA's corrosion monitoring programs. The report provides data and discussion relating to the corrosion control, monitoring and inspection programs that together form the core of the integrity management system.

The Corrosion Management Program covers pipelines, flow lines, well lines, wellheads, headers, pressure vessels and tanks, as well as other field and facility piping systems. Corrosion monitoring and mitigation tools can include but are not limited to corrosion weight-loss coupons, electrical resistance probes, non-destructive examination inspection techniques, smart pigs, visual inspections, Kinley caliper surveys, monitoring of process flow conditions, and bioprobes. Badami currently has no specific corrosion monitoring program because production fluids are considered low risk from a corrosivity standpoint; however, an inspection program for corrosion detection is in place.

Corrosion management entails two main functions, corrosion monitoring and corrosion control. Corrosion control is the action of preventing or reducing corrosion to acceptable levels. Corrosion control measures reflect the active or potential corrosion mechanisms in the system. For pipelines, corrosion control measures can be broadly subdivided into internal and external corrosion mechanisms. The external corrosion mechanism is constant for all services while the internal differs with service. The metal loss criteria for pipe replacement are in American National Standards Institute/ American Society of Mechanical Engineers (ANSI/ASME) B31G-1984, *Manual for Determining the Remaining Strength of Corroded Pipelines, A Supplement to ANSI/ASME B31 Code for Pressure Piping*. Corrosion control measures encompass a range of alternatives including chemical inhibition, materials selection, coatings, cathodic protection, and process control. These may be applied individually or in combination.

Inspection programs share similarities with monitoring programs but measure corrosion directly. Inspection provides documentation of equipment fitness for service. Inspections are generally performed on a quarterly to annual basis, but in some cases it may be five years or longer between inspections. Examples include ultrasonic testing, radiographic testing and smart pig inspections.

Internal Corrosion and Erosion of the Endicott Production System

The Endicott production system transports multiphase fluids. The properties of fluids are similar throughout the system, although temperature, pressure, and velocity vary. The water cut, gas-to-oil ratio (GOR), and solids content vary from line to line. There is a low risk of corrosion for the Badami pipelines, as there is little water production and low carbon dioxide content. Table 2-1 summarizes the significant corrosion mechanisms.

TABLE 2-1: INTERNAL CORROSION MECHANISMS RELEVANT TO ENDICOTT PRODUCTION SYSTEM

CORROSION MECHANISM	SEVERITY OF MECHANISM	CONTROL METHOD
Carbon dioxide corrosion	High	Materials
Velocity enhanced carbon dioxide	High	Materials Velocity control
Erosion	Medium/High	Velocity Well POP procedure Erosion monitoring
Microbially Induced Corrosion (MIC)	Low	Materials
Chemical attack	Low	Chemical selection Operating procedures Equipment design

Carbon dioxide corrosion is the primary corrosion mechanism. The control of carbon dioxide corrosion is achieved primarily through materials selection. The majority of the producing system is constructed from corrosion-resistant duplex stainless steel. The only surface production equipment made of carbon steel is the C-spools that connect the well to the well lines. The C-spools are inspected frequently to assure their integrity and are repaired or replaced as needed.

Velocity-enhanced carbon dioxide corrosion has become more predominant as mixture velocities have increased with increases in gas handling capacity. Velocity-enhanced carbon dioxide corrosion is managed via velocity control.

Erosion is associated with extremely high velocities and solids production. Solids production is unpredictable because it is the result of an event downhole, such as the breakdown of a cement job or production of unconsolidated reservoir rock. Velocity limits for erosion control rely on the approach

defined in API RP 14E, using the C-factor of 100. Lines are ranked approximately monthly in terms of risk using the ratio V/Ve, where V is the mixture velocity and Ve is the calculated erosion velocity limit. An operating limit of 3.0 is used. These limits are subject to revision as more experience is gained at managing erosion.
Microbially induced corrosion (MIC) has not been accurately quantified in the Endicott production systems. However, sulfate-reducing bacteria (SRB) and general anaerobic bacteria (GAnB) are present. Control of MIC is through materials selection, the same as carbon dioxide corrosion.

Chemical attack has been associated with highly corrosive scale inhibitor pooling in production pipework during shut-ins. There have also been instances of injection quill failure, leading to contact of the neat (pure) chemical with the pipewall during normal operations. Chemical attack at Endicott is no longer a concern as the scale inhibition program has been discontinued.

