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BOEM 2020-001

BEAUFORT SEA: HYPOTHETICAL VERY LARGE OIL SPILL AND GAS RELEASE

U.S. Department of the Interior
Bureau of Ocean Energy Management
Alaska OCS Region

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LIST OF ABBREVIATIONS AND ACRONYMS

µm	micrometer(s)
µPa	microPascal
AAC	Alaska Administrative Code
ACGIH	American Conference of Governmental Industrial Hygienists
ANWR	Arctic National Wildlife Refuge
API	American Petroleum Institute
ARRT	Alaska Regional Response Team
bbl	barrel(s)
BOEM	Bureau of Ocean Energy Management
BOP	blowout preventer
BP	British Petroleum
BS	boundary segment
BSEE	Bureau of Safety and Environmental Enforcement
BTEX	benzene, toluene, ethylbenzene, xylene
CAA	Clean Air Act
CAH	Central Arctic Caribou Herd
CBS	Chukchi-Bering Sea
CDE	catastrophic discharge event
CFR	Code of Federal Regulations
C_2H_6	ethane
CH_4	methane
cm	centimeter(s)
CO	carbon monoxide
CO_2	carbon dioxide
CWA	Clean Water Act
dB	decibel
DOC	Department of Commerce
DOI	U.S. Department of the Interior
DPP	development and production plan
DWH	Deepwater Horizon
EIS	environmental impact statement
EP	exploration plan
EPA	Environmental Protection Agency
ERA	environmental resource area
ESA	Endangered Species Act
ESI	environmental sensitivity index
EVOS	Exxon Valdez oil spill
FOSC	Federal On-Scene Coordinator
FPEIS	Final Programmatic Environmental Impact Statement
ft	foot/feet
FWS	Fish and Wildlife Service
GLS	grouped land segment
HAK	Hilcorp Alaska, LLC
HAP	hazardous air pollutant(s)
in	inch(es)
IPF	impact-producing factor
kHz	kilohertz
km	kilometers
LA	launch area(s)
LOWC	loss of well control
LS	land segment
m	meter(s)

mi	mile(s)
mm	millimeter(s)
MMbbl	million barrels
MODU	Mobile Offshore Drilling Unit
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	nautical mile(s)
NO_2	nitrogen dioxide
NOAA	National Oceanic Atmospheric Administration
NRC	National Research Council
NRDA	Natural Resource Damage Assessment
NSB	North Slope Borough
NTL	notice to lessees
O_3	ozone
OCS	Outer Continental Shelf
OSA	oil-suspended particulate matter aggregate
OSHA	Occupational Safety and Health Administration
OSRA	oil spill risk analysis
PAH(s)	polycyclic aromatic hydrocarbon(s)
PCH	Porcupine Caribou Herd
PEL	permissible exposure limit
PM	particulate matter
ppb	parts per billion
ppm	parts per million
psia	pounds per square inch absolute
RMS	root mean square
ROV	remotely operated vehicle(s)
SBS	Southern Beaufort Sea
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SO_2	sulfur dioxide
SOA	State of Alaska
SUA	subsistence use areas
TAGA	Trace Atmospheric Gas Analyzer
TAH	total aromatic hydrocarbons
TAqH	total aqueous hydrocarbons
TCH	Teshekpuk Lake Caribou Herd
TLVs	threshold limit values
TPH	total petroleum hydrocarbons
USCG	U.S. Coast Guard
VLOS	very large oil spill and gas release
VOC	volatile organic compound
WCD	worst case discharge

1 INTRODUCTION

BOEM developed this report to provide a robust analysis of potential environmental impacts from a very low-probability event — a very large oil spill and gas release (VLOS) on the Beaufort Sea Outer Continental Shelf (OCS). This document will be made available to the Department of the Interior (DOI) and Bureau of Ocean Energy Management (BOEM) decision makers, including those responsible for developing the National Oil and Gas Leasing Program, holding individual OCS oil and gas lease sales, and reviewing proposed Exploration Plans (EPs) and Development and Production Plans (DPPs).

The mathematical probability associated with VLOS events is very low. The VLOS scenario and impacts described herein are meant to inform DOI and BOEM decision makers, but do not represent what BOEM expects to result from any oil and gas activities on the Beaufort Sea OCS.

1.1 What is a VLOS?

BOEM, Alaska OCS Region defines a VLOS as a very low-probability high-volume (≥150,000 bbl), extended-duration release regardless of the cause, whether natural disaster or manmade. As a high-volume, extended-duration oil spill and gas release, a VLOS would typically qualify for the purposes of the National Oil and Hazardous Substances Pollution Contingency Plan as a “spill of national significance”. A spill of national significance means that due to its severity, size, location, actual or potential impact on the public health and welfare or the environment, or the necessary response effort, is so complex that it requires extraordinary coordination of federal, state, local, and responsible party resources to contain and cleanup the discharge” (40 Code of Federal Regulations (CFR) Part 300, Appendix E).

1.2 What Could Precipitate a VLOS?

Historical data indicate that VLOSs typically occur from loss of well control (LOWC) events, which can then escalate into uncontrolled blowouts. These are severe incidents that create the possibility for not only a VLOS, but also human injury or death. A LOWC is an uncontrolled flow of reservoir fluid that may result in the release of gas, condensate, oil, drilling fluids, sand, or water. It is a broad term that includes very minor well control incidents as well as the most severe well control incidents that escalate into uncontrolled blowouts. The Bureau of Safety and Environmental Enforcement (BSEE) defines a LOWC in the context of its incident-reporting requirement (30 CFR § 250.188). BSEE loss of well control means:

- uncontrolled flow of formation or other fluids, which may be to an exposed formation (an underground blowout) or at the surface (a surface blowout);
- flow through a diverter; or
- uncontrolled flow resulting from a failure of surface equipment or procedure.

Historically, LOWC incidents occurred during development drilling operations, but they can also occur during exploratory drilling, well completions, or production or workover operations. These LOWC events may occur when fluids from one formation enter the wellbore and then invade a different formation exposed to the wellbore, or, when formation fluids enter the wellbore or casing annulus and then escape at the seafloor or the rig floor.

OCS spills may result from a pipeline rupture, however such events will not likely result in a VLOS. The largest OCS pipeline spill occurred in 1967 in the Gulf of Mexico, a result of internal pipeline corrosion following initial damage by an anchor. In 13 days, 160,638 barrels (bbl) of oil leaked (ABS Consulting, 2016). No significant environmental impacts were recorded likely due to the spill's 22-mile (mi) (5 kilometers (km)) distance to shoreline. Since that time, newer leak detection technology and shut off valves have been developed, which generally limit the spill volume to the oil in the pipeline between the two shut off valves.

1.2.1 Historical OCS and Worldwide Loss of Well Control Incidents

From 1964 to 2017, there were 307 U.S. OCS LOWC incidents from all OCS wells, 66 of which resulted in crude or condensate spills of any measurable size (BOEM, 2018a). Seven of the eight OCS well control incident events resulting in a large spill occurred between 1964 and 1970 (Table 1-1). From 1964 to 1970, 13 U.S. OCS LOWC incidents from all wells spilled slightly more than 212,500 bbl. The three largest were 80,000 bbl, 65,000 bbl, and 53,000 bbl from production wells, all of which occurred before 1971 in the Pacific and Gulf of Mexico OCS (Anderson, Mayes, and LaBelle, 2012; ABS Consulting, 2016). The Gulf of Mexico OCS incidents occurred 7–48 mi (13–26 km) from shore, and there was minor shoreline contact with oil (Anderson, Mayes, and LaBelle, 2012; NOAA, 1992). The Pacific OCS incident occurred 6 mi (10 km) from shore, and the California coastline was substantially oiled.

Table 1-1 OCS Platform LOWC Spills ≥1,000 Barrels, 1964 through 2018

Date	Planning Area Block Number	Water Depth (feet)	Distance to Shore (miles)	Volume of Oil Spilled (bbl)	Operator	Facility or Structure
10/3/1964	EI 208	94	48	5,180	Continental Oil	Platforms A, C, & D destroyed, blowouts (several days).
10/3/1964	SS 149	55	33	5,100	Signal O & G	Platform B destroyed, blowout (17 days).
7/19/1965	SS 29	15	7	1,688	Pan American	Well #7 drilling, blowout (8 days), minimal damage.
1/28/1969	Santa Barbara Channel	190	6	80,000	Union Oil	Well A-21 drilling, blowout (10 days), 50,000 bbl during blowout phase, subsequent seepage 30,000 bbl (over decades), 4,000 birds killed, considerable oil on beaches.
3/16/1969	SS 72	30	6	2,500	Mobil Oil	Submersible rig Rimtide drilling in heavy seas bumped by supply vessel, rig shifted and sheared wellhead, blowout (3 to 4 days).
2/10/1970	MP 41	39	14	65,000	Chevron Oil	Platform C, fire of unknown origin, blowout 12 wells (49 days) lost platform, minor amounts of oil on beaches.
12/1/1970	ST 26	60	8	53,000	Shell Oil	Platform B, wireline work, gas explosion, fire, blowout (138 days), lost platform and 2 drilling rigs, 4 fatalities, 36 injuries, minor amounts of oil on beaches.
4/20/2010	MC 252	4,992	53	4.9 million	BP E & P	Deepwater Horizon rig, gas explosion, blowout (87 days to cap well), fire. Drilling rig sank, 11 fatalities, multiple injuries, beaches, wildlife affected, temporary closure of area fisheries, considerable oil on beaches.

Source: Anderson, Mayes, and LaBelle, 2012; ABS Consulting, 2016; BSEE, 2018a.

Since 1971, substantial new regulatory requirements were implemented to improve safety and reduce the likelihood of such LOWC spills occurring (Visser, 2011). From 1971 to 2017, there were 277 U.S. OCS LOWC incidents from all wells, 53 of which resulted in crude or condensate spills of any size. Excluding the volume of oil spilled from Deepwater Horizon (DWH), the total oil volume spilled from 52 U.S. OCS LOWC incidents from all wells was less than 2,000 bbl, and the largest single incident was 450 bbl. The

DWH event was the only VLOS to occur between 1971 and 2018 (BSEE, 2018a). During that same period, more than 38,000 wells were drilled and almost 16 billion bbl of oil were produced.

Few U.S. OCS exploration wells encounter LOWC incidents, and even fewer result in an oil spill. From 1971 to 2017, industry drilled 14,311 exploration wells in the OCS, including 86 in the Alaska OCS. During this period, there were 77 LOWC incidents in the Gulf of Mexico or Pacific OCS associated with exploration drilling. Of those 77 incidents, 15 LOWC incidents resulted in a spill of any size. Fourteen (18 percent) resulted in oil spills ranging from 0.5 bbl to 200 bbl, for a total 354 bbl. One LOWC incident, the DWH, resulted in a VLOS. These statistics show that while 14,311 exploration wells were drilled, there were 15 LOWC incidents that resulted in a spill of any size; 14 were small spills and one, the DWH, was a VLOS.

A literature review of international offshore LOWC incidents from 1965 through 2018 identified eight incidents that resulted in an oil spill of greater than or equal to 150,000 bbl (Table 1-2). One of the well control incidents was the result of military action.

Table 1-2 Worldwide Offshore LOWC Spills ≥150,000 Barrels, 1965 through 2018

Name	Source	Country/ Body of Water	Start-End	Days	Volume Spilled (bbl)	Source
Deepwater Horizon/ Macondo MC 252	Expl. Well	U.S./Gulf of Mexico OCS	4/20/2010–7/15/2010	87	3,190,000–4,900,000	McNutt et al., 2011; National Oil Spill Commission 2011; U.S. District Court, 2015.
Ixtoc	Expl. Well	Mexico/Gulf of Mexico	6/3/1979–3/23/1980	295	3,500,000	OSIR, 1998; Etkin, 2009; Fingas, 2000; NOAA, 1992.
Bull Run Dubai	Dev. Well	Dubai, UAE	1/1/1973–1980	no data	2,000,000	Gulf Canada Resources, Inc. 1982; Etkin et al., 2017.
Nowruz Oil Field No. 3 Well*	Platform	Iran/Persian Gulf	2/4/1983–no data	224	1,904,762	OSIR, 1998; Etkin, 2009; Fingas, 2000; NOAA, 1992.
Abkatun 91	Prod. Well	Mexico/Gulf of Mexico, Bay of Campeche	10/23/1986–no data	no data	247,000	OSIR, 1998; Etkin, 2009; Fingas, 2000; Etkin et al., 2017.
Montara	Dev. Well	Australia/Timor Sea	9/21/2009–11/3/2009	74	28,600–214,300	Commonwealth of Australia, 2011; Montara Commission of Inquiry, 2010, p 38.
Ekofisk Bravo Platform B14	Prod. Well	Norway/North Sea	4/22/19–4/30/1977	8	202,381	OSIR, 1998; Etkin, 2009; Fingas, 2000; NOAA, 1992.
Funiwa No. 5 Well	Prod. Well	Nigeria/Niger Delta	1/17/1980–2/1/1980	14	200,000	OSIR, 1998; Etkin, 2009; Fingas, 2000; NOAA, 1992.

Note: * = act of war

Two VLOS events resulting from blowouts have occurred in U.S. and Mexican waters of the Gulf of Mexico. The first occurred on June 3, 1979 and was the Ixtoc I well blowout in shallow water (depth of 164 feet (ft) (50 meters (m)) and 50 mi (80 km) offshore in the Bay of Campeche, Mexico). It spilled 3.5 million barrels (MMbbl) of oil in 10 months (NOAA, 1992, 2010a; ERCO, 1982).

The second occurred on April 20, 2010 and was the Macondo well blowout (Deepwater Horizon explosion, oil spill, and response) in deep water (water depth of 4,992 ft (1,522 m)) and 48 mi (77 km) offshore of Louisiana. It continuously spilled oil and released gas until it was terminated by a relief well approximately 3 months later. It is clear from the current government estimate of 4.9 MMbbl that the spill volume exceeds the 150,000-barrel threshold for a VLOS (Lubchenco et al., 2010; McNutt et al., 2011). Due to their classification as a VLOS, the Macondo and Ixtoc I well blowouts were utilized to develop the VLOS event scenario for this analysis.

1.2.2 Historical OCS VLOS Frequencies and Risk Factors

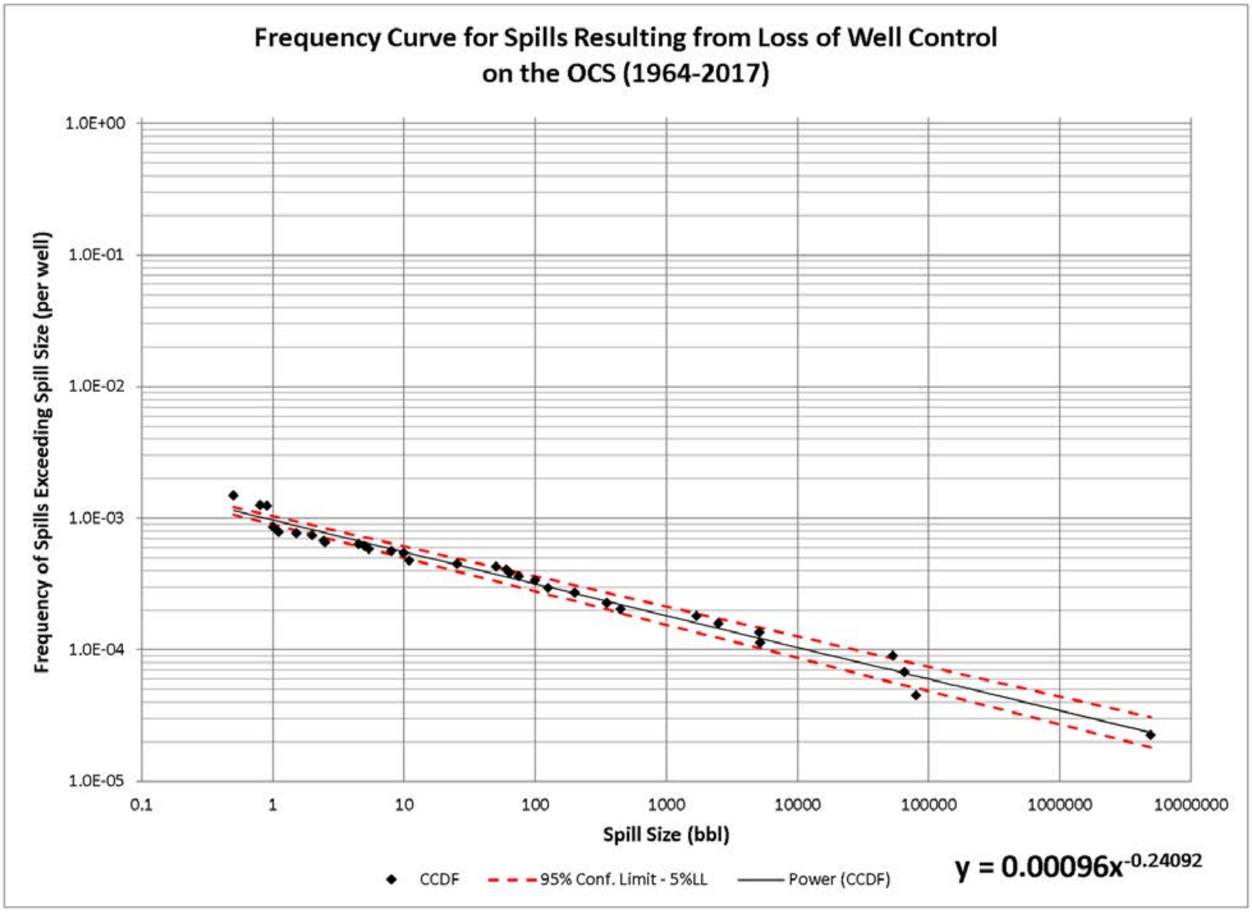
The chance of a VLOS occurring is very low. VLOSs (≥150,000 bbl) happen very infrequently, and there are limited data for use in BOEM's statistical analysis and predictive efforts. In general, historical data show that LOWC events escalating into blowouts and resulting in oil spills are infrequent, and those resulting in large accidental oil spills are even rarer (ABS Consulting, 2016; Bercha Group, 2014; Holand, 2017; Izon, Danenberger, and Mayes, 2007; Ji, Johnson, and Wikel, 2014; Robertson et al., 2013; BOEM, 2012, 2016). However, as the 2010 DWH spill illustrates, there is a very small chance for a VLOS to occur and to result in unacceptable impacts (USCSB, 2014).

Quantifying the frequency of a VLOS from a LOWC event is challenging as relatively few spills that can serve as benchmarks have occurred on the OCS (Scarlett et al., 2011). Inclusion of rare events, like the DWH spill, in the record requires sophisticated analysis due to the small number of events. The U.S. Coast Guard (USCG) noted that the DWH volume is 86 percent of all discharges by volume recorded for U.S. waters in the preceding 37 years ending in 2009 (USCG, 2012). These rare events are small in number and do not have sufficient historical data for traditional statistical methods such as average probabilities.

The frequency of an unlikely or rare event, such as a LOWC incident, escalating into a VLOS, is determined using the best available historical OCS data. The results of this quantitative approach showed the relative unlikelihood of such very low probability spill incidents, wherein spill size is one of the many factors that could determine the severity of events (BOEM, 2012, 2016). First, BOEM defined a reasonable range of potentially very large OCS oil spill sizes by applying extreme value statistics to historical OCS spill data (Ji, Johnson, and Wikel, 2014). Then, extreme value statistical methods and complementary risk assessment methods (Bercha Group, 2014) were used to characterize the potential frequency of different size spills.

Figure 1-1 shows the frequency of a LOWC event occurring and resulting in a spill of different volumes based on an analysis of this historic data from 1964 to 2017 (BOEM, 2018a). This analysis has been updated and used to calculate frequency (per well) of a spill exceeding 150,000 bbl, which is the VLOS volume assumed for the purpose of analysis. This frequency was determined to be >0.00001–<0.0001 ($>10^{-5}$–$<10^{-4}$) per well.

The 2012-2017 Five-Year Program Final Programmatic Environmental Impact Statement (FPEIS) (BOEM, 2012) provides a detailed discussion of the OCS well control incidents and risk factors that could contribute to a long duration LOWC. Risk factors include geologic formation and hazards; water depth and hazards, geographic location (including water depth); well design and integrity; LOWC prevention and intervention; scale and expansion; human error; containment capability; response capability; oil types and weathering/fate; and specific regional geographic considerations including oceanography and meteorology (Table 1-3).



Source: BOEM, 2018a

Figure 1-1 Estimated Frequency of OCS Crude and Condensate Spills both Resulting from Loss of Well Control per Well Drilled and Exceeding a Specified Spill Volume

The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology’s (SINTEF) Offshore Blowout Database, where risk-comparable drilling operations are analyzed and worldwide offshore oil and gas blowouts are tracked, supports the conclusion that blowouts are rare events (IAOGP, 2010; DNV, 2010a,b, 2011). Blowout frequency analyses of the SINTEF database suggest that the highest risk operations are associated with exploration drilling in high-pressure, high-temperature conditions (DNV, 2010a,b, 2011). A high-pressure, high-temperature environment includes well conditions with pressures over 15,000 pounds per square inch absolute (psia) (30 CFR § 250.804(b)). The highest reservoir pressure and temperature encountered by a Beaufort OCS exploration well is 15,400 psia, at a reservoir temperature of 320°F (Lawrence et al., 1994). It is possible to drill a well that meets the definition of a high-pressure, high-temperature environment based on historical well conditions.

Table 1-3 Risk Factors that Affect a VLOS Event

Risk Factors	Factors That Affect Occurrence	Factors That Contribute to a VLOS
Geology	Drilling location, drill depth; mature versus frontier areas. Formation and reservoir pressure; reservoir volume. Seabed complexity. Shelf hazards.	Larger reservoir volume. Higher reservoir pressures and temperatures. Uncertainty associated with drilling in frontier areas.
Water depth	Increased water depth increases complexity of operation.	Shallow water depth increases probability of contact with humans, sensitive species, and sensitive environments.
Well design and integrity	Drill string length. Mud program. Cementing and casing design. Well integrity. New technologies (associated with expansion). Secondary barrier systems (BOPs, backup control systems, ROVs). Human error. Scale of operations and expansion.	Exploratory drilling and improper well construction. Prevention system failure. Source of blowout: wells and platforms (as opposed to pipelines). Human error, often involving lack of understanding of new technologies.
Loss of well control, prevention, and intervention	Improperly maintained or operated equipment. Mechanical failure. Equipment failure.	Mechanical failure. Equipment failure.
Scale and expansion	Complexity of operations, both physical and operational. Human error. Coordination and management.	Human error. Coordination and management.
Human error	Lack of training and preparedness. Extreme working environments.	Lack of training. Failure to take precautionary measures.
Containment capability	Not Applicable	Subsea versus surface containment.
Response capability	Not Applicable	Distance from shore (duration). Response capability in remote areas. Capping at the well; drilling relief well, chemical and mechanical response.
Geography	Region-specific meteorology. Distance to shore: proximity to coastline. Extreme temperature or weather, prevalence of ice.	Distance to shore: proximity to coastline increases response time. Hurricanes historically associated with high-volume spills.
Oil types, weathering, and fate	Temperature of oil: higher oil temperatures and lower water temperatures (Arctic) increase likelihood of breakage. Tidal patterns. Currents and hurricanes.	Oil weathering and evaporation rates. Mechanical recovery, dispersal, or burning. Transport/ice. Oil persistence. Ambient temperatures affect rate of oil flow from blowout location.

Source: BOEM, 2012, Table 4.3.3-2.

1.3 Methodology

BOEM uses two approaches to analyze a VLOS event. The first approach is a bounding analysis for each individual resource category (marine mammals or birds). A bounding analysis involves selecting and evaluating a different set of factors and scenarios for each resource in the context of a VLOS. The second approach involves the selection of a single set of key events that, when combined, result in very high consequences. The second approach is used for a site-specific analysis and, consequently, its possible application is more limited. Accordingly, this analysis combines the two approaches, relying on a generalized scenario while identifying site-specific severity factors for individual resources. This combined approach allows for the logical investigation of a range of possible, although not probable, consequences of a LOWC escalating into an uncontrolled blowout resulting in a long duration, very large volume oil spill and gas release in the Beaufort Sea Planning Area.

1.3.1 Geographic Scope

Throughout its history, the BOEM, Alaska OCS Region and its predecessors conducted numerous NEPA worst case or VLOS analyses. BOEM, headquarters also conducted catastrophic discharge event analyses at the programmatic level for Alaska OCS program areas including the Beaufort Sea. This analysis focuses on the Beaufort Sea Planning Area for which there are 10 historical worst-case, catastrophic discharge event, or VLOS analyses ranging from 100,000 bbl to 4.6 MMbbl (Table 1-4). Through time, the VLOS volume has increased based on changing regulatory requirements and the largest historical spill from different source types, including the DWH oil spill. After the DWH in 2010, BOEM regulations required the calculation of a worst-case discharge (WCD) for each EP or DPP of the highest flowing well. BOEM, Alaska OCS Region also estimated a VLOS for the Beaufort Sea Planning Area for National Environmental Policy Act (NEPA) analyses.

Table 1-4 Worst Case, Catastrophic Discharge Event, or Very Large Oil Spill NEPA Analyses in portions of the Beaufort Sea OCS

Citation	Name	Section	Size (barrels)	Source
BOEM (2018d)	Liberty DPP FEIS	Appendix A	4.6 million	Blowout
BOEM (2016)	2017-2022 5-Year FPEIS	4.4.5	1.7–3.9 million	Blowout
BOEM (2012)	2012-2017 5-Year FPEIS	4.3.3 and 4.4.2	1.7–3.9 million	Blowout
Minerals Management Service (MMS) (2003)	Beaufort Sea Sales 186, 195, and 202 FEIS	IV.I Low-Probability, Very Large Oil Spill	225,000	Blowout
MMS (2002)	Liberty DPP FEIS	IX Low-Probability, Very Large Oil Spill	225,000 200,000	Blowout Tanker
U.S. Army Corps of Engineers (1999)	Northstar DPP FEIS	8	225,000	Blowout
MMS (1998)	Beaufort Sea Sale 170 FEIS	IV.L Effects of a Low-Probability, High-Effects, Very Large Oil Spill Event	160,000	Pipeline
MMS (1996)	Beaufort Sea Sale 144 FEIS	IV.M Effects of a Low-Probability, High-Effects, Very Large Oil Spill Event	160,000	Pipeline
MMS (1990a)	Beaufort Sea Sale 124 FEIS	IV.N Low-Probability, High Effects Very Large Oil Spill Event	160,000	Pipeline
MMS (1987)	Beaufort Sea Sale 97 FEIS	IV.I Worst Case Analysis (Whales)	100,000	Blowout

1.3.2 Scenario and Impact-Producing Factors

A hypothetical yet feasible scenario (Chapter 2) was developed to provide a framework for identifying the impacts of an extended oil spill and gas release from an uncontrolled blowout. Unless noted, this scenario is based on a large volume, long duration LOWC-related oil spill similar to the Gulf of Mexico Ixtoc I and Macondo well blowouts and spills. As noted above, because each VLOS event is unique, its outcome depends on many factors. Therefore, the precise impacts from any future VLOS cannot be predicted based on this scenario, but the general impacts can be well estimated. Chapter 3 discusses the types of impact-producing factors that can occur under the Scenario, which is broken down into three phases.

1.3.3 Oil Spill Trajectory Analysis

BOEM conducted oil spill risk analysis (OSRA) modeling to estimate the percent chance of a large spill contacting a particular resource area within a particular time period (conditional probability) (Li and Smith, 2020). BOEM used the conditional probabilities to estimate the percentage of trajectories contacting physical, biological, and social resources from a hypothetical future blowout and high-volume, long duration flow resulting in a VLOS. Conditional probabilities do not factor in the very low probability of a VLOS occurring in the first place.

The OSRA report discusses the 11 launch areas (LAs) within the planning area representing the places where a VLOS could originate from an exploration, development, or production activity. Appendix A, Figure A1 shows how the LAs were grouped geographically for this analysis. Four types of onshore and offshore resource areas are used in the OSRA model: environmental resource areas (ERAs), land segments (LSs), grouped land segments (GLSs), and boundary segments (BSs). ERAs and BSs represent offshore areas while LSs and GLSs represent nearshore or onshore coastal areas of biological, social, or economic resources or resource habitats. The analysis considered 122 ERAs, 132 LSs, 52 GLSs, and 40 BSs representing biological, economic, or social resource areas (Appendix A, Figures A2 through A5, and Tables A1 through A13).

For purposes of this VLOS analysis, the conditional probabilities were considered to represent the estimated percentage of trajectories contacting ERAs, LSs, GLSs, or BSs. Higher percentages of trajectories contacting a given location could mean more oil reaches the location depending on weathering and environmental factors.

Results from the Li and Smith (2020) trajectory analysis provide input to the impact assessment. The OSRA calculated where a VLOS from a specific geographic location might travel on the ocean's surface and what environmental, social, or economic resource areas might be contacted if and where a VLOS occurs. Trajectory simulations are performed for three timeframes: annual (January 1–December 31), winter (November 1–June 30), and summer (July 1–October 30). The seasonal timeframes generally represent Arctic summer (open water) or Arctic winter (ice cover). For analyzing potential impacts of a VLOS, the percentage of trajectories within 120 days during summer and 360 days during the winter are summarized. During summer (open water) 120 days allows a VLOS to weather 30 days beyond the last flow of oil. During winter (ice cover) 360 days allows the VLOS to freeze into the ice and melt out and weather the following summer. A VLOS trajectory analysis was evaluated for all resources except economy, air quality, and public health. Specific ERAs and their vulnerability were not identified for these resources. However, the general results of the trajectory analysis were considered in estimating impacts on these resources. Further detail on this OSRA model run is discussed in Li and Smith (2020) and Appendix A.

1.3.4 Physical, Biological, and Socioeconomic Impacts

This report evaluates the impacts to Arctic OCS physical, biological, and socioeconomic resources from a LOWC escalating into a long duration blowout, resulting in a VLOS, and associated response, recovery, and cleanup activities. Although the most recent EISs prepared by BOEM for oil and gas lease sales on the Alaska OCS analyze the potential impacts from oil spills that are more reasonably foreseeable, this analysis focuses on the most likely and most significant impacts created by a high-volume, extended duration oil spill and gas release. Because severe consequences may not occur for all resources, factors affecting the severity of impacts are identified by the individual resource.

1.4 How to Use This Analysis

The purpose of this technical analysis is to assist BOEM in analyzing potential impacts from a catastrophic discharge event herein called a VLOS. This analysis, based on credible scientific evidence, identifies the most likely and most significant impacts from a high-volume blowout resulting in a VLOS that continues for an extended period of time. The scenario, impact-producing factors, and impacts discussed in Chapters 2, 3, and 5 are the result of a VLOS and should not be confused with the scenario and impacts anticipated to result from activities or the more reasonably foreseeable accidental events of a proposed action.

Chapter 2 provides an overview of the VLOS scenario. Chapter 3 describes the scenario presented for all three phases of a long duration blowout event and identifies the impact-producing factors associated with each phase. Chapter 4 synthesizes information on the effects of oil and gas releases used to evaluate impacts. Chapter 5 provides the impact analyses of each phase of a VLOS on various environmental resources. These chapters can be used to differentiate the conditions of a VLOS from the routine activities and accidental events described in lease sale EISs.

This technical analysis is designed to be incorporated by reference in future NEPA documents and Endangered Species Act consultations, and other environmental review processes. Therefore, factors that affect the severity of impacts of a high-volume, extended-duration spill and gas release on individual resources are highlighted in Chapter 3 for use in subsequent programmatic and project-specific analyses.

To analyze a hypothetical VLOS event in an area such as the Beaufort Sea, several assumptions and generalizations were made. However, for future project-specific analyses, BOEM should also consider specific details such as potential flow rates for the specific proposed activity, the properties of the targeted reservoir, and the proximity to environmental resources of the proposed activities and whether this analysis should be revised based on new information.

2 VERY LARGE OIL SPILL AND GAS RELEASE SCENARIO

A scenario was developed to analyze the environmental impacts of a VLOS in the Beaufort Sea Planning Area. Scenarios are conceptual views of the future and represent possible sets of activities. They serve as planning tools that make possible an objective and organized analysis of hypothetical events.

The VLOS scenario is predicated on an unlikely event—a LOWC during exploration or development that leads to a long duration blowout and a resulting VLOS. It is recognized that the frequency for a VLOS on the OCS from a well control incident is very low. Various studies have used different techniques to arrive at a similar range of values. Recent analyses have estimated the frequency ranges between 0.00001 and 0.0001 ($>10^{-5}$–$<10^{-4}$) per well (BOEM, 2018a; Bercha Group, 2014).

The VLOS discharge quantity is “conditioned” upon the assumption that all the necessary chain of events required to create the VLOS actually occur (successful geology, operational failures, escaping confinement measures, reaching the marine environment, etc.). The low chance that the exploration well would successfully locate a large oil accumulation, coupled with the observed low incidences for accidental discharges in the course of actual drilling operations, development, or production, predicts a very small, but not impossible, chance of a VLOS event. However, this consideration of probability is not, nor should it be, integrated into the VLOS scenario. The VLOS discharge quantity is, therefore, not “risked” or reduced by the very low frequency for the occurrence of the event.

2.1 Cause of Spill

The scenario assumes a LOWC escalates into an uncontrolled blowout, and a subsequent explosion and fire occur. A blowout associated with a single well could result in a fire that would burn for 1 or 2 days. The exploration drilling rig or production platform may sink. If the blowout occurs in shallow water, the sinking rig may land in the immediate vicinity; if the blowout occurs in deeper water, the rig could land some distance away. For example, the DWH drilling rig sank, landing a short distance from the subsea wellhead. Water depths in the Beaufort Sea Planning Area range from about 25 ft to more than 14,000 ft. Drilling in waters over 300 ft deep is considered unlikely.

For modeling flow rates, the location of the blowout and leak was specified as occurring near the mudline (at the top of the blowout preventer). The model adopted for the Beaufort VLOS is based upon a blowout to the atmosphere occurring on a manmade gravel island. A blowout could occur in other locations, such as at the seafloor, along the riser anywhere from the seafloor to the sea surface, or below the seafloor (outside the wellbore). BOEM modeled a discharge to atmospheric pressure, which does contribute to a forecast of higher oil discharge rates and cumulative volumes. The environmental effects analysis in Chapter 5 encompasses all these possibilities as different blowout and leak locations may have bearing on spill response and intervention options.

2.2 Timing of the Initial Event

The hypothetical VLOS is estimated to occur any time of the year, January through December, in shallow waters of the Beaufort Sea (the landfast ice zone) and during the open-water season July through October in deeper waters of the Beaufort Sea (on the continental shelf and farther offshore). BOEM considered the following with respect to leasing blocks and development beyond the shelf break in the Beaufort Sea Program Area: historic boundaries of Lease Sale Area IDs; historic leasing patterns and activity;

bathymetry of the Beaufort Sea shelf; resource potential; and economic/technical accessibility. While exploration may occur anywhere in the planning area during the open-water season, development is likely to occur on the shelf first and operate year-round.

2.3 Hypothetical VLOS Volume

In 2011, BOEM generated a hypothetical discharge model for the Beaufort Sea Planning Area that was subsequently modified in 2015 with additional information from the Liberty DPP. BOEM first generated a hypothetical oil discharge model that estimated the highest possible uncontrolled flow rate that could occur from any known prospect in the planning area, given real world constraints (BOEMRE, 2011). The discharge model was constructed using a geologic model for a specific prospect in conjunction with a commercially available computer program (AVALON/MERLIN) that forecasts the flow of fluids from the reservoir into the well, models the dynamics of multiphase (primarily oil and gas) flow up the wellbore, and assesses constraints on flow rate imposed by the open wellbore and shallower well casing. This model utilized information and selected variables that, individually and collectively, provided a maximized rate of flow. The most important variables for the discharge model included thickness, permeability, oil viscosity, gas content of oil, and reservoir pressure. Many other variables of lesser importance were also required. BOEM calculated a VLOS could range from 1.7–3.9 MMbbl over 60 to 300 days of discharge (BOEM, 2012).