Internal Corrosion of the Produced Water and Seawater System

The produced water injection system is defined as starting at the water outlets off the separation vessels and ending at the reservoir. It includes the process piping, storage tanks, injection pumps, flow lines and well lines that store or transport produced water, and the injection wells. At Endicott, the produced water is co-mingled with very low amounts of seawater and injected simultaneously into the formation. Table 2-2 summarizes the major corrosion mechanisms relevant to this produced water/seawater system.

TABLE 2-2: INTERNAL CORROSION MECHANISMS RELEVANT TO PRODUCED WATER AND SEAWATER INJECTION SYSTEM

CORROSION MECHANISM	MECHANISM SEVERITY	CONTROL METHOD
Carbon dioxide corrosion	Low	Corrosion inhibition
MIC	High/Medium	Corrosion inhibition Biocide injection Maintenance pigging
Oxygen corrosion	Medium/Low	De-aeration and oxygen scavenger injection
Chemical attack	Medium	Chemical selection Operating procedures Equipment design

Carbon dioxide corrosion is a significant issue for the upstream system but the oil stabilization process removes the vast majority of the carbon dioxide, substantially reducing its partial pressure. The carbon dioxide corrosion inhibitor is dosed into the produced water/seawater system and is fully capable of controlling carbon dioxide corrosion.

MIC is an issue in the injection system because the low fluid velocities in tanks and pipework allow bacteria colonies to become established and thrive. The current corrosion inhibitor is known to be toxic to SRBs and GAnBs and the bacteria count has decreased. In addition, the Inter-Island Water Line that transports injection water from the production facility to the Satellite Drilling Island is regularly pigged to displace solids and bacteria. Periodic biocide treatment on this line is also conducted.

The Endicott crude oil transmission pipeline is scheduled to be maintenance pigged quarterly depending on pipeline condition and fluid velocity. The Badami crude oil transmission pipeline is maintenance pigged two times per year. These frequencies are subject to change as data and conditions dictate.

Oxygen corrosion is not an issue in production water systems alone. However, because the production water and seawater are co-mingled at Endicott, the chance increases of introducing oxygen into the injection system from dissolved oxygen in the seawater. Raw seawater is highly corrosive to carbon steel due to the presence of high levels of dissolved oxygen. Due to the extreme corrosivity of raw seawater, it is only handled in corrosion-resistant materials, such as stainless steels, copper or nickel based alloys, or plastics. The seawater treatment plant removes the vast majority of the oxygen from the water by mechanical means. Additionally, dissolved oxygen is further lowered by supplemental injection of oxygen scavenger into the seawater. At current levels seawater is only mildly corrosive, and carbon steel is a suitable material.

Internal Corrosion of the Gas Lift, Gas Injection, and Miscible Injectant Systems

The gas lift, gas injection, and miscible injectant systems contain dehydrated gas, which is non-corrosive. There are therefore no active corrosion mechanisms and correspondingly no corrosion control activities.

External Corrosion

External corrosion is a risk to equipment outside of modules and facilities. It can be subdivided into atmospheric corrosion and corrosion under insulation (CUI). No production equipment is buried directly in the tundra. Therefore, external corrosion at pipewall/soil interfaces is not an issue. Atmospheric corrosion in the Arctic is a slow process due to the low relative humidity, lack of rainfall, and low temperatures. External corrosion is only a significant issue for insulated equipment, where the polyurethane (PU) foam insulation can trap moisture next to the pipewall. This warm, moist environment, together with the oxygen in the air, can lead to corrosion.

Insulation-and-jacket systems or tape wrap that exclude water serve as one means of protective coating. The insulation systems used on pipelines is a combination of shop-applied PU foam on the linepipe spools with an external galvanized steel jacket. Badami facility piping does not utilize galvanized steel jacketing. The insulation is completed at weld joints using a range of methods, but involve the application of PU foam and galvanized steel jacketing. This insulation is generally resistant to moisture ingress, except at areas of damage. The major challenge in managing external corrosion is detection. Once it is detected it can be easily and effectively mitigated by removing wet insulation.

Evidence of external corrosion is investigated to determine the extent of corrosion. Pipeline repairs necessitating pipe replacement are cause for an internal inspection of the affected sections of pipe in the immediate vicinity to establish repair boundaries.

Pipeline Examination and Replacement

In compliance with 18 AAC 75.080(g), buried or below-grade facility oil piping is inspected for damage and corrosion any time it is exposed in accordance with API 570, Section 9.2.6, *Piping Inspection Code: Inspection, Repair, Alteration and Rerating of In-Service Piping Systems.* If damage is found, piping is repaired or replaced with fusion-bonded epoxy-coated or stainless steel piping.

Replacement buried or below-grade facility oil piping installed after May 14, 1992, will be corrosion-protected and welded with no clamped or threaded connections in accordance with 18 AAC 75.080(d).