In 2015, the operator Hilcorp Alaska, LLC (HAK) submitted an estimation of a WCD volume as part of their Liberty DPP. The WCD estimation is required by 30 CFR § 550.250(a)(iv) to accompany a DPP and provides a basis for an Oil Spill Response Plan in accordance with 30 CFR Part 254. The WCD volume information submitted by the operator is independently verified by BOEM's Office of Resource Evaluation.

The WCD volume information submitted by the operator and independently verified by BOEM, Office of Resource Evaluation, provides a basis for the oil and gas volumes used in the VLOS scenario for the Beaufort Sea Planning Area (BOEM, 2018b). Because the flow rate associated with the WCD estimation submitted with the Liberty DPP is higher than the flow rate used in BOEM's initial VLOS estimate, the Liberty well WCD cumulative flow is assumed to also be a VLOS for the Beaufort Sea Planning Area (BOEM, 2018b). HAK estimated 4.6 MMbbl could be released over the course of 90 days (BOEM, 2018c; HAK, 2015). This estimate assumes that the hypothetical LOWC was stopped by a relief well rather than other proposed well control methods which have shorter estimated times to stop the flow. In addition to the 90-day oil spill volume, HAK estimated a first day oil spill volume of 91,219 bbl and a first day gas release of 84,538,512 standard cubic feet (HAK, 2015, Table 14-3). The American Petroleum Institute (API) gravity of the oil discharged from the well is estimated to be 27° API (HAK, 2015, Appendix I).

BOEM estimates that 7.26 billion standard cubic feet of gas could be released over 90 days (Sherwood, 2018). The quality and quantity of components in natural gas vary widely by the field, reservoir, or location from which the natural gas is produced. Natural gas is primarily made up of methane (CH_4) and ethane (C_2H_6), which make up 85 percent to 90 percent of the volume of the mixture.

2.4 Duration of Flow

The duration of the OCS spill from a blowout depends on the time required for successful intervention. A variety of methods exist by which an operator or responder can stop the flow of oil. The availability of some of these techniques could vary under individual EPs or DPPs. Under BOEM's Notice to Lessees (NTL) 2015-N01, all EPs and DPPs must specify as accurately as possible the time it would take to contract for a rig, move it on site, and drill a relief well (BOEM, 2015a). For purposes of analysis within this VLOS scenario, BOEM estimates the discharge would be stopped within 90 days of the initial event. This duration reflects the "maximum duration of the potential blowout" discussed in NTL 2015-N01 and required under 30 CFR § 550.213(g) and 550.243(h).

2.5 Duration of Oiling

The duration of the shoreline oiling is measured from initial shoreline contact until the well is capped or killed and the remaining surface oil dissipates offshore. Depending on the spill's location in relation to winds, ice, and currents as well as the well's distance to shore, oil could reach the coast within 3 days to 360 days based on BOEM's oil spill trajectory analysis (Li and Smith, 2020). While it is estimated that the majority of spilled surface oil would evaporate and naturally disperse offshore within 30 days of stopping the flow or after meltout in the Arctic spring, some oil may remain in coastal areas until cleaned or naturally weathered, as seen following the Exxon Valdez oil spill (EVOS) and DWH event (Lindeberg et al., 2018; Nixon et al., 2016; Taylor and Reimer, 2008). The generation of oil-suspended particulate material or subsurface plumes from the wellhead would stop when the well was capped or killed. Subsurface plumes would dissipate over time due to mixing and advection (Boehm and Fiest, 1982).

2.6 Volume of Oil Reaching Shore

In the event of a VLOS, not all the oil spilled would contact shore. The volume of oil recovered and chemically or naturally dispersed would vary. The following are low to high recovery and cleanup rates from previous high-volume, extended spills (Wolfe et al., 1994; Gundlach and Boehm, 1981; Gundlach et al., 1983; Lubchenco et al., 2010):

- 10–40 percent of oil recovered or reduced (including burned, chemically dispersed, and skimmed)
- 25–40 percent of oil naturally dispersed, evaporated, or dissolved
- 20–65 percent of the oil remains offshore until biodegraded or until reaching shore

In the case of the DWH event, "it is estimated that burning, skimming, and direct recovery from the wellhead removed one quarter (25 percent) of the oil released from the wellhead. One quarter (25 percent) of the total oil naturally evaporated or dissolved, and just less than one quarter (24 percent) was dispersed (either naturally or as a result of operations) as microscopic droplets into Gulf of Mexico waters. The residual amount—just over one quarter (26 percent)—is either on or just below the surface as light sheen and weathered tar balls, has washed ashore or been collected from the shore, or is buried in sand and sediments" (Federal Interagency Solutions Group, 2010). For general planning purposes, USCG estimates that 5–30 percent of oil would reach shore in the event of an offshore spill (33 CFR Part 154, Appendix C, Table 2).

2.7 Length of Shoreline Contacted

While larger spill volumes increase the chance of oil reaching the shoreline, other factors that influence the length and location of shoreline contacted include the duration of the spill and the well's location in relation to winds, ice, currents, and the shoreline. The length of oiled shoreline increases over time as the spill continues. Varying winds and currents throughout the VLOS event refloat oil from already-impacted places and could oil other areas, increasing the oiled area.

A VLOS from a nearshore site would allow less time for oil to be weathered, dispersed, and/or recovered before reaching shore. This could result in a more concentrated and toxic oiling of the shoreline. A release site farther from shore could allow more time for oil to be weathered, dispersed, and recovered. This could result in a broader, patchier oiling of the shoreline. Landfast ice, occurring in winter, could preclude oil from contacting the shoreline by acting as a barrier. Landfast ice could reduce oil spreading particularly if the landfast ice is covered in snow, which may absorb and retain some portion of spilled oil in place. Landfast ice may also provide a more effective platform for oil spill response and recovery efforts.

2.8 Environmental Variables

Severe or extreme weather and sea ice are environmental variables that could change aspects of how oil behaves or could affect containment, response, or cleanup operations. Episodes of severe and extreme weather over the Arctic could affect the behavior of sea surface oil, accelerate dispersion of the oil, impact shoreline conditions, and put marine vessels at risk. High wind and wave action can drive oil floating on the surface into the water column, and oil stranded on shorelines can be moved into nearshore waters and sediment or strand above high tide lines during storms. Episodes of severe storms characterized by strong winds (25 to 30 mi per hour) and precipitation during summer or winter can dictate the movement of sea-surface oil drift and direct oil toward or away from the coastline.

Storm tracks in the planning area are driven in response to the intensity and location of the Beaufort high and Aleutian low pressure systems. In general, these tracks originate in the eastern North Pacific and propagate northwards into the Beaufort Sea Planning Area (Pickart et al., 2009). These storms can cause extreme weather conditions in areas near ice/ocean or land/ocean boundaries (Tao et al., 2016). While less common, these storms cover a larger area and can cause surface winds at or near gale force, up to 45 mi per hour, with waves 15 to 20 ft. In addition, recovery of sea-surface oil could be impeded by the formation of sea ice during severe cold outbreaks that occur over the Arctic winter. Any of these conditions could temporarily delay or stop the response and recovery effort.

2.9 Response, Recovery, and Cleanup Countermeasures

The VLOS scenario would trigger an extensive spill response, recovery, and cleanup effort. VLOS response efforts in the Beaufort Sea would include the recovery and cleanup techniques and estimated levels of activities described below. Both mechanical and non-mechanical methods of oil spill response could be used in the Beaufort Sea to mitigate the impacts of a VLOS on the environment. Severe weather and/or the presence of ice could interfere with or temporarily preclude each of these methods. The effect of ice is analyzed in detail below in Section 2.9.3.

In the event of a VLOS, two governmental organizations would assume prominent roles in coordinating response efforts: the Federal On-Scene Coordinator (FOSC), and the Alaska Regional Response Team (ARRT). The ARRT is an advisory board to the FOSC that provides federal, state, and local governmental agencies with the ability to participate in response to pollution incidents. During a response, the FOSC would consult with the ARRT on a routine basis for input regarding response operations and priorities. In addition to their advisory role during a response event, the ARRT is responsible for developing the Alaska Regional Contingency Plan, which details governmental incident response planning and responsibilities for the State of Alaska (SOA). The Area Committees are responsible for four Area Contingency Plans, which provide region-specific response planning information for establishing operations in the event of a major response effort to an oil spill or hazardous material release. The Area Contingency Plans identify notification requirements, emergency response command structures, response procedures, community profiles, in-region response assets, logistics guidance, and spill scenarios that could be encountered in the region. Additionally, the plans identify sensitive areas along with geographic response strategies to protect the resources from oil. For activities in the Beaufort Sea, the applicable regional documents are the Arctic & Western Alaska Area Contingency Plan and the Inland Area Contingency Plan for the North Slope (EPA and ADEC, 2018; USCG and ADEC, 2018).

2.9.1 Mechanical Countermeasures

Mechanical countermeasures include source control and containment, and mechanical recovery. Second only to protecting human life and safety, when an oil spill occurs the first action is to stop the pollution at its source. Source control is particularly important for preventing a LOWC from escalating and containment equipment prevents additional spillage beyond the initial amount from a spill, which is considered a priority during response. Source control and containment is particularly important for preventing a LOWC from escalating into a long duration blowout. For operations on the OCS, source control and containment equipment, supporting equipment, and collocated equipment must include, but is not limited to, the following: (1) Subsea containment and capture equipment, including containment domes and capping stacks; (2) Subsea utility equipment, including hydraulic power sources and hydrate control equipment; (3) Collocated equipment, including dispersant injection equipment; (4) Riser systems; (5) Remotely operated vehicles (ROVs); (6) Capture vessels; (7) Support vessels; and (8) Storage facilities (30 CFR § 250.462). For Arctic gravel islands, source control may utilize a surface capping stack, surface utility equipment, or intentional well ignition.

The preferred means of spill response is mechanical recovery of the oil, which physically removes oil from the ocean, sea ice, or land. Mechanical recovery at sea is accomplished using devices such as vessels, containment booms, and skimmers. A containment boom is deployed in the water and positioned within an oil slick to contain and concentrate oil into a pool thick enough to permit collection by a skimmer. An oil release to solid ice conditions is easier to respond to because the oil’s spreading in the environment is drastically limited by the snow and ice. As the ice thickness grows, heavy equipment is used to recover oil. The skimmer or heavy equipment collects the oil and transfers it to a storage vessel (storage barges, oil tankers, tanks, or bladders) where it will eventually be transferred to shore for appropriate recycling or disposal.

2.9.2 Non-Mechanical Countermeasures

The use of dispersants and in-situ burning are the two non-mechanical techniques used most commonly in response to an oil spill. Dispersants and in-situ burning focus on changing the characteristics of the oil within the environment rather than using mechanical equipment (physical containment and recovery equipment, such as booms and skimmers) to recover or remove the oil (NRC, 2005).

Dispersants. Although recent research in the use and effectiveness of chemical dispersants has shown varied results, use of dispersants may still be a response option for the Beaufort Sea. Some research has shown that dispersants can be effective in cold temperatures and ice under certain conditions (EPPR, 2017a; Faksness et al., 2017; Lewis and Prince, 2018). Completed field scale tests in broken ice conducted by SINTEF (Sørstrøm et al., 2010) have demonstrated that results from lab scale and large wave tank tests hold true in actual ocean conditions. Oil released into the ocean during broken ice conditions was readily dispersed and addition of vessel propeller wash and increased wave energy further increased oil dispersion. It was also demonstrated that in these cold conditions weathering of the oil was significantly slowed providing a greater window of opportunity in which to successfully apply dispersants.

Dispersants are applied by injection at the source or through aerial or vessel-based spray techniques. A study funded by BSEE concluded that dispersant application in the Beaufort Sea would be virtually impossible under winter conditions and that even in summer, aerial application would be impossible half the time and vessel application about 20 percent of the time (EPPR, 2017b). Dispersant use is limited to ocean application in waters generally deeper than 10 m; this depth restriction is used to avoid or reduce potential toxicity concerns with respect to nearshore organisms.

The Alaska Regional Contingency Plan does not have preapproved dispersant application zones for the Beaufort Sea, so each request for dispersant application would be evaluated and approved or disapproved on a case-by-case basis by the FOSC in consultation with the Environmental Protection Agency (EPA), DOI, and Department of Commerce (DOC). The decision regarding how and when dispersants would be applied would also reside with the FOSC in consultation with SOA, EPA, DOI, and DOC. Procedures governing the application of dispersants are provided in the Alaska Regional Contingency Plan, Appendix III (Dispersant Use Plan for Alaska, Revision 1) (ARRT, 2018, Appendix III). However, the FOSC is not limited to this procedure and may utilize other sources of information in determining what the most appropriate dispersant method would be given a specific situation. If dispersants were approved and additional volumes were needed, dispersant stockpiles are located in Anchorage and the lower 48 states.

In-situ Burning. In-situ burning is the controlled burning of spilled oil. Burning alters the composition of the spilled oil through the combustion process, diminishes the volume, and then moves many of the petroleum-related compounds from the water surface into the atmosphere (Mullin and Champ, 2003). In-situ burning is a viable response method for the Beaufort Sea and could be approved by the FOSC in consultation with the Unified Command and the ARRT. Any in-situ burning would be conducted in accordance with the In-situ Burning Guidelines (ARRT, 2018, Appendix IV). In-situ burning is a method that can be used in open ocean, broken ice, nearshore, and shoreline cleanup operations. In broken ice conditions, the ice serves to act as a natural containment boom limiting the spread of oil and concentrating it into thicker slicks, which aid in starting and maintaining combustion. In-situ burning has the potential to remove in excess of 90 percent of the volume of oil involved in the burn. In-situ burning experiments of oil in ice conducted as part of the SINTEF Joint Industry Program (Sørstrøm et al., 2010) have likewise demonstrated that cold temperatures serve to slow weathering of the oil, in turn expanding the window of opportunity for in-situ burning application over that experienced in more temperate regions.

2.9.3 Effect of Ice on Response Actions

For all response options, the presence of ice can both aid and hinder oil spill response activities. Ice acts as a natural containment device preventing the rapid spread of oil across the ocean surface; it also serves to concentrate and thicken the oil allowing for more efficient skimming, dispersant application, and in-situ burning operations. Once shorefast ice is formed, it serves as a protective barrier limiting or preventing oil from contacting shorelines. Cold temperatures and ice will slow the weathering process by reducing volatilization of lighter volatile compounds of the oil, reducing impact of wind and waves, and extending the window of opportunity in which responders may utilize their response tools.

Conversely, ice can limit responders' ability to detect and locate the oil, access the oil by vessel, prevent the flow of oil to skimmers, require thicker pools to permit in-situ burning, and eventually encapsulate the oil within a growing ice sheet making access difficult or impossible. Once incorporated into the ice sheet, further recovery operations would have to cease until the ice sheet becomes stable and safe enough to support equipment and personnel to excavate and/or trench through the ice to access the oil. The other response option is embedding tracking devices in the ice and monitoring its location until the ice sheet begins to melt and the oil surfaces through brine channels, at which time it could be collected or burned. For a comprehensive list of Arctic oil spill response research projects that BSEE has funded, the reader is referred to BSEE Arctic Oil Spill Response Research (BSEE, 2018b).

2.9.4 Levels of Response, Recovery, and Cleanup Activities

The levels of activities required to apply the techniques described above are dependent on the specific timing and location of a VLOS. As weather, ice, and logistical considerations allow, the number of vessels and responders would increase exponentially as a spill continues. The levels of activities described below are reasonable estimates provided as a basis for analysis. These estimates are based on the Arctic and Western Alaska Area Contingency Plan and the Inland Area Contingency Plan for the North Slope, past spill response and cleanup efforts including the EVOS and DWH events, and the best professional judgment of BSEE and BOEM spill response experts.

- Between 5 and 10 staging areas would be established.
- Several communication and medical centers would be established.
- About 15 to 20 vessels (vessels associated with the drilling program, other vessels and barges from Prudhoe Bay, vessels from Cook Inlet and Prince William Sound, and other vessels of opportunity) could be used in offshore areas. Some of these would be capable of oil skimming. The majority of open ocean vessels would be positioned relatively close to the source of the oil spill to capture oil in the thickest slicks, thus enabling the greatest rate of recovery.
- Thousands of responders (from industry, federal and state government, and private entities) could assist spill response and cleanup efforts as the spill progresses. Weather permitting, roughly 300–400 skimming, booming, and lightering vessels could be used in areas closer to shore. Based on the trajectory of the slick, shallow water vessels would be deployed to areas identified as priority protection sites.
- Booming would occur, dependent upon the location of the potentially impacted shoreline, environmental considerations, and agreed upon protection strategies involving the local potentially impacted communities. About 100 booming teams could monitor and operate in multiple areas.
- Use of dispersants and/or in-situ burning could occur if authorized by the FOSC. Use of dispersants would likely concentrate on the source of the flow or be conducted to protect sensitive resources. In-situ burning operations would likewise be conducted in the area of thickest concentration to ensure the highest efficiency for the effort. In-situ burning may also be utilized in nearshore and shoreline response where approved by the FOSC.
- Dozens of planes and helicopters would fly over the spill area, including impacted coastal areas. Existing airport facilities along the Arctic coast (including airports at Deadhorse, Utqiaġvik, Kaktovik, and any other suitable airstrips) would be used to support these aircraft. If aircraft are to apply dispersants, they could do so from altitudes of 50 to 100 ft.
- Workers could be housed offshore on vessels or in temporary camps at the 5–10 staging areas. A small number of workers could be housed in existing hotels.

Depending on the timing and location of the VLOS, the above efforts could be affected by seasonal considerations. In the event that response efforts continue into the winter season, small vessel traffic would come to a halt once the forming ice begins to cover the ocean surface. Larger skimming vessels could continue until conditions prevent oil from flowing into the skimmers. At this point, operations could shift to in-situ burning if sufficient thicknesses are encountered. The lack of daylight during winter months would increase the difficulties of response.

As ice formation progresses, the focus of the response would shift to placing tracking devices in the forming ice sheet to follow the oil as it is encapsulated into the ice sheet. Once the ice sheet becomes solid and stable enough, recovery operations could resume by trenching through the ice to recover the oil using heavy equipment. This would most likely occur in areas closer to shore because the ice would be more stable. In late spring and early summer, as the ice sheet rots, larger ice-class vessels could move into the area and begin recovery or in-situ burning operations as the oil is released from the ice sheet. The ice would work as a natural containment boom keeping the oil from spreading rapidly. As the ice sheet decays, oil encapsulated in the ice would begin surfacing in melt pools at which time responders would have additional opportunities to conduct in-situ burn operations. Smaller vessels could eventually re-commence skimming operations in open leads and among ice flows, most likely in a free skimming mode (without boom) along the ice edge.

While it is estimated that the majority of spilled oil on the water surface would be dissipated within a few weeks of stopping the flow (Federal Interagency Solutions Group, 2010) during open-water or after meltout in the Arctic spring, oil has the potential to persist in the environment long after a spill event and has been detected in sediment 30 years after a spill (Etkin, McCay, and Michel, 2007). On coarse sand and gravel beaches, oil can sink deep into the sediments. In tidal flats and salt marshes, oil may seep into the muddy bottoms (Michel and Rutherfort, 2013).

Effectiveness of intervention, response, and cleanup efforts depend on the spatial location of the blowout, leak path of the oil, and amount of ice in the area. For the purpose of analysis, effectiveness of response techniques is not factored into the spill volume posited by this scenario nor considered during oil spill trajectory modeling.

2.10 Opportunities for Prevention and Intervention

Potential intervention and response methods are discussed below as a joint response because their concerted application could substantially decrease the estimated time each would take to regain well control and therefore the duration, volume, and environmental effects of a VLOS. These methods are not mutually exclusive; several techniques may be employed if necessary. It may also be possible to apply multiple techniques simultaneously. The availability and effectiveness of these techniques may vary depending on the nature of the blowout, as well as seasonal considerations. Before discussing LOWC intervention and response techniques, some of the prevention methods and protocols are discussed that could prevent a kick or blowout that would have otherwise led to a VLOS.

The primary well control planning and operational protocols operators have in place include selecting the well location to avoid overpressured zones, pore pressure/fracture gradient knowledge, casing design, pressure control equipment, and operational monitoring. A primary barrier or tool preventing a blowout is the column of drilling fluid present in the well during drilling (Wild Well Control, 2010; DNV, 2010b). The drilling fluid, with a greater hydrostatic pressure than the pore pressure or formation pressure, keeps the formation fluids from entering the wellbore (DNV, 2010b; API, 2006, 2010). Secondary barriers to preventing a blowout include the use of blowout preventer (BOP) equipment, kill choke lines, wellhead seals, and casing and cement (DNV, 2010b), some of which are discussed below.

Natural bridging or plugging could also occur in which a loss of pressure within the wellbore (in the event of a blowout) causes the surrounding formation to cave in, thereby bridging over or plugging the well (Willson, Nagoo, and Sharma, 2013). While natural bridging or plugging could render certain forms of operator-initiated well control infeasible, it could also impede or block the release of hydrocarbons from the reservoir from reaching the surface. The majority of Gulf of Mexico OCS blowouts from 1960 through 1996 were controlled by bridging (either passive or active) (Skalle, Jinjun, and Podio, 1999).

2.10.1 Well Intervention

If a kick or LOWC occurred, crew on the original drilling rig could initiate well control procedures. These techniques stop LOWC events the vast majority of the time without any oil being spilled. The procedures would vary given the specific situation, but could include:

- **BOP Use.** The use of BOP equipment (both ram and annular types) to control the well. The rams can seal the wellbore (DNV, 2010b) and are distinguished by function including shearing blind rams (which can cut the drill pipe) and blind rams (which can seal an empty wellbore without pipe in the hole) (IADC, 2015). The annular, pipe ram, and variable bore ram type preventers can prevent movement of the pipe by closing in on the annulus where drilling fluid is moving towards the surface, and it can seal the open hole and close in on a variety of sizes of pipe (Rigzone, 2016; Wild Well Control, 2016).
- **Kill Weight Fluids.** Pumping kill weight fluids into the well to control pressures, once the BOP is closed.
- **Replace/Repair.** Replacing or repairing any failed equipment to remedy mechanical failures that may have contributed to the LOWC (such as repairing the existing BOP) (ExxonMobil, 2003).

2.10.2 Well Ignition

Voluntary ignition of the gas and oil emerging from the wellhead is one option for blowout response on artificial drilling islands. ExxonMobil considered the surface intervention of well control that is supplemented by well ignition as the best available technology in its Oil Discharge Prevention and Contingency Plan for the Point Thomson project (ExxonMobil, 2003). Well ignition could reduce the volume and environmental impact of a VLOS. Well ignition works by exposing the blowout plume to a flame so that the oil (and the methane gas vapor cloud) evaporates and burns (Conroy, Ananth, and Tuttle, 2016; HAK, 2015). Burn efficiency is determined by dividing the volume of oil burned and evaporated by the total oil spilled. Burn efficiency can affect the spill volume and environmental impacts because the unburned oil can settle on the surrounding area. For 85–95 percent burn efficiencies, the estimated unburned oil volumes differed by about 240,000 bbl for a hypothetical WCD after 30 days (Conroy, Ananth, and Tuttle, 2016).

2.10.3 Well Capping

Well capping is another well control technique that could be used. If the original BOP has failed, a capping stack is brought in (Madrid and Matson, 2014). The capping stack includes a separate BOP ram (Madrid and Matson, 2014) and a connector module that connects the capping stack to the wellbore (Wijk, 2014). Capping is the installation of pressure control (or diverter) equipment (known as a capping stack) on the well to regain control of the blowout through post-capping kill operations. Post-capping kill operations can include direct shut-in (BOP or choke shut-in blind rams on the BOP are closed or fluid is diverted through a choke and shut-in (Abel, 1995)), bullheading, or a bullhead top kill operation in which kill mud and cement can be pumped through the capping stack (Wijk, 2014) when the well is on shut-in or diversion (Abel, 1995), and/or using the volumetric method. The volumetric method bleeds mud from the system to allow for gas expansion (Abel, 1995). The capping stack can shut-in and hold pressure on the blowout well using chokes/valves, and it can also provide for further wellbore intervention (Chen et al., 2013). The soft shut-in method refers to the chokes progressively limiting the flow (Madrid and Matson, 2014). The capping stack valves can also close and prevent the flow of oil (Chen et al., 2013). HAK (2015) states that the most likely method to stop the blowout after failure of the BOP on a gravel island is well capping and is similar to the primary mechanism for controlling on-land losses of well control. Hilcorp estimates the time to attain well control through the use of well capping is 10 to 20 days based on case studies (HAK, 2015, Section 14). Hilcorp considers the use of well capping and relief well drilling the best available and safest technology (HAK, 2015). Before capping could take place, the original drill rig would be moved off the wellhead to allow access for installation of the capping stack. If the rig moving system were disabled, then bulldozer, block and tackle, and/or crane would be used (HAK, 2015).

2.10.4 Relief Well

An operator drilling from a Mobile Offshore Drilling Unit (MODU) during the open water season in the Arctic OCS would comply with BSEE regulation 30 CFR § 250.472. What are the relief rig requirements for the Arctic OCS? A relief well is drilled during ongoing relief operations or after surface intervention methods have failed (Flores et al., 2014). After a relief rig has drilled a relief well down to the appropriate subsurface location to intercept the wellbore of the blowout well, kill fluid is then pumped from the relief well to the blowout well to regain well control (Flores et al., 2014; Wild Well Control, 2010). A relief well may be drilled from an existing gravel island assuming the island was within the area necessary for drilling a relief well (Bratslavsky Consulting Engineers Inc. and SolstenXP, 2018).

As previously mentioned, the availability and/or effectiveness of certain response and intervention techniques can depend on the type of the blowout and time. With respect to the specific discharge point of a blowout, three major distinctions factor into decisions about responses. Possible discharge paths include 1) at the surface (and the rig is not destroyed) through leak paths on the BOP or wellhead; 2) below the platform/seafloor, outside the wellbore; and 3) at the surface drilling location (and the rig is destroyed). Opportunities for operational intervention and response vary in each of these circumstances.

3 SCENARIO PHASES AND IMPACT-PRODUCING FACTORS

This chapter specifically identifies the ways in which the hypothetical VLOS event described in Chapter 2 could impact the environmental, social, or economic environment by phase. The intent of this chapter is to facilitate a thorough yet focused impacts analysis in Chapter 5.

The events constituting the VLOS scenario are first categorized into three distinct phases. These phases, which range from the initial LOWC escalating into a blowout event to long-term recovery, are presented chronologically. Within each phase, one or more components may cause impacts to the environment. These components are termed “Impact-Producing Factors,” or IPFs, and are used in Chapter 5 to guide the environmental, social, or economic impacts analysis. The specific IPFs listed here are intended to inform, rather than limit, the discussion of potential impacts.

3.1 Well Blowout Incident, Offshore Spill, and Onshore Contact (Phase 1)

Phase 1 of the hypothetical VLOS scenario comprises a LOWC escalating into a blowout and its immediate consequences. Potential IPFs associated with Phase 1 include the following:

- **Explosion.** Gas released during a blowout could ignite causing an explosion and the violent release of intense heat, toxic black smoke, and debris into the atmosphere.
- **Fire.** A blowout could result in a fire that will burn until the fire is extinguished, or the well is capped.
- **Redistribution of Sediments**. A subsea blowout could redistribute sediment along the seafloor.
- **Sinking of Rig**. The drill rig or platform could lose structural support, collapse, and sink to the seafloor.
- **Psychological/Social Distress.** News and images of the event could cause various forms of distress.
- **Contact with Oil or Natural Gas.** Offshore resources (including resources at surface, water column, and seafloor) could be contacted with spilled oil or natural gas. Onshore resources could come into direct contact with spilled oil or natural gas.
- **Contamination.** Pollutants from an oil spill and gas release may contaminate environmental resources, habitat, and/or food sources.
- **Loss of Access.** The presence of oil or gas could prevent or disrupt access to and use of affected areas.

3.2 Spill Response and Cleanup (Phase 2)

Phase 2 of the scenario encompasses spill response and cleanup efforts in offshore federal and state waters as well as onshore federal, SOA, trust, and private lands along the coastline. Potential IPFs associated with Phase 2 include the following and are categorized by season. See Section 2.9, Response, Recovery, and Cleanup Countermeasures, for a general description of responses year-round.

3.2.1 Summer Response

- **Vessels.** Vessels could be used in support of spill response and cleanup activities.
- **Aircraft.** Aircraft could be used in support of spill response and cleanup activities.
- **Vehicles.** Vehicles could be used in support of spill response and cleanup activities.
- **Skimmers.** Boats equipped to skim oil from the surface.
- **Booming.** Responders could deploy booms—long rolls of materials that float on the surface and corral oil, or sorbents that absorb oil.
- **In-situ Burning.** Remedial efforts may include burning of spilled oil. Operations could be monitored by air.
- **Dispersants.** Dispersants could be introduced into the environment.
- **Shoreline Cleaning.** Cleanup efforts including cold water washing, hand cleaning using oil absorbent materials, and placement and recovery of sorbent pads, could be used on beaches and other coastal areas contacted by an oil spill.
- **Co-opting of Resources.** Funds, manpower, equipment, and other resources required for spill response and cleanup would be unavailable for other purposes.
- **Bioremediation.** Contaminated material could be removed or treated by adding fertilizers or microorganisms that degrade oil.

3.2.2 Winter Response

- **Vehicles and Equipment.** Bulldozers, dump trucks, graders, front loaders, snowblowers, and snow machines could be used on ice roads, frozen ice, or snow for supporting spill response and mechanical recovery.
- **In-situ Burning.** Remedial efforts may include burning of spilled oil.

3.2.3 Shoulder Season Response

- **Vessels.** Airboats and workboats could be used in support of spill response and cleanup activities.
- **Vehicles and Equipment.** Hovercraft, trenchers, heavy equipment, and all-terrain vehicles could be used in support of spill response and cleanup activities.
- **In-situ Burning**. Remedial efforts may include burning of spilled oil. A helicopter could be used to support in-situ burning operations.
- **Skimmers.** Boats equipped to skim oil from the surface.
- **Booming**. Responders could deploy booms—long rolls of materials that float on the surface and corral oil, or sorbents that absorb oil.

3.2.4 All Seasons

- **Surveillance and Monitoring.** For an effective response, it is important to know the location, extent, thickness, and movement of spilled oil. Surveillance allows information sharing of deployment and response operations and provides information for protections of sites.

- **Wildlife Response.** Trained personnel conduct wildlife protection under a federal permit. They may use wildlife deterrents (hazing), pre-emptive capture and relocation of uncontaminated wildlife, capture and treatment of contaminated wildlife, and subsequent release, if appropriate, and recovery of contaminated carcasses to prevent the recontamination of other wildlife.
- **Drilling of Relief Well.** A drilling rig (either present or transported offshore to a location in open-water or the frozen ice season) could drill a relief well to control the blowout. The drilling rig cannot be transported during freeze-up or breakup conditions.
- **Waste Management.** Waste handling and associated activities are common to all response actions apart from natural recovery. Depending upon the size of the spill, response actions can produce large volumes of waste (contaminated soils, used sorbents, personal protection equipment) that are handled, stored, decontaminated, transported, and/or disposed of properly.

3.3 Post-Spill, Long-Term Recovery (Phase 3)

Phase 3 of the scenario focuses on the long-term. The exact length of time considered during this Phase would vary by resource. Potential IPFs associated with Phase 3 include the following:

- **Unavailability of Environmental Resources.** Environmental resources and food sources may become unavailable or more difficult to access or use.
- **Contamination.** Pollutants from an oil spill may contaminate environmental resources, habitat, and/or food sources.
- **Perception of Contamination.** The perception that resources are contaminated may alter human use and subsistence patterns.
- **Co-opting of Human Resources.** Funds, manpower, equipment, and other resources required to study long-term impacts and facilitate recovery would curtail availability for other purposes.
- **Psychological/Social Distress.** Distress stemming from a VLOS could continue into the long-term.
- **Damage Assessment Studies.** Through the Natural Resource Damage Assessment (NRDA) process, federal trustee agencies conduct numerous studies to identify the injuries from a spill, quantify the extent of natural resource damage, and specify the type and amount of restoration to compensate the public for the natural resource services that were injured or lost.

4 GENERAL OIL AND GAS BEHAVIOR AND EFFECTS

This chapter discusses the release, behavior, fate, and persistence of oil or gas in various environments and its subsequent general effects on resources. Accidental and research oil spills and/or gas releases in laboratory, tank, and field settings, provide scientific data regarding the behavior, fate, and impacts of crude oils and natural gas. Oil spills and gas releases to the environment can affect organisms in various acute and chronic ways.

4.1 Behavior and Fate of a Crude Oil Spill and Gas Release

Once oil enters the environment, it begins to change through physical, chemical, and biological processes. The constituents in crude oil break down over varying periods. Collectively, these processes are referred to as oil weathering and alter the chemical and physical characteristics and toxicity of spilled oil. Along with the weathering processes, the physical environment, depth of release, spill volume, and unique composition and physical properties of oil determine the oil’s fate in the environment (NRC, 1985, 2003, 2014).

Weather, ocean currents, sea ice, and temperature interact to disperse and volatilize oil slicks. Oil moves through the water horizontally and vertically by several processes including spreading, dispersion, advection (tides, current, and Langmuir circulation), entrainment, deposition to seafloor sediments, resuspension from seafloor, uptake and excretion by biota, and stranding on shorelines. Waves and winds can mix oil droplets on the surface into subsurface waters. The various mechanisms by which oil moves in seawater are also influenced by the type and degree of sea ice present and the location of the spilled oil (on the water, under the ice, encapsulated in the ice, or on top of the ice). When the ocean is covered with ice, oil may linger on the ice near the location of a blowout or move slowly away from the source. Spilled oil could linger under the ice, freeze into the ice, and disperse slowly in spring as sea ice melts. In the Beaufort Sea Planning Area, sea ice occurs seasonally and has a substantial effect on oil behavior (Dickins, 2011; Fingas and Hollebone, 2014; Lee et al., 2011; Wilkinson et al., 2017).

Figure 4-1 and Figure 4-2 show the major oil weathering processes include spreading, evaporation, dispersion, dissolution, emulsification, microbial degradation, photochemical oxidation, and sedimentation to the seafloor or stranding on the shoreline (Afenyo, Veitch, and Khan, 2016; Allen, 1980; Boehm, 1987; Lee et al., 2015; Payne et al., 1987; Tarr et al., 2016; Wiens, 2013). These processes are complex and act simultaneously as well as independently. Spreading, evaporation, dispersion, emulsification, and dissolution are most important during the early stages of a spill, whereas photo-oxidation, sedimentation, and biodegradation are longer-term processes. The time interval for these processes ranges from hours to decades (Farrington, 2014). Weathering removes the more volatile, highly soluble, and toxic lower-molecular weight components and leaves behind the less soluble, higher-molecular weight components with lower toxicity potential (Di Toro, McGrath, and Stubblefield, 2007).

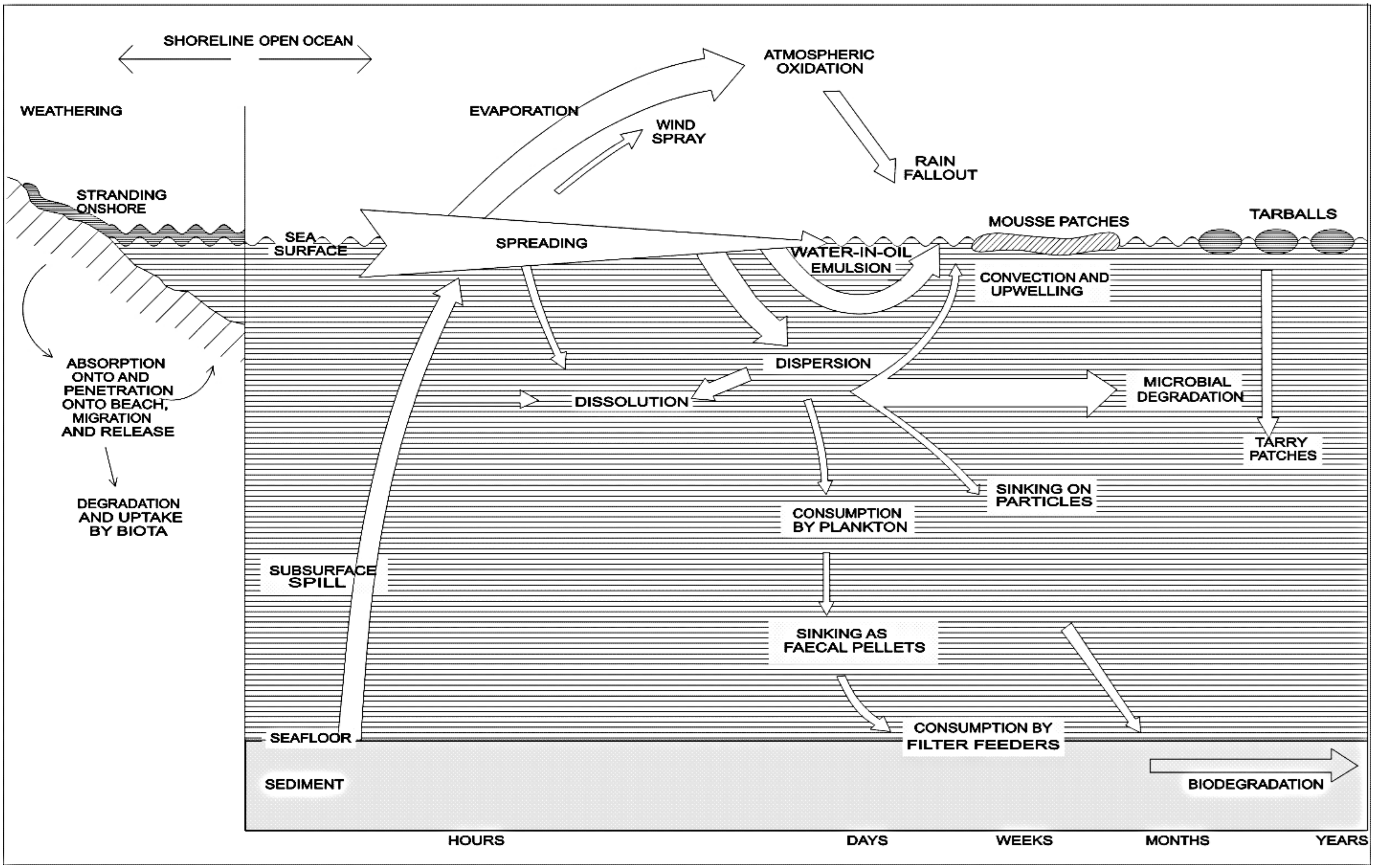


Figure 4-1 Oil Weathering in Open Water (Modified from Allen, 1980)

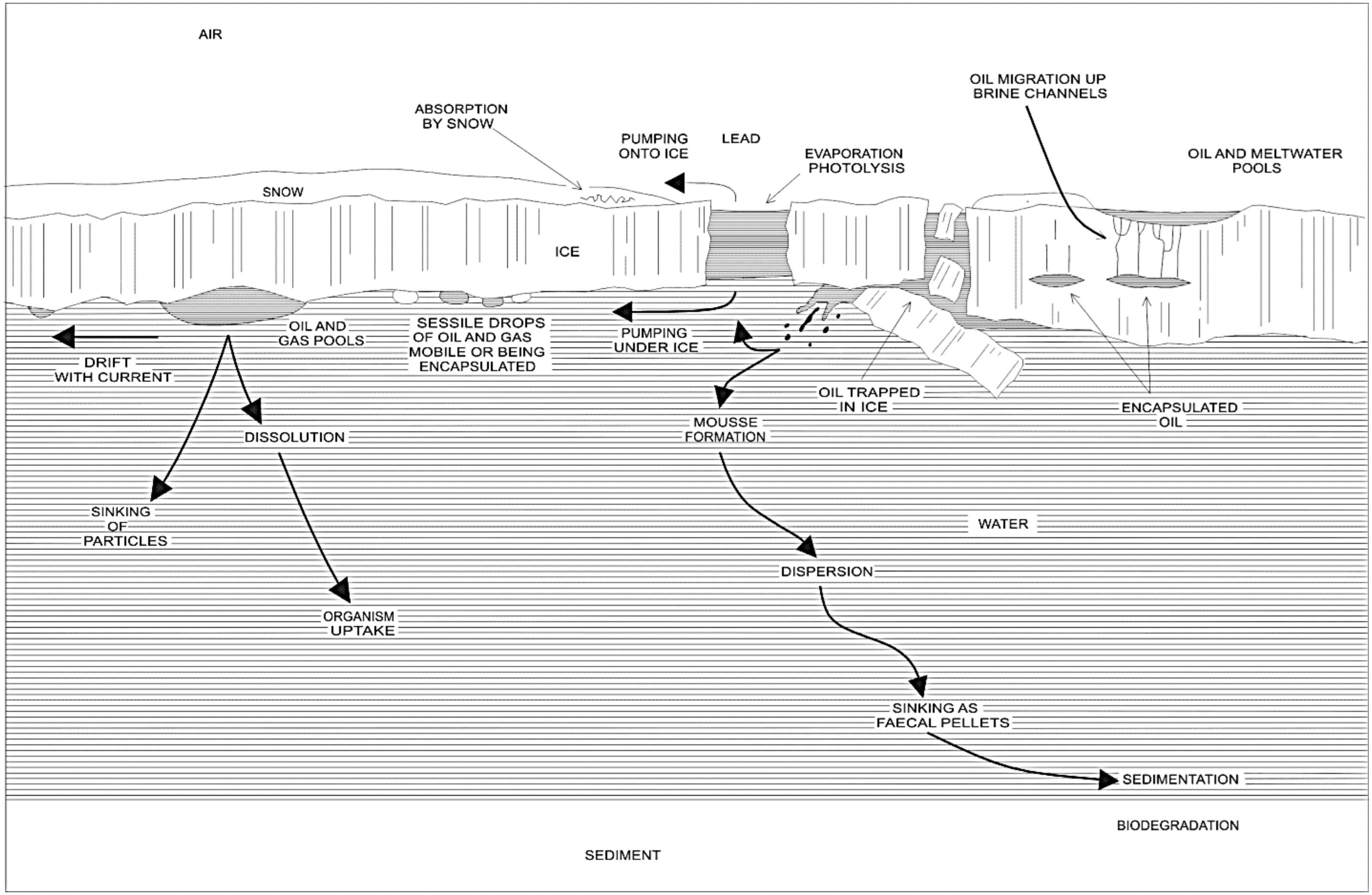


Figure 4-2 Oil Weathering in Ice (Modified from Allen, 1980)

Spreading. After a spill occurs, spreading and advection begin and are important processes in the first few hours of a spill. The term “spreading” describes the effects on oil by a variety of physical properties (including viscosity, buoyancy, and surface tension) as well as how it moves (advection). In open water, the oil spreads horizontally in an elongated pattern oriented in the direction of wind, waves, and currents and nonuniformly into thin sheens (0.5-10 micrometers (μm)) and thick patches (0.1-10 millimeters (mm)) (Elliott, 1986; Elliott, Hurford, and Penn, 1986; Galt et al., 1991). In the cooler subarctic and Arctic waters, oil spills spread less and remain thicker than in temperate waters because of differences in the viscosity of oil due to lower water temperature. In warmer temperature waters spills spread more rapidly.

In sea ice, spreading is dependent on the type and amount of sea ice. Oil spreading and ice floe motion were studied to determine how floe motion, ice concentration, slush concentration, and oil types affect spreading in ice. Spreading rates decreased as ice concentrations increased; but for ice concentrations <20–30 percent, spreading was similar to open-water (S.L. Ross Environmental Research Ltd. and D.F. Dickins Assocs. Ltd., 1987). An oil spill in broken ice would spread less and would spread between ice floes into any gaps greater than about 8–15 centimeters (cm) (3–6 inches (in)) (Free, Cox, and Shultz, 1982). Slush ice rapidly decreased spreading. If the ice-cover motion increased, then spreading rates increased; especially with slush ice present (Gjøsteen and Løset, 2004). Oil spilled beneath a wind-agitated field of pancake ice would be pumped up onto the surface of the ice or, if currents are slow enough, bound up in or below the ice (Payne et al., 1987).

During initial freeze-up, oil can freeze into the sea ice, be transported with the ice drift for long distances, and be released when melting occurs (Dickins, 2011). Under landfast ice the oil will move very little (Danielson and Weingartner, 2007). During the late spring, as ice warms, the entrainment potential of oil into the underside of ice is expected to increase (Petrich, Karlsson, and Eicken, 2013). The oil viscosity, pour point, and density play a major role in controlling the rate of migration in brine channels in a given ice salinity. Brackish ice provides fewer pathways and slows down the surfacing rate. Generally, the difference in timing of exposure of oil through migration channels is <10 days (MAR Inc. et al., 2008).

Evaporation. Evaporation results in a preferential loss of the lighter, more volatile organic compounds (VOCs), increasing density and viscosity, and reducing vapor pressure and toxicity (Mackay, 1985). Evaporation decreases the oil’s toxicity because the lighter more toxic VOCs dissipate. Evaporation contributes to the disappearance of oil from the sea surface. Evaporation of VOCs accounts for 30–40 percent of crude loss with approximately 25 percent occurring in the first 24 hours (Fingas, 2016; NRC, 1985). A laboratory analysis of oil spilled during the DWH event showed 23 percent of the oil evaporated within the first 2 hours following the initial explosion (de Gouw et al., 2011). The initial evaporation rate increases with increasing wind speeds, temperatures, and sea state. The rate of evaporation differs depending on volatility of the oil and increases with higher temperatures. The lower the temperature, the less crude oil evaporates as shown experimentally with both Prudhoe Bay and Endicott crudes (Fingas, 1996). Normal evaporative processes occur on spills in ice-covered waters, although at a lower rate (Jordan and Payne, 1980). Evaporation decreases in the presence of broken ice and stops if the oil is under or encapsulated in the ice (Payne et al., 1987; Brandvik and Faksness, 2009). Volatile components of the spill would be more likely to freeze into the ice rather than evaporate. Oil that is frozen into the underside of ice is unlikely to undergo any evaporation until its release in spring. In spring, as the ice sheet deteriorates, the encapsulated oil will rise to the surface through brine channels in the ice. As oil is released to the surface, evaporation will occur.

Dispersion. Dispersion of oil spills occurs from wind, waves, currents, or ice causing entrainment in the water column as well as the breakup of the oil spill. Entrainment is an important process that results in the transport of small oil particles (0.5 μm–several mm) or oil-in-water emulsions into the water column

(Jordan and Payne, 1980; NRC, 1985). Small droplets (<0.5 mm or less) rise slowly enough to remain dispersed in the water column (Payne and McNabb, 1985). The entrainment of oil and the breakup into droplets is also governed by separate parameters related to interfacial tension and viscosity. Except for high viscosity oil, oil properties did not influence entrainment but did influence the droplet size (Johansen, Reed, and Bodsberg, 2015; Zeinstra-Helfrich, Koops, and Murk, 2016).

The dispersion rate is directly influenced by sea state; the higher the sea state and breaking waves, the more rapid the dispersion rate (Mackay, 1985). The presence of broken ice also promotes dispersion (Payne et al., 1987). Any waves within the ice pack tend to pump oil onto the ice. Some additional oil dispersion occurs in dense, broken ice through floe-grinding action. More viscous and/or weathered crudes may adhere to porous ice floes, essentially concentrating oil within the floe field and limiting the oil dispersion.

Dissolution. Dissolution is very slow compared with evaporation; most volatiles usually evaporate rather than dissolve. Dissolution results in the loss of soluble, low molecular weight aromatics such as benzene, toluene, ethylbenzene, and xylene (BTEX) (NRC, 1985). Low molecular weight aromatics, which are acutely toxic, rapidly dissolve into the water column. The highest dissolution rates of aromatics from a slick occur in the first few hours of a spill and accumulate in the underlying water (Payne et al., 1984). The slick would become patchy, with the total area of isolated and discreet patches stretching orders of magnitude larger than the amount of surface area originally covered by oil. By the time dissolved oil reaches depths of 10 m (33 ft) in the water column, it becomes diluted and may spread horizontally over about 10,000 m (6.2 mi). Dissolved hydrocarbon concentrations underneath a slick tend to remain <1 part per million (ppm) (Malins and Hodgins, 1981).

Dissolved hydrocarbon concentration can increase due to the promotion of dispersion by broken ice (Payne et al., 1987). Faksness and Brandvik (2008a) studied the dissolved water-soluble components encapsulated in first year sea ice. Their data show a concentration gradient from the surface of the ice to the bottom, indicating there is transport of the dissolved components through brine channels. Field studies also showed that high air temperature leads to more porous ice, and the dissolved water-soluble components leak out rapidly, but under cold air temperatures and less porous ice, the water-soluble components leak more slowly and have potentially toxic concentrations (Faksness and Brandvik, 2008b).

Emulsification. Emulsified oil results from oil incorporating water droplets in the oil phase and generally is referred to as mousse (Mackay, 1982). The measurable increases in viscosity and specific gravity observed for mousse change its behavior, including spreading, dispersion, evaporation, and dissolution (Payne and McNabb, 1985). The formation of mousse slows the subsequent weathering of oil and makes the oil more persistent. The presence of slush ice and turbulence promotes the formation of oil-in-water emulsions (Payne et al., 1987). The viscosity of the oil at ambient temperatures, the availability and amount of mixing energy, and the asphaltene content can influence when an emulsion can form (MAR Inc. et al., 2008).

Microbial Degradation. Microbial degradation of hydrocarbons is an important process by which substantive fractions of spilled oil are weathered or eliminated from the environment. In a variety of environments, both terrestrial and marine, microorganisms have evolved over time to utilize petroleum hydrocarbons as a source of carbon and energy (Atlas and Hazen, 2011; Prince, Gramain, and McGenity, 2010). Natural oil seeps are found throughout the subarctic and Arctic nearshore and offshore (NRC, 2003), and provide a continuous food source for oil-degrading microorganisms (Hazen, Prince, and Mahmoudi, 2016).

Oil-degrading microorganisms reduced the size of both the EVOS and DWH oil spills (Atlas and Hazen, 2011). The potential for subarctic and Arctic marine bacteria to degrade oil has been studied (Atlas et al., 1983; Braddock, 1998; Braddock, Gannon, and Rasley 2004; McFarlin et al., 2014; Sharma and Schiewer, 2016). These studies indicate oil-degrading microorganisms exist within the Alaska OCS and are thought to occur widely throughout the region. Biodegradation rates in cold and temperate environments are similar (Braddock and McCarthy, 1996; McFarlin et al., 2014; Sharma and Schiewer, 2016). These subarctic and Arctic microorganisms have adapted to cold temperatures.

Photo-oxidation. Photo-oxidation is the process by which oil exposed to solar radiation undergoes oxidation resulting in the generation of polar, water-soluble, oxygenated products. Photo-oxidation is an additional process that contributes to the degradation and transformation of crude oil compounds after their release into the environment (Garrett et al., 1998; Dutta and Harayama, 2000; Prince et al., 2003). Light intensity near the water's surface will be lower at northern latitudes due to a low angle of incidence, and the Alaska OCS Region has a wide range of daylight hours based on the season. Due to longer exposure times during the summer months, photo-oxidation may be a much more important process for oil degradation in northern than in more temperate climates (Serova, 1992; Ivanov et al., 2005). Recently, Ward et al. (2018) argued that photo-oxidation played a much greater role in the DWH oil spill and that text and models should be revised to consider the greater contribution of the photo-oxidation process.

Sedimentation. Oil and oil residues can interact with settling particles in the water column, providing a natural removal process from the sea surface to the seafloor (Tarr et al., 2016). A small portion of the oil from a surface spill would be deposited in the sediments in the immediate vicinity of the spill or along the pathway of the slick. The observed range in deposition of oil in bottom sediments following offshore spills is 0.1–8 percent of the slick mass (Jarvela, Thorsteinson, and Pelto, 1984) and in the DWH oil spill, approximately 5–10 percent of the spilled oil reached the seafloor (Chanton et al., 2015; Valentine et al., 2014). Sediments, marine snow, and tarballs can facilitate the sedimentation of oil in both the nearshore and offshore. Marine snow is particles of mostly organic debris, such as dead or decomposed organisms, fecal matter, and sand, that drift downward through the ocean from the upper levels, serving as a food source for a variety of organisms inhabiting the deeper regions where sunlight does not reach. Generally, a higher percentage of deposition occurs in spills nearshore where surf, tidal cycles, and other inshore processes can mix oil into the bottom (Manen and Pelto, 1984).

Sediments can interact with dispersed oil droplets or dissolved oil components by direct aggregation to form oil-suspended particulate matter aggregates as well as adsorption on or incorporation in the sediment phase (Gong et al., 2014; Lee, 2002; Sterling et al., 2005). The added density can sink these particles to the seafloor. Oil stranded on the shoreline can also become mixed with sediments, wash off the beach, and be deposited.

Oil-associated marine snow was identified during the DWH (Passow, 2016). These oil-marine snow particles are microbially processed and their density increases until they sink to the seafloor (Passow et al., 2012). Yan et al. (2016) described black carbon sedimentation derived from the in-situ burning of surface oil slicks for about 2 months following the completion of burning as well as the episodic sinking of spill-associated substances mainly being mediated by marine particles, especially diatoms.

As a result of various physical and chemical processes, oil can eventually coagulate into residues called tarballs (Warnock, Hagen, and Passeri, 2015). Through time, tarballs may settle out of the water column or beach in the nearshore. Varying in size, most are coin shaped, can travel hundreds of miles, and are persistent in the environment (NRC, 2003). Beyer et al. (2016) provides a summary of the chemical studies performed on tarballs resulting from the DWH blowout. Composed of chemicals characteristic of crude oil, these environmentally persistent and recalcitrant components of the oil and oil residues can remain for a long time at oil-impacted beach environments.

Exposure, Fate, and Persistence. The nature and extent of oil spill effects on organisms, populations, and ecosystems (biological resources) varies widely. Biological resources using the water surface may be injured by exposure to surface slicks, and those living in the water column may be injured by exposure to dissolved and dispersed oil in the water column. Risk of injury is directly related to oil's physical properties, chemical composition, and concentrations, and to its physical and chemical transformations as it spreads on or through the water column (Boehm, Neff, and Page, 2013). Regardless of whether released at the surface or into the subsurface, petroleum constituents can undergo processes that partition oil components into different physical forms (dissolved, droplet, and particulate phases) and alter the form and composition of the oil.

The fate of oil in the environment depends on many factors, such as the source and composition of the oil, as well as its persistence (NRC, 2003). Persistence can be defined and measured in different ways (Davis et al., 2004), but the National Research Council (NRC) generally defines persistence as how long oil remains in the environment (NRC, 2003). The persistence of an oil slick is also influenced by the effectiveness of management and oil spill response efforts and affects the resources needed for oil recovery (Davis et al., 2004). The persistence of an oil slick may also affect the severity of the impacts from the spilled oil. Persistence is related to how an oil spill may interact with the various types of shoreline. The amount and distribution of oil on a shoreline and its persistence is a function of beach geomorphology and wave action exposure (Evans et al., 2017, Lindeberg et al., 2018; Michel et al., 2013; Page et al., 2013).

Oil spill response efforts can move impacts from one portion of the environment or resource to another. In-situ burning and burn residue studies have indicated an increase in heavy polycyclic aromatic hydrocarbons (PAHs) (Fritt-Rasmussen, Wegeberg and Gustavson, 2015). The PAH increase is related to the type of oil (Buist et al., 1999) and the efficiency of the burn (Gustavson et al., 2012). PAHs are ubiquitous in an oil spill but burning may transfer the bioaccumulation potential to different portions of the environment and organisms.

Crude Oils. Crude oils are not a single chemical but instead are complex mixtures of thousands of compounds made up of carbon and hydrogen (hydrocarbons), plus other compounds containing sulfur, oxygen, nitrogen, and metals. Thus, the behavior of the oil and the hazard the oil poses to natural and social resources depends on the composition of the specific oil encountered (Michel, 1992). Generally, oils can be divided into three groups of compounds: (1) lightweight; (2) medium-weight; and (3) heavyweight components. In general, these groups are characterized as outlined in Table 4-1.

The oil reservoirs sampled in and adjacent to the Alaska OCS fall within the lightweight to medium-weight category. The one exception is the offshore Hammerhead oil field (15.5 mi (25 km) north of Point Thomson) which features an anomalously heavy biodegraded crude oil (19° API) (Curiale, 1995; NRC, 2014). Oil with an API gravity of 10° or less would sink and has not been encountered in the Alaska OCS; therefore, it is not analyzed in this document. Heavyweight oil may persist in the environment longer than the other two categories of oil, but the medium-weight components within oil present the greatest hazard to organisms because, with the exception of the alkanes, these medium-weight components are persistent, bioavailable, and toxic (Michel, 1992).

Table 4-1 Properties and Persistence by Oil Component Group

Properties and Persistence	Lightweight	Medium-Weight	Heavyweight
Hydrocarbon Compounds	Up to 10 carbon atoms	10–22 carbon atoms	>20 carbon atoms
APIº Gravity	>31.1º	31.1º–22.3º	<22.3º
Evaporation Rate	Rapid (within 1 day) and complete	Up to several days; not complete at ambient temperatures	Negligible
Solubility in Water	High	Low (at most a few milligrams/liter)	Negligible
Acute Toxicity	High because of monoaromatic hydrocarbons (BTEX)	Moderate because of diaromatic hydrocarbons (naphthalenes—2 ring PAHs)	Low, except because of smothering (heavier oils may sink)
Chronic Toxicity	None, does not persist because of evaporation	Moderate because PAH components (naphthalenes—2 ring PAHs)	Moderate because PAH components (phenanthrene, anthracene—3 ring PAHs)
Bioaccumulation Potential	None, does not persist because of evaporation	Moderate	Low, may bioaccumulate through sediment sorption
Compositional Majority	Alkanes and cycloalkanes	Alkanes that are readily degraded	Waxes, asphaltenes, and polar compounds (not significantly bioavailable or toxic)
Persistence	Low because of evaporation	Alkanes readily degrade, but the diaromatic hydrocarbons are more persistent	High; very low degradation rates and can persist in sediments as tarballs or asphalt pavements

Key: API = American Petroleum Institute; BTEX = benzene, toluene, ethylbenzene, and xylene; PAH = polycyclic aromatic hydrocarbon.

Source: Michel, 1992; Michel and Rutherford, 2013.

Chemical Classes of Crude Oil. There are four main classes of compounds in crude oil: saturated hydrocarbons, aromatic hydrocarbons, asphaltenes, and resins. When crude oil is released into the aquatic environment, the aromatic hydrocarbons are of greatest concern due to their persistence and potential toxicity to marine organisms. This class of hydrocarbons contains the acutely toxic monoaromatics (one 6-carbon benzene ring) of benzene, toluene, ethylbenzene, and xylene isomers—referred to as BTEX—and the polycyclic aromatic hydrocarbons (2 or more 6-carbon benzene ring) known as PAHs. Volatile aromatic hydrocarbons, namely the BTEX, are frequently the most abundant aromatic hydrocarbons in crude oils. They are also the most toxic because they are relatively water-soluble. Exposure durations to BTEX are generally brief, rarely persisting in the water column long enough to injure biological resources (Neff, 1979; Boehm, Neff, and Page, 2013) because they are lost rapidly by evaporation (Page et al., 2002).

BTEX and the lightweight PAHs (2- and 3-ring aromatics) make up at least 90 percent of the aromatic hydrocarbons in crude oil and the more toxic and higher molecular weight PAHs (4-rings and greater) occur in much lower concentrations (Wiens, 2013). To determine the overall toxicity of PAHs in water or sediment, the contributions of every individual PAH compound in the petroleum mixture must be included (EPA, 2011b). PAH compounds, on the other hand, are less volatile, rapidly tend to become associated with particulates, and are more likely to occur in bottom sediments (Neff, 1979). The weathering process of oil and the inherent transformations of oils' physical and chemical characteristics determines its fate, persistence, and toxicity (Boehm, Neff, and Page, 2013).

Hydrocarbon toxicity (either in marine water or sediments) is strongly correlated to hydrocarbon solubility (Di Toro, McGrath, and Stubblefield, 2007). Sediment properties such as particle size, surface area, concentration, and surface chemistry play an important role in oil-sediment interactions (Gong et al., 2014), and hydrocarbons in solution in sediment pore water are the most bioavailable and toxic to marine organisms. However, the higher molecular weight hydrocarbon components typically found in crude oil-contaminated sediments have a higher affinity for the oil phase and very little partitions into the pore water (Page et al., 2002). Research suggests that the toxicity of weathered oil residues in marine sediments are not from the oil residue components themselves, but from the toxic byproducts of photo- and biodegradation (Page et al, 2002; Neff et al., 2000; Tarr et al., 2016; Wolfe et al., 1995). Hydrocarbon degrading-bacteria produce water-soluble metabolites of aliphatic and aromatic hydrocarbons, and may produce toxic levels of ammonia and sulfide, all of which contribute to the toxicity of the water (Page et al., 2002).

Natural Gas. Gases associated with crude oil are commonly referred to as natural gas. Natural gas is primarily composed of methane (CH_4) and ethane (C_2H_6) which make up 85–90 percent of the volume of the mixture. Methane is a colorless, odorless, and tasteless gas. It is not toxic in the atmosphere, but is classified as a simple asphyxiate, possessing an inhalation and explosion hazard (Baldassare and Chapman, 2018; Speight, 2007). As with all hydrocarbon gases, if inhaled in high enough concentration, oxygen deficiency could occur and result in suffocation. The specific gravity of methane is 0.55 (Air = 1.0). Being lighter than ambient air, it has the tendency to rise and dissipate into the atmosphere rather than settle into low areas. Upon reaching the surface, the gaseous methane would react with air forming water and carbon dioxide (CO_2) which would then disperse into the atmosphere.

An ideal gas is a gas with a very simple relationship between pressure, volume, and temperature. For well control incidents at shallow to moderate depths, the gas is considered an ideal gas with a specific volume decreasing linearly with pressure. Dissolution of gas from rising bubbles may be minimal for incidents at shallow to moderate depths since the residence time of gas bubbles is expected to be short (Reed et al., 2006). In shallow to moderate water depths, the force from the rising gas of a blowout could break the ice (Dickins, Buist, and Pistruzak, 1981). Experimental gas releases in the Arctic indicated gas uplifted the ice sheet and vented through the cracks early in the season but also remained as gas pockets underneath the undulating ice surface in late winter (Dickins and Buist, 1981).

In deep water, leaked methane is compressed by ambient pressure such that it does not form bubbles and enters the water in a dissolved phase. Limited research is available for the biogeochemistry of hydrocarbon gases in the marine environment (Patin, 1999). Dissolved gas is neutrally buoyant and will not float to the surface. Instead, the dissolved gas moves with the water as it drifts in currents and interacts with particulate organic matter (Karl and Tilbrook, 1994). Theoretically, methane could stay in the marine environment for long periods of time (Patin, 1999) as methane is highly soluble in seawater at the high pressures and cold temperatures found in deepwater environments (NRC, 2003, p. 108). Methane diffusing through the water column would likely be oxidized in the aerobic zone and would rarely reach the air-water interface (Mechalas, 1974). Methane is a carbon source and its introduction into the marine environment could result in diminished dissolved oxygen concentrations due to microbial degradation.

The DWH explosion and oil spill resulted in the emission of an estimated 9.14×10^{9} to 1.29×10^{10} moles of methane from the wellhead (Kessler et al., 2011; Valentine et al., 2010) with maximum subsurface methane concentrations of 183–315 micromoles (Valentine et al., 2010; Joye et al., 2011). Methane released from the DWH explosion and oil spill was generally confined to the subsurface, with minimal amounts reaching the atmosphere (Kessler et al., 2011; Ryerson et al., 2011). Because of the depth of the DWH spill, nearly all of the gas remained in the deep ocean, forming plumes of dissolved or dispersed hydrocarbons (Kessler et al., 2011; Ryerson et al., 2011; Valentine et al., 2010). This methane release corresponded to a measurable decrease in oxygen in the subsurface plume due to respiration by a community of methanotrophic bacteria (Joye et al., 2011; Kessler et al., 2011; Yang et al., 2016). The researchers further suggested that a vigorous deepwater bacterial bloom respired nearly all the released methane within this time. By analogy, large-scale releases of methane from hydrates in the deep ocean are likely to be met by a similarly rapid methanotrophic response. However, hypoxic conditions were never reached (OSAT, 2010). Hypoxic conditions are generally believed to occur when dissolved oxygen falls below 2 milligrams/liter (1.4 milliliter/liter) (OSAT, 2010).

4.2 General Effects of Oil and Gas on Resources

The processes controlling the fate of spilled or released hydrocarbons are accompanied by interactions with the physical, biological, and social environment (Beyer et al., 2016; Chang et al., 2014). Most, but not all, of these interactions have adverse impacts of varying lengths depending on the concentration and exposure conditions. The effects of oil or gas on the ecosystem will depend on the effects on particular species, the species' spatial and temporal distribution, interactions among or between species, and persistence of oil within habitats.

The types of acute and chronic effects of spilled oil on marine and terrestrial organisms, ecosystem, and social systems are discussed for estuarine, coastal, and continental shelf areas, as are periods of recovery from effects of spilled oil or a natural gas release. Individual spills differ in many important details. However, common fates, processes, and the same or similar effects across several oil spills or gas releases have been noted. It is now reasonably accepted that the longest lasting effects (years to decades in some cases) occur when spilled oil enters coastal wetlands such as marshes or cobble armored beaches and in some cases subtidal mud areas.

4.2.1 Air Quality

The airborne constituents associated with a release of crude oil would release potentially harmful emissions into the atmosphere, particularly those pollutants regulated under the Clean Air Act (CAA): nitrogen dioxide (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and particulate matter (PM_{10} and $PM_{2.5}$). An oil spill or gas release would also include volatile organic compound (VOC) emissions, which are a precursor to ozone (O_3). Additional airborne constituents associated with oil or natural gas releases, which have environmentally harmful consequences, are methane (CH_4) and black carbon. Mechanisms that lead impacts on air quality include:

- Aerosol formation by wind and wave action can transfer oil components into the atmosphere (Aeppli et al., 2013; Arey et al., 2007; de Gouw et al., 2011).
- Evaporation of volatile components degrades air quality in the immediate vicinity of the spilled oil (Hanna and Drivas, 1993; Harrill et al., 2014; Middlebrook et al., 2012).
- A fire or in-situ burning response operations increase emissions of NO_X, SO_2, and CO, but decrease emissions of VOCs as compared to evaporation (Fingas, 2017).
- Response operations increase aircraft, surface vehicle, and ship emissions (Middlebrook et al., 2012).

Oil spills, whether occurring at an exploration or production facility, or over water, would lead to localized evaporative emissions. Computer modeling conducted to evaluate emissions from oil spills considered several different VOC and other compounds including benzene, ethylbenzene, toluene, and o-xylenes, which are classified by the EPA as hazardous air pollutants (HAP). The results showed that these compounds vaporize almost completely within a few hours following a spill. The ambient concentrations would peak within the first several hours after a spill and would be reduced by two orders of magnitude after about 12 hours (Hanna and Drivas, 1993). Emissions of VOC would be high initially due to evaporation of freshly surfaced oil. A laboratory analysis of oil spilled during the DWH event showed the first 23 percent of the oil evaporated within the first 2 hours following the initial explosion. During the DWH, the emissions of VOC were confined to a relatively narrow plume as the sea surface transport of oil did not exceed a few kilometers (de Gouw et al., 2011).

Situations where a spill is caused by or is immediately followed by fire would result in a large black smoke plume containing PM (PM_{10}, $PM_{2.5}$, and black carbon) and other products of combustion, such as

NO_X, SO_2, CO, VOC, and CO_2. The fire could also produce PAHs, a type of VOC, which are known to be hazardous to human health. In particular, the intense heat of the fire would elevate the level of NO_x emissions, and concentration of PM in the initial smoke plume would have the potential to temporarily degrade visibility in the immediate area. It is also during this phase that black carbon has the highest chance of being deposited on the surface, perhaps even leading to localized accumulation of black carbon. The location of high pollutant concentrations due to the smoke depends on the stability of the atmosphere at the time of the explosion. The rising plume of pollutants would become increasingly diluted with height, and surface concentration levels would not be as high in the immediate vicinity of the fire (Evans et al., 1991). Over time, wind would transport the smoke plume and eventually affect areas outside the immediate vicinity of the fire.

4.2.2 Water Quality

The effects of oil spills and gas releases on water quality are dependent on type of oil and its chemical characteristics: how and where the oil is released into the water, the ambient temperature, sediment type and quality, and other environmental factors of the receiving environment at the time of the release. The fate and behavior of spilled oil, including weathering processes, also influence its impacts on water quality (Section 4.1). Physical, chemical, and biological processes in the aquatic environment, coupled with the specific composition of the spilled oil, impact water quality.

- Impairment of water quality is regulated through the Clean Water Act (CWA) administered by the EPA, and the SOA’s Water Quality Standards, 18 Alaska Administrative Code (AAC) 70 (ADEC, 2018).
- Water quality impacts are influenced by the spills’ initial release to either the surface water, subsurface, or seafloor affecting the distribution, composition, and persistence of oil constituents (Boehm, Neff, and Page, 2013; Camilli et al., 2010).
- Toxicity and persistence of petroleum hydrocarbons varies with time, specific hydrocarbons, and location within the water column (Allen, Smith, and Anderson, 2012; Capuzzo, 1987; Neff, 2002; Neff and Durrell, 2011; Speight, 2007; Wiens, 2013).
- Fate, toxicity, bioaccumulation, and bioavailability of petroleum settling to the seafloor or shoreline varies due to sediment type and quality (Allen, Smith, and Anderson, 2012; Capuzzo, 1987; Neff, 1979, 2002; Neff and Durrell, 2011; Sharma and Schiewer, 2016; Wade et al., 2011; Wang et al., 2003).
- Natural gas displaces oxygen in the water column and, when released at depth, has been linked to an increase of methanotrophic activity (Joye et al., 2011; Valentine et al., 2010; Wimalaratne et al., 2015; Yvon-Lewis, Hu, and Kessler, 2011).

Regulatory Administration of Clean Water Act. The EPA administers and enforces the CWA in cooperation with other federal agencies, native tribes, state governments, municipal governments, and industries. Currently, the water quality of the Beaufort Sea OCS meets the CWA’s Section 303(d) criteria for the protection of marine life, and no bays, inlets, lagoons or other waterbodies of the Beaufort Sea are identified as impaired by the SOA (ADEC, 2018). This rating indicates that the water quality of the Beaufort Sea is good and is not impaired by pollutants.

Numeric Water Quality Criteria for Petroleum Hydrocarbons. There is no federal numeric water quality criterion for collective hydrocarbons that definitively concludes the level of impact of oil on water quality (EPA, 1986). The SOA, however, has adopted water quality standards, including human health and aquatic life criteria, for toxic substances at 18 AAC 70 for marine waters. These criteria provide a numerical benchmark useful in assessing the level of toxicity in the water column resulting from hydrocarbon contamination. Specifically, the applicable criteria are:

1. total aqueous hydrocarbons (TAqH) in the water column may not exceed 15 µg/L (15 parts per billion (ppb));
2. total aromatic hydrocarbons (TAH) in the water column may not exceed 10 µg/L (10 ppb); and
3. surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration (ADEC, 2008).

The measurement of TAqH in a water or sediment sample is the result of summing the highly volatile total aromatic hydrocarbons (TAH — also known as BTEX) and PAH compounds. Another useful measurement in the water column is total petroleum hydrocarbons (TPH). In the event of an oil spill, it is typical to measure and analyze for TAqH, PAH, TAH, and TPH in the water column. TPH themselves may not be a direct pointer of hazard to humans or the environment, but their presence indicates the health status of the water body and is also used for source tracking of the contaminants in the coastal waters and sediments (Adeniji, Okoh, and Okoh, 2017).