Corrosion Surveys

Corrosion surveys are part of the Corrosion Management Program. Corrosion survey methods include smart pigging, conventional nondestructive testing (NDT) methods, guided wave inspections, and excavation and visual inspection. The technologies are discussed in detail in Part 4.10. Table 2-3 demonstrates the Corrosion Survey Programs for various pipeline segments.

TABLE 2-3: SUMMARY OF PIPELINE CORROSION SURVEYS

PIPELINE	NUMBER OF ROAD/ANIMAL CROSSINGS	CORROSION SURVEY METHOD	FREQUENCY
Endicott			
Crude Oil Transmission Pipeline	25	NDT, Smart pig, Excavation & Visual	1 to 10 years, depending on method
Diesel/Gas Line	1	NDT, Excavation and Visual inspection	5 years
Inter-Island Water Injection &, Inter-Island Gas Line	1	NDT, guided wave validation	5 years
Well Line Water Injection Line	2	Guided wave validation for carbon steel line;	5 years
Three-Phase Production Line	1	NDT & Visual inspection in vaults	Annually
Badami			
Crude Oil Transmission Pipeline	1	Smart Pig	Every 5 years if flows allow

The three-phase Endicott production pipeline is fabricated of duplex stainless steel, which is corrosion-resistant. The three-phase line at the road crossing between Satellite Drilling Island (SDI) and Main Production Island (MPI) is in a vault, and is visually inspected annually for corrosion. The well water injection line is also fabricated of duplex stainless steel, servicing Well 5-03.

Other Requirements

Aboveground facility piping is supported consistent with the ASME B31 standard to which it was built.

As required by 18 AAC 75.080(n)(1), aboveground facility piping and valves are inspected visually as described in Table 2-7.

In compliance with 18 AAC 75.080(n)(2), the aboveground diesel transfer lines at MPI and the Badami facility pad pipelines exposed to traffic are protected from damage by vehicles with bollards marked with reflectors.

As required by 18 AAC 75.080(o), BPXA notifies ADEC within one year after facility oil piping is no longer in ADEC-required maintenance and prevention programs and the tasks to remove facility piping from service are complete. Facility piping removed from service for more than one year is free of accumulated oil, identified as to origin, marked with the words “Out of Service” and the date taken out of service, secured to prevent un-authorized use, and blank-flanged or isolated from the system. Notification of the out of service status and the task completions may be made by the one-year anniversary of removal from the maintenance and prevention programs.

Flow line regulations 18 AAC 75.047 do not apply to Badami.

Endicott flow lines no longer maintained under an ADEC-required corrosion monitoring and preventive maintenance program are within one year made free of accumulated oil and isolated from the system. The pipe is treated with a cleaning pig, completely drained of oil, or blown with air or with another method to evacuate standing oil. ADEC is then notified within one year of the removal from service and when the tasks are complete [18 AAC 75.047(f)]. Placarding is not required. For the purposes of complying with ADEC flow line regulations, “in-service” means included in a regular maintenance and inspection program required by 18 AAC 75.047, whether the piping holds oil or not. Notification of the out of service status and the task completions may be made by the one-year anniversary of removal from the maintenance and prevention programs.

The aboveground portions of flow lines are supported as outlined in *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids* (ASME B31.4) [18 AAC 75.047(g)].

2.2 DISCHARGE HISTORY [18 AAC 75.425(e)(2)(B)]

Discharge history of oil spills to water or tundra and other oil spills greater than 55 gallons was obtained for the period January 1992 through June 2006 by querying BPXA’s spill reporting database. The discharge history is provided in Appendix B and includes the following information:

- Date of discharge,
- Material discharged,
- Amount discharged, including the volume that reached navigable waters as applicable,
- Cause, and
- Corrective and preventive actions taken.

2.3 POTENTIAL DISCHARGE ANALYSIS [18 AAC 75.425(e)(2)(C) and 40 CFR 112.20(h)(4)]

The potential for oil spills is understood from historical spill data. Examples of potential oil spills are described in Table 2-4. Table 2-5 summarizes potential pipeline spills and release quantities. Spill prevention actions involve the training, operating procedures, leak detection, inspections, and secondary containment outlined in Part 2.