Vessel Spills. Where oil is released to the sea surface from vessels (Exxon Valdez, North Cape, Selendang Ayu, Prestige), the concentrations of hydrocarbons in the water column to which organisms are exposed, and the resulting biological effects, are likely to be short-lived, when compared with subsea and subsurface oil spills. This, in part, is due to the low persistence of surface oil slicks and dissolved and dispersed oil constituents as they are mixed into the subsurface water by waves (Boehm, Neff, and Page, 2013).

EVOS was, until the DWH oil spill in the Gulf of Mexico, the most comprehensively sampled oil spill and remains the largest tanker oil spill in U.S. history (Boehm, Neff, and Page, 2013). No water column-PAH measurements were made during the first week after the spill, therefore, it is unknown what the levels of PAH in the water column measured. Wolfe et al. (1994) estimated that approximately 23 percent of the oil released was dispersed into the near-surface water column over an area of 10×10^8 m^2 during a storm that occurred 3 days after the spill. Theoretical concentrations of total PAH (TPAH) in the upper 10 m of the water column were estimated at 12 µg/L (Boehm, Neff, and Page, 2013).

One week after the EVOS spill, concentrations of TPAH in the upper 30 m of the spill zone's water column were sampled and measurements from March 31 through April 1989 ranged from <0.01 to 41.6 µg/L, with most samples containing <1 µg/L. Of the entire 1989 National Oceanic and Atmospheric Administration (NOAA) and Exxon data set of 1,626 water samples, 9 samples contained TPAH concentrations that exceeded the SOA's water quality standard of 10 µg/L. Samples from 1989 in which TPAH >10 µg/L were rare, and none over 1 µg/L were found in 1990.

The results of the NOAA and Exxon water sampling program present a consistent picture of the changes in the ambient water PAH concentrations over time. Elevated levels of TPAH occurred during the month after the spill and were measured at background levels by 1990–1991 (Boehm, Neff, and Page, 2013).

Surface and Subsurface Oil Spills from Well Blowouts. Prolonged oil releases from well blowouts in subsurface waters have the potential to impact the entire water column to varying depths depending on the flow rate of the release. Plumes of oil droplets are dispersed within the water column and these oil droplets may adsorb onto marine detritus and suspended sediments, or they may be mixed with drilling mud and deposited near the source (BOEM, 2017; Gong et al., 2014). The release scenario, as well as the application of chemical dispersants at or below the water surface, affects the distribution, composition, and persistence of oil constituents in the water column (Boehm, Neff, and Page, 2013).

Estimates of the rate of release of oil during the first 4 months of the Ixtoc I blowout range from 10,000 to 30,000 bbl per day. The dispersant, Corexit 9527, was applied to surface waters via aerial application to disperse oil in the region. Field evaluation by the Gulf Universities Research Consortium (Linton and Koons, 1983), indicated that the dispersant effectively dispersed the Ixtoc I crude from the surface into the upper 3 m (9.8 ft) of the water column. This observation is validated by the water sampling program performed by Boehm and Fiest (1982) as part of a NOAA-sponsored study. Four months into the Ixtoc I release, liquid hydrocarbons in the subsurface plume still measured >10,000 µg/L within 8 km (4.3 nautical miles (nmi)) of the release, to 20 µg/L at 24 km (12.9 nmi) from the release, and to 5 µg/L at 40 km (21.6 nmi) from the release (Boehm and Fiest, 1982). Limited biological studies during and following the spill did not reveal adverse effects (NRC, 1989).

At the Ekofisk Bravo release in the North Sea (1977, surface), concentrations of volatile liquid hydrocarbons (present mostly as an oil-in-water emulsion) ranged up to 0.35 ppm within 19 km (10.2 nmi) of the site, starting 1.5 days into the 7.5-day release (Grahl-Nielsen, 1978). Lesser amounts of oil (<0.02 ppm) were detectable in some samples 56 km (30.2 nmi) from the site, but not at 89 km (48 nmi). In more restricted waters during flat calm, a test spill during the Baffin Island Oil Spill Project resulted in maximum hydrocarbon concentrations in the water column of 1–3 ppm (Green, Humphrey, and Fowler, 1982). These concentrations were reached within 2 hours of the spill and persisted through 24 hours. No oil was detected deeper than 3 m (9.8 ft), and the most oil and highest concentrations were in the top 1 m (3.3 ft) (Mackay and Wells, 1983).

In the DWH well blowout, water quality sampling was performed throughout the entire water column, from the seafloor (about 1,500 m or 4,921 ft) to the surface. The use of chemical dispersants both at the deep point of release and on the water's surface necessitated sampling and measuring other chemicals in addition to PAHs. Crude oil from the DWH contained approximately 3.9 percent PAHs by weight, which results in an estimated release of 2.1 x 10^{10} grams of PAHs (Reddy et al., 2012). Camilli et al. (2010) conducted a subsurface hydrocarbon study 2 months after the DWH seafloor release in the Gulf of Mexico. They found a continuous oil plume at a depth of approximately 1,100 m (3,609 ft) that extended for 35 km (21.7 mi) from the release site. The plume consisted of monoaromatic hydrocarbons (BTEX) at concentrations >50 µg/L. The plume persisted for months at this depth with no substantial biodegradation. They also measured concentrations throughout the water column and found similarly high concentrations of aromatic hydrocarbons in the upper 100 m (328 ft). PAHs were found at very high concentrations (reaching 189 µg/L) by Diercks et al. (2010) after the DWH at depths between 1,000 and 1,400 m (3,280–4,593 ft) extending as far as 13 km (7.0 nmi) from the subsurface release site.

Low molecular weight alkanes (i.e., methane, ethane, propane and iso- and n-butanes) are constituents of crude oil and natural gas, with methane being the most abundant low molecular weight hydrocarbon (Cline, 1981). Releases of natural gas into the water column displace oxygen and, when released at depth, have been linked to an increase of methanotrophic activity (Weber, et al., 2016; Wimalaratne, et al., 2015; Yvon-Lewis, Hu, and Kessler, 2011). Rapid methane releases could especially result in multiple small-scale anoxic zones (Joye, et al., 2011). Joye et al. (2011) estimated that the DWH released 500,000 tons of hydrocarbon gases at depths, comprising approximately 40 percent of the total hydrocarbons released. Methane, ethane, propane, butane, and pentane were measured throughout the water column. They found high concentrations of dissolved hydrocarbon gases in a water layer between 1,000 and 1,300 m (3,280–4,265 ft). These concentrations exceeded the background concentration of hydrocarbon gases by up to 75,000 times. Results from a study by Yvon-Lewis, Hu, and Kessler (2011) showed that beginning 53 days after the DWH and for 7 days of continuous chemical analysis at sea, there was a low flux of methane from the DWH release to the atmosphere. Based on these methane measurements at the surface water and on current measurements at depth, they concluded that the majority of methane from the release remained dissolved in the deep ocean waters. Valentine et al. (2010) reported that two months after the DWH release, propane and ethane gases at depth were the major gases driving rapid respiration by bacteria. They also found these gases at shallower depths but at concentrations that were lower by orders of magnitude. Multiple plumes transported in different directions were detected at depth, indicating complex current patterns.

Methane release in the DWH and biodegradation by deepwater methanotrophs was studied by Kessler et al. (2011). They found that a deepwater bacterial bloom respired the majority of the methane in approximately 120 days. Similarly, Hazen et al. (2010) found indigenous bacteria at 17 deepwater stations biodegrading oil 2–3 months after the DWH release. Kujawinski et al. (2011) studied the fate of 771,000 gallons of chemical dispersants injected at the DWH wellhead near the seafloor (1,500 m or 4,921 ft). Their results show that the dispersants injected at the wellhead were concentrated in hydrocarbon plumes at 1,000–1,200 m (3,281–3,937 ft) depth 64 days after dispersant application was stopped and as far away as 300 km (161 nmi). They concluded that the chemical dispersants injected at the wellhead underwent negligible or slow rates of biodegradation in the affected waters.

The DWH release occurred at a depth of 1,500 m (4,921 ft), whereas potential Beaufort Sea drilling would likely be less than 91.4 m (300 ft). This difference in depth is important given how gas and liquids behave differently at various pressures. It is likely that more gas will remain in solution (dissolved) at greater depths.

Water temperatures in the Beaufort Sea are similar to the deepwater temperatures in the Gulf of Mexico. Both methane and petroleum hydrocarbon degraders are present and active in the Beaufort Sea ice, water, and sediment (Atlas, Horowitz, and Busdosh, 1978; Braddock, Gannon, and Rasley, 2004; Damm et al., 2007; Gerdes et al., 2005), suggesting that the Beaufort Sea could likely support similar levels of hydrocarbon (including methane) degradation.

4.2.3 Vegetation and Wetlands

Impacts of oil spills to vegetation and wetlands depend on the type and amount of oil, the amount of plant coverage, the plants' seasonality at the time of the release (spring vs. fall), the depth of penetration of the oil into the sediments, and the type and effectiveness of any cleanup or remedial actions (NRC, 2003). Impacts of oil spills on vegetation and wetlands include:

- Crude oil persistence impacts wetlands and shorelines with low-permeable, fine-grained sediments (Atlas and Bragg, 2013; Harper and Morris, 2014; Mendelssohn et al., 2012; Michel et al., 2017; Michel and Rutherford, 2013).
- Crude oil exhibits less toxicity to plants than refined products such as diesel, however repetitive oiling to the root zone can cause plant death (Achuba, 2006; Hester and Mendelssohn, 2000; Jorgenson, 1997; Lin and Mendelssohn, 1996, 2012; McKendrick, 2000; Walker et al., 1978).
- Rehabilitation and restoration of tundra vegetation from oil and diesel spills can be long-term with oil byproducts remaining in the soil for many years (Conn et al., 2001; Jorgenson et al., 2003; McKendrick and Mitchell, 1978).

Oil spill persistence on water or on the shoreline of coastal wetlands can vary widely, depending on the size of the oil spill, degree of weathering, environmental conditions at the time of the spill, substrate of the shoreline, and site-specific coastal processes such as ongoing shoreline erosion. Many coastlines of the Beaufort Sea have been identified with a high environmental sensitivity index (ESI) such as low-lying tundra and salt and brackish water marshes. Oil on beaches may be stranded on the surface, penetrate into subsurface layers and/or become buried as sediments erode, shift, and accumulate as part of the natural beach cycle and other coastal processes. Oil will not penetrate water-saturated sediments. However, in areas of high suspended sediment concentrations, oil will associate with sediment particles, lose its buoyancy and sink, resulting in deposition and contaminated sediments (NOAA, 2010; Page et al., 2013). Permeable substrates, generally associated with larger sand grain sizes and holes created by infauna, could increase oil penetration, especially that of light oils and refined petroleum products (Pezeshki et al., 2000). For oil to persist, low-permeable, fine-grained sediments need to be present. Low-permeable substrates inhibit water flow between sediment grains and further slows oil removal by inhibiting the delivery of oxygen and nutrients to support biodegradation (Page et al., 2013). Light oils may penetrate peat shores, however, peat resists penetration of heavy oils (NOAA, 2010).

Oil type is a primary determinant of toxicity. Heavy crude oils exhibit a small degree of direct toxicity to plants, whereas light crudes can cause necrosis and plant mortality on contact (Mendelssohn et al., 2012). Highly toxic refined products such as diesel, if they are weathered enough, will eventually show reduced toxicity, but the less toxic residuals can still coat vegetation (Mendelssohn et al., 2012). This condition prevents photosynthesis, thereby impairing the assimilation of carbon used for growth and transpiration, which promotes evaporative cooling.

Frequent, repetitive oiling of vegetation also depletes the underground nutrient reserves used to generate new shoots (Mendelssohn et al., 2012). The time of the year in which an oil spill occurs also influences the spill’s impacts on vegetation. Spills during colder periods when the plants have a lower metabolism or are dormant have a reduced impact relative to oil exposure during warmer seasons (Mendelssohn et al., 2012). However, arguably the most important determinant of severity is whether the oil penetrates the soil and comes into contact with nutrient-absorbing roots and shoot-regenerating rhizomes, as this can cause plant death (Mendelssohn et al., 2012). Perennial marsh plants, which regenerate new above ground shoots each spring, usually recover from stem and leaf oiling, but oiling of subsurface plant organs more often results in plant death. Not all plant species are similarly susceptible to oil; species-specific differences in responses to oil can be dramatic (Lin and Mendelssohn, 1996).

Onshore crude oil spills onto wet tundra can kill the moss layers and above ground parts of vascular plants, and sometimes kills all macro-flora in the affected area (McKendrick and Mitchell, 1978). Spills that saturate the tundra can produce severe, long-lasting effects, and vegetation recovery is slow (NRC, 2003). Dry tundra is considered to be more susceptible to crude oil damage than moist or wet tundra, because the light fractions can be carried into the soil before they evaporate, damaging or killing roots or buds (Behr-Andres et al., 2001). Small onshore spills of diesel or No. 2 fuel cause higher mortality to vegetation than crude oil (Mendelssohn et al., 2012; NRC, 2003) by directly killing leaves, roots, and buds on contact. Walker et al. (1978) noted that diesel fuels can remain in tundra soils for more than 20 years with no recovery of tundra plant communities after 1 year.

In summary, higher mortality and poorer recovery of vegetation and wetlands generally result from spills of lighter petroleum products (such as diesel fuel), thick deposits of oil, spills during the growing season, contact with sensitive plant species, completely oiled plants, and deep penetration of oil and accumulation in substrates (Stebbins, 1970; Caudie and Maricle, 2014).

4.2.4 Invertebrates

Exposure to oil or its toxic components causes lethal (mortality) to sublethal toxicity to marine invertebrates. Impacts of oil on marine invertebrates vary depending on level of exposure, life history, feeding behavior, and ability of a species to metabolize toxins. Benthic and planktonic invertebrates are exposed to oil in different ways and vary in their ability to avoid exposure. Impacts from a spill can occur through exposure of organisms to toxins, changes in oxygen and light availability in the water, and physical damage to organisms by settled oils. Potential impacts to marine invertebrates related to accidental spills include the following:

- Direct toxic effects can include lethal (mortality) or sublethal consequences such as impacts on biomass and community composition, as well as effects on behavior, reproduction, growth and development, immune response, and respiration (Auffret et al., 2004; Bellas et al., 2013; Blackburn et al., 2014; Hannam et al., 2010).
- Spills that are not immediately lethal can have short- or long-term impacts on biomass and community composition, behavior, reproduction, feeding, growth and development, immune response, and respiration (Dupuis and Ucan-Marin, 2015; Blackburn et al., 2014). The level of toxicity is influenced by how marine invertebrates are exposed, their life history, feeding behavior, and ability of a species to metabolize toxins.
- Chronic exposure to oil and its byproducts can cause cellular damage and impair feeding, mobility, reproduction, growth, and development in marine invertebrates (Bellas et al., 2013; Blackburn et al., 2014).
- Indirect toxic effects can occur through the inhibition of air-sea gas exchanges and hypoxia from the degradation of oil (Abbriano et al., 2011; Blackburn et al., 2014; Ozhan, Parsons, and Bargu, 2014).
- Other lethal or sublethal impacts include physical smothering of organisms by settled oil and reduced photosynthesis through changes in light penetration into the water column (Blackburn et al., 2014; González et al., 2013; Ozhan, Parsons, and Bargu, 2014).
- Oil or its toxic components in plankton can biomagnify/bioaccumulate through the food webs and affect higher trophic levels (Blackburn et al., 2014).

The zooplankton community includes free-floating embryos and larvae of species that settle on the seafloor as adults, including sea urchins, mollusks, and crustaceans. Exposure to oil at this life stage can result in impaired development and decreased settlement of juveniles and can have increased risk of long-term population-level impacts (Anselmo et al., 2011; Blackburn et al., 2014). Both planktonic and benthic invertebrates may bioaccumulate hydrocarbons through diffusion or ingestion, which can lead to cascading impacts on the food web. Toxicity studies carried out with benthic crabs and shrimp indicate they may not immediately die from toxins, thus allowing greater opportunities for consumption by upper-level predators and biomagnification to occur (Brodersen, 1987). Phytoplankton may not die immediately from the effects of exposure to oil, allowing them to be consumed by other organisms in locations away from contamination sites (Jiang et al., 2010).

Phytoplankton populations can change quickly on small spatial scales making it difficult to predict how a phytoplankton community as a whole would respond to an oil spill. Some phytoplankton species are more tolerant of oil exposure than others, and changes to community structure may be very subtle or undetectable (Abbriano et al., 2011; Gonzalez et al., 2013). Oil on the water surface can limit light available for phytoplankton photosynthesis (Ozhan, Parsons, and Bargu, 2014). Impacts of oil on planktonic and marine microbial populations generally are short lived and do not affect all groups evenly, and in some cases stimulate growth of species (Graham et al., 2010; Hing et al., 2011). Planktonic communities can recolonize from adjacent areas through water currents and have short lifecycles coupled with high reproductive potential (Abbriano et al., 2011). Zooplankton communities have been shown to reestablish several weeks to months after an oil spill, indicating a high capacity for recovery (Varela et al., 2006). Phytoplankton associated with the ice environment may be locally decimated by an oil spill, especially if the oil is incorporated into multiyear ice formation. Impacts on the plankton bloom, and therefore on production of the area, may be felt throughout the food web.

Oil spills have been shown to result in a severe reduction or complete disappearance of amphipods and echinoderms, and the subsequent replacement by opportunistic polychaetes in oiled areas (Jewett et al., 1999; Bellas et al., 2013). Benthic organisms may be exposed to oil for longer periods of time than pelagic organisms because they live in and on the seafloor where oil may persist (Almeda et al., 2013; Blackburn et al., 2014). Exposure can also occur over multiple life stages because many species are planktonic as larvae but benthic as adults; these species may be exposed to a spill in the water column and also in seafloor sediments, which increases contact with contaminants. The varying responses of benthic invertebrates to oil can lead to long-term alterations in the structure and biodiversity of benthic communities (Carls, Harris, and Rice, 2004; Jewett et al., 1999). Deposit-feeding and burrowing benthic invertebrates can be impacted by chronic exposure to hydrocarbons in polluted sediments, resulting in population fluctuations due to greater exposure on the seafloor and in sediments, reduced mobility, and increased susceptibility to predation (Blackburn et al., 2014).

4.2.5 Fish

Adverse effects to fish resources from spills can occur in both freshwater and marine environments. Impacts can occur through exposure of various life stages of fish to toxins, impacts to fish prey resources, and interference with access to important habitat areas. Although oil is toxic to fish at high concentrations, certain species are more sensitive than others, and oil can have toxic effects even in low concentrations. Potential impacts to fish related to accidental spills include the following:

- Immediate mortality, or other sublethal effects such as abnormal development and growth, reproductive damage, and behavioral changes (Rice et al., 2000; Short, 2003; Carls, Rice, and Hose, 1999; Hjermann et al., 2007; Dupuis and Ucan-Marin, 2015; Nahrgang et al., 2016; Incardona, 2017).
- Reduced prey availability (see Section 4.2.4).
- Toxic concentrations can build up in coastal areas where oil is trapped in shallow bays and inlets, and the presence of oil can interfere with spawning or access to spawning grounds (Heintz et al., 2000; Wertheimer et al., 2000).

Some contaminants in oil can cause sublethal effects on sensory systems, growth, reproduction, and behavior of fish. These sublethal effects may reduce overall fitness and affect the ability to endure other disturbances. Both acute and chronic oil exposure in spawning or nursery areas can cause mortality to eggs and immature stages, abnormal development, or delayed growth (Carls, Rice, and Hose 1999; Hjermann et al., 2007). Strong-swimming demersal and pelagic fish that are exposed to oil spills in the upper water column may be capable of swimming away from oil slicks. Eggs, larvae, and juvenile stages of fish in the water column would have continued exposure to oil due to their limited mobility. In general, the early life stages of fish (eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al., 2000; Short, 2003).

It is likely that individuals encountering a spill could suffer deformities or mortality, even at low oil concentrations (Bejarano et al., 2017). Arctic cod, an important keystone fish species in the Arctic, has been shown to have especially high sensitivity to oil pollution when exposed as eggs (Nahrgang et al., 2016). Low levels of PAHs from chronic pollution can accumulate in salmon tissues and may increase embryo mortality, reduce marine growth, or increase straying away from natal streams by returning adults (Heintz et al., 2000; Wertheimer et al., 2000). Fish may be excluded from preferred feeding habitat if it becomes oiled. Migratory fish, such as whitefish and Pacific salmon, could lose access to important spawning and rearing habitat.

Chronic oil spills could have an adverse effect on fish because residual oil can build up in sediments and affect living marine resources. Prey items that are impacted by oil contamination may no longer be available for consumption by fish species. Toxins from hydrocarbons may bioaccumulate in fish tissue, especially for benthic feeding fish that forage in contaminated areas. These effects on the food chain could have indirect effects on larger predatory fish by reducing the available prey base and foraging opportunities.

4.2.6 Marine Mammals

Oil spills can affect marine mammals, their habitats, and their prey through a variety of direct and indirect pathways which can have both long-term individual impacts and population-level impacts depending on the spill size, location, and environmental factors present at the time of the spill (Helm et al., 2015). An oil spill affects each group of marine mammals differently. Marine mammals live in offshore and nearshore waters and could be exposed to spilled oil at sea. Ice seals, Pacific walrus, and polar bears could also be exposed to spilled oil at terrestrial nearshore areas and on sea ice. The effects of oil spills on Arctic marine mammals can be inferred from studies on spill effects in other areas of the world and from controlled experiments. These effects include, but are not limited to, the following:

- Short- and long-term respiratory effects such as pulmonary emphysema and inflammation and infection of respiratory tissue through inhalation of VOCs from crude oil or natural gas (Geraci and St. Aubin, 1990; Godard-Codding and Collier, 2018; Hansen, 1985; Helm et al., 2015; Neff, 1990; Schwacke et al., 2014).
- Inflammation, ulcers, bleeding, and damage to organs from ingestion of oil (and dispersants) directly or via contaminated prey. However, some marine mammals may metabolize and eliminate hydrocarbons (Derocher and Stirling, 1991; Engelhardt, 1982, 1983; Geraci and St. Aubin, 1990; Kooyman, Gentry, and McAlister, 1976; Øritsland et al., 1981).
- Irritation, inflammation, or necrosis of skin, as well as chemical burns of skin, eyes, and mucous membranes from dermal contact (Hansen, 1985; Øritsland et al., 1981; Engelhardt, 1982, 1983; Derocher and Stirling, 1991; Werth, Blakeney, and Cothren, 2019). Venues of dermal contact include oiling of whale baleen, fur on polar bears and ice-seal pups, and oiling of skin, eyes, conjunctive membranes, and cetacean blowholes.
- Elevated cortisol and altered endocrine levels in some individual marine mammals from exposure to hydrocarbons (Geraci and St. Aubin, 1990).
- Short- and/or long-term reductions in prey availability, habitats, and populations (FWS, 2015a; Sections 4.2.4 and 4.2.5).
- Disruption of social groups leading to decreased survival and lowered reproductive success (Geraci and St. Aubin, 1990; Matkin et al., 2008).
- Habitat degradation (Garlich-Miller et al., 2011; Wilson et al., 2014; Wilson, 2018).
- Delayed recovery of habitat from chronic exposure to residual oil components, which could produce lingering effects on marine mammals (Peterson et al., 2003).
- Disturbance or displacement from cleanup crews, vessels, or aircraft during spill response activities (FWS, 2015b; Ziccardi et al., 2015).

Whales

Whales may have direct contact with oil by swimming through oil on the surface and/or subsurface. Whales could be directly affected by oil through inhalation of VOCs, ingestion (of the oil itself or of contaminated prey), fouling of baleen, reduced foraging efficiency, and oiling of their skin. Effects attributable to oil contamination are more likely to occur during periods of natural stress, such as during molting, or times of food scarcity and disease infestations. Whales could also be impacted by oil if the quality or quantity of their prey were reduced and by temporary displacement from some feeding areas.

The effects of oil contacting whales would depend on the size, timing, duration, and weathering of the spill; how many whales were contacted by the spill; and the whales' ability or inclination to avoid spilled oil. Neither baleen nor toothed whales seem to consistently avoid oil, although they can detect it (Geraci, 1990). Geraci (1990) and Harvey and Dahlheim (1994) reported that fin whales, humpbacks, dolphins, killer whales, and Dall's porpoises were observed entering oiled areas and behaving normally. Conversely, observations of cetaceans behaving in a lethargic fashion or having labored breathing have been documented in gray and killer whales, and in Dall's and harbor porpoises (Harvey and Dahlheim, 1994).

Information about spill impacts on whales is inferred by the known physiology of whales, properties of petroleum, and discrete examples (Geraci and St. Aubin, 1990). Engelhardt (1987) theorized that some whales, such as belugas, would be particularly vulnerable to effects from oil spills because they use ice edges and leads, where spilled oil would accumulate, during their Arctic spring migration (April-June). If oil got into leads or ice-free areas frequented by migrating whales, a large portion of their population could be exposed to spilled oil. Some whales could die as a result of contacting spilled oil, particularly if there are periods of prolonged contact. However, the number of whale deaths would likely be small.

Whale exposure to oil can occur from inhalation of VOCs present in fresh crude oil. To mammals, the most toxic VOCs are the BTEX compounds and lightweight alkanes (Neff, 1990). Bratton et al. (1993) theorized that whales could inhale VOCs that would irritate their mucous membranes or respiratory tract leading to hydrocarbon absorption into the bloodstream. Other literature indicates severe adverse effects can occur from inhaling VOCs from crude oil, such as respiratory system damage, neurological disorders, liver damage, anesthetic effects, and sudden death concurrent with excessive adrenalin release (Geraci, 1988; Geraci and St. Aubin, 1982; Godard-Codding and Collier, 2018; Hansen, 1985; Neff, 1990; J. Lentfer, as cited in Harvey and Dahlheim, 1994; Loughlin, 1994). Consequently, whale mortalities could occur if they surfaced in large quantities of fresh oil.

Whales can be exposed to oil through eating, whenever their mouth is open, or through contaminated prey (Godard-Codding and Collier, 2018). Baleen whales may be at highest risk because of their small populations and their specialized feeding patterns and structures (baleen) (Helm et al., 2015). Geraci and St. Aubin (1990) suggested that baleen whales are particularly vulnerable to direct impacts from oil, causing fouling of baleen plates, which could impact feeding behavior. A study in which baleen from fin, sei, humpback, and gray whales were oiled, found 70 percent of the oil adhered to baleen plates rinsed away within 30 minutes, and more than 95 percent of the oil disappeared from baleen after 24 hours (Geraci, 1988, 1990). However, the authors acknowledged that this study used dry baleen to determine the impacts of oil and that baleen from living whales could yield different results (Geraci and St. Aubin, 1990). If baleen is fouled and if crude oil is ingested, there could be adverse effects on the feeding efficiency and food assimilation of whales.

The effects of oil contact on whale skin are limited. Whales have a thick epidermis and tight intercellular bridges, which inhibits oil absorption through their skin (O'Hara and O'Shea, 2001). Histological data and ultrastructural studies by Geraci and St. Aubin (1990) indicated that exposures of skin to crude oil for up to 45 minutes in four species of toothed whales had no effect, and longer exposures caused skin irritation. Overall, they concluded that a whale's skin is an effective barrier to petroleum (Geraci and St. Aubin, 1990). Although oil is unlikely to adhere to smooth skin, it may stick to rough areas on the surface (Henk and Mullan, 1997).

Age may also affect the degree of impact from oil exposure. Because whale calves are smaller, swim slower, take more breaths, are on the surface more often, and have higher metabolisms than adults, they could be impacted more from VOC inhalation (Shaffer et al., 1997; Woodward, Winn, and Fish, 2006; Würsig, Koski, and Richardson, 1999). In addition, they could receive pollutants through their mothers' milk, as well as through direct ingestion.

Oil exposure could have significant impacts to whale prey species. Spills could have ecosystem-level impacts by altering benthic community structure over significantly large areas of the seabed (Carmen, Fleeger, and Pomarico, 1997; Millward et al., 2004), which might affect competition and food availability for higher trophic level consumers, such as whales. Spilled oil could negatively affect gray whales by contaminating benthic prey, particularly in primary feeding areas (Würsig, 1990; Moore and Clarke, 2002). For bowhead whales, a spill could adversely affect prey species such as copepods, amphipods, and other invertebrates and fish. Studies have shown a marked decrease in secondary production among amphipod populations exposed to a spill and long recovery periods (Dauvin, 1989, as cited in Highsmith and Coyle, 1992). Because arctic amphipods have longer generation times and lower growth rates, spill recovery would probably take longer (Highsmith and Coyle, 1992). If fish stocks, particularly Arctic cod, anadromous, and coastal spawning species were to experience adverse population-level impacts, the effects on belugas could involve starvation, malnutrition, and potential losses to beluga stocks.

Ice Seals (Ringed, Spotted, and Bearded Seals)

The impacts on ice seals exposed to oil depend on the number and ages of seals contacted, contact duration, spill volume, and the amount of weathering the spill has experienced at the time of contact. Feeding and movement patterns affect a seal's susceptibility to oil exposure (Helm et al., 2015).

Oil exposure can cause mortality; eye damage; brain, liver, and kidney lesions; gastric problems; skin irritation; increased PAH concentrations in fat; increased petroleum-related aromatic compounds in bile; and abnormal behavior such as lethargy, disorientation, and unusual tameness (Engelhardt, 1985, 1987; Frost et al., 1997; Geraci and Smith, 1976; Loughlin, 1994; Lillie, 1954; Spraker, Lowry, and Frost, 1994). Ice seals exposed to oil can manifest eye damage, including corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes (Geraci and Smith, 1976; Lillie, 1954).

Ringed and bearded seals may have some ability to metabolize and eliminate hydrocarbons (Kooyman, Gentry and McAlister, 1976). Seals that ingested crude oil displayed increased gastrointestinal motility and vocalizations, temporary kidney lesions, and decreased sleep (Geraci and Smith, 1976; Smith, 1987; Engelhardt, 1985, 1987). Ingestion of a small amount of oil in a controlled experiment did not appear to permanently harm ringed seals, though larger doses could cause long-term kidney, liver, and tissue damage (Engelhart, Geraci, and Smith, 1977; Geraci and Smith, 1976).

Much of what is known about the effects of oil on seals in natural systems is the result of research on harbor seals following the EVOS. The effects of oil exposure are expected to be similar for ice seals in the Arctic due to anatomical similarities among phocid seals. Visibly oiled harbor seals collected several weeks following the EVOS also had mild acanthosis and orthokeratotic hyperkeratosis of the epidermis (both afflictions of thickening of the skin) (Spraker, Lowry, and Frost, 1994). Heavy oiling did not appear to interfere with seal locomotion during the EVOS (Lowry, Frost, and Pitcher, 1994), but in previous spills seal pups encased in oil have drowned due to their inability to swim (Davis and Anderson, 1976). Studies suggest seals intent on feeding will not avoid an area due to oil or oil sheens (Geraci and St. Aubin, 1990). Harbor seals showed no avoidance of spilled oil during the EVOS and were observed swimming in oiled water and surfacing in oil slicks to breathe at the air-water interface where volatile hydrocarbon vapors were present (Frost and Lowry, 1994).

Seals could be exposed to oil in preferred habitats. In Prince William Sound, oiled seals were observed in oiled haulouts (Frost et al., 1997), with many seals remaining oiled until their molt (Frost, Manen, and Wade, 1994). Some of the haulout sites remained oiled through the pupping season, and many pups became oiled shortly after birth (Frost et al., 1997). The studies did not indicate if skin exposure negatively affected seals. EVOS studies also showed harbor seals were temporarily displaced from oiled haulouts but returned the following year at the same rate as unoiled sites (Frost and Lowry, 1994; Frost, Lowry, and Ver Hoef, 1999); however, fewer pups were produced at oiled sites (Frost et al., 2004). In the Arctic, ice seals may react similarly in regard to their use of oiled habitat. Oil exposure in the shorefast-ice breeding habitat would likely have the greatest impact on ice seals (Smith, 1987). If a spill causes females to relocate pups from oiled areas, seal pups could be immersed in oil compromising the insulative properties of their lanugo, and impair their mobility in the water causing potential seal pup mortalities (Davis and Anderson, 1976; Smith, 1987).

Pacific Walruses

Walrus can be exposed to oil through direct contact, ingestion of oil or oil-contaminated prey, and inhalation of VOCs. The effects of oil exposure on walruses would most likely be limited to individual animals because they are considered extralimital in the Beaufort Sea. No haulouts occur in the Beaufort Sea; however, if oil persists and moves into the Chukchi Sea, these habitats could be impacted. Observed direct effects to walruses from oil are limited; most information is derived from other pinnipeds.

Similar to other pinnipeds, walruses are susceptible to oil contamination of their eyes, and prolonged direct exposure to oil could cause lesions, conjunctivitis, and possibly permanent eye damage. Direct oil exposure of adult walruses is not believed to have any effect on the insulating capacity of their skin and fat. Because of their thick skin and fat layers, walruses exhibit no grooming behavior, which reduces their chance of ingesting oil. Shared anatomical similarities between ice seals and walruses suggest the effects of oil ingestion on walruses should be similar and include kidney, liver, and other tissue damage (Kooyman, Gentry, and McAlister, 1976).

Effects of inhalation would include pulmonary hemorrhage, inflammation, congestion, and nerve damage. If walruses were also under stress from molting or pregnancy, the increased heart rate associated with the stress could circulate the hydrocarbons more quickly. Oil exposure could affect walrus calves differently than adults. Calves exposed to oil in the water may not be able to regulate heat loss and may become more susceptible to hypothermia. Oiled calves may be unable to swim away from the contamination, and a cow would not leave without the calf, resulting in the potential exposure of both animals. Further, an oiled calf could become unrecognizable to its mother either by sight or smell, and be abandoned (FR, 2013).

Habitat, coupled with season (open-water or ice-covered), and the biology of the walrus can amplify oil exposure effects. An offshore spill during open-water season may only affect a few walruses swimming through the affected area. However, oil along ice edges and ice leads in fall or spring presents a greater risk because of the presence of walrus in prime feeding areas over the continental shelf during this period. A spill affecting habitats where walruses are concentrated, such as along off-shore leads or polynyas, would affect more animals than spills in other areas. Spilled oil during the ice-covered season may become part of the ice substrate and be eventually released back into the environment during the following open-water season exposing new individuals to the oil. Walruses are most vulnerable to the effects of an oil spill at coastal haulouts (Garlich-Miller et al., 2011), particularly along the northern coast of Russia (Kochnev, 2004). Displacement from these crucial areas likely would result in population-level impacts on recruitment and survival.

Oil exposure could occur from the ingestion of contaminated benthic prey. Determining oil spill effects on walrus prey species is difficult as clam-patch size and density are highly variable, and such information for high-latitude mollusks is sparse (Ray et al., 2006). Benthic prey severely contaminated by a spill may be killed immediately. Benthic recovery would be slow in the cold, seasonally ice-covered Arctic marine environment. Bivalve mollusks are not effective at processing hydrocarbon compounds, resulting in highly concentrated accumulations and long-term retention of the contamination within the organism. Consequently, walruses would be very susceptible to the effects of bioaccumulation of contaminants associated with spilled oil, which could affect their reproduction, survival, and immune systems (MMS, 2004).

Polar Bears

Oil exposure could potentially result in effects that could reduce the polar bears' health, reproductive fitness, and longevity, and increase susceptibility to disease of individual bears. Polar bears are curious and are attracted to petroleum products encountered in the wild and may actively investigate oil spills, become oiled, ingest oil, or inhale VOCs (Amstrup and Nielsen, 1989; Amstrup et al., 1989; Derocher and Stirling, 1991).

Polar bears could ingest oil when grooming or consuming oiled prey. Long-term or chronic oil ingestion could lead to gastrointestinal ulcers and lesions, biochemical changes indicative of stress, and liver and kidney failure (Neff, 1990; Øritsland et al., 1981).

Prolonged exposure to VOCs could damage respiratory and central nervous systems (Helm et al., 2015). In addition, skin damage and hair loss can occur after contact with oil (Øritsland et al., 1981; Derocher and Stirling, 1991). Under experimental conditions conducted by Øritsland et al. (1981), three polar bears were exposed to surface oil (~1 cm thick) in a pool. Once oiled, the bears actively ingested oil through grooming and licking behavior causing thermoregulatory and metabolic stresses. Øritsland et al. (1981) reported that ingestion of oil also led to anorexia, tissue damage from uremia (toxins kidneys normally exclude in urine enter the bloodstream instead), dehydration, anemia (deficiency of red blood cells), and renal failure, eventually leading to death in two of three animals.

Oiled fur loses its insulative value and causes increased heat loss (Hurst and Øritsland, 1982; Øritsland et al., 1981). Polar bears mostly rely on their subcutaneous layer of fat for insulation when swimming and rely on both fat and fur for insulation when out of the water. Consequently, any oiling could compromise the insulating value of their fur. High levels of exposure could result in death, while chronic low levels of exposure may result in long-term sub-lethal effects that reduce fitness.

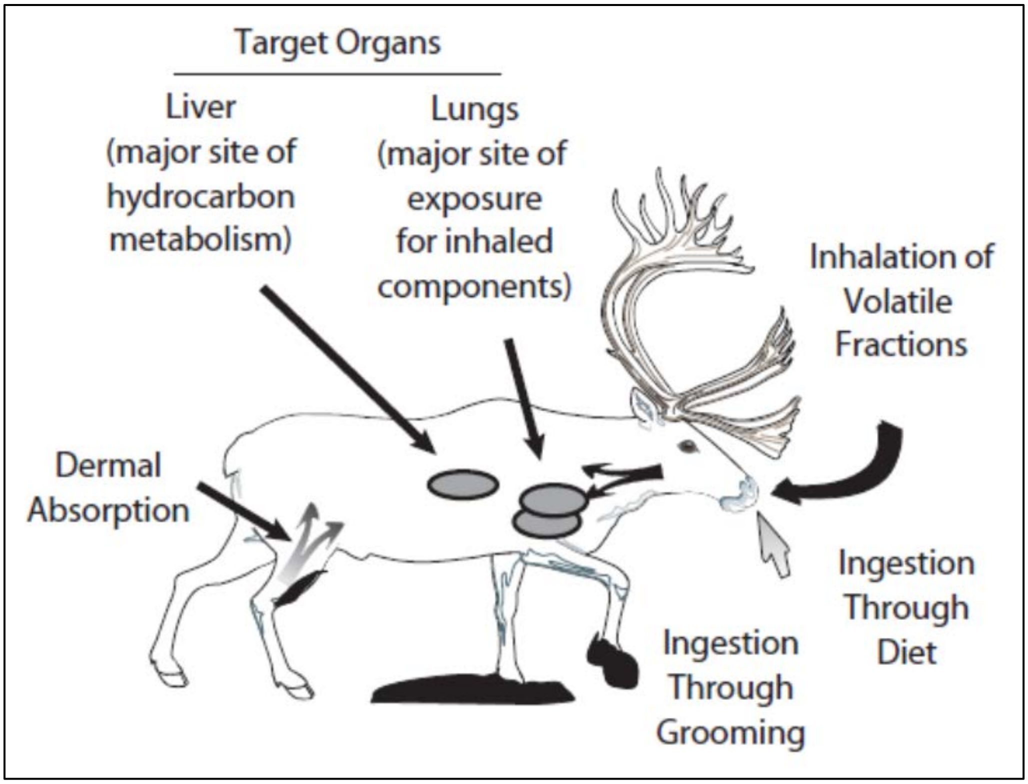
Oiled habitat could preclude polar bears from using it for resting, feeding, or transit, which could increase stress and possibly reduce life functions. This could happen through direct contact of oil to the environment or indirectly as a result of oil spill response activities. Oiled areas may also preclude polar bears from preferred denning habitat. Polar bears are particularly vulnerable to disturbance when nutritionally stressed, such as during denning, and any exposure during this time could reduce denning success and possibly result in death of cubs through abandonment. If polar bear food sources such as ringed seals become oiled over a wide area, the likelihood of bears killing or scavenging contaminated ringed seals would increase temporarily. Polar bears could also be impacted by reductions in seal numbers arising from oil-related deaths, or an absence of seals in oil-contaminated habitat (Helm et al., 2015).

4.2.7 Terrestrial Mammals

The general effects of an oil spill on terrestrial mammals can be both immediate and long-term from physical contact, inhalation, and/or ingestion of contaminants (Osweiler 2018; AMAP 2010; Figure 4-3).

Impacts can range from temporary injuries such as skin irritation and damage, to long-term disease and organ failure; for example, cancer, liver disease, and compromised immune or reproductive systems (Osweiler, 2018). Mortality may occur due to just one, or a combination of exposures, but is most commonly associated with hypothermia and inhalation. Spills may also affect vertebrate animals through habitat degradation and prey or forage species contamination by toxic compounds, including PAHs (Burns et al., 2014). Potential effects of an oil spill on terrestrial mammals may include:

- Effects of oil contact: irritation, inflammation, or necrosis of skin; chemical burns of skin, eyes, or mucous membranes; absorption of toxic compounds through skin (Osweiler, 2018); and hypothermia resulting from compromised fur (Garshelis and Estes, 1997). Short- and long-term respiratory effects may include inflammation, pulmonary emphysema, or infection (MDNR, 2019).
- Effects of oil ingestion: gastrointestinal inflammation; ulcers; bleeding; liver, kidney, and brain tissue damage; cancer/tumor development; compromised immune/reproductive systems; and altered respiration and heart rate (MDNR, 2019; AMAP, 2010; Burns et al., 2014; Frisch, Øritsland, and Krog, 1974).
- Effects of oil spills on habitat include physical and chemical degradation (Burns et al., 2014).



Source: AMAP, 2010.

Figure 4-3 Pathways of Hydrocarbon Exposure and Metabolism in Terrestrial Mammals

Few studies directly address toxicity of crude oil with respect to terrestrial mammals in the Arctic. Impacts of spilled oil on terrestrial mammals could vary widely based on the type and quantity of oil (or other hydrocarbon product) to which the animals are exposed (AMAP, 2010).

The most obvious consequence of exposure to an oil spill is physical oiling. The loss of thermal protection provided by fur that has been compromised by a hydrocarbon product (crude as well as refined products) could potentially lead to hypothermia and death (Williams et al., 1988; AMAP, 2010). Mortality due to hypothermia could occur at any time of year for terrestrial mammals.

Absorption, inhalation, or ingestion may occur following a terrestrial mammal’s exposure to oil. The type and level of impact depends largely on the composition of the hydrocarbon. Lighter hydrocarbons are more likely to be inhaled and affect the lungs, liver, or kidneys (AMAP, 2010), or be absorbed through the skin. If oiled individuals attempt to clean themselves by licking their fur, they could ingest enough toxic compounds to cause injury or death.

It is also possible that terrestrial mammals could ingest hydrocarbons through contaminated food, however most terrestrial mammals would avoid ingestion of contaminated forage or prey after a spill event. In a study that was not spill related, Lundin, Riffell, and Wasser (2015) found moose and wolves near high oil production areas had high PAH ratios, suggesting consumption of contaminated foods. In this area, moose ingested PAHs from eating contaminated vegetation at oil production areas, while wolves ingested PAHs from eating contaminated moose. It is therefore possible for PAHs to enter the food web in this manner, and they can potentially bio-accumulate in carnivores.

Overall, impacts on individuals and populations resulting from oil spills would vary based on the location, severity, and type of oil spill or hydrocarbon exposure.

4.2.8 Birds

Spills can have lethal and sublethal physiological and behavioral effects on birds, and indirect effects via contamination and disturbance of prey resources and habitats. The effects of oil spills on birds are well documented and the evidence for these effects is briefly discussed below. In particular, potential oil spill impacts to birds include the following:

- Mortality or stress resulting from direct contact (Balseiro et al., 2005; Haney, Geiger, and Short, 2014a,b; Maggini et al., 2017; O’Hara and Morandin, 2010).
- Toxic (lethal or sublethal) reactions from inhalation, direct ingestion, or ingestion of contaminated prey (Balseiro et al., 2005; Bursian et al., 2017).
- Effects to migration and reproduction via physiological damage to adults (Dorr et al., 2019; Golet et al., 2002).
- Other productivity effects, such as via oil contamination of eggs and nest material, or adults delivering contaminated prey to chicks (Stout et al., 2018; Zuberogoitia et al., 2006).
- Modified prey abundance (Esler et al., 2002; Golet et al., 2002; Irons et al., 2000).
- Damage to and displacement from foraging or molting habitat (Day et al., 1997; Esler et al., 2002; Wiens et al., 2004; Henkel, Siegel, and Taylor, 2014).
- Disturbance and displacement of breeding birds and nest failure from cleanup activities in nesting habitat (Andres, 1997; Fraser and Racine, 2016; DWH Trustees, 2016).

Direct oil contact alone often causes death from hypothermia, shock, or drowning. Contact with oil can irritate or inflame sensitive tissues (skin, eyes) and foul plumage, the primary cause of stress and mortality in oiled birds (Leighton, 1993). This loss of insulation, waterproofing, and buoyancy in the plumage causes hypothermia, exhaustion, drowning, or starvation deaths (Balseiro et al., 2005; Burger and Fry, 1993). Even small volumes of oil (oil sheens) have the potential to affect feather microstructure, and compromise buoyancy, flight characteristics, and thermoregulatory capabilities (O'Hara and Morandin, 2010; Maggini et al., 2017).

Indirect effects of oil pollution potentially result from reduction, contamination, and displacement of food sources, and contamination of multiple habitats. For example, fish or invertebrate prey may experience mortality as a result of a spill, or there may be effects to primary producers that carry up through the food web (Henkel, Siegel, and Taylor, 2014; Golet et al., 2002).

Birds can ingest and inhale oil during feeding, grooming, and preening. Ingestion and inhalation of oil can lead to tissue and organ damage, interfere with food detection, predator avoidance, homing of migratory species, disease resistance, growth rates, and respiration (Balseiro et al., 2005). Ingested oil can cause short- and long-term reproductive failure in birds, including delayed maturation of ovaries, altered hormone levels, thin eggshells, reduced egg productivity and survival of embryos, and nest abandonment (Burger and Fry, 1993; Bursian et al., 2017). Lightly oiled birds could bring oil contamination or contaminated food to a nest while heavily oiled birds would be unable to return to the nest, resulting in abandonment and starvation of the young. Lost reproduction from mortality of breeding-age adults exponentially increases future impacts (DWH Trustees, 2016).

Habitat fouling can also lead to displacement of birds to less productive areas, even potentially increasing foraging time for parents feeding chicks or affecting ability to complete migration (Henkel, Siegel, and Taylor, 2012; Andres, 1997; Day et al., 1997; Golet et al., 2002). The exposure from oiled habitat could range from acute (birds may be covered by lethal amounts of oil) to chronic (birds are exposed to smaller amounts of oil over a longer period of time). Long-term, low-level contamination of food sources and habitats can lead to chronic toxicity in birds through the accumulation of hydrocarbon residues that may adversely affect their physiology, growth, reproduction, and behavior. Effects of chronic exposure can range from lethal to sub-lethal. The migratory nature of birds and their complex relationships with multiple habitats and prey bases can potentially lead some spills to have widespread or population-level impacts (Henkel, Siegel, and Taylor, 2012).

The magnitude and extent of impacts to birds depends on an array of spill and environmental variables, including time of year the spill occurs, the volume and product type, environmental conditions at the time of the spill, the species and/or habitats and habitat quality exposed, the condition of birds when they are exposed, and results—beneficial and/or negative—from any cleanup activities (Haney, Geiger, and Short, 2014a,b; Tan, Belanger, and Wittnich, 2010; Wiens et al., 2004). Besides disturbance and habitat exclusion, cleanup activities potentially can lead to a variety of other impacts. For example, recent studies demonstrate that burn residue from in-situ burning of an oil spill can foul feathers equally or worse than oil (Fritt-Rasmussen et al., 2016).

4.2.9 Economy

Oil spills can have both negative and/or positive impacts on local markets, employment, income, and revenues. Geography, type and amount of oil, social values, climatic conditions, laws, timing of the spill, and cleanup logistics all significantly affect an oil spill's economic impact (Etkin, 1999; White and Molloy, 2003; Xin and Wirtz, 2009). The three most important predictors of an economic impact are determined by a spill's size, location, and the existing natural resources. The economic impacts of oil spills include:

- Mixed-economy (market and subsistence economy) losses occur for communities dependent on the marine environment for subsistence resources (Impact Assessment, Inc. 1990, 2011a,b; McDowell Group, 1990; Picou et al., 2009).

- Local businesses incur losses caused by direct damage in the spill-affected area(s) (Cirer-Costa, 2015; Eastern Research Group, 2014; McDowell Group, 1990; Murtaugh, 2010; Ritchie et al., 2013).
- Increases in disaster response spending cause an increase in short-term employment, income, and revenues in the spill affected areas (Cohen, 1993, 1997; Fall et al., 2001).
- Local governments experience revenue impacts (Impact Assessment, Inc. 1990, 2011a,b; Recovery and Relief Services, 2015).

Spills occurring closer to shore may have greater economic impacts and are more expensive to clean (Chang et al., 2014). However, this may not be true for all Alaska regions considering the complexity of oil in ice and the subsistence lifestyle. In Alaska, oil spills occurring farther from shore may have just as much impact as those occurring closer to land. This is especially true for the North Slope Borough (NSB) economy since the resource (bowhead whale) is unavailable to purchase and cannot be harvested or towed in or near the spill area.

Short- and long-term economic impacts can occur from an oil spill; short-term impacts include profit losses for local businesses (tourism, services, and restaurants) caused by oil spill damage in addition to loss of tax revenues the community would have received from the oil that can no longer be developed. Wages for spill response jobs are often higher than those of many local jobs. Therefore, labor shortages may occur should local workers seek cleanup jobs which leave unfilled vacancies in local communities (McDowell Group, 1990).

Increases in disaster response spending can create a short-term recovery boom through oil and gas related services for those participating in the recovery process and workers displaced from primary industries (Chang et al., 2014). Depending on the number of workers required to clean up the spill, inflation in the local economy may occur with the influx of cash earned and spent due to recovery efforts. The discussion of employment for oil spill response is based on a spill in Alaskan waters, the EVOS, of 240,000 bbl in 1989. This event generated employment for up to 10,000 workers. The following years from 1990 to 1992 generated a smaller number of workers returning in the warmer months. During the EVOS, many local residents quit their current jobs to work on the cleanup effort due to higher wages. This retroactively caused sudden and significant inflation in the local economy (Cohen, 1993).

Short-term revenue impacts, as well as unreimbursed expenditures and costs, affect local governments (Impact Assessment Inc., 1990, 2011a,b). Sales tax revenues related to tourism goods and services may decrease due to changes created by the oil spill as witnessed in DWH (Eastern Research Group, 2014). If a spill were to occur, the NSB would not experience short-term impacts with revenues since NSB oil and gas revenues come from property taxes, not production. However, the SOA would experience a loss in production taxes, corporate income tax, and royalties. If an exploration moratorium were to occur similar to DWH, marginal negative revenue impacts may be experienced by the SOA. However, small businesses and employment may experience negative impacts as witnessed in DWH (USDOC, 2010; Bluey, 2011). Likewise, the SOA heavily relies on oil and gas development in the Beaufort Sea region, but the total impact would be significantly less due to the State’s diverse revenue streams and larger economy compared to a single community.

Long-term effects include potential negative impacts to the mixed economy, particularly subsistence hunting. Depending on the size and duration of the oil spill, environmental impacts could have long-lasting effects on tourism, natural resources, and subsistence hunting as observed after the EVOS (Cohen, 1993). Although tourism in the NSB is orders of magnitude smaller than Southcentral Alaska, it is still an impact on the local economy.

4.2.10 Sociocultural Systems

Oil spills cause psychological, social, public health, economic, and cultural impacts on society. The sociocultural system includes social organization, cultural identity, and local institutions. Effects from an oil spill on the sociocultural systems of local communities could come from disruption of subsistence through oiling of habitats and subsistence resources; spill response and cleanup activities, including changes in population, employment, and income; and social and psychological stress due to fears of potential contamination of resources (Palinkas et al., 1993). In Arctic communities, effects are tied to impacts to subsistence, because subsistence harvest, processing, and sharing are the foundations of sociocultural systems in Alaska Native communities. An oil spill or gas release would likely have effects on the sociocultural systems of Beaufort Sea communities, with the exact consequences depending on the size, timing, location, movement, and type of product(s) spilled. Effects could include:

- Increased social stress in communities, including loss of credibility and trust in authorities, frustration and anger, breakdown in family ties, and a weakening of community well-being (Chang et al., 2014; Impact Assessment, Inc., 1990; Lord, Tuler, and Webler, 2012; Palinkas, 2012; Palinkas et al., 1993; Webler and Lord, 2010).
- Breakdown of kinship networks and sharing patterns, as well as breakdown of some formal institutions such as whaling captains' associations.
- Social and psychological distress over potential losses of cultural values and identity (Palinkas et al., 1993; Webler and Lord, 2010).
- Increased demand on the health and social services available in communities (Chang et al., 2014; Goldstein, Osofsky, and Lichtveld, 2011; Impact Assessment, Inc., 1990; Palinkas et al., 1993; Rodin et al., 1992).
- Higher rates of substance abuse, crime, domestic violence, and mental illnesses (Chang et al., 2014; Goldstein, Osofsky, and Lichtveld, 2011; Impact Assessment, Inc., 1990).
- Disruption of economy and interruption of way of life, along with decreased emphasis on subsistence as a livelihood and an increased emphasis on earning wages, particularly through participation by local individuals in spill response and cleanup employment (Lord, Tuler, and Webler, 2012; Palinkas, 2012; Palinkas et al., 1993; Webler and Lord, 2010).

In northern coastal Alaska, a healthy, well-functioning sociocultural system largely depends on peoples' access to subsistence areas and fish, caribou, waterfowl, and marine mammals. An oil spill or gas release could reduce or eliminate opportunities to practice subsistence activities, having long-lasting, widespread, and severe impacts on sociocultural systems. Impacts to sociocultural systems could be severe if one or more important subsistence resources became unavailable, undesirable for use, or available only in greatly reduced numbers for one or more seasons. For example, an oil spill could interrupt subsistence whaling for an entire season or more. Impacts would result from physical disruption to whale harvest activities and potential contamination of the mataaq (blubber) and whale meat. A disruption of social organization and sharing networks could lead to a decreased emphasis on the importance of the family, cooperation, sharing, and other Iñupiaq values. Multiyear disruptions of subsistence harvests of marine mammals, especially bowhead whales, could disrupt sharing networks, subsistence task groups, and whaling crew structures and would most likely severely impact the sociocultural systems in northern coastal villages.

Effects to the sociocultural system from response and cleanup for an oil spill could be severe and last for one or more years. Participating in spill response and cleanup, as local residents did in the EVOS in 1989, could cause residents to not participate in subsistence activities and not seek or continue employment in service positions in their communities. A sudden and dramatic increase in income earned from working on cleaning up the EVOS and being unable to pursue subsistence harvests because of the spill caused substantial amounts of distress and related social problems (Fall and Field, 1996; Gill, Picou, and Ritchie, 2012; Impact Assessment, Inc., 2011a). In the case of EVOS, the spill, subsequent litigation, and settlement processes have fundamentally altered life throughout the affected region; very large maritime oil spills tend to be costly and socially disruptive over a long period of time (Impact Assessment, Inc., 2011a).

4.2.10.1 Subsistence Activities and Harvest Patterns

Impacts of oil spills on subsistence activities and harvest patterns could occur through changes in the availability, quality, and use of subsistence resources. Impacts would result from contact of crude oil with shorelines and fish and wildlife and potential contamination of subsistence foods. Subsistence harvesters could purposively avoid affected subsistence areas and reduce their harvests of a particular subsistence food resource due to potential contamination (Fall et al., 2006; Impact Assessment, Inc., 2011a). Important subsistence resources could become unavailable or undesirable for one or more seasons, resulting in significant and sustained food insecurity (Suprenand et al., 2020). Impacts could include:

- Direct mortality of targeted subsistence resources or their prey, displacement of subsistence resources, or reduced numbers of species used for subsistence purposes (Fall et al., 2006; Picou and Martin, 2007).
- Displacement of people from traditional harvest areas and/or increased competition for subsistence resources (Impact Assessment, Inc., 2011a).
- Contaminated resources unfit for human consumption or undesirability of subsistence resources as foods and avoidance of oiled resources and areas (Impact Assessment, Inc., 2011b).
- More difficult pursuit of resources resulting in increased effort or higher risk and cost due to increased travel distances.
- Reduced consumption of subsistence foods and other products, food insecurity, and loss of or reductions in traditional subsistence practices (Impact Assessment, Inc., 2011b; Suprenand et al., 2020).

Marine mammals could be unavailable for harvest for one or more seasons if contaminated by spilled oil. Concerns about potential contamination in communities nearest the spill could substantially curtail traditional practices of harvesting, sharing, and processing whales and seals for one or more seasons. Severe loss of opportunity to practice traditional subsistence whaling would threaten the foundations of Iñupiaq culture, identity, and social organization in affected communities and the region.

The International Whaling Commission, which sets the quota for the subsistence harvest of bowhead whales, could reduce the harvest quota following an oil spill or gas release as a precaution to ensure that overall population mortality did not increase (Galginaitis, 2014; USACE, 1999; MMS, 2002). A lower bowhead harvest quota could have adverse impacts to food security and sharing practices in whaling communities, depending on how much quotas were reduced.

Oil contamination of beaches used in fall or sea ice used in spring could have a major impact on whaling, because even if bowhead whales were not directly oiled and contaminated, subsistence whalers would not be able or willing to bring them ashore and butcher them on oiled beaches or sea ice (Galginaitis, 2014). This would most likely persist for one or more seasons or until beaches were adequately cleaned and restored.

Whale, seal, waterfowl, and caribou hunting practices could be adversely affected by spill response and cleanup activities if subsistence hunters took employment in spill cleanup. This situation could divert time, effort, and equipment away from hunting towards oil spill response and cleanup for one or more seasons. Earning cash from paid work in spill response and cleanup could allow some subsistence hunters to purchase newer equipment and fuel needed to effectively pursue subsistence harvests if or when lost harvest opportunities became available after spill response and recovery.

4.2.10.2 Community Health

An oil spill or gas release could adversely affect health. Potential adverse impacts to health from large oil spills fall into four categories (Goldstein, Osofsky, and Lichtveld, 2011):

- Impacts related to worker safety
- Toxicological effects in workers, visitors, and community members
- Mental health effects from social and economic disruption
- Environmental effects that have consequences for human health

There is evidence in the literature of a positive relationship between exposure to spilled oils and the appearance of physical, psychological, endocrine, and gene-level effects in exposed humans, especially those involved in response and cleanup (Aguilera et al., 2010; Diaz, 2011). Large oil spills have caused serious mental health impacts such as post-traumatic stress disorder. Mental health impacts are caused by social disruption, income loss, loss of economic and subsistence resources, and high levels of worry over contamination of the environment and foods harvested from oiled environments (Eykelbosh, 2014; Grattan et al., 2011; Laffon, Pásaro, and Valdiglesias, 2016; Osofsky, Osofsky, and Hansel, 2011; Palinkas, 2012).

Spill response and cleanup workers from both inside and outside Alaskan communities could experience potential health hazards from toxic oil byproducts. Crude oils contain over one thousand different hydrocarbons, trace metals, and sulfur; some of these cause respiratory, liver, kidney, blood, and neurological effects at doses exceeding critical thresholds (Goldstein, Osofsky, and Lichtveld, 2011). Drowning, cold exposure, and falls would pose hazards to oil spill response workers. Changes in air quality could occur as a result of spills of crude or refined oil. Adverse health consequences of an oil spill to community members and cleanup workers could occur from exposure to oil vapors, particulate matter from controlled burns of spilled oil, hydrocarbons, and heavy metals.

Large oil spills can have long-lasting and widespread adverse but reversible physical and mental health impacts for community members living in affected areas (Eykelbosh, 2014; Goldstein, Osofsky, and Lichtveld, 2011). Researchers working on health impacts in Alaska related to the EVOS in 1989 found community members had symptoms of post-traumatic stress, including greater degrees of recurrent, unprovoked negative thoughts about the spill, and avoidance behaviors such as suppression of thoughts and behaviors related to the spill (Picou et al., 1992). These intrusive stresses declined somewhat over time but remained elevated compared to the control community 18 months after the spill; avoidance behaviors remained constant over time, indicating persistent, long-term psychological harm to individuals (Eykelbosh, 2014, p. 19). The trauma associated with oil spills, whether due to income loss, disruption of culturally important activities such as subsistence, or the stress of long-term uncertainty, can lead to depression, generalized anxiety disorder, and post-traumatic stress (Eykelbosh, 2014, p. 34).

An oil spill or gas release could cause adverse impacts to air and water quality, which in turn could have long-lasting and widespread effects on community health related to respiratory illnesses and contaminated marine and coastal waters used for hunting and fishing. Disruption of subsistence harvest from a VLOS lasting one or more seasons could have major impacts to community health due to increased food insecurity, declines in nutritional health, dysfunctional social organization, loss of identity, and diminished well-being.

4.2.11 Archaeological Resources

Oil spills, the use of chemical dispersants, and cleanup operations can have effects on archaeological resources resulting in contamination, degradation, disturbance, or vandalism. These effects can occur to sites both on land and underwater. In particular, potential oil spill impacts to archaeological resources include the following:

- Oiling of known or unknown cultural or archaeological sites (Jesperson and Griffin, 1992; Reger et al., 2000; Wooley and Haggarty, 2013).
- Changes in the biodegradation rate of wood and the increase of soft-rot fungal activity in the presence of crude oil (Ejechi, 2003).
- Disruption of the composition and metabolic function of biota colonizing archaeological resources degrades wood and corrodes metal (Damour et al., 2019; Mugge et al., 2019; Salerno et al., 2018).
- Crude oil contamination of organic material used in C-14 dating; although there are methods for cleaning contaminated C-14 samples, greater expense is incurred (Dekin, 1993).
- Disturbance and potential vandalism to cultural or archaeological sites (Wooley and Haggerty, 2013; Reger et al., 2000).

Dekin (1993) concluded that three main types of damage to archaeological sites were oil, vandalism, and erosion. Onshore archaeological sites could be damaged from oil contamination of the site. Direct physical disturbance of archaeological sites during cleanup work is also a factor. The effects of cleanup were slight during the EVOS because the cleanup work plan was constantly reviewed, and cleanup techniques were changed as needed to protect archaeological and cultural resources (Bittner, 1993). Various mitigating measures used to protect archaeological sites during oil spill cleanup are avoidance (preferred), site consultation and inspections, onsite monitoring, site mapping, artifact collection, and cultural resource awareness programs (Haggarty et al., 1991; Wooley and Haggerty, 1995).

In the EVOS, the greatest effects came from vandalism because more people knew about the resource locations and were present at the sites. This type of damage increases as the population and activities increase during the cleanup process. Two studies of the number of archaeological sites damaged by the EVOS came to similar findings. In the first study by Mobley et al. (1990), of 1,000 archaeological sites in the area affected by the EVOS, about 24 sites, or less than 3 percent, were damaged. In the second study by Wooley and Haggarty (1995), of 609 sites studied, 14 sites, or 2 to 3 percent of the total, suffered major effects.

Interdisciplinary research and analysis of data from six deepwater historic shipwrecks in the Gulf of Mexico, collected both before and after the DWH, suggests that sites located within the spill-affected areas experienced enhanced metal corrosion since the spill. Multiple lines of evidence suggest that deepwater shipwrecks within spill-exposed areas were impacted by the spill. These include changes in the structure and function of microbial communities, sediment physical properties, sediment geochemistry, and archaeological observations of time-series data. Recent 3D optical and acoustic scans of these shipwrecks, as well as laboratory and field experiments conducted at these sites, indicate that exposure to oil spill residues, including dispersants, may impact the shipwreck's resident microbial communities including the biofilm that forms on all exposed surfaces and provides a protective coating on sunken shipwrecks. The most significant changes were observed at the site in closest proximity to the spill origin, the World War II German U-boat *U-166* (Damour et al., 2019; Mugge et al., 2019; Salerno et al., 2018).

5 EFFECTS OF A VLOS

The previous chapter summarized the general effects of an oil spill and/or gas release on various resources. This general effects information is considered in relation to the scenario discussed in Chapters 2 and 3 and the effects of a VLOS are analyzed by resource. The impact scale applied in this report is as follows:

- Negligible: Little or no impact
- Minor: Impacts are short-term and/or localized, and less than severe
- Moderate: Impacts are long-lasting and widespread, and less than severe
- Major: Impacts are severe

5.1 Air Quality

Following the initial well control incident, emissions would occur during each phase of the event due to fires (including in-situ burning), evaporative emissions from the oil, and emissions from sources operating during the oil spill recovery and cleanup process. The Arctic climate, severity of the oil spill, and the characteristics of the pollutant sources would all influence the behavior of emissions. Therefore, the severity of impacts to air quality from a VLOS would depend largely on whether the spill occurs in the winter or in summer. A VLOS and/or recovery occurring during the winter would likely result in greater impacts to air quality than a spill occurring during the summer.

5.1.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Well Control Incident. If the LOWC leads to a fire, the ignition of oil or gas would result in a large black smoke plume containing PM and other products of combustion, such as NO_X, SO_2, CO, VOC, and CO_2. The fire could also produce PAHs, which are hazardous to human health. It would be during this initial event when the majority accumulation of black carbon would occur. The deposits would be more severe if the initial explosion occurred in the winter when the maximum amount of ice and snow are present.

The heat of the fire would immediately cause the pollutants within the plume to disperse in an upward buoyant flow. The location of high pollutant concentrations due to the smoke depends on the stability of the atmosphere at the time of the explosion. Should the VLOS occur during winter months, the upward transport of the pollutants could be constrained by fumigation conditions that limit mixing with the surrounding air and restrict wind transport. In this case, pollutant concentration levels at nearby locations would likely reach levels that exceed the federal and SOA thresholds. Otherwise, the rising plume of pollutants would become increasingly diluted with height, and surface concentration levels would not be as high in the immediate vicinity of the fire (Evans et al., 1991). In either case, over time the smoke plume would be transported by the wind and eventually impact surface areas downwind from the fire.

VOC emissions would be high during Phase 1 due to evaporation of freshly surfaced oil. During the DWH event, the emissions of VOC were confined to a relatively narrow plume as the sea surface transport of oil did not exceed a few kilometers (de Gouw et al., 2011). Consequently, the VOC impacts would be most severe immediately following the explosion and decrease as the oil slick spreads. The risk to air quality from VOC emissions stems from the anticipated likelihood that the VOCs will combine with NO_X to form ozone which is a criteria pollutant.

With increasing distance from the location of the fire, some of the gaseous pollutants, particularly VOC, would undergo chemical reactions resulting in the formation of secondary organic aerosols, which are mostly semi-volatile organic material. Computer modeling conducted to evaluate emissions from a large oil spill considered several different VOC and other compounds including benzene, ethylbenzene, toluene, and o-xylenes, which are classified by the EPA as HAPs. The results showed that these compounds vaporize almost completely within a few hours following a spill. The ambient concentrations would peak within the first several hours after a spill and would be reduced by two orders of magnitude after about 12 hours. The heavier compounds would take longer to vaporize and may not peak until about 24 hours after spill occurrence (Hanna and Drivas, 1993).

Offshore Spill. Impacts from this phase of the VLOS would continue until the sea is clear of all or most of the oil. As long as there is an oil slick on the sea surface there will be evaporative emissions and some level of air quality degradation until nearly all volatile hydrocarbons are depleted from the oil. As such, impacts from this phase would occur simultaneously and in combination with the impacts occurring during Phase 2.

During the DWH event, air samples collected by British Petroleum (BP), the Occupational Safety and Health Administration (OSHA), and USCG offshore showed levels of BTEX that were mostly under detection levels. Among the 20,000 samples taken by BP, there was only one sample where benzene exceeded the OSHA occupational permissible exposure limits (PEL) (Avens et al., 2011). However, even in low concentrations, some HAP emissions may be hazardous to personnel working in the vicinity of the spill site, which could be reduced by monitoring and using protective gear including respirators.

VOC emissions would be highest at the source of the spill. Concentrations of pollutants depend largely on the volume of the oil over the sea surface and the type of oil that was spilled. However, emissions would decrease with time. Even if the oil were not recovered, VOC concentrations would decrease as the oil surface area increases and gets thinner through transport by the current. This phase of the VLOS could continue for weeks so that emissions would eventually disperse in the wind, even allowing for frequent temperature inversions during winter when winds are very light. Average wind speeds over the Arctic are sufficient to disperse the evaporated pollutants over such a long period of time. Air quality impacts would be the greatest in the areas where oil is thick over the sea surface, which would likely be at the beginning of Phase 2 and could occur during a winter VLOS. However, as time goes by and the oil volume decreases, decreases in impacts to air quality are expected.

Onshore Contact. As the spill nears shore, evaporative emissions from the sea surface oil slick would continue to occur. As such, a portion of the most volatile hydrocarbons would evaporate by the time the oil reaches the shoreline. Therefore, potential for harmful VOC emissions would depend on the remaining volatility of the oil and the volume of oil accumulating on the shore. Combined with the other effects of weathering such as dissolution and dispersion, further harmful emissions from the oil would likely be limited.

Once the oil is onshore, even minor emissions could cause short-term effects to human health. The emissions may cause temporary eye, nose, or throat irritation, nausea, or headaches, but the doses are not thought to be high enough to cause long-term harm (EPA and CDC, 2010). Conversely, responders could be exposed to levels higher than the PEL established under OSHA guidelines (King and Gibbins, 2011). During the DWH event, 15,000 air samples collected nearshore by BP, OSHA, and the USCG showed most levels of BTEX were under detection levels. Among the many samples taken by BP, there was only one indicating benzene exceeded the OSHA PEL (BOEM, 2017). All other sample concentrations were below the more stringent American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit values (TLVs) (King and Gibbins, 2011). All measured concentrations of toluene, ethylbenzene, and xylene were within the OSHA PELs and ACGIH TLVs.

The VOC emissions from oil collecting onshore would cause a negligible to minor impact to air quality that is short-term and not expected to cause permanent harm. However, responders are at risk for exposure to harmful levels of benzene and should take safety precautions to avoid exposure.

5.1.2 Phase 2 (Spill Response and Cleanup)

During this phase new sources of emissions include dispersants, in-situ burning, and the use of offshore vessels and aircraft. Emergency response and cleanup of a VLOS would result in a slight emission increase due to elevated activity of vessels and equipment in the area of the release. The impact of response equipment emissions would most likely be very small and localized to the immediate area of response activity.

Dispersants. The objective of using a dispersant is to transfer oil from the sea surface into the water column (NRC, 2005), which reduces VOC emissions to the air. While the use of dispersants can decrease the size of the oil slick, toxic emissions are possible from the chemicals and solvents used in dispersants that could be potentially harmful. Following the DWH event, the EPA mobilized the Trace Atmospheric Gas Analyzer (TAGA) buses that are self-contained mobile laboratories that conduct air quality monitoring (EPA, 2011a). The EPA conducted monitoring for two chemicals in dispersants that have the greatest potential for air quality impacts, EGBE (2 butoxyethanol) and diproplyene glycol monobutyl ether. The TAGA analysis detected levels of these chemicals in the air along the Gulf Coast that were below the threshold that would likely cause health effects. Consequently, EPA suggests that using dispersants for oil spill cleanup would cause little or no impact on air quality (EPA, 2011a).

In-situ Burning. The burning of the oil results in emissions of NO_X, SO_2, CO, VOC, and CO_2 within a plume of black smoke. Monitoring studies of controlled oil burning at sea showed levels of NO_X, SO_2, and CO were below detection levels (Fingas et al., 1995). The study found that VOC emissions were below levels detected from the unburned oil and PAHs were not at a level considered harmful. Results of smoke-plume modeling showed concentrations of PM did not exceed the health criterion of 150 mg/m^3 when measured 3 mi downwind of the burning (McGrattan et al., 1995). Considering the low concentrations of pollutants found in monitoring and modeling, and the short-term nature of in-situ burning, there would be a short term, localized, and less than severe impact to air quality.