TABLE 2-4: POTENTIAL SPILLS FROM VARIOUS SOURCES

LOCATION	CAUSE	PRODUCT	SIZE	DURATION	ACTIONS TAKEN TO PREVENT POTENTIAL DISCHARGE
Fuel tank	Rupture Overflow	Fuel	595 bbl 20 bbl	4 hours 8 minutes	Bermed and lined storage areas and double-walled tanks.
Fuel lines transfer	Rupture	Fuel	500 bbl	varies	Berms are provided and liners are used in sensitive areas that may be affected by a spill.
Fuel delivery vehicle	Rupture Broken hose	Fuel	200 bbl 75 bbl	4 hours 1.5 hours	Unified Fluid Transfer Procedures.
Fuel transfer on land	Line rupture	Fuel	100 bbl	2 hours	Permanent and portable liners.
Wellhead	Leak	Crude Oil	100 bbl	varies	Cellar boxes initially and automatic shut-off.
Well	Uncontrolled flow from wellbore	Crude Oil	2,250 bbl per day	varies	Blowout prevention equipment.
Diesel transfer to tank truck	Tank overfill	Diesel	200 gallons	30 seconds	Transfer procedures in place; secondary containment.
Diesel transfer from barge to diesel tank	Hose rupture	Diesel	440 to 880 gallons	1 to 2 minutes	Transfer procedures in place; secondary containment; hose watch.
Diesel tank	Tank rupture	Diesel	15,000 bbl	Instant	Secondary containment; tank inspection program.

TABLE 2-5: POTENTIAL PIPELINE SPILLS AND RELEASE QUANTITIES

PIPELINE SEGMENT	TYPE OF FAILURE	LENGTH OF PIPE (feet)	POTENTIAL LOSS (bbl)	ACTIONS TAKEN TO PREVENT POTENTIAL DISCHARGE
Endicott				
MPI to Y	Corrosion or accident	16,541	3,800	Leak detection system & corrosion management
Y to 200-ft. breach	Corrosion or accident	2,794	640	Leak detection system & corrosion management
200-ft. breach	Corrosion or accident	352	90	Leak detection system & corrosion management
200-ft. breach to 500-ft. breach	Corrosion or accident	4,962	1,140	Leak detection system & corrosion management
500-ft. breach	Corrosion or accident	595	140	Leak detection system & corrosion management
500-ft. breach to shore valve	Corrosion or accident	12,848	2,950	Leak detection system & corrosion management
Shore to Sagavanirktok River	Corrosion or accident	44,899	10,300	Leak detection system & corrosion management
Sagavanirktok River to Trans Alaska Pipeline System	Corrosion or accident	46,940	10,780	Leak detection system & corrosion management
Badami				
Sagavanirktok River	Corrosion or accident	3,604 ft.	543 bbl	Leak detection system & corrosion management
Shaviovik River	Corrosion or accident	3,953 ft.	593 bbl	Leak detection system & corrosion management
No Name River	Corrosion or accident	1,152 ft.	189 bbl	Leak detection system & corrosion management
Other low point (Mile 17)	Corrosion or accident	4,000 ft.	600 bbl	Leak detection system & corrosion management
Kadleroshilik River	Corrosion or accident	1,406 ft.	203 bbl	Leak detection system & corrosion management

2.4 CONDITIONS INCREASING RISK OF DISCHARGE [18 AAC 75.425(e)(2)(D)]

Conditions specific to BPXA's North Slope operations that potentially increase the risk of an oil spill, and actions taken to reduce the risk of a spill, are as follows:

- Heat may cause gases to expand, increasing the likelihood of discharge. North Slope facilities are engineered to accommodate temperature fluctuations.

- Icy roads, white-out conditions, and cold snaps present obvious threats to field operations. BPXA Security's strict adherence to vehicle safety, speed limits, and the posting of warning signs assist in minimizing the potential for vehicular accidents that may result in a spill. In addition, North Slope facilities are engineered to withstand arctic conditions.

- Changes in traffic patterns may increase the risk of vehicles colliding into well lines. BPXA Security's strict adherence to vehicle safety, speed limits, and the posting of warning signs or traffic cones helps to minimize the potential for vehicular accidents that may result in a spill.

- If the Trans Alaska Pipeline System (TAPS) unexpectedly shuts down the pipeline, the risk to BPXA systems increases. BPXA's advanced communication system enables immediate communication between TAPS and the North Slope operators, which allows for the coordination of impacts and minimizes the risks due to a shutdown of the pipeline.

- High winds could increase the risk of discharge during fuel transfers, particularly during barge to tank transfers. If wind speed appears to pose a threat to communications or hoses and booming, transfer operations will be postponed until the wind subsides.

- As the fields age, the discharge potential increases. To minimize spills related to aging facilities, BPXA uses a computerized preventative maintenance program, has a corrosion control program, does valve inspections in accordance with Alaska Oil and Gas Conservation Commission (AOGCC) regulations, has leak detection monitoring, and conducts regular visual inspections.