In general, the use of wellhead ignition as a response measure will have similar impacts as those described for in-situ burning. Where in-situ burning would increase emissions of NO_X, SO_2, $PM_{2.5}$, PM_{10}, and CO, it would decrease VOC emissions as compared to evaporation. The only difference is that with wellhead ignition the burn area is more concentrated and would lead to a higher temperature burn than an in-situ burn spread over a larger area. The higher temperature would allow for a more efficient combustion but would also increase the buoyancy of the plume. The rising plume of pollutants would become increasingly diluted with height, and surface concentration levels would not be as high in the immediate vicinity of the fire (Evans et al., 1991). The location of high pollutant concentrations due to the smoke depends on the stability of the atmosphere at the time of the response. Over time, the smoke would be transported by the wind and eventually affect surface areas at a distance from the fire. Due to the more concentrated plume, the impacts of wellhead ignition would occur over a smaller area than an in-situ burn but would have increased, although short-lived, adverse effects onshore.

Offshore Vessels. Offshore vessels would be used during the open-water and shoulder seasons to remove oil at sea or apply dispersants. A VLOS may require up to a hundred or more diesel-powered oil-skimming vessels, and other marine equipment such as icebreakers, over the course of time required to confine and remove such a large amount of oil from the surface. It is a time-consuming process that would likely take weeks or months to complete and would result in thousands of tons of emissions, particularly NO_X, but also including CO, PM, SO_2, VOC, and CO_2 (Discovery News, 2010; EPA, 1996).

Emissions from this number of vessels would likely result in temporary severe levels of effect to air quality.

Aircraft and Surface Vehicles. A portion of dispersants used to decrease the size of the oil slick may be applied using aircraft. During the response and cleanup process, other aircraft, including helicopters, may be needed for personnel and equipment transport. Aircraft emissions depend partly on the physical characteristics and performance parameters of each aircraft type. In addition to the physical characteristics of the aircraft operating at the site, emissions further depend on the time that each aircraft type operates in the various modes that define a landing and takeoff cycle. A landing and takeoff cycle consists of the approach, landing, taxi operations, idle time, takeoff, and departure. Emissions from landing and takeoff cycles could impact air quality within the immediate area of the runways and landing pads. In addition to aircraft, surface-based vehicles would support cleanup activities. Surface vehicle emissions are expected to be similar to the everyday emissions from vehicles regularly operating in the area. Surface vehicles would have a negligible contribution. Aircraft and vehicle emissions are likely to cause little to no, up to short-term, localized, and less than severe impact to air quality.

5.1.3 Phase 3 (Post-Spill, Long-Term Recovery)

Following the mechanical removal or other disposition of the oil by burning, evaporation, or weathering, few, if any, additional recovery efforts would be required that would affect local air quality. In order for NRDA and recovery efforts to proceed on a long-term basis, the continued use of marine vessels, small boats, aircraft, and surface vehicles would be required. Emissions from these sources would be far below the levels experienced during any of the previous phases of the VLOS. Emissions from limited cleanup vessels and equipment would continue as long as the spill recovery is ongoing but would most likely not have an effect on air quality.

5.1.4 Conclusion

A VLOS in the Beaufort Sea could emit large amounts of regulated potentially harmful pollutants into the atmosphere. The greatest deterioration of air quality would occur during Phases 1 and 2, particularly if the spill occurs in the winter when fumigation conditions are more likely, and precipitation is less frequent. Fire and spread of surface oil would cause moderate to major levels of effect from PM and VOC emissions in the immediate vicinity of the flames. With distance from the fire and further spreading of surface oil, the concentrations of VOC could produce moderate effects around the spill area. Impacts continue for weeks during Phase 1 but could continue for months under Phase 2. Arctic winds would disperse pollutants and limit impacts on air quality to the immediate area of the spill. Considering the decrease in pollution sources over time and the meteorological conditions existing over the Arctic, minor levels of effect to air quality would be expected. Concentrations of VOCs and criteria pollutants would return to pre-incident levels following the conclusion of Phase 2. Air quality would not be permanently affected in the region.

5.2 Water Quality

5.2.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Well Control Incident. Water quality would be impacted by the initial release and suspension of natural gas and oil into the water column, the disturbance of sediments at the seafloor, the exposure to combustible compounds resulting from an explosion and ensuing fire, and contaminants released into the water column resulting from the destruction and sinking of the oil platform. The severity of these impacts would depend on the duration of the initial release, but an increase in sediment resuspension, pollutant concentrations, and an acute exceedance of natural background concentrations for many water quality parameters (salinity, temperature, dissolved oxygen, etc.) would be expected. When natural gas (primarily methane – CH_4) is released into the water, it rises through the water column as a function of pressure and temperature – two factors influenced by water depth. Water depths in the majority of the Beaufort Sea Planning Area range from about 25 ft to more than 14,000 ft. When released at depth in deeper, colder waters, some of the natural gas would enter the water as a water-soluble fraction and may persist in the marine environment for long periods of time (Patin, 1999), reducing dissolved oxygen levels. When released at or near-surface, surface water quality would have higher concentrations of CO_2 than background levels and this increase could affect biological processes and chemical reactions in the microlayer at the water-air interface, such as egg and larvae respiration (GESAMP, 1995).

Offshore Spill. A subsea release of hydrocarbons for 90 days would disperse and suspend plumes of oil droplets within and throughout the water column creating large patches of sheen and oil on the water surface, throughout the water column, and upon any landfast ice surface. The dissolution rates of aromatic hydrocarbons would be expected to be extremely high near the localized region of the well flow. Fresh oil and aromatic hydrocarbons could adsorb onto marine detritus and suspended sediments in the water column or mix with drilling muds and be deposited on the seafloor. The dissolved components and oil droplets that remain suspended in the water column or mixed down by surface turbulence would exceed background concentrations of naturally occurring petroleum hydrocarbons, and affect water quality. These large volumes of oil would affect the water chemistry of the impacted areas of the Beaufort Sea most likely exceeding the SOA’s Water Quality Standards for total aqueous hydrocarbons of 15 µg/L (15 ppb) for several months.

A subsea or below the seafloor blowout has the potential to resuspend sediments and disperse potentially large quantities of bottom sediments. Depending upon the particle size of the seafloor sediment and the subsea current patterns, sediment could travel several kilometers and stay suspended for several hours to days in the Beaufort Sea. Sediment resuspension can lead to a temporary change in the oxidation-reduction chemistry in the water column, including a localized and temporal release of any formerly sorbed metals, as well as nutrient recycling (Caetano et al., 2003; Fanning et al., 1982). Sediments would likely have the potential to become contaminated with oil components and some persistent forms of oil (tarballs) could continue to affect Beaufort Sea water quality for months and years.

In offshore marine waters, advection and dispersion would reduce the effect of toxic oil fractions or their toxic degradation products including products resulting from photo-oxidation. Higher molecular weight compounds with lower toxicity potential would likely interact with settling particles in the water column providing a natural removal process (Di Toro, McGrath, and Stubblefield, 2007; Tarr et al., 2016). However, temperature has significant influence on the fate of crude oil in marine environments (Bacosa et al., 2018) with decomposition and weathering processes such as hydrocarbon degradation, microbial growth, and hydrocarbon mineralization occurring much slower in cold waters than in temperate regions (Sharma and Schiewer, 2016). Just as persistent toxic-oil fractions or their weathered decomposition products remained toxic to freshwater zooplankton for 7 years after an experimental spill in Prudhoe Bay (Barsdate et al., 1980), it is highly likely that Beaufort Sea water quality could be impacted by oil toxicity levels for long periods, particularly if a spill occurred in deeper, colder waters.

Additionally, isolated waters of embayments and lagoons, shallow waters under thick ice, or a fresh spill in rapidly freezing ice would not be exposed to natural weathering and degrading processes and hydrocarbon toxicity levels would most likely remain high. Furthermore, an oil spill that occurs in broken ice or under pack ice during the Arctic winter would freeze into the ice, move with the ice, and melt out of the ice the following summer. Spills in first year ice would melt out in late spring or early summer, whereas spills in multiyear ice would melt out later in the summer or in subsequent summers. Before being released from the ice, oil-contaminated ice could drift for hundreds of kilometers over many months or years, depending upon its drift trajectory. Spills released from the ice would be relatively unweathered and would have the characteristics of fresh oil, including higher toxicity levels. Under these conditions, spilled oil and the associated PAHs would affect water quality at the sea surface and in the water column until the oil degrades, dilutes, and disperses.

Onshore Contact. Shoreline energy (wave activity/intensity) influences hydrocarbon weathering when oil comes into contact with any shoreline and is an important factor for natural removal and cleaning of stranded oil (Gong et al., 2014). High energy causes significant sediment motion and flushing of interstitial waters in beach sediments and coastal marshes. By contrast, low shoreline energy and protected coastal geography have led to multi-decadal persistence of petroleum following various oil spills (Bacosa et al., 2018; Gong et al., 2014). The Beaufort Sea shoreline is characteristically a low-energy system with the exception of high-energy storm surges. Oil that contacts the shoreline would mix into the nearshore and beach sediments, then remobilize and disperse, causing persistent elevation of hydrocarbon concentrations in nearshore waters. Impacted habitats would include estuaries, embayments, river deltas, and other shoreline environments. Due to the remoteness and inaccessibility of the Beaufort Sea shorelines, persistent hydrocarbon shoreline contamination would be expected for many years. High-energy storm surges would further oil contamination by driving contaminated sediment and nearshore waters inland through river deltas and low-lying coastal shorelines.

5.2.2 Phase 2 (Spill Response and Cleanup)

Dispersants. Application of dispersants can reduce the size of oil droplets, change the oil surface physicochemical properties, increase oil dispersion in the water column, and thereby alter the rate and extent of the interactions between oil and sediment (Gong et al., 2014). As chemically dispersed surface oil breaks into smaller droplets it can distribute vertically in the water column and adhere to sediment organic matter and be transported to the seafloor and interstitial water. In the shallow nearshore waters of the Beaufort Sea, wind, wave, and current action would likely mix the dispersant-oil mixture into the water column and down to the seafloor environment. Data from the DWH blowout shows that the presence of Corexit 9500 (dispersant) greatly increased sediment uptake of dispersed oil and PAHs (Gong et al., 2014). Similar results would be expected if this dispersant was applied in the Beaufort Sea. Recent papers also show that some dispersants can inhibit or leave unaffected biodegradation of oil in the water column, while others noted accelerated biodegradation (Fingas, 2014).

Numerous studies on the aquatic toxicity of dispersants have been underway since the use of >1 million gallons during the DWH oil spill (Judson et al., 2010; Lewis and Pryor, 2013). Judson et al. (2010) analyzed the toxicity of eight oil spill dispersants and compared their relative potential to harm human and aquatic life. The results of the cytoxicity tests (a measure of how toxic a chemical is to living cells) indicated that none of the eight dispersants tested, including the dispersant product used in the Gulf, displayed biologically significant endocrine disrupting activity. EPA is conducting further toxicity tests to determine the relative toxicity of the oil and the dispersants to aquatic species. White et al. (2014) reported dispersant persistence in marine sediments; however, only limited knowledge exists on how dispersants affect the oil-sediment interactions and how such interactions alter the fate, transport, and transformation of persistent oil-sediment in the marine environment (Gong et al., 2014).

In-Situ Burning. Flame temperatures for crude oil to burn on water are about 900–1,200 °C, but the temperature at the oil slick/water interface is never more than the boiling point of water and is usually around ambient temperatures (Buist, 2003). In-situ burning could increase the surface water temperature in the immediate area and produce hydrocarbon residues. The upper-most layer of water (millimeter or less) that interfaces with the air is referred to as the microlayer. Important chemical, physical, and biological processes take place in this layer and it serves as habitat for many sensitive life stages and microorganisms (GESAMP, 1995). Disturbance to this layer through temperature elevation could cause negative effects on biological, chemical, and physical processes.

Residues from in-situ burning can float or sink depending on the temperature and age of the residue. The residue is primarily composed of higher weight molecular hydrocarbons that exhibit little water or lipid solubility and has no detectable acutely toxic compounds. The current recommendation is to collect the residue prior to its sinking to the seafloor (Mullin and Champ, 2003), resulting in little to no effects to water quality.

During a winter VLOS, in-situ burning would melt sea ice resulting in hydrocarbon residues that would either float, sink, or adhere to adjacent ice. Recovery of in-situ residues would be more difficult and more likely to remain in the environment.

Offshore Vessels and Skimmers. Mechanical recovery of oil would result in more vessel traffic and potential impacts to water quality from deck drainage, sanitary and domestic discharges, brine and cooling water discharges, small spills, anchoring in benthic habitat, disturbance of microlayer, and potential for introduction of invasive species from foreign or out-of-state vessels. In winter, icebreakers could disrupt and affect the movement of spilled oil trapped beneath or in the ice, potentially spreading oil contamination and complicating oil recovery efforts. Mitigation efforts to minimize impacts from vessel discharges in the Beaufort Sea are in place through the EPA Vessel General Permit.

Drilling of Relief Well. Muds and cuttings from drilling a relief well would be disposed of in the approved and permitted waste disposal well or on the seafloor adjacent to the relief well. A temporary increase in suspended solids in the immediate vicinity of the relief well would be expected.

Beach Cleaning and Booming. These activities could result in a temporary increase and resettlement of suspended sediment in waters, resuspension of hydrocarbons, and runoff of treatment-laden waters that could affect nearshore temperature and nutrient concentrations. The potential exists for a more long-lasting and widespread impact resulting from the introduction of invasive species from small boats, waders, and clothing worn by workers from outside of the Alaska Arctic region.

5.2.3 Phase 3 (Post-Spill, Long-Term Recovery)

During long-term recovery, contamination of marine and freshwater aquatic environments could continue from oil and oil residues in seafloor sediments or shorelines either by diffusion, storm events, bioturbation, erosion, or anthropogenic disturbances. The most likely oil residue to persist and pose a long-term risk would be the heavier molecular chained PAHs. Assessing any ecological significance of long-term exposure to PAHs would require the use of multiple lines of evidence, an appropriate set of ecosystem components, and an appropriate ecological risk characterization that would most likely result from damage assessment studies during the NRDA process.

5.2.4 Conclusion

A VLOS would severely affect water quality locally and potentially in far-reaching inaccessible areas for months to years by increasing and exceeding background concentrations of hydrocarbons in the water column and marine sediments. Major impacts on water quality would also occur from response and cleanup vessels, in-situ burning of oil, dispersant use, and activities on shorelines associated with cleanup, booming, beach cleaning, and long-term monitoring. During the event, a sustained degradation of water quality from hydrocarbon contamination would most probably exceed the SOA water quality criteria for all marine beneficial uses, having severe ramifications on the chemical, physical, and biological uses of the water. Acute and lethal toxicity levels of hydrocarbons would be expected within the first days of the release, followed by chronic toxicity levels persisting long-term in marine sediments. Toxic levels of hydrocarbons suspended within the water column and settling to marine sediments would impair the water's ability to sustain the aquatic ecosystem, cause deleterious effects to aquatic life, and make the water unfit and unsafe for all beneficial uses such as water supply for humans, aquatic life, and wildlife. Sediment quality would also likely be impacted with levels of hydrocarbons persisting long-term and leaching back into the water column during storms, weather events, or any seafloor disturbance to the contaminated marine sediments. Bioaccumulation of persistent hydrocarbons in marine sediments could occur causing long-term impairment to the reproduction and propagation of fish, aquatic life, and wildlife. Long-term impacts would be expected because cold Arctic temperatures slow the natural weathering processes of oil, increasing the duration for exceedances of ambient water quality resulting in a longer recovery period for the aquatic ecosystem. A VLOS occurring in the Beaufort Sea planning area, therefore, would likely have severe and major impacts on water quality of the Chukchi and Beaufort seas.

5.3 Vegetation and Wetlands

5.3.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Well Control Incident and Offshore Spill. There are no potential impacts to vegetation and wetlands from the initial blowout event or oiling of offshore waters due to the distance from an offshore spill.

Onshore Contact. The potential for spilled oil to contact shorelines, vegetation, and wetland environments is influenced by the timing of a VLOS, the seasonal effects of currents and subsequent advection of oil, timing and duration of oil spill, presence or absence of fast or pack ice, and general weather patterns (wind and storm events). Fate of spilled oil on shorelines is determined primarily by three factors:

1. The geomorphology, geography, season, weather, and wave exposure of the spill site which controls where and in what amounts the shorelines are oiled.
2. The physical and chemical properties of the oil which affect weathering.
3. The influence of cleanup and natural oil loss on the distribution and level of oil on shorelines over time (Page et al., 2013).

The Beaufort Sea coast of northern Alaska extends from Point Barrow eastward to the Canadian border, a straight-line distance of 379 mi, and has 1,216 mi of mainland coast. Dominating this coastline are low, organic-rich tundra-exposed bluffs, bays and inlets, lagoons with barrier islands, tapped basins, and deltas. Sediments are mostly silts and sands with occasional gravel, and bank heights generally are low (6–12 ft), especially for deltas (<3 ft) (Jorgenson and Brown, 2005). The nearshore Beaufort Sea and the barrier islands are ice covered most of the year, with open water from mid-July to October. During open water, the shoreline is characterized by small tides and persistent wind-driven currents creating a low potential for spilled oil to reach beyond the intertidal area. Seasonal storm events, however, can raise water levels as much as 6.5 ft and could force oil and oil residues into upper shoreline areas, wetlands, and inside delta areas as far as 16,500 ft along the Beaufort Sea (Kowalik, 1984; Reimnitz and Maurer, 1979).

Natural degradation and persistence of oil on beaches would be influenced by the crude oil and volume of oil reaching the shoreline. Specific contact location characterized by type of sand and grain size, degree of penetration into the subsurface, exposure to weathering action of waves, and sand movement onto and offshore would determine level of shoreline contamination on Beaufort Sea coasts. Appendix A, Table A12, *Land Segment (LS) ID and the Percent Type of Environmental Sensitivity Index Shoreline Closest to the Ocean for United States, Alaska Shoreline*, identifies the shoreline characteristics for the Beaufort

Sea. Spilled oil may persist for extended periods on peat shores, however if cleaned up, it would be expected to persist for less than a decade (Owens and Michel, 2003). Residual oil and residues could remain in the shallow subsurface sediments, particularly in low-energy coastlines such as lagoons on the Beaufort Sea coast. On sheltered beaches, heavy oiling left for long periods could form an asphalt pavement relatively resistant to weathering (Hayes et al., 1993). Oil deposition above the level of normal wave activity would take place if the spill occurs during spring tides or storm surges. High energy causes significant sediment motion and flushing of interstitial waters in beach sediments and coastal marshes (Gong et al., 2014). Although petroleum-degrading microbial communities are present, biodegradation along Arctic coastlines would likely be slow (Prince, Owens, and Sergy, 2002; Braddock, Lindstrom, and Price, 2003). This is due to low temperatures and because biodegradation would be limited to only a few months per year (Sharma and Schiewer, 2016). Therefore, spilled oil could persist for many years, with continued effects on potential recovery (Owens et al., 1983; Braddock, Lindstrom, and Price, 2003; Owens, Taylor, and Humphrey, 2008).

Various factors influence the extent of impacts to vegetation and wetlands. These factors include the oil type and degree of weathering, volume of oil contacting vegetation and wetlands, duration of exposure, season, plant species, percentage of plant surface oiled, substrate type, soil moisture level, and oil penetration into the soil (Hayes et al., 1993; Hoff, 1995; NOAA, 2010; Pezeshki et al., 2000). Vegetation regrowth and recovery on the North Slope are generally better where oil spills occur in flooded areas or on saturated soils, than on unsaturated soils (BLM, 2012). Coastal wetlands in sheltered areas (such as embayments and lagoons) that are not exposed to strong water circulation or wave activity, would be expected to retain oil longer with longer lasting effects on biota (Culbertson et al., 2008) and multi-decadal persistence of petroleum (Bacosa et al., 2018). Impacts to wetland vegetation may cause plant mortality and loss of wetland functional values.

5.3.2 Phase 2 (Spill Response and Cleanup)

If a VLOS resulted in extensive oiling of the waters and coastal areas of the Beaufort Sea, it could require intensive cleanup, restoration, and remediation activities conducted by potentially thousands of workers and hundreds of pieces of equipment deployed in the coastal zone. The effort could result in the unprecedented imposition of people, noise, and activity on the area’s remote and undeveloped landscape. Spill cleanup operations might adversely impact coastal beaches if the removal of contaminated substrates affects beach stability and results in accelerated shoreline erosion.

Skimming, booming, in-situ burning, and other spill response and cleanup operations can be effective means of preventing offshore oil spills from reaching coastal wetlands and other vegetation. Booming and cleanup activities can involve increases in vehicle, vessel, and foot traffic; use of heavy mechanized equipment; and high-pressure washing, all of which can cause damage to the environment and biological communities of wetland habitats, particularly if activities are unmonitored. On the other hand, positive, tactical booming techniques could provide protections for high functional wetlands deflecting oil spills towards wetlands with lower functional values.

Cleanup, including chemical and physical methods, can be more damaging to vegetation than the oil itself, with impacts recurring as long as the cleanup continues (Peterson et al., 2003). Cleanup methods used on shorelines contacted by oil could include excavation, cold-water washing, manual cleaning using oil absorbent materials, and placement and recovery of sorbent pads. Manual removal of oil by spill response personnel can break plant shoots, which may do more harm to the vegetation than the oil itself, or they may push oil farther into the soil (Mendelssohn et al., 2012). In addition to mechanical cleanup and recovery activities, dispersants could be introduced into the environment, likely at the sea surface, and applied using aircraft or vessels. Dispersants may have an adverse effect on wetland habitats depending on the type of dispersant used and its fate in the coastal ecosystem. White et al. (2014) reported dispersant persistence in marine sediments, however only limited knowledge exists on how dispersants affect the oil-sediment interactions and how such interactions alter the fate, transport, and transformation of persistent oil-sediment in the marine environment (Gong et al., 2014). Bioremediation could be employed as a strategy to remove and/or detoxify pollutants if environmental conditions are favorable. Bioremediation is safe and effective (Atlas and Bragg, 2013) and would likely have a negligible effect on coastal and estuarine habitats.

In-situ burning can also occur onshore and in marshes (Michel and Rutherford, 2013). Lindau, Delaune, and Jugsujinda (2003) report that an in-situ burning experiment in Louisiana only had short-term detrimental effects on salt and freshwater marsh plants and should be considered a viable remediation method under certain environmental conditions.

5.3.3 Phase 3 (Post-Spill, Long-Term Recovery)

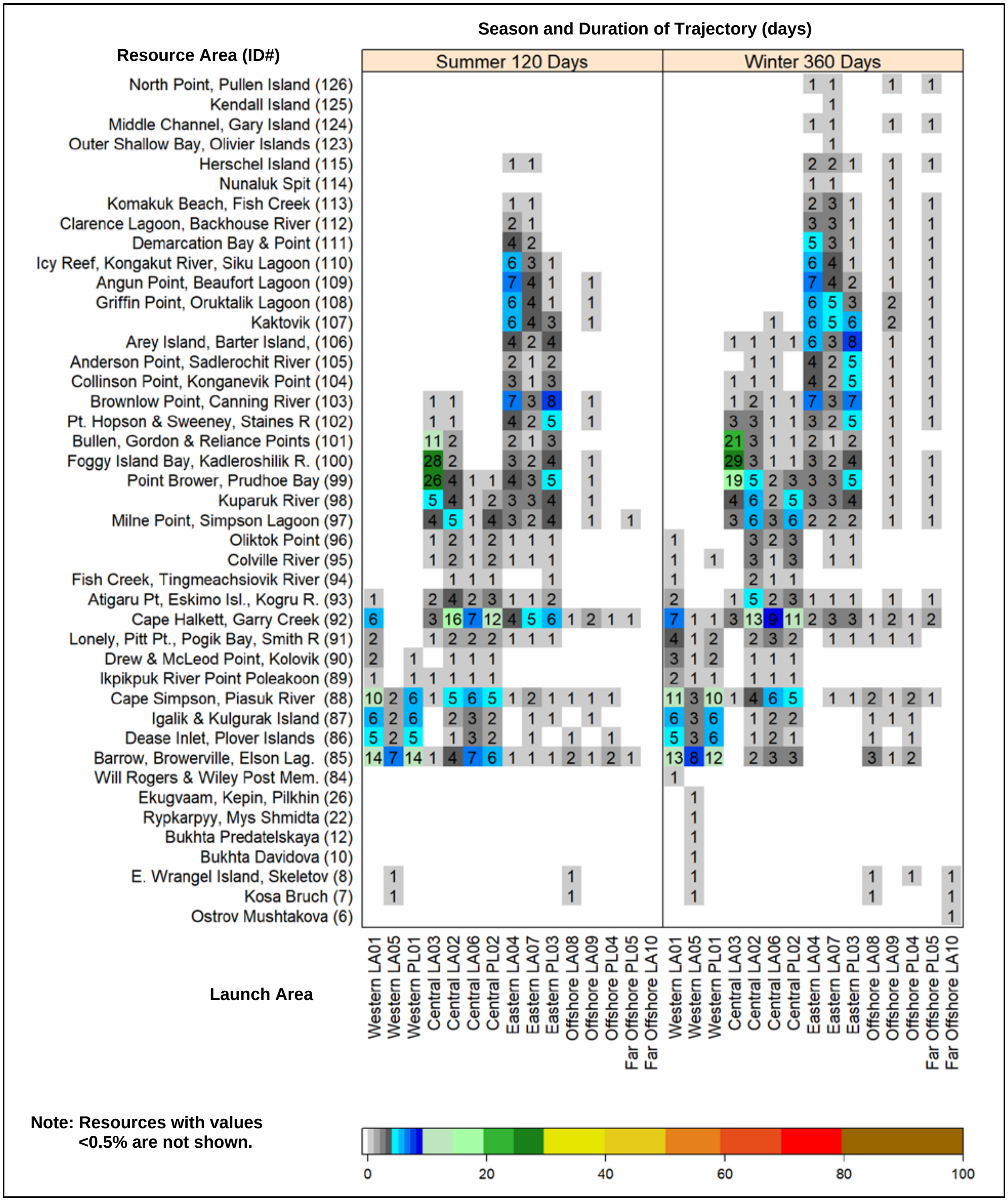
Long-term adverse effects to vegetation and wetland habitats are possible due to the severity of the VLOS and OSRA estimates. Because spills occur under different chemical, environmental, and biotic conditions, impacts and wetland recovery trajectories can vary greatly and be difficult to predict, particularly in the absence of a site-specific wetland ecological risk assessment. Wetland vegetation is the ecosystem component providing the foundation for wetland structure and function on which many important ecosystem services rely (habitat, nutrient cycling, and storm protection). Vegetation recovery can be relatively rapid in situations where oiling impacts only the upper shoots and leaves. Recovery could be longer term should oil penetrate the soil and substrate. Vegetation recovery is an important indicator of wetland recovery (Mendelssohn et al., 2012). Damage assessment studies on post-spill recovery would likely occur as a result of the NRDA process.

Storm surges along the Beaufort Sea coastline are an important factor in influencing the extent of oiling on shorelines, vegetation, and wetland habitats. In 1970, Reimnitz and Maurer (1979) observed the effects of tidal surges from a major storm event that inundated low-lying tundra and delta regions on the Beaufort Sea shoreline, leaving debris lines from flotsam as far as 16,500 ft inland. A storm of equal or greater magnitude could force weathered oil far inward and leave residue over wide areas of tundra and river shores. In such cases, full recovery of wetlands, including benthic communities, may require more than 10 years depending on site and spill characteristics (Culbertson et al., 2008). Any asphalt pavements that form could remain in some wetland substrates for decades.

Long-term effects could include a change in plant community composition or the displacement of sensitive species by more tolerant species. Impacts to soil microbial communities might result in long-term wetland effects, and wetland recovery would likely be slowed.

5.3.4 Oil Spill Trajectory Analysis

BOEM identified 132 LSs and their ESI for this analysis (Appendix A, Tables A11 and A12; Figures A4a–c). The ESI is a numerical index ranking the vulnerability of a coastline’s natural characteristics to impacts from oil spills. The higher the ESI number, the more vulnerable the coastline is to oil spills. Figure 5-1 displays 43 LSs with ≥1 percent of trajectories contacting from any individual LA within 120 or 360 days, summer or winter, respectively. Although every LS in Figure 5-1 has some percent of trajectories contacting, the majority range from 1–4 percent. For this analysis, 21 LSs with ≥5 percent of trajectories contacting during summer or winter are discussed further. Most LSs contacted are directly adjacent to the individual Western, Central, or Eastern shelf area. Within those shelf areas, LAs nearest to shore have the highest chance of contacting LSs. As identified by the ESI, the majority of shorelines within the LSs, are characteristically sandy/gravel beaches, saltwater marshes, and inundated low-lying tundra (Appendix A, Table A12).



Resource Area (ID#)	Summer 120 Days															Winter 360 Days														
	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10
North Point, Pullen Island (126)																							1	1			1		1	
Kendall Island (125)																								1						
Middle Channel, Gary Island (124)																							1	1			1		1	
Outer Shallow Bay, Olivier Islands (123)																								1						
Herschel Island (115)								1	1														2	2	1		1		1	
Nunaluk Spit (114)																							1	1			1			
Komakuk Beach, Fish Creek (113)								1	1														2	3	1		1		1	
Clarence Lagoon, Backhouse River (112)								2	1														3	3	1		1		1	
Demarcation Bay & Point (111)								4	2														5	3	1		1		1	
Icy Reef, Kongakut River, Siku Lagoon (110)								6	3	1													6	4	1		1		1	
Angun Point, Beaufort Lagoon (109)								7	4	1		1											7	4	2		1		1	
Griffin Point, Oruktalik Lagoon (108)								6	4	1		1											6	5	3		2		1	
Kaktovik (107)								6	4	3		1									1		6	5	6		2		1	
Arey Island, Barter Island, (106)								4	2	4									1	1	1	1	6	3	8		1		1	
Anderson Point, Sadlerochit River (105)								2	1	2										1	1		4	2	5		1		1	
Collinson Point, Konganevik Point (104)								3	1	3									1	1	1		4	2	5		1		1	
Brownlow Point, Canning River (103)				1	1			7	3	8		1							1	2	1	1	7	3	7		1		1	
Pt. Hopson & Sweeney, Staines R (102)				1	1			4	2	5		1							3	3	1	1	3	2	5		1		1	
Bullen, Gordon & Reliance Points (101)				11	2			2	1	3									21	3	1	1	2	1	2		1			
Foggy Island Bay, Kadleroshilik R. (100)				28	2			3	2	4		1							29	3	1	1	3	2	4		1		1	
Point Brower, Prudhoe Bay (99)				26	4	1	1	4	3	5		1							19	5	2	3	3	3	5		1		1	
Kuparuk River (98)				5	4	1	2	3	3	4		1							4	6	2	5	3	3	4		1		1	
Milne Point, Simpson Lagoon (97)				4	5	1	4	3	2	4		1		1					3	6	3	6	2	2	2		1		1	
Oliktok Point (96)				1	2	1	2	1	1	1						1				3	2	3		1	1					
Colville River (95)				1	2	1	2	1	1	1						1		1		3	1	3		1	1					
Fish Creek, Tingmeachsiovik River (94)					1	1	1			1						1				2	1	1								
Atigaru Pt, Eskimo Isl., Kogru R. (93)	1			2	4	2	3	1	1	2						2			1	5	2	3	1	1	1		1		1	
Cape Halkett, Garry Creek (92)	6			3	16	7	12	4	5	6	1	2	1	1		7	1	1	3	13	9	11	2	3	3	1	2	1	2	
Lonely, Pitt Pt., Pogik Bay, Smith R (91)	2			1	2	2	2	1	1	1						4	1	2		2	3	2		1	1	1	1	1		
Drew & McLeod Point, Kolovik (90)	2		1		1	1	1									3	1	2		1	1	1								
Ikpikpuk River Point Poleakoon (89)	1		1	1	1	1	1									2	1	1		1	1	1								
Cape Simpson, Piasuk River (88)	10	2	6	1	5	6	5	1	2	1	1	1	1			11	3	10	1	4	6	5		1	1	2	1	2	1	
Igalik & Kulgurak Island (87)	6	2	6		2	3	2		1	1		1				6	3	6		1	2	2				1	1	1		
Dease Inlet, Plover Islands (86)	5	2	5		1	3	2		1		1		1			5	3	6		1	2	1				1		1		
Barrow, Browerville, Elson Lag. (85)	14	7	14	1	4	7	6	1	1	1	2	1	2	1		13	8	12		2	3	3				3	1	2		
Will Rogers & Wiley Post Mem. (84)																1														
Ekugvaam, Kepin, Pilkhin (26)																	1													
Rypkarpyy, Mys Shmidta (22)																	1													
Bukhta Predatelskaya (12)																	1													
Bukhta Davidova (10)																	1													
E. Wrangel Island, Skeletov (8)		1									1						1									1		1		1
Kosa Bruch (7)		1									1						1									1				1
Ostrov Mushtakova (6)																														1

Note: Resources with values <0.5% are not shown.

Figure 5-1 Percentage of Trajectories Contacting Land Segments (≥1% within 120 days Summer and 360 days Winter)

Summer. A Western Shelf VLOS results in a percentage of trajectories contacting Utqiaġvik/ Browerville/Elson Lagoon eastward to Cape Simpson (85–88) and Cape Halkett/Garry Creek (92) with the highest percentage of trajectories (14 percent) contacting Utqiaġvik. A Central Shelf VLOS has the highest percentage of trajectories contacting any LSs. Within the Central Shelf, LA3 has the highest value (28 percent) for Foggy Island Bay/Kadleroshilik River (100). The LSs contacted are identical to the Western Shelf, with additional percentages of trajectories contacting Milne Point (97) eastward to Bullen Point (101). A VLOS from the Eastern Shelf has the lowest percentage of trajectory contact ranging from 5–8 percent contacting Cape Halkett (92), Prudhoe Bay (99), Pt. Hopson (102), Brownlow Point (103), and Kaktovik eastward to Icy Reef (107–110) (Figure 5-1).

Winter. A Western Shelf VLOS has the same percentage of trajectories contacting LSs as provided above in the summer. For a Central Shelf VLOS, the highest percentage of trajectories contact Foggy Island Bay/Kadleroshilik River (100) with percentage of trajectories contacting Cape Simpson (88), Cape Halkett to Atigaru Point (92–93), and Milne Point eastward to Bullen Point (97–101) ranging from 5–29 percent. An Eastern Shelf VLOS has the lowest percentage of trajectories contacting LSs, however the percentage of trajectories contacting Prudhoe Bay (99) and Pt. Hopson eastward to Demarcation Bay (102–111) range from 5–8 percent (Figure 5-1).

5.3.5 Conclusion

A VLOS would severely affect marine and freshwater vegetation and wetlands along the coastlines of the Beaufort and Chukchi seas for months to years. Hydrocarbon contamination of marine and freshwater vegetation and wetlands would likely cause major impacts, and impacts from response and cleanup vessels, in-situ burning of oil, dispersant use, and activities on shorelines associated with cleanup, booming, beach cleaning, and long-term monitoring are also expected.

Hydrocarbon contamination of marine and freshwater wetlands would most probably exceed the SOA water quality criteria, applicable to all freshwater and marine beneficial uses, having severe ramifications on the chemical, physical, and biological functions of the wetlands. Substantial oiling of wetland vegetation, the ecosystem component that provides the foundation for wetland structure and function on which many important ecosystem services rely, would likely be severely impacted. Root and shoot-regenerating rhizome damage caused by repetitive oiling would likely be lethal to wetland vegetation resulting in a complete loss of wetland habitat and its associated function and use by aquatic life and wildlife. Oil contacting tundra wetland soils would be expected to migrate laterally and vertically, possibly contacting permafrost and spreading deeper into soil layers. Response of tundra wetland vegetation to oil is species dependent, with tundra mosses most sensitive to oil damage and plant death expected. Manual recovery of oil by spill response personnel can cause major impacts by harming vegetation and driving oil farther into wetland soil or sediments. Long-term, persistent effects of contaminated fresh and marine wetland sediments would result in reduced regrowth of wetland vegetation, aquatic life, and wildlife resulting in slower revegetation and recovery of the wetland ecosystem. A VLOS, therefore, would likely have severe and major impacts on marine and freshwater vegetation and wetlands along the coastlines of the Chukchi and Beaufort seas.

5.4 Invertebrates

5.4.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Invertebrates could be exposed to an explosion or fire, contact with oil, and contamination or loss of access to preferred habitat during Phase 1 of the VLOS scenario. An explosion and possible fire at the sea surface from a well control incident would result in an increase of pressure and temperature of the immediate environment. Hot water, followed by released gas and oil, would negatively change the habitat of the area. Severity of effects would depend on released energy. Changes in the temperature and chemistry of the water column would result in the localized loss of pelagic and benthic invertebrates and their associated habitat near the wellhead. Sediment upheaval and redistribution of sediments into the water column and their subsequent deposition on the seafloor could affect pelagic organisms within the plume and all benthic organisms buried by the sediments, respectively. The severity of the effects would depend on the concentration of sediments or oil within the water column, density of ejected sediments, and duration of the sediment plume within the water column before deposition to the seafloor. A fire at the surface could create localized effects on plankton populations due to heat of the fire and release of material as a result of the event, including oil, melting plastics and rubbers, and chemicals used by response crews in attempting to control the fire.

Direct exposure to oil and gas would impact invertebrate communities during this phase. An offshore oil spill would directly affect plankton communities and benthic invertebrates because they have no or limited ability to avoid contact with surface and subsurface oil. A spill occurring in winter may persist for a longer period of time than during ice-free conditions (Drozdowski et al., 2011), resulting in greater effects on invertebrates if it is trapped under the ice. The potential effects of oil exposure on phytoplankton, zooplankton, microbial communities, and benthic invertebrates are described in detail in Section 4.2.4, including mass die-offs, impaired growth and behavior, and effects on populations (both negative and positive for some microbes). Oil contacting intertidal and subtidal zones could result in lethal and sublethal impacts on benthic invertebrates including adverse effects on reproduction, recruitment, physiology, growth, development, and behavior (feeding, mating, and habitat selection) owing to exposure to oil and accumulation of oil in tissues. Chronic contamination of nearshore benthic communities could occur if oil persists on beaches and in shallow nearshore sediments. These potential impacts could extend for hundreds of square miles during a VLOS. Habitat loss due to oil contamination could have a major impact on specialized habitats, such as the Boulder Patch, due to expected slow recovery from disturbances (Konar, 2007). Mixing and tidal flushing would dilute spilled oil and reduce the potential for exposure, while invertebrates in coastal habitats such as bays and estuaries would be more susceptible to exposure and associated impacts.

Nearshore coastal marine environments, with intertidal and subtidal floral and faunal communities, would likely experience the longest-term effects resulting from contact with oil. Organisms inhabiting these diverse environments are subject to similar effects as those listed in the previous section, but some factors are specific to onshore contact. Oil in shallow water that is weathered may be more toxic than fresh oil (Barron et al., 2008). Oil in the sediment can persist for many years. River and creek delta areas exhibiting estuarine habitats would be affected through wind and tidal exposure from oil, and the potential impact of storm events which can spread oil farther onto shoreline areas. The effects to shoreward invertebrate communities would depend on factors such as seasonality of spill, locations of onshore contact, and persistence of oil within the water before contact. Recovery from the effects to invertebrate populations where oil contacts the shore zone could take several years, depending on area of contact and duration and severity of exposure.

5.4.2 Phase 2 (Spill Response and Cleanup)

Impacts from spill response and cleanup operations would be influenced by the time of year. A spill occurring in winter may persist for a longer period of time than during ice-free conditions (Drozdowski et al., 2011), resulting in greater effects on invertebrates if it is trapped under the ice.

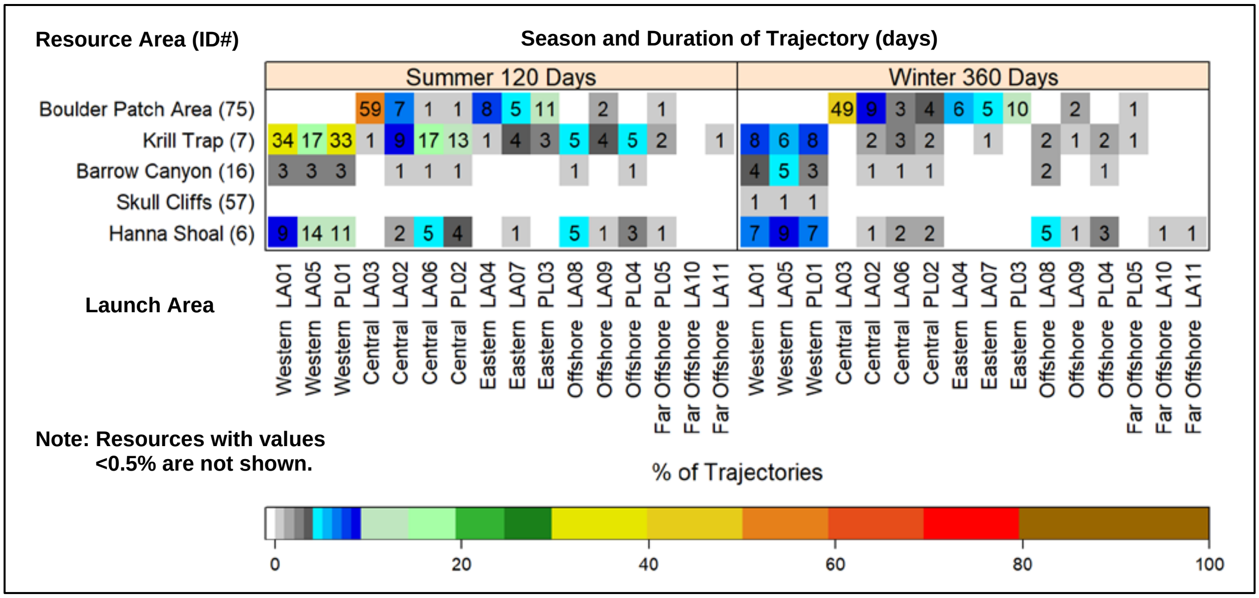
Physical damage to invertebrates from containment and collection procedures could occur. Lethal impacts may occur to planktonic organisms but are not expected at the population level. Benthic invertebrates would not likely be affected by mechanical recovery activities occurring at the surface. In-situ burning of spilled oil could impact organisms and benthic habitat in the immediate area due to residue from the burn sinking to the bottom. Death of planktonic invertebrates is possible in the immediate burn area. Some benthic organisms may be smothered. Impacts from mechanical recovery or burning are expected to be short-term and localized to the area of the spill. Dispersants used in spill response activities can result in greater toxic impacts to invertebrates than crude oil alone (Lee, Köster, and Paffenhöfer, 2012; Almeda et al., 2013), and can also have negative impacts on the food web (Ortman et al., 2012; Trannum and Bakke, 2012). Effects of spill response could be long-lasting and widespread for both the plankton and benthic communities, especially if dispersants are used (Almeda, Hyatt, and Buskey, 2014).

5.4.3 Phase 3 (Post-Spill, Long-Term Recovery)

Impacts affecting invertebrates in long-term recovery are similar to the previously described scenarios. Phytoplankton populations should recover quickly, as described in Section 4.2.4. Long-term and chronic effects would be most evident in populations of benthic and pelagic animals and organisms associated with the Boulder Patch kelp beds. Even with the recovery of zooplankton through the currents of surrounding waters and the reproductive capacity of resident populations of benthic and pelagic invertebrates, the recovery of invertebrate populations may take 1–2 years if the impacting factors analyzed in earlier sections should culminate in causing population-level effects to this diverse group of organisms. Damage assessment studies (NRDA) could impact some individuals through noise and disturbance, but those impacts would be limited to individuals and would be a fraction of the impacts associated with a VLOS.

5.4.4 Oil Spill Trajectory Analysis

BOEM identified five invertebrate resource areas (Appendix A, Table A2, Figures A3a–c, and A3g). Figure 5-2 shows five resource areas with ≥1 percent of trajectories contacting them in summer or winter.



Summer 120 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Boulder Patch Area (75)				59	7	1	1	8	5	11		2		1		
Krill Trap (7)	34	17	33	1	9	17	13	1	4	3	5	4	5	2		1
Barrow Canyon (16)	3	3	3		1	1	1				1		1			
Skull Cliffs (57)																
Hanna Shoal (6)	9	14	11		2	5	4		1		5	1	3	1		

Winter 360 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Boulder Patch Area (75)				49	9	3	4	6	5	10		2		1		
Krill Trap (7)	8	6	8		2	3	2		1		2	1	2	1		
Barrow Canyon (16)	4	5	3		1	1	1				2		1			
Skull Cliffs (57)	1	1	1													
Hanna Shoal (6)	7	9	7		1	2	2				5	1	3		1	1

Figure 5-2 Percentage of Trajectories Contacting Invertebrate Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. In general, a VLOS that occurs near a specific resource area has a higher percentage of trajectories contacting that resource area. A summer nearshore VLOS may spread into the Chukchi Sea and contact important resource areas there. A Western Shelf VLOS has a substantial chance of impacting the Krill Trap (7) with 17–34 percent of trajectories contacting this area within 120 days. The percentage of trajectories contacting the same resource decreased for a VLOS originating in the Central Shelf (1–17 percent) and Eastern Shelf (1–4 percent). Hanna Shoal (6) showed similar trends, but with fewer trajectories contacting (9–14 percent from a Western Shelf VLOS, <0.5–5 percent from a Central Shelf VLOS, and <0.5–1 percent for an Eastern Shelf VLOS). Barrow Canyon (16) is estimated to be contacted by <0.5–3 percent of nearshore trajectories, depending on the VLOS location. The Boulder Patch (75), predictably, was contacted by the highest percentage of trajectories when the VLOS originated in the nearshore Central or Eastern shelves (1–59 percent). Offshore and Far Offshore trajectories were estimated to contact the Krill Trap (7) and Hanna Shoal (6) up to 5 percent of the time. Other resource areas may be contacted by 1–2 percent of trajectories.

Winter. In the OSRA, a VLOS occurring in winter showed similar trends to a summer VLOS although the percent of trajectories that contacted important resource areas generally decreased. The presence of ice in winter conditions serves to protect Chukchi Sea resource areas from contact by containing some of the spilled oil. The Krill Trap (7) and Hanna Shoal (6), in particular, were contacted by 6–9 percent of Western Shelf trajectories, which is a decrease from the summer estimates. Similarly, the percentage of trajectories from the Central Shelf that contact the Krill Trap (7) decreased to <0.5–3 percent. However, Barrow Canyon’s (16) percentages increased slightly, up to 5. The OSRA still showed a substantial percentage of trajectories originating in the Central and Eastern shelves contact the Boulder Patch (3–49 percent). Offshore and Far Offshore VLOSs were not very different from the summer scenario, although the Krill Trap (7) was less likely to be contacted.

5.4.5 Conclusion

BOEM (2018d) described the impacts of oil contaminating invertebrate communities for large and small oil spills. The amount of oil spilled in a VLOS would be greater than described in that analysis, so the overall impact on invertebrates would be greater and would likely occur over a larger area. A VLOS would likely have less than a one-year effect on phytoplankton populations, but could persist for longer if recolonization is slow. However, short-term, local-level effects would potentially affect local food webs, which may result in longer-lasting and widespread impacts. Severity of effects would be determined by duration of oil spill, weather patterns, and the resultant distribution and geographic coverage of surface oil slicks. Invertebrate populations within benthic, pelagic, and onshore environments are at greater risks from a VLOS due to their slower reproductive rate, longer life spans, and the potential of adult breeding populations being negatively affected and leading to a longer recovery rate. Phytoplankton and zooplankton populations extirpated by oil slicks that are constantly shifting and forming in new areas due to influences of wind, weather, and waves would not be available to organisms that depend on them for food and survival. Ice algae population effects would be determined by similar factors. Oil in leads or incorporated into first year ice may affect primary productivity, which would result in negative impacts to the fish and invertebrates that rely on ice algae to survive. Invertebrate populations may require one or more years to recover from these effects, and cascading impacts would be expected throughout the food web. A VLOS would likely have major, widespread, long-lasting, and severe impacts on invertebrate communities in Stefansson Sound, the Chukchi and Beaufort seas, and especially to the Boulder Patch and Krill Trap.

5.5 Fish

5.5.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

A fire would cause the surface water temperature to rise immediately, which would be lethal for epipelagic fish, eggs, and larvae. Subsurface water temperature would increase more slowly and could cause changes in physiological processes, particularly for benthic fish that are more sedentary. If a fire continued and subsurface temperatures continued to rise, subsurface egg and larvae mortality could occur over time. Free-swimming fish not obligated to a specific habitat would likely move out of the area if the temperature continued to rise. Chemical reactions in the water, such as oxygen concentration, would be altered by rising temperature, which could also affect the physiology of fish.

The potential effects of oil exposure on fish are described in detail in Section 4.2.5, including lethal and sublethal toxicity, changes in behavior, reproductive effects, contamination of fish prey and habitats, habitat loss, and changes to the food web. Acute and chronic exposures could occur in riverine, estuarine, and marine environments which includes habitats in the water column, bottom sediment, and sea ice. The severity of the effects on fish would depend on several factors including the duration of exposure on the surface, the season of the year (open-water, ice), and the life stage of the fish (egg, larvae, juvenile, adult). A VLOS occurring in winter may persist for a longer period of time than during ice-free conditions (Drozdowski et al., 2011), resulting in larger effects on fish if it is trapped under the ice.

Loss of access to preferred habitat can impact the spawning, rearing, and feeding strategies of fish. Anadromous fish, because they depend on several environments in their complex life history, can be particularly impacted if oil reaches mouths and deltas of anadromous streams and rivers. Oil on the coastline presents a barrier to access (or egress) to spawning, feeding, overwintering, and coastwise migration for anadromous species. A VLOS could wash over river deltas, into river mouths and be transported upstream by tidal action. Oil in anadromous water bodies would present contaminants to sensitive spawning areas and life stages. There are many anadromous rivers, streams, and lagoons along the Beaufort Sea coast that provide spawning and rearing locations for whitefish and salmon (Appendix A, Table A3). Several fish species such as capelin, sand lance, saffron cod, and some sculpin species are not considered anadromous, but they use nearshore substrates for spawning and rearing habitats. Nearshore species would be affected through similar pathways as anadromous fish if an oil spill hit the nearshore or shoreline, particularly during critical spawning or rearing times. Acute and chronic effects of oil on nearshore and intertidal fish, eggs, and larvae can have accumulating, cascading effects on fish populations over time. Sand lance would be especially negatively affected by oil in their nearshore habitats because they burrow in sand when not out foraging in the water column and they also overwinter in those burrows (Moles and Wade, 2001; Pearson, Woodruff, and Sugarman, 1984).

Offshore fish species would experience a variety of effects from a VLOS depending on life history stage (adult, subadult, egg, larvae); habitat association (bottom dwelling, mid-water column, upper water column, beneath ice, or in ice crevices); the range of depth inhabited; the breadth of the species’ habitat, prey, and range; the life history and behaviors of the species (migratory, sedentary, reproductive strategy, etc.); and plasticity of the species to adjust to environmental stressors.

Some species and life stages of fish exposed to oil or gas would be limited in their ability to escape or avoid contaminants. Changes in water quality, due to release of either oil or gas, can affect the organisms living in the marine environment. Gas releases are expected to produce more acute impacts, generally from changes in water quality, while oil spills can have both acute and chronic effects as described above. Sedentary, burrowing, or territorial fish may not avoid exposure in time to prevent negative impacts. Fish eggs and larvae are often unable to move out of contaminated areas. The exposure concentration that these species (including some poachers, eelpouts, sculpin, flounders, snailfish, and nesting saffron cod) would experience could be greater than that to which free swimming fish would be exposed. Fish that can swim relatively faster and more efficiently (such as salmon and cod) would more likely avoid some of the effects of oil at various concentrations if they have the sensory ability to detect oil or gas components.

Some fish species associate with sea ice to feed, hide, and spawn. Most notable of these in the Beaufort Sea is the Arctic cod which associates with ice in various life stages and seasons for shelter and as a forage habitat to feed on microorganisms on the underside of the ice. Under-ice amphipods are an important food source for Arctic cod (Gradinger and Bluhm, 2004; Lønne and Gulliksen, 1989). Rough, irregular textures of the underside of ice may provide preferred habitat for Arctic cod to avoid predators

(Cross, 1982). Arctic cod migrate between offshore and onshore areas for seasonal spawning under the ice during winter months (Craig, 1984). Oil and gas released in a winter scenario would pool under the ice and eventually freeze, which prolongs exposure to Arctic cod eggs and larvae, hiding adults, and amphipods inhabiting the under-ice environment. Melt-out of annual sea ice in spring and summer would release oil pooled underneath and trapped in ice and leads. All of these pathways would affect offshore and nearshore Arctic cod and other fish species, including those living in association with ice, those in the water column below ice, and ultimately the benthic species affected by sinking oil-laden particulate.

5.5.2 Phase 2 (Spill Response and Cleanup)

VLOS impacts and cleanup operations would be influenced by time of year. A VLOS occurring in winter may persist for a longer period of time than during ice-free conditions (Drozdowski et al., 2011), resulting in larger effects on fish if it is trapped under the ice.

Physical damage to fish from containment and collection procedures could occur. Pelagic fishes may be affected by mechanical recovery of spilled material but are expected to avoid an oiled area and to move away from vessels, booms, or skimmers. If spill response activities occur during spawning runs, some fish could experience difficulty reaching their spawning grounds. However, these avoidance impacts would be short-term and localized to the spill area.

Benthic fish would not likely be affected by mechanical recovery activities occurring at the surface. In-situ burning of spilled oil could impact organisms in the immediate area due to residue from the burn sinking to the bottom. Death of pelagic fishes that did not move away from the spill is possible in the immediate burn area. At the seafloor, habitat can be altered by residue from a burn. Some benthic organisms may be smothered. Impacts from mechanical recovery or burning are expected to be short-term and localized to the area of the spill. The use of dispersants has been shown to increase the exposure of fish eggs to hydrocarbons (Ramachandran et al., 2004). Dispersants used in spill response activities can have negative impacts on the food web (Ortman et al., 2012; Trannum and Bakke, 2012).

Effects of spill response could be long-lasting and widespread for both the planktonic and benthic fish communities if a VLOS occurs near spawning grounds or dispersants are used.

5.5.3 Phase 3 (Post-Spill, Long-Term Recovery)

In long-term recovery, there would be a continued presence of people in the area for monitoring and research. Monitoring and research from NRDA activities would include small boat and aircraft landings on shorelines and people walking and wading through aquatic habitats. These activities could result in trampling of fish habitats, noise and disturbance to fish, and removal of fish from the system for research purposes. Over the long-term, contamination of aquatic environments from oil (and possibly dispersant residue on the seafloor) would continue from oil weathering. Sunlight (UV radiation) increases the toxicity of PAHs, so summer sunlight in Arctic Alaska may exacerbate the amount and degree of toxicity exposure.

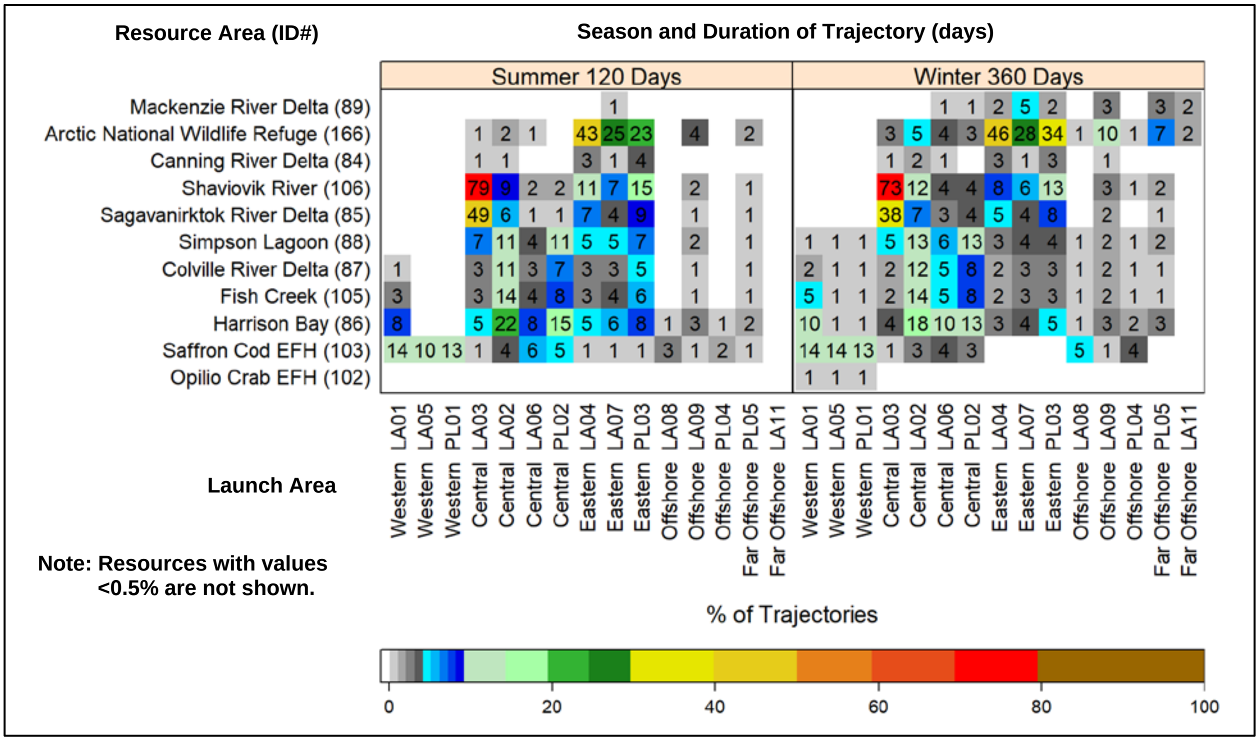
Long-term chronic effects from oil would occur in fish that occupy estuarine, intertidal, and freshwater habitats where oil accumulates and weathers, which is especially toxic to lipid-rich eggs. If chronic exposures persist, stress may manifest sublethal effects later in the form of histological, physiological, and behavioral responses, including impairment of feeding, growth, and reproduction (Heintz et al., 2000). Chronic toxicity and stress may also reduce fecundity and survival through increased susceptibility to predation, parasite infestation, and zoonotic diseases. The frequency of a single symptom does not necessarily reflect the effects of oil on the organism, so the cumulative effects of all symptoms of toxicity must be considered in evaluating acute and chronic effects of oil on fish.

Contaminant exposure can make a spawning site unavailable for multiple generations if the oil is detectable by the fish. If a population continues to spawn and/or rear offspring in oil-contaminated areas, abnormal development, genetic alterations, or abnormal behavior may repeat through successive generations. The likely results would be fewer juvenile fish survive, so that recruitment from the early life stages is reduced and adult populations decline. Declining adult populations may not be replaced at sustainable levels. Ultimately, these cumulative effects on individuals can affect the population abundance, and subsequently, community structure (Ott, Peterson, and Rice, 2001; Rice et al., 2000).

Furthermore, as a result of environmental stress and changes resulting from oil spills and a warming environment due to climate change, previously unknown fish populations could move into new areas and complicate recovery (Cheung et al., 2009).

5.5.4 Oil Spill Trajectory Analysis

BOEM identified 71 fish resource areas for the analysis (Appendix A, Table A3, Figures A3a–c, A3e–f; A4a–c, and A5a–c). Figure 5-3 shows 11 offshore resource areas and Figure 5-1 shows 43 onshore resources with ≥1 percent of trajectories contacting them in summer or winter.



Season and Duration of Trajectory (days)

Summer 120 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
Mackenzie River Delta (89)									1						
Arctic National Wildlife Refuge (166)				1	2	1		43	25	23		4		2	
Canning River Delta (84)				1	1			3	1	4					
Shaviovik River (106)				79	9	2	2	11	7	15		2		1	
Sagavanirktok River Delta (85)				49	6	1	1	7	4	9		1		1	
Simpson Lagoon (88)				7	11	4	11	5	5	7		2		1	
Colville River Delta (87)	1			3	11	3	7	3	3	5		1		1	
Fish Creek (105)	3			3	14	4	8	3	4	6		1		1	
Harrison Bay (86)	8			5	22	8	15	5	6	8	1	3	1	2	
Saffron Cod EFH (103)	14	10	13	1	4	6	5	1	1	1	3	1	2	1	
Opilio Crab EFH (102)															

Winter 360 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
Mackenzie River Delta (89)						1	1	2	5	2		3		3	2
Arctic National Wildlife Refuge (166)				3	5	4	3	46	28	34	1	10	1	7	2
Canning River Delta (84)				1	2	1		3	1	3		1			
Shaviovik River (106)				73	12	4	4	8	6	13		3	1	2	
Sagavanirktok River Delta (85)				38	7	3	4	5	4	8		2		1	
Simpson Lagoon (88)	1	1	1	5	13	6	13	3	4	4	1	2	1	2	
Colville River Delta (87)	2	1	1	2	12	5	8	2	3	3	1	2	1	1	
Fish Creek (105)	5	1	1	2	14	5	8	2	3	3	1	2	1	1	
Harrison Bay (86)	10	1	1	4	18	10	13	3	4	5	1	3	2	3	
Saffron Cod EFH (103)	14	14	13	1	3	4	3				5	1	4		
Opilio Crab EFH (102)	1	1	1												

Launch Area

Note: Resources with values <0.5% are not shown.

Figure 5-3 Percentage of Trajectories Contacting Fish Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. In general, trajectories from a VLOS in summer are likely to contact important Saffron Cod (103) habitat in the Chukchi Sea <0.5–14 percent of the time, with the highest likelihood occurring when the VLOS originates in the Western Shelf. The percentage of these trajectories that contact resource areas in the Beaufort Sea ranged from <0.5–79 percent and were highest for each area when the VLOS originated near that particular area. The Shaviovik and Sagavanirktok rivers both had substantial percentage of trajectories contacting them from a Central Shelf VLOS (up to 79 percent and 49 percent, respectively). A VLOS in the Eastern Shelf contacted the Arctic National Wildlife Refuge (ANWR) and the Shaviovik River more often than other ERAs. An Offshore and Far Offshore VLOS contacted some

ERAS, but in relatively low frequency (<0.5–4 percent of trajectories). Land segments were contacted by oil trajectories relatively infrequently, although the area around Prudhoe Bay and the surrounding bays and deltas was contacted more often (Figure 5-1, 28 percent).

Winter. Winter VLOS trajectories from the Western Shelf are estimated to contact more fish ERAs than summer spills due to persistence in ice and the longer travel time. As with summer spills, the highest percentage of trajectories contacted Saffron Cod (103) habitat in the Chukchi Sea. A VLOS originating in the Central and Eastern Shelf showed similar contacts as summer spills, with some decreased numbers in percent of trajectories contacted. Generally, the percentage of trajectory contacts for the three most contacted resource areas in summer (ANWR and the Sagavanirktok and Shaviovik rivers) remained similar (ranging from 3–73 percent). Offshore and Far Offshore VLOS showed increases in both the number of ERAs contacted as well as the percentage of trajectories to make contact, particularly for ANWR and essential fish habitat in the Chukchi Sea. A higher percentage of trajectories contacted land segments in the Beaufort Sea than in summer, but in general, the trends were similar.

5.5.5 Conclusion

Although the effects of oil contacting fish would be similar to small and large spills (BOEM, 2018d), the amount of oil spilled in a VLOS would be greater and would cover larger areas, so the overall impact of a VLOS on fish would be larger. Offshore and nearshore fish species exposed to oil could be affected by acute or chronic toxicity and shifts in prey availability. The effects on fish and their populations would depend on a variety of factors, including life stage, season of the reproductive cycle, species distribution and abundance, locations of the species in the water column or benthos, the extent and location of spawning areas in riverine systems, and migratory patterns. Early life-history stages of fish and shellfish species would be particularly vulnerable to effects at individual and population levels. Long-term changes in population structure may be observed if fish can’t access spawning or rearing sites. Changes in the food web are likely to occur. Impacts to fish from a VLOS in the Beaufort Sea would be widespread, long-lasting, and severe, and thus major.

5.6 Marine Mammals

5.6.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

5.6.1.1 Well Control Incident

An explosion at a wellhead would produce a loud sound wave that could disturb or injure marine mammals in the vicinity. If the incident occurred during the open-water season, cetaceans and pinnipeds could be startled and frightened by the loud noise. Startle responses would include short-term avoidance of the area, fleeing, increasing swimming speed, and possible short-term endocrine responses (McCauley et al., 2000a,b). Some individual cetaceans and pinnipeds close to the event could experience auditory injuries. Injuries would mostly include temporary hearing acuity losses, however animals very close to the explosion could experience permanent hearing loss. If the incident occurred in winter, cetaceans would not be in the area, but ringed seals could be present. At that time, however, seals are in the water or in their lairs and at least partially insulated from noise. Overall, it is anticipated that behavioral reactions or injuries would affect no more than a few individuals, so population-level impacts would not occur.

It is unlikely that a well control incident would have adverse effects on polar bears. This is primarily due to their scarcity and geographical distribution. During the open-water season, the majority of polar bears would be on pack ice or onshore, but during winter polar bears could approach gravel islands or MODUs. Underwater noise is not likely to injure them because they swim with their ears elevated above the waterline or travel on ice. Noise from an in-air explosion attenuates more rapidly than in the aquatic medium, so polar bears would have to be unreasonably close to an explosion for injuries to occur. For these reasons the noise of an explosion from a well control incident is unlikely to injure polar bears.

5.6.1.2 Offshore Spill

Whales

An offshore VLOS could affect whales during their spring and fall migrations through the Beaufort Sea. The most likely whales impacted from a VLOS are bowheads and belugas because they are common in the Beaufort Sea (Harwood et al., 2010; Quakenbush, Small, and Citta, 2010; Stafford et al., 2018).

Inhalation and ingestion. Whales could be exposed to VOCs during open-water or when sea ice is present. Prolonged exposure of migrating or feeding bowheads to inhalation of VOCs from fresh oil in the spring lead system has the potential to affect multiple whales (Geraci, 1990). During spring migration, females with newborn calves, whose movements are somewhat constrained by the polynya system, could be exposed to some VOCs released from fresh oil trapped in ice. It is likely that a major portion of VOCs would have evaporated over the winter through active cracks, ice movements, and movement through brine channels in the polynya ice cover when temperatures were at or above critical temperature (NORCOR, 1975; Fingas and Hollebone, 2014). VOCs are likely to disperse by May and early June, when most females with calves migrate through the spring lead system, and exposure would be minimal. Mortality could result if high VOC concentrations occurred and females with calves were exposed for long periods. VOCs may be particularly harmful to newborn calves that must frequently breathe and spend more time at the surface than adult females. Depending on the timing and numbers of females with calves inhaling VOCs from fresh oil, mortality of a large portion of a year’s cohort of calves, and perhaps some individual females and other age and sex classes, could occur.

One or more large aggregations of bowhead whales could be contacted by fresh oil with high concentrations of VOCs during the open-water season. Aggregations of between 50 and 100 bowheads were observed in some years, particularly in the feeding area identified northeast of Utqiaġvik (Moore et al., 2010). Exposure of bowhead whale aggregations could result in mortalities, especially if calves are present.

Ingestion of contaminated prey could expose whales to levels of toxicity high enough to alter endocrine and reproductive system function and, in severe cases, might result in some mortalities. Temporary and/or permanent injury and non-lethal effects could occur. During the open-water period, whales could ingest dissolved, suspended, or floating oil components while feeding on or near the surface. Oil components or chemical dispersants could be consumed by whales feeding on prey anywhere in contaminated water column layers to the seafloor. Oil may sink to the seafloor and persist in sediment and whales could disturb and ingest oil when they feed near the seafloor. Gray whales may ingest oil when bottom feeding on benthic invertebrates. Ingestion of petroleum hydrocarbons can lead to subtle and progressive organ damage or rapid death in mammals. Further, oil ingestion can decrease food assimilation (St. Aubin, 1988). Decreased food assimilation could be particularly important in very young animals, those that seasonally feed, and those that need to put on high levels of fat to survive. Ingestion of oil may result in temporary or permanent damage to bowhead endocrine function and reproductive system function; if sufficient amounts of oil are ingested, mortality of individuals may occur.

Fouling of baleen. Temporary baleen fouling could occur, but the medium weight oils probable for the Beaufort Sea make it less likely to adhere to and impair the function of the baleen fibers than would more viscous, weathered, or emulsified oil. Medium weight oil should result in less interference with feeding efficiency.

Oiling of skin and membranes. Spilled oil appears to have limited impact on whale skin. In toothed whales, Harvey and Dahlheim (1994) observed Dall's porpoises, killer whales, and harbor porpoises in oil on the water's surface from the EVOS. The whales did not appear to alter their behaviors when in areas where oil was present. Some temporary irritation or permanent damage could occur to conjunctive tissues, mucous membranes and around the eyes, abrasions, conjunctivitis, and swollen nictitating membranes (Geraci and Smith, 1976; Davis, Schafer, and Bell, 1960).

Displacement from habitat. A VLOS may result in whales being displaced from birthing, feeding, breeding, migration, rearing/nursing, and resting habitats. These areas are critical to the maintenance of individuals and populations. Displacement from critical areas could last as long as there are spill response and cleanup vessels present and possibly longer. Further, depending on the extent of damage to features that attract whales to the area, the habitat may not recover, or could take many years to recover to suitable conditions. Whales may lose access to feeding areas or to areas where prey concentrate. For example, oil contamination of benthic sediments leading to mortality of benthic invertebrate prey species for gray whales might require many years to recover and might lead to the abandonment of some feeding areas. The severity of impacts depends on the value of the feeding area affected. If a high value area is affected and alternate feeding areas of similar value are scarce, adverse effects to nutritional fitness, reproductive capacity, fetal growth rates, and neonatal survivorship could occur. In some cases, a whale species may require two or more generations within a restored and unaffected habitat to return to pre-VLOS distribution patterns.

Loss of access and use of the spring polynya system by migrating bowhead and beluga whales could result in variable mortality of newborn calves, delayed migration, and/or migration route avoidance or deflection and redistribution of whales to adjacent areas with greater ice cover. Depending on the specifics of a given event, mortality of a portion of an annual cohort of calves could result, which in turn could have longer-term effects on population-level recruitment and reproduction. A VLOS could result in modification of whale migration patterns and short-term body condition and health effects.

Disturbance to prey. Toothed whales, such as belugas, prey on fish species (Arctic cod, saffron cod, herring, and pollock) and large copepods in the water column and on or near the surface. A VLOS could cause reduction or mortality of local forage fish populations, which could create periods in which summer prey would not be available to whales. The fish populations in lagoons along the Beaufort and Chukchi coasts would be vulnerable to oil contamination. Prey recovery periods would determine distribution and abundance recovery periods for belugas. Hence, impacts to the distribution and abundance of prey would largely determine the seasonal distribution and habitat use by whales.

Depending on oceanographic and climatic variables, zooplankton food concentrations that may normally attract feeding aggregations of bowhead whales may not be available due to the presence of oil. A VLOS could displace feeding whales from active feeding or cause whales to avoid an otherwise available aggregated food source and feeding opportunity. Depending on the specifics and magnitude of a lost feeding opportunity and its contribution to the annual energy and nutrient requirement of individual whales, effects on health and reproduction could occur. Situations where effects could be more important include impaired access to the relatively consistent food aggregations northeast of Point Barrow and any large aggregations of food, attracting and holding large numbers of whales for an extended period of time (from a few days to weeks).

A VLOS probably would not permanently affect zooplankton populations, the bowhead's major food source, and severe effects would most likely occur nearshore (Richardson et al., 1987). The amount of zooplankton lost in a VLOS could be small compared to what is available on the whales' summer feeding grounds in the eastern Beaufort Sea and in the vicinity of Barrow Canyon (Bratton et al., 1993). A VLOS, depending on the timing and location relative to the distribution and aggregations of zooplankton, could reduce feeding opportunities for a majority of the bowhead population during that year. The significance to bowhead health of the loss of that opportunity depends on major feeding opportunities bowheads may find later in the year to meet annual energy demands.