- High water and/or ice during break-up could increase the risk of discharge over river crossings. The pipeline support members have been designed to withstand ice conditions expected at the river crossings. High water and ice conditions are monitored during weekly overflights of the Badami pipeline as well as during routine flights to and from Badami.

The Endicott pipeline has one river crossing at the Sagavanirktok River. To prevent damage to the crossing from ice floes, slots are cut in river ice prior to break-up each year. In addition, river water levels are monitored during high water to ensure that lateral bridge support members do not become submerged. The crossing is observed daily by Security personnel who are responsible for reporting abnormal conditions.

2.5 DISCHARGE DETECTION [18 AAC 75.425(e)(2)(E) and 40 CFR 112.20(h)(6)]

2.5.1 Drilling Operations

Each drilling rig has a system of controls, monitors, alarms and procedures to assist in the early detection of potential discharges. For both down hole and surface operations, these detection systems include automated monitoring devices as well as standard operating procedures (SOPs) governing the monitoring, handling and containment of fluids.

During down hole operations, much of the discharge detection effort centers on well control with an emphasis on detecting wellbore influxes (kicks). The primary control to prevent a discharge associated with a kick is the density of the hydrostatic column of drilling fluid in the wellbore. The drilling fluid density and other critical parameters are closely monitored by drilling fluid specialists and trained members of the rig crew. Modifications to the mud density are made in accordance with the AOGCC approved well plan to maintain the proper fluid density at various intervals. The BOPE (blow out prevention equipment) and associated mechanical well control equipment is defined as the secondary well control system. The AOGCC requires frequent documented testing of these safety systems and such tests are normally witnessed and verified by AOGCC field representatives.

For surface operations, discharge detection systems use automated equipment, visual, audio or manual detection in combination with policies and procedures governing the handling and containment of fluids. Rig pit systems are equipped with pit volume totalizers (PVT) that constantly monitor and record pit volume gains and losses. Unexpected gains or losses of drilling fluids initiate alarms, which sets in motion initial crew responses to secure the well. The well is monitored to further identify the cause of the event. If events indicate a kick or loss of circulation, countermeasures are initiated through written procedures to ensure well control is maintained. Countermeasures are initiated by means of the secondary well control equipment until the well can be stabilized with the primary well control means (e.g., weighted drilling muds) or installed barriers (e.g., cement plugs, bridge plugs).

Rig surface systems are continuously monitored for external leakage as well. Fluid transfers associated with drilling operations are carefully planned, permitted and monitored using BPXA and contractor fluid transfer guidelines. Strict adherence to these procedures ensures immediate detection of spills associated with fluid transfer operations, which significantly reduces the probability of occurrence.

2.5.2 Automated Methods

Operator control of the system is through computers. The system is reliable as the communications network is completely redundant. Each of the three operator consoles is a separate entity, and critical process loops are under redundant control.

Automated control systems and visual monitoring of instrument/control panels are used to control flow rates as well as detect potential discharges. The control systems and instrumentation consist of a “process control” system as well as an independent emergency shutdown (ESD) system. Several independent ESD systems limit the scope of any single failure. An ESD can be initiated by process conditions outside set limits or manually by operators at the instrument/control panels and by personnel at ESD punch-button locations throughout the facility. Process conditions that will trigger the ESD system include loss of pressure in a pipeline, excess pressure or equipment malfunction within a production facility, or high or low liquid levels in vessels and tanks. The ESD system is provided and maintained for the explicit purpose of stopping oil flow when these pipeline or facility problems are encountered. A cascading shutdown system is used to shut in wells and pipelines prior to relieving pressure on vessels or other process systems at the production facilities.

The Endicott control system monitors and operates the oil production wells, process facilities, and pipelines. The control system involves a microprocessor-based distribution control system (DCS) that employs three major categories of digital instrumentation and control, integrated into a single system. The three categories are the DCS, the Supervisory Control and Data Acquisition (SCADA), and the Programmable Logic Controller (PLC). The combined system interfaces with the communications network.

When an emergency requiring shutdown of one or more of the facilities occurs, the PLC system is used. The PLC system is integrated into the DCS. The PLC processor can accept operator commands and transfer status/alarm information to the main operator's console. The MPI and SDI have redundant PLC systems that provide maximum system integrity for performance of ESD functions. Operational and ESD procedures are discussed in the following paragraphs.

At each process center, control systems and visual monitoring of instrumentation are used to control injection flow rates, pressures, and distribution. Pressure-relieving devices are installed on pressurizing units. The facilities are visually inspected on a routine basis for detection of spills and equipment malfunctions.

Production facilities at Endicott are continuously monitored with a microprocessor-based DCS. Incoming alarms from the facilities, wells, or pipelines are documented by date and time via an alarm typewriter in the Unit 601 control room. This system capability allows for the quick tracking of cause-and-effect relationships during upset conditions. In addition, a manually operated, fully automated shutdown system is available if the computerized system is down and the facilities experience excess pressure or malfunction during production. Production wells automatically shut in when low producing pressures are detected.

Automated control systems and visual monitoring of instrument/control panels at the Badami facility are used to control flow rates as well as detect potential discharges. Programmable Logic Controllers (PLC) based control systems control the process in the plant. The operators interface with the PLCs by using the HMI (Human Machine Interface). The HMI system consists of two redundant personal computer servers with operating software that allows the operator to monitor the process, start up and shut down the plant and individual processes and equipment, and make process adjustments. As part of the PLC system, an independent ESD system automatically limits the scope of any single failure. An ESD can be initiated by process conditions outside set limits or manually by operators at the instrument/control panels and by personnel at ESD punch-button locations throughout the facility. Process conditions that will trigger the ESD system include excess pressure or equipment malfunction within a production facility, or high or low liquid levels in vessels and tanks. The ESD system is provided and maintained for the explicit purpose of stopping oil flow when pipeline or facility problems are encountered.

2.5.3 Oil Storage Tanks

Badami's two stationary tanks, the diesel storage tank and slop oil tank, are fitted with level transmitters for control room monitoring of tank liquid levels.

The diesel tank is equipped with leak detection for the tank bottom and has been installed in accordance with API 650, Appendix I. The system includes a bathtub-shaped liner imbedded approximately 12 inches into the foundation gravels and coming up to the outside edge of the tank. A drain is installed in the center of the bottom of the liner. The drain consists of high-density polyethylene piping routed to a steel sump outside of the perimeter of the tank to allow for visual inspection for hydrocarbon leaks from the bottom of the tank. The tank is inspected as described in Table 2-7.

The slop oil tank is elevated above a secondary containment area that is visually inspected for leaks as described in Table 2-7.

Endicott stationary tanks are aboveground and mounted on modules or skids within secondary containment. Additional containment is provided via overflow lines to the secondary containment basins. The tanks are fitted with a level transmitter for control room monitoring of tank liquid levels. The tanks are visually inspected as described in Table 2-7.

Portable tanks may be used for oil storage, well work and dewatering operations. The tanks are monitored while they are in use and during fluid transfers. The tanks' secondary containments are visually inspected as described in Table 2-7 when the tanks are storing oil.

Badami's stationary and portable oil storage tanks less than 10,000 gallons and regulated by 40 CFR 112 are described in Appendix A.

2.5.4 Flow Lines

Lines from oil-producing wells are equipped with low-pressure transmitters used to isolate producing wells in the event of a line rupture. If the pressure in the line drops below thresholds the line shuts in. Small leaks that would not activate the low-pressure switch would be identified by operations personnel performing routine checks. Given that production fluids are mostly gas and water, with smaller amounts of oil, leaks would involve relatively large amounts of visible steam and gas easily identified by both sight and sound.

2.5.5 Wells

The production wells at Endicott are fitted with trees that consist of a manual master valve, a manual swab valve, hydraulically actuated Sub-Surface Safety Valve (SSSV), hydraulically actuated Surface Safety Valve (SSV), and hydraulically actuated wing valve (SDV-Shut Down Valve). When the low-pressure transmitter senses a pressure below the threshold it will close the SSSV and SSV simultaneously.

The Badami production wells are fitted with trees that consist of a manual master valve, a manual swab valve and hydraulically actuated SSV and wing valve (SDV-Safety Divert Valve). When the low-pressure transmitter senses a pressure below the threshold it will close the SDV first followed by the SSV.

2.5.6 Crude Oil Transmission Pipelines

The Endicott pipeline leak detection system monitors the crude oil transmission pipeline from the Main Production Island (MPI) to Pump Station 1 (PS1) for a loss of fluid. The system has demonstrated the ability to detect a daily discharge equal to not more than one percent of daily throughput.

Additionally, as a voluntary measure, Security provides daily drive-by visual surveillance of the Endicott crude oil transmission pipeline. The Endicott pipeline route is entirely road-accessible, and therefore does not require aerial surveillance. Visual pipeline inspection is facilitated by the aboveground construction of the pipelines.

Leak detection for the Badami sales oil pipeline consists of weekly aerial visual inspection unless precluded by safety or weather conditions and monitoring of flow variations in the pipeline. At the Central Processing Facility, meters are installed on the A, B and C meter runs. The C Meter run provides metering flows less than 1,056 barrels of oil per day (bopd). A flow conditioner smoothes the oil flow upstream from the meter. At the Badami pipeline tie-in with the Endicott pipeline, the flow of oil from the Badami pipeline into the Endicott pipeline is measured with a sensing elements designed to handle flow rates up to 2,000 barrels of oil per hour (boph). Oil flow data are transmitted from the meter at Remote Terminal Unit No. 3 (RTU-3) to the Badami control room and then relayed to Endicott via the process control network. The meter supports API equations for net oil calculations. The data also are used for leak detection in the Ed Farmer and Associates (EFA) Leak Net host computer at Endicott. MassPack segment 5 performs the oil mass balance calculations for the pipeline segment from Badami to RTU-3.

Custody transfer metering systems on the Endicott MPI, at Badami and at Pump Station 1 of the TAPS measure volumes accurately and enhance the performance of the leak detection system. The systems provide corrected flow data to the LeakNet System via connected Allen-Bradley PLC-5s on the MPI, Badami, and at PS1. Pressure, temperature, and instantaneous flow information is provided from both the MPI and PS1 locations.

The Endicott/Badami pipeline system to Pump Station 1 (PS1) is monitored using an EFA LeakNet system. Currently only the MassPack algorithm is used for leak detection.

The EFA Mass Pack software performs conventional mass balances over 1 minute, 1 hour, and 24 hours with three corresponding alarm thresholds. The system displays a volumetric flow balance and acquires total inlet and outlet (PS1) crude flow data every minute. Calculations are carried out as shown in Table 2-6.

TABLE 2-6: VOLUMETRIC FLOW BALANCE CALCULATIONS

FREQUENCY	WARNING (bbl)	ALARM (bbl)
Endicott to PSI		
Last minute	15	40
Last 60 minutes	60	300
Last 24 hours	150	170
Badami to Endicott Tie-In		
Last minute	20	25
Last 60 minutes	n/a	n/a
Last 24 hours	15	16

Results exceeding these tolerances trigger alarms and initiate a response to investigate the cause and shut down production if required.

Mass Pack includes intelligence for smoothing the volume balances for transients. Increases (line packing) in the inlet flow rate can be tuned to show up in the outlet over time. Mass Pack leak detection is based on first principles and is often the most reliable of the three software detection methods.

Leak Alarm Response

In the event of a catastrophic rupture of the Endicott/Badami crude oil transmission pipeline, the control operator would immediately detect a total loss of pressure while simultaneously sensing no reduction in flow. Following confirmation, the pipeline would be shut down.

The leak detection system also will alarm for smaller continuous leaks.

If a leak alarm sounds upstream of the Flow Station 2 bypass, the Eastern Offtake Center contacts the Endicott Control Room to determine whether the alarm can be explained. If the alarm is downstream of the Flow Station 2 bypass, Eastern Offtake Center personnel will explain the alarm.

If the alarm can be explained, the leak detection system is reset.

Following an "unexplained" alarm from Endicott and Badami to Pump Station 1, the Eastern Offtake Center contacts Security to request a ground-based visual surveillance of the specific pipeline segment. The Eastern Offtake Center provides Endicott with the results.

If weather or safety prevents ground-based surveillance, then Security requests a Forward Looking Infrared (FLIR) overflight by Shared Services Aviation. If the FLIR overflight reveals an anomaly, the aircraft radios Kuparuk Security which notifies BPXA Security.

BPXA notifies ADEC in writing within 24 hours if a significant change occurs in or is made to the crude oil transmission pipeline leak detection system, and if as a result of the change, the system no longer meets the ADEC performance requirements in 18 AAC 75.055 (18 AAC 75.475). Suspension of the leak detection capability trigger notices to ADEC only if they preclude detection within 24 hours of a leak as large as 1 percent of the annual average daily throughput.

2.5.7 Visual Inspections

Table 2-7 summarizes the visual inspections performed on regulated equipment. Supervisors regularly review the records of daily visual inspections of ADEC-regulated tanks' secondary containments that are required by 18 AAC 75.075.

Flow lines and pipelines are inspected at least monthly, as required by 18 AAC 75.080(n)(1).

More specifically, the following personnel have been identified to support the inspection process:

- Security fills out inspection forms following pipeline inspections. In addition, during routine trips, Security will report oil or gas discharges to the spill reporting telephone line.
- Employees are responsible for conducting visual inspections of their work areas and contacting the operator or Environmental Advisor for clean-up.

Contractors are responsible for visual inspections of work areas and cleaning up spills they may cause. The Environmental Advisor is available to provide support or verification of clean-up efforts.

2.5.8 DOT Pipeline Safe Operations and Emergency Response Equipment Inspection

Inspections of the DOT-regulated sales oil pipeline are conducted as follows:

- Visual inspections at intervals not exceeding three weeks, but at least 26 times per year,
- Mainline and branch valve inspections at intervals not exceeding 7.5 months, but at least two times each year,
- Vertical support member (VSM) inspections annually during the walking-speed survey, and
- A VSM elevation survey at least once every five years.

TABLE 2-7: VISUAL SURVEILLANCE REQUIREMENTS

INSPECTION	RESPONSIBLE POSITION	REGULATING AGENCY	INSPECTION DESCRIPTION	FREQUENCY	REGULATORY CITATION	RECORD KEEPING
Oil Storage Tank in Operation	Badami Operations Lead Tech	EPA (Badami)	Visual inspection bulk oil storage containers 55 gallons to 10,000 gallons	Annual	40 CFR 112.9(c)(3), 112.9 (d)	Appendix A-1, A-3, "EPA Storage Tank Integrity Inspection Procedure" or PRIDE
	Endicott O&M Team Lead	ADEC	Visual inspection of external conditions of oil storage tanks >10,000 gallons in operation	Monthly	18 AAC 75.065 and .066 following API 653	ADEC-Regulated Oil Storage Tank Monthly In-service Inspection Report
Wastewater Tank 1802	Endicott O&M Team Lead	ADEC	Visual inspection of tank	Every 12 hours	See ADEC waiver letter in Part 2.6	Daily log
Secondary Containment Areas at ADEC-Regulated Tanks	Badami Operations Lead Tech	ADEC	Visual inspection for oil leaks or spills, defects and debris	Daily, without record and weekly with record	18 AAC 75.075	Visual field inspection form
	Endicott O&M Team Lead	EPA (Badami)	Visual inspection	Regular	40 CFR 112.9(c)	Appendix A-1, A-3, "EPA Storage Tank Integrity Inspection Procedure" or PRIDE
Secondary Containment at ADEC Tank Truck Loading Areas	Badami Operations Lead Tech Endicott O&M Team Lead	ADEC	Visual Inspection	At transfer or at least monthly	18 AAC 75.075(g)	Visual field inspection form; Daily field shift log
Overfill protection device on field-built oil storage tanks >10,000 gallons	Badami Operations Lead Tech Endicott O&M Team Lead	ADEC	Test overfill protection device	Monthly	18 AAC 75.065(l)	Monthly In-Service Inspection Report
Facility Oil Piping and Valves outside Process Modules, from Well through Manifold Building; to and from ADEC Tank	Badami Operations Lead Tech	ADEC	Visual inspection of oil piping and valves that are visible	Daily contingent on weather and safe access	18 AAC 75.080(n)(1)	Visual field inspection form; Daily field shift log; Wells daily review sheet
	Endicott O&M TL	EPA (Badami)	Examine for maintenance	Periodic	40 CFR 112.9 c (3)	Appendix A-1, A-3, "EPA Storage Tank Integrity Inspection Procedure" or PRIDE
Crude Oil Transmission Pipeline	Badami Operations Lead Tech/Shared Services Aviation	ADEC (Badami)	Aerial surveillance for remote pipelines	Weekly, unless precluded by safety or weather conditions	18 AAC 75.055(a)(3)	Visual field inspection form
	Endicott Security	DOT	Surveillance of sales oil pipeline right of way surface conditions	26 times a year, not to exceed 3 weeks between surveillances	49 CFR 195.412(a)	Surveillance form (Badami); DOT Pipeline Inspection Checklist Report (Endicott)

2.6 COMPLIANCE SCHEDULE AND WAIVERS [18 AAC 75.425(e)(2)(G)]

Waivers follow this page. Waiver content is as follows:

- Request for Secondary Containment Waiver for [Endicott] Waste Water Tank (Tag No. T-E3-1802). ADEC Letter No. 96-43-RKW, File No. 305.50 (089) (December 17, 1996).
- Temporary Waiver of Requirement for Secondary Containment at Tank T-E3-1810 Tank Truck Loading Area (October 12, 2004)
- Waiver of Requirement for Secondary Containment at Tank BAD-01 Tank Truck Loading Area (October 12, 2004)
- Waiver of Daily Secondary Containment Area Inspection Requirements during Bad Weather at Greater Prudhoe Bay, Milne Point, and Endicott and Badami (March 4, 2005)

TABLES