Spilled oil could affect gray whales by contaminating benthic prey and sediments, particularly in prime feeding areas (Würsig, 1990; Moore and Clark, 2002). If a VLOS caused extensive mortality in a high latitude amphipod population with low fecundity and long generation times, marked decreases in secondary production would occur (Highsmith and Coyle, 1992). Reduction or mortality of benthic prey larval stages that live in the water column could reduce the availability of benthic biomass that whales feed on. A VLOS could reduce productivity of nearshore and offshore shoals, which could force gray whales and other species to seek alternate, less optimal foraging areas of the shelf offshore for up to several years until nearshore or shoal benthic communities recover. Impacts to these whales could occur over a period of years depending on the amount of reduction in benthic biomass and the quality and availability of alternate feeding habitat.

Pinnipeds

A VLOS has the greatest potential to affect pinnipeds and their habitats in the Beaufort and Chukchi seas. Seals exposed to hydrocarbons could experience short-term physiological effects, effects to their prey resources, and long-term adverse effects that may lead to death.

After a VLOS, the benthic invertebrates eaten by walruses and seals could ingest hydrocarbons from water, sediments, and food. Long-term or chronic oil ingestion from contaminated food may result in kidney or liver damage, or ulcers in the digestive tracts of walruses and seals. Although similar studies have not been done with walrus, their physiology is comparable, suggesting they can likewise process and excrete hydrocarbons. Assuming walruses share this ability, some short-term impacts may be mitigated. Chronic exposure could result in long-term, adverse physiological effects up to and including death in some cases. Exposure to VOCs could cause respiratory distress and inflammation of mucous membranes and eyes.

Walrus, which have large, protruding eyes, would be particularly vulnerable to abrasions and ulcerations to their eyes from oiling. Ice seals and walruses rely primarily on a thick layer of blubber for insulation and are unlikely to suffer from hypothermia as a result of oiling, though skin inflammation and/or lesions could occur. Oil may impede the ability to dive by increasing buoyancy, which would in turn increase the energy expenditures of feeding, particularly for younger, smaller individuals. Oil, especially heavy oils and weathered tarry oil, may impede swimming and diving by adhering to an individual’s skin, and reduce the swimming efficiency of the affected animal. Sand, gravel, or other debris may adhere to their oiled skin and further impede locomotion and ability to use vibrissae to locate prey items.

A potential effect of a VLOS could be the loss of fishes and invertebrates from local populations, particularly Arctic and saffron cod, arthropods, mollusks, and other invertebrates. Adult ringed and spotted seals rely mostly on fishes for the majority of their diets, although young seals may consume large numbers of arthropods. Bearded seals mostly feed on mollusks, Polychaeta, arthropods, and sometimes fish. Impacts to these food sources over a large area could reduce the quantity and quality of the food base value to seals for years. Such losses in prey could reduce productivity or even cause short-term absence of ice seals from affected areas.

The loss of biota from oiled areas could be replenished by immigration from other areas within a few years. High reproductive rates, mobility of many marine organisms, and the influx of immigrant organisms via ocean currents make this possible. Some prey groups, such as mollusks, may recover more rapidly than others due to differing maturation rates and reproduction potentials. Any ensuing prey distribution changes could contribute to the absence of several thousand individual bearded and ringed seals, and several hundred spotted seals from an area where the food stocks have been depleted or destroyed. Depending on the scale of spill impacts on benthic invertebrates, walruses or seals could be forced to travel farther to find food, possibly increasing the energy expenditures associated with foraging. Most Pacific walruses in the Arctic remain in the Chukchi Sea during summer and overwinter in the Bering Sea, with few using the Beaufort Sea during summer. If Hanna Shoal were contacted by a VLOS, thousands of walruses could be directly and indirectly impacted. Due to the scarcity of Pacific walruses in the Beaufort Sea, a VLOS contacting habitats there should not immediately affect the walrus stock.

Polar Bears

Polar bears could encounter offshore fresh or weathered oil during the open-water and ice seasons. Polar bears would encounter a VLOS while traveling through affected offshore areas. Oil exposure could occur while swimming in the water, traveling on the ice edge, or on barrier islands.

A VLOS during summer could affect polar bears coming ashore due to sea-ice retreat or in preparation for denning later in the fall/winter season. A VLOS during winter could affect polar bears on nearshore or offshore ice or at polynyas and open lead systems. A VLOS in winter would be difficult to cleanup, and oil could become entrained in the ice, melting out in spring, and contacting lead systems and coastal areas. In winter, polar bears range throughout the ice-covered waters of the Beaufort Sea (FWS, 2016). They may be found near polynyas and open leads where they prey on seals. In spring, new family units emerge from dens and could come into contact with oil that has melted out of the ice.

Polar bear populations have been observed to increase or decline alongside seal populations (Stirling, 2002). Polar bear densities are dependent on both ringed seal distribution and ice conditions, both of which may have chronic effects from a VLOS. Therefore, impacts to ringed seal populations from a VLOS could indirectly affect polar bear populations. The potential for exposure of polar bears to oil that has overwintered could increase because of how they hunt on ice. On ice, polar bears hunt ringed seals in spring leads, pack ice, fast ice, and at their breathing holes and dens; but in the spring, polar bears preferentially hunt seal pups in lairs (Stirling and Archibald, 1977).

High levels of exposure of individual bears could result in death due to organ damage and possible hypothermia. Chronic low levels of exposure may result in long-term, sublethal effects that reduce fitness. Because of the size of a VLOS, impacts would probably be regional. Two stocks of polar bears occur in the Beaufort Sea, the Southern Beaufort Sea (SBS) stock and the Chukchi-Bering Sea (CBS) stock. The SBS stock size is low (1,526) with a downward trending population trajectory, so impacts to a few tens of individuals could have stock-wide repercussions (Muto et al., 2018). Since the CBS stock is larger than the SBS stock, stock-wide impacts would require larger numbers of polar bears to be affected.

5.6.1.3 Onshore Contact

Whales would not be impacted if a VLOS contacted a coastline.

Pinnipeds

Bearded and ringed seals spend their lives on or around sea ice and usually do not haul out onshore. Spotted seals are the only seal species likely to be affected by a VLOS contacting coastlines. Known spotted seal haulouts along the Beaufort Sea coast occur at the mouths of the Colville and Sagavanirktok rivers, Dease Inlet, and Smith Bay.

Occasionally, a few walruses may haul out onshore in the Beaufort Sea, and a few individuals could be affected at coastal locations, though no established walrus haulout areas have been observed there. Walrus at haulouts are very sensitive to smells and may avoid oil at the shoreline or ice edge due to the smell, or they may remain in the area despite the presence of oil. If walrus avoid oiled coastal areas, they may be excluded from important resting areas once sea ice disappears from the coast in summer. Walrus cannot remain at sea indefinitely; they must haul out to rest and regain body heat. Calves and young walrus are more restricted on how much time they can spend at sea and cannot swim as far or for as long as adults. A VLOS should not produce population-level effects because most onshore contacts would occur in the Beaufort Sea where Pacific walruses are rare.

Polar Bears

Polar bears use barrier islands for denning and resting after long swims to shore from the pack ice; they use the coastline for traveling to important onshore denning and winter sea ice feeding habitats (Derocher et al., 2013; Fischbach, Amstrup, and Douglas, 2007; FWS, 2015a). If a VLOS contacted these onshore areas, polar bears could experience adverse impacts. Polar bears could contact oil as they move along the coast or barrier islands, or while moving between shore and the ice edge. In recent years, more polar bears have congregated on shore while waiting for the sea ice to form. Large aggregations of bears from the SBS stock now occur near Cross Island and Barter Island, where bears scavenge on subsistence-harvested whale carcasses. Bear aggregations also occur onshore. Wrangel Island, Russia has large numbers of bears from the CBS stock. Were oil to contact one of these aggregations of bears, it would constitute a severe impact to the SBS or CBS stock of polar bears.

Regardless of whether contact occurred at sea, on ice, or on land, the results to the physical health of the polar bear would be the same as those described for an offshore VLOS. If polar bears avoid coastal areas that have been oiled, they may be excluded from important feeding, resting, and denning areas, which could adversely affect fitness or reproduction.

5.6.2 Phase 2 (Spill Response and Cleanup)

5.6.2.1 Whales

Oil spill response and cleanup has the potential to affect whales and their habitats as a result of a VLOS. Potential impacts would be related to the following factors:

- Noise and disturbance from presence of vessels transiting to the affected area, and activity in the affected area, including boom and skimming operations.
- Aircraft overflights, including potential application of dispersants from low flying aircraft.
- In-situ burning, including noise and disturbance from support operations.
- Animal rescue, scientific recovery, and disposal of contaminated carcasses.
- Skimmer and boom team composition, number, distribution, and noise.
- Relief well drilling and discharges, including support activities (icebreakers and vessel discharges).
- Remediation activities.

Noise and disturbance from vessels. Cleanup operations following a VLOS would involve multiple marine vessels operating in the spill area for extended periods of time, perhaps over multiple years. The impact of vessel activities would be related to noise and presence of vessels. Vessel strikes of whales are not expected during VLOS response and cleanup because whales are capable of detecting and avoiding slow-moving vessels, particularly those operating at speeds under 10 knots, and the numbers and distribution of whales would reduce likelihoods of vessel strikes in open-water (Laist et al., 2001).

The primary underwater noise associated with oil spill vessel operations is continuous propeller noise from tugboats, especially when pushing or towing loaded barges (NOAA, 2018). Other noise sources include onboard diesel generators and the firing rate of the main engine, but both are subordinate to propeller noise (Gray and Greeley, 1980). The continuous sounds for sea-going barges have been measured at a peak sound source level of 170 decibels (dB) re 1 microPascal (μPa) root mean square (RMS) at 1 m (broadband), and they are emitted at dominant frequencies of less than 5 kilohertz (kHz), and less than 1 kHz (Miles, Malme, and Richardson, 1987; Richardson et al., 1995; Simmonds, Dolman, and Weilgart, 2004). Coastal barges and tugboats produce a peak sound source level of approximately 164 dB re 1 μPa RMS at 1 m (Richardson et al., 1995). The source level of approximately 170 dB at 1 m are associated with tugboat noise and are anticipated to decline to 120 dB re 1μPa RMS within 1.15 mi of the source (Richardson et al., 1995). Vessels usually do not produce sound source levels capable of producing injuries to whales (Richardson et al., 1995; NOAA, 2016).

If approached by a vessel, whales could be forced to interrupt their normal behavior and rapidly swim away, sometimes changing course. Surfacing, respiration, and diving cycles can be affected. Vessels moving slowly and in directions not toward the whales usually do not elicit strong reactions (Malme et al., 1989; Richardson and Malme, 1993). Whales often tolerate the approach of slow-moving vessels within a few thousand feet, especially when there are no sudden changes in direction or engine speed (Heide-Jørgensen et al., 2003; Richardson et al., 1995; Wartzok et al., 1989). However, they may react at long distances if they are confined by ice, shallow water, or were previously harassed by vessels (Richardson et al., 1995). Behavioral disturbances are usually brief, have discountable energetic costs, and are not biologically significant to the affected animal.

The responses of baleen whales, such as bowhead whales, are mixed. They either show tolerance to vessels that are stationary, or distant and strongly avoid nearby moving vessels. The responses of toothed whales differ from those of baleen whales since most toothed whale species commonly approach moving vessels that they do not perceive as threats (as killer whales regularly approach vessels of all sizes, and some dolphins and porpoises seem to relish riding in the bow waves of passing vessels). However, some species, such as belugas, may display strong avoidance reactions to vessels, particularly if they belong to a hunted population (Richardson et al., 1995). Toothed whales (belugas) would likely respond to vessels by altering call types, frequency use, and call rates, and avoiding ships (Finley et al., 1990; Lesage et al., 1999). Individual toothed whales that encounter vessel traffic associated with VLOS response and cleanup would likely respond by avoiding the area.

Migrating whales may show greater responses to certain noises than they would while engaged in non-migratory activities. Vessel activities associated with VLOS response and cleanup should not disrupt migrations or elicit responses greater than small deflections around vessels; some whales may avoid vessels. During spring migrations (April through June), whales should not encounter any vessels associated with VLOS response and cleanup because the surface of the Beaufort Sea would be frozen and inaccessible to vessels. Also, the presence of large ice floes throughout the spring system would preclude vessel-based cleanup operations.

Temporary, non-lethal effects would result from noise and presence of vessel operations associated with VLOS response and cleanup.

Noise and disturbance associated with skimmer and booming operations. Booming efforts and associated skimmers utilize vessels to conduct operations and may produce noises that could affect whales. Offshore skimmer operations would be restricted to the localized area of the spill source and the specific high value nearshore and coastal areas. For example, few belugas would come into contact with the human activities associated with cleanup operations in nearshore areas, where localized intensive boom and skimming efforts to protect lagoons and other coastal resources would occur. Avoidance behavior and stress to some belugas is likely with concentrated cleanup activities. Effects on whales from these operations are likely to be short-term, localized, and less than severe because the nearshore operations, noise, and sensitive coastal sites are not important fall migratory habitats for beluga whales.

Noise and disturbance from aircraft. After a VLOS, it is likely that overflights by helicopters and fixed-winged aircraft would be used to track the spill and determine distributions of wildlife that may be impacted from the VLOS. Most whales are unlikely to react noticeably to occasional single passes by helicopters flying at altitudes above 500 ft. At altitudes below 500 ft, some whales probably would dive quickly in response to the aircraft noise and may have shortened surface time (Patenaude et al., 1997; Richardson and Malme, 1993). Whale reactions to a single helicopter flying overhead would probably be temporary (Richardson et al., 1995). Whales are likely to resume their normal activities within minutes after overflights.

Fixed-wing aircraft flying at low altitudes often elicit behavioral responses. Reactions to circling aircraft are sometimes conspicuous if the aircraft is below 1,000 ft, uncommon at 1,500 ft, and undetectable at 2,000 ft. Repeated low-altitude overflights at 500 feet sometimes caused whales to turn abruptly and make hasty dives (Richardson and Malme, 1993). The effects from an encounter with aircraft are brief, and the whales would resume their normal activities within minutes. Under the intensive and frequent overflight patterns of large aircraft dispensing chemical dispersants at low altitudes (less than 984 ft), whales would likely respond more strongly to the disturbance.

Whales could be disturbed away from movement corridors and displaced from feeding areas in response to aircraft activity associated with a VLOS. This displacement could last as long as there is a large amount of oil and related cleanup aircraft present, especially during application of dispersants. Intensive and frequent low elevation overflights associated with spill response, cleanup, assessment, monitoring, and media operations could potentially disturb and displace whales within the spill area or between the VLOS and shore-based facilities. Intentionally diverting whales away from an oil slick would be possible and could mitigate impacts. This is especially the case during the fall migration or feeding opportunities. If there is exposure to oil, whales could inhale toxic fumes and consume contaminated prey.

In-situ burning. Deployment of in-situ burning operations would primarily occur near the localized origination point of the VLOS and in prioritized nearshore areas. Noises from boom and burn operations would likely be masked by the noise emanating from the relief drilling effort, which bowhead whales could avoid. There would be monitors ensuring that marine species would not be near the burning. Harassment of migrating whales, while stressful, may be justified to prevent whales from intercepting or migrating through extended areas of spilled oil and burning operations; the intent would be to encourage whales to detour around hazardous accumulations of oil and continue migration to the west.

Noise and disturbance from drilling a relief well. Drilling a relief well could be a source of noise and disturbance to whales with essentially the same impacts as drilling an exploration or development well. Relief well drilling operations are likely to employ MODUs (with icebreaker support vessels, if necessary) and are estimated to operate at a given well site for a period of no less than a month.

If MODUs engaged in drilling relief wells are attended by icebreakers, the MODU noise frequently may be masked by icebreaker noise, which often is louder. Response distances of whales would vary, depending on icebreaker activities and sound-propagation conditions. Bowhead whales most likely would respond to the sound of the attending icebreakers at distances of 1.24–15.53 mi from icebreakers (Miles, Malme, and Richardson, 1987); these researchers reported half of the observed bowhead whales exhibited avoidance to an icebreaker underway in open water at a range of 1.25 to 7.46 mi. For an icebreaker pushing ice at a range of 2.86 to 12.4 mi, when the sound to noise ratio was 30 dB, the same proportion of whales exhibited avoidance. Belugas are sensitive to high frequency noise produced by industrial activities such as icebreakers (Cosens and Dueck, 1993). Icebreaker propeller cavitation noise modeled by Erbe and Farmer (2000) indicated icebreaker noise was audible over ranges of 21.8 to 48.5 mi, and the zone of behavioral disturbance to whales was only slightly smaller. Masking of beluga communication signals would likely occur if icebreaker operations were conducted.

The greatest potential for whales to encounter relief well operations would occur during the fall migration when the majority of the population migrates west. Some whales near drilling operations would be expected to respond to noise from MODUs by adjusting their migration speed and swimming direction to avoid closely approaching these noise sources. Whales would be likely to detour around an operating relief drilling effort and continue their westward migration. These whales may encounter noise from booming, skimming, support vessels, and other activities after detouring around a relief well drilling operation. Reactions are likely to be localized, temporary, and non-lethal.

Drilling a relief well would result in discharges that could affect whales; there could be alterations in whale habitat as a result of pollution and habitat destruction. Bottom-founded MODUs may cover areas of epibenthic invertebrates used for food by bowhead and gray whales, and drilling muds and cuttings from the relief well may cover portions of the seafloor and cause localized pollution. The amount of disturbed area would be localized and inconsequential in comparison to the vast foraging habitat available in the Beaufort Sea. Any potential effects on whales from discharges are directly related to whether or not any potentially harmful substances are released into the marine environment; what their fate in the environment is (rapid dilution or bio magnification through the food chain); and thus, whether they are bioavailable to whales. Little or no effects would likely occur, because the amount of area of seafloor impacted would be inconsequential in relation to the available habitat.

Animal rescue, scientific recovery, rehabilitation, and disposal. Rescue operations for larger whales are not anticipated. However, rescue efforts for other species may bring small vessels near large whales. Any cetacean rescues would be for the smallest whales.

Beluga whale rescues during a VLOS are considered highly improbable by the National Marine Fisheries Service (NMFS). In the event that any rescue attempts are possible, they would occur in the lagoons, where contact with oil could occur in nearshore waters close to equipment and personnel. Rescue efforts for injured or stranded belugas may bring small vessels into the vicinity of other belugas already stressed from oil contact and vessels. Further injury or mortality could occur during rescue operations and during post-rescue treatment and recovery. Recovery of stranded, floating, and otherwise dead or severely injured belugas or other marine species would likely be onshore (stranded) or in shallow water and most likely not at sea. Stranded belugas may be in groups of live animals or with injured and deceased animals. Rehabilitation and treatment facilities would most likely be on board a ship or land based, and some mortality and injury could occur during transport from rescue site to such facilities. Disposal of contaminated carcasses (if any) and oil-contaminated materials (absorbent pads, protective gear, etc.) would be done at an authorized disposal site onshore. Rescue operations are likely to involve only a few whales and population-level effects are not expected. Negligible effects are anticipated because whales would most likely avoid small vessels.

General Response. For a VLOS, remediation activities may include short- and long-term monitoring and research studies to evaluate effectiveness of cleanup actions; treatment of affected areas to neutralize toxic effects; and removal and disposal of contaminated soil, water, and equipment to eliminate risk of exposure to oil (booms, cleaning wastes, and sewage from operations). Aircraft and vessel operations would support many short-term activities during the initial spill response and throughout spill containment and treatments to minimize volume, spread, and environmental consequences. Activities could include surveillance missions; placement of transmitter-equipped buoys to track spill edge in real time; media coverage; monitoring wildlife; application of dispersants; treatments of shorelines and waters; and various activities associated with spill research, monitoring, and evaluation.

Chemical dispersants are used to break up surface oil and disperse it into the water column, some of which may sink and affect benthic organisms preyed upon by gray whales. Dispersants could potentially affect productivity, survivorship, and contamination of benthic sediments and invertebrates (gray whale prey), and pelagic zooplankton near shore and in the marine and ice environments. Overall, it is possible that the use of dispersants, if permitted, could lead to adverse effects through either reduction of food availability, bioaccumulation, or contamination of whales' prey.

5.6.2.2 Pinnipeds

Spill response activities could disturb and displace seals or walruses from affected marine and coastal areas. Negative short-term impacts from disturbance would be outweighed by beneficial effects from intentionally or unintentionally hazing seals away from oiled areas.

Vessel and aircraft traffic associated with a VLOS response and cleanup may displace seals. Such effects have been observed in numerous ship- and air-based surveys in the Beaufort and Chukchi seas (Blees, Hartin, and Ireland, 2010; Brewer et al., 1993; Brueggeman et al., 1991, 2009, 2010; Funk et al., 2010; Treacy, 1996). Some activities such as in-situ burning, animal rescue, use of skimmers and booms, and drilling relief wells could further displace seals. Most pinnipeds would have already left the area after a VLOS. Marine mammal observers would reduce conflicts between cleanup and the remaining pinnipeds in the area. Moreover, if the prey base were adversely affected, most seals would leave the affected area out of necessity so they could feed. The use of dispersants is unlikely to have any immediate direct effects on seals; however, there may be some adverse consequences to using certain types of dispersants that could affect the food web, and the long-term effects of dispersant use may extend beyond the treatment area.

Cleanup activities such as beach cleaning may be performed with a high degree of success using newer technologies such as ionic solutions (Hogshead et al., 2010; Painter, 2011). However, other activities such as spill cleanup under ice or in areas of broken ice may be less successful, and more seals could be affected. The effects of these activities on seals could vary, depending on the presence of seals in an area and pre-existing stress levels. Hazing seals from oiled areas could preclude many of the most severe potential impacts.

5.6.2.3 Polar Bears

Polar bears are likely to avoid the VLOS area due to response activities and associated noise. Small bears and females with cubs would be more likely to avoid an area where VLOS response activities occur (Andersen and Aars, 2008). Increased activity in polar bear habitat (vehicle travel over tundra or sea ice) may increase the likelihood of disturbance to maternal dens. In contrast, hungry or nutritionally stressed polar bears might be attracted to the spill response activity or engaged in scavenging the carcasses that died from oil exposure.

Some polar bears may be curious and could approach personnel who are on shore or in vessels. Wildlife response activities could involve deterring bears away from an area or capturing and transporting an oiled bear for cleaning and treatment, though it is unlikely that an oiled bear would survive. Additional human-polar bear interactions could result in an increase in polar bear take through deterrence or in defense of human life.

In-situ burning would release soot and other pollutants into the air. If the soot is carried by air currents to shore or to ice floes, polar bears may be exposed to enough smoke and soot to experience respiratory effects, or may have their coats soiled by pollutants, which they then might ingest while grooming.

As the spill response continues, the oil would spread, and response activities would affect a larger area. Cleanup efforts would likely focus on the spill site, towns, and areas critically important to fish or wildlife. The later in the open-water season (September to October) the VLOS occurs, the more likely polar bears will encounter oil and/or disturbance from cleanup efforts because bears move toward the coast as winter begins to set in.

Cleanup efforts could focus on oiled shoreline and washing methods or dispersants could be used. While dispersants can be effective at breaking up oil into smaller droplets, they contain toxic chemicals such as hydrocarbon solvents and glycols. Dispersants may cause skin irritations, respiratory impacts, or impacts to sensitive tissues around the eyes, noses, and mouths of exposed polar bears.

Response and cleanup activities could result in short- or long-term displacement of polar bears and their prey from preferred habitats. Cleanup activities would decrease the likelihood that polar bears may come into contact with oil. However, displacement of bears and prey by response and cleanup activities would not produce population-level impacts but could adversely affect polar bears in the immediate vicinity of the VLOS.

The cleanup process could be continued the year following a VLOS. Skimmers and other methods may be used to try to capture the remaining oil the following spring and summer. This could lead to additional disturbance to polar bears in the leads and polynyas where bears tend to focus their hunting efforts. Polar bears may be exposed to oil in the leads and open water between or on floes, depending on the distribution of the remaining oil once it melts out of the winter ice.

5.6.3 Phase 3 (Post-Spill, Long-Term Recovery)

Over the long-term, marine mammals would experience continued exposure to aircraft and vessel noise and traffic. Aircraft and vessel operations would support many long-term NRDA efforts for monitoring the recovery of resources, fate of oil and/or dispersants in the Arctic environment, and research and monitoring on the effectiveness of cleanup and restoration practices. Research monitoring and studies are subject to scientific research permits and Marine Mammal Protection Act authorizations issued by NMFS and the U.S. Fish and Wildlife Service (FWS). These permits and authorizations would provide stipulations, best practices, and enforcement measures to protect marine mammals. Vessel maneuvers, aircraft elevation limitations, limits to seasonal period of activity, tagging and handling limits, and requiring marine mammal observers are some of these measures. It is reasonable to expect post-spill monitoring for marine mammals as a result of a VLOS. Effects on marine mammals from NRDA activities are expected to be negligible to minor.

5.6.3.1 Whales

Although baleen whales may have the capability to metabolize ingested oil compounds, chronic consumption of bottom-accrued oil fractions or contaminated prey may result in impaired endocrine function, reproductive impairment, or mortality. Further, because of their extreme longevity, bowheads are vulnerable to long-term accumulation of pollutants. Monitoring of populations would be necessary to document any long-term effects.

Displacement from, or avoidance of, nearshore habitats could occur over several years after a VLOS. Post VLOS recovery of whales to pre-spill abundance and habitat use patterns would depend on the recovery periods necessary to restore pre-spill levels of prey populations and the quality of preferred habitats. Recovery would depend on the amount of human activity in and adjacent to preferred habitats. Effects to any given species of whales are expected to have little or no impact or be short-term, localized, and less than severe.

5.6.3.2 Pinnipeds

Contamination of prey species in the food web could continue for years or more than a decade after a VLOS. Walrus and bearded seals may continue to be dietarily exposed to hydrocarbons which may lead to reduced fitness and possibly population-level effects over time. However, ringed seals can excrete some amount of ingested hydrocarbons, and evidence suggests the same may be true for bearded and spotted seals, and Pacific walruses (Geraci and St. Aubin, 1990). Contamination of the seabed and portions of the coast could persist for years; however, the permafrost underlying the soil at the shoreline may prevent crude oil from permeating deep into the soil, lowering the oil's residence time in coastal areas. Due to the migratory nature of most pinnipeds in the Beaufort Sea, consequences could occur outside the VLOS area and into the Chukchi or Bering seas. The long-term recovery from a VLOS should be moderate for pinnipeds unless Hanna Shoal is contacted, which could lead to severe impacts to walruses.

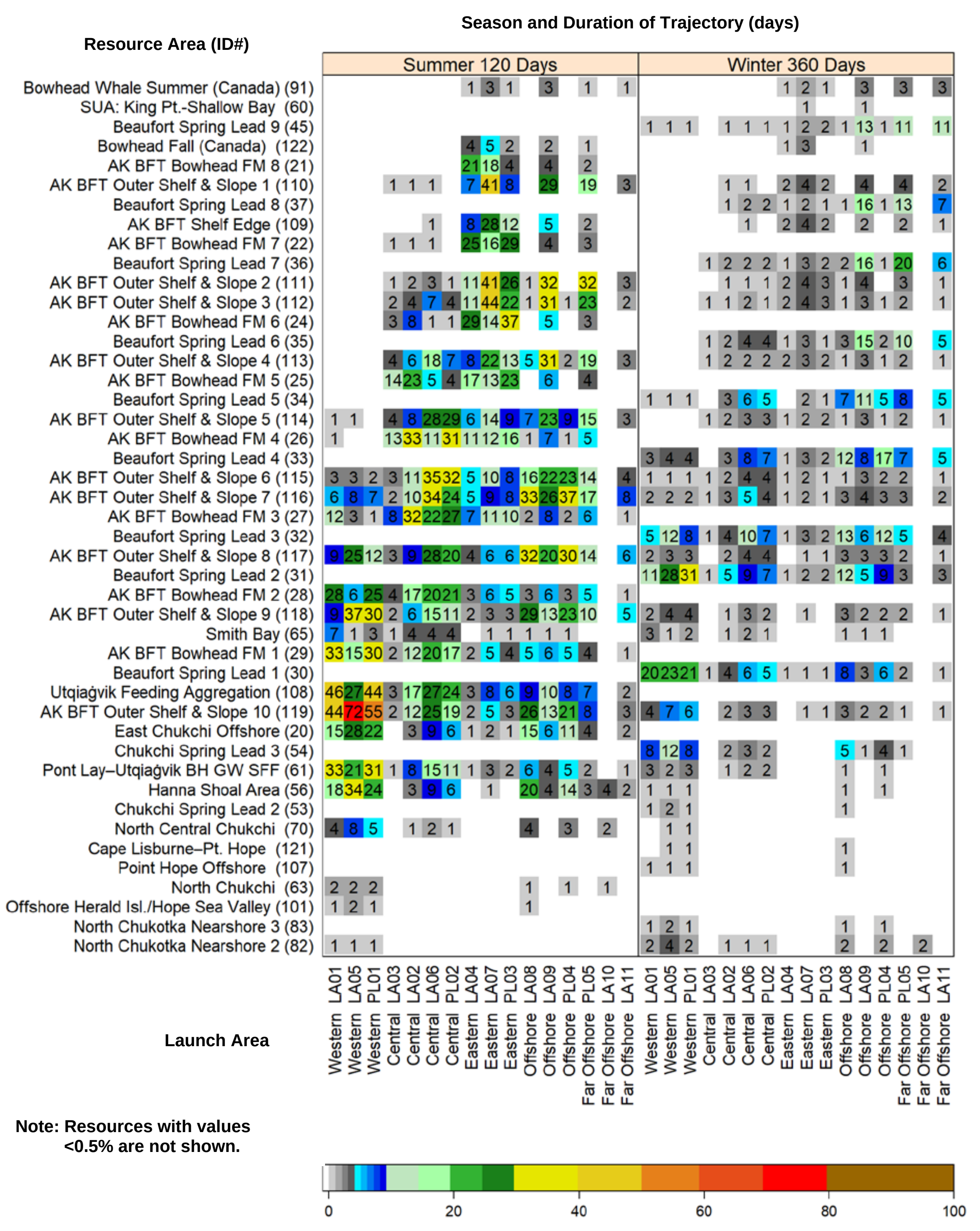
5.6.3.3 Polar Bears

Polar bears eating contaminated bearded seals or walruses may ingest hydrocarbons, which may lead to reduced fitness over time. Depending upon the types of NRDA studies conducted, polar bears may experience increased disturbance from the additional boat, plane, and shoreline traffic.

5.6.4 Oil Spill Trajectory Analysis

Whales. BOEM identified 51 whale resource areas for the analysis (Appendix A, Table A4 and Figures A3b–g). Figure 5-4 shows 45 whale resource areas with ≥1 percent of trajectories contacting them in summer or winter. Six biologically important areas for whales are not estimated to be contacted (<0.5 percent), but depending on the location of a VLOS numerous whale resource areas could be contacted. Throughout the areas where a VLOS could occur, there is a lower percentage of trajectories contacting whale resource areas in the winter than in the summer when more habitat is seasonally occupied. However, the spring leads are vulnerable to a VLOS only during winter.

Summer. A Western Shelf VLOS has the highest percentage of trajectories contacting the Alaska Beaufort (AK BFT) Outer Shelf & Slope 10 (119), the outer western shelf areas of the whale migration corridor (117, 118, 108), and portions of the bowhead whale fall migration corridor (28, 29). A Western Shelf VLOS has the highest percentage of trajectories (15–34 percent) contacting Chukchi Sea areas (20, 56, 61) and all other Chukchi areas (82, 83, 101, 63, 70) are <10 percent. A Central Shelf VLOS has higher percentages of trajectories contacting the outer shelf areas representing whale migration corridors north and east of Harrison Bay (26, 27, 114, 115, 116). An Eastern Shelf VLOS has 6–44 percent of trajectories contacting portions of the whale migration corridors (110–114) and the bowhead whale fall migration (22, 24, 25, 26). An Offshore VLOS has 13–37 percent of trajectories contacting whale habitat associated with the Outer Shelf and Slope (115–119) in the central to western Beaufort Sea, while the Far Offshore has <0.5–32 percent of trajectories contacting Outer Shelf and Slope (110–114) in the central to eastern Beaufort Sea.



Resource Area (ID#)	Summer 120 Days																Winter 360 Days															
Launch Area	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Bowhead Whale Summer (Canada) (91)								1	3	1		3		1		1								1	2	1		3		3		3
SUA: King Pt.-Shallow Bay (60)																									1			1				
Beaufort Spring Lead 9 (45)																	1	1	1		1	1	1	1	2	2	1	13	1	11		11
Bowhead Fall (Canada) (122)								4	5	2		2		1										1	3			1				
AK BFT Bowhead FM 8 (21)								21	18	4		4		2																		
AK BFT Outer Shelf & Slope 1 (110)				1	1	1		7	41	8		29		19		3					1	1		2	4	2		4		4		2
Beaufort Spring Lead 8 (37)																					1	2	2	1	2	1	1	16	1	13		7
AK BFT Shelf Edge (109)						1		8	28	12		5		2								1		2	4	2		2		2		1
AK BFT Bowhead FM 7 (22)				1	1	1		25	16	29		4		3																		
Beaufort Spring Lead 7 (36)																				1	2	2	2	1	3	2	2	16	1	20		6
AK BFT Outer Shelf & Slope 2 (111)				1	2	3	1	11	41	26	1	32		32		3					1	1	1	2	4	3	1	4		3		1
AK BFT Outer Shelf & Slope 3 (112)				2	4	7	4	11	44	22	1	31	1	23		2				1	1	2	1	2	4	3	1	3	1	2		1
AK BFT Bowhead FM 6 (24)				3	8	1	1	29	14	37		5		3																		
Beaufort Spring Lead 6 (35)																				1	2	4	4	1	3	1	3	15	2	10		5
AK BFT Outer Shelf & Slope 4 (113)				4	6	18	7	8	22	13	5	31	2	19		3				1	2	2	2	2	3	2	1	3	1	2		1
AK BFT Bowhead FM 5 (25)				14	23	5	4	17	13	23		6		4																		
Beaufort Spring Lead 5 (34)																	1	1	1		3	6	5		2	1	7	11	5	8		5
AK BFT Outer Shelf & Slope 5 (114)	1	1		4	8	28	29	6	14	9	7	23	9	15		3				1	2	3	3	1	2	2	1	3	1	2		1
AK BFT Bowhead FM 4 (26)	1			13	33	11	31	11	12	16	1	7	1	5																		
Beaufort Spring Lead 4 (33)																	3	4	4		3	8	7	1	3	2	12	8	17	7		5
AK BFT Outer Shelf & Slope 6 (115)	3	3	2	3	11	35	32	5	10	8	16	22	23	14		4	1	1	1	1	2	4	4	1	2	1	1	3	2	2		1
AK BFT Outer Shelf & Slope 7 (116)	6	8	7	2	10	34	24	5	9	8	33	26	37	17		8	2	2	2	1	3	5	4	1	2	1	3	4	3	3		2
AK BFT Bowhead FM 3 (27)	12	3	1	8	32	22	27	7	11	10	2	8	2	6		1																
Beaufort Spring Lead 3 (32)																	5	12	8	1	4	10	7	1	3	2	13	6	12	5		4
AK BFT Outer Shelf & Slope 8 (117)	9	25	12	3	9	28	20	4	6	6	32	20	30	14		6	2	3	3		2	4	4		1	1	3	3	3	2		1
Beaufort Spring Lead 2 (31)																	11	28	31	1	5	9	7	1	2	2	12	5	9	3		3
AK BFT Bowhead FM 2 (28)	28	6	25	4	17	20	21	3	6	5	3	6	3	5		1																
AK BFT Outer Shelf & Slope 9 (118)	9	37	30	2	6	15	11	2	3	3	29	13	23	10		5	2	4	4		1	3	2		1		3	2	2	2		1
Smith Bay (65)	7	1	3	1	4	4	4		1	1	1	1	1				3	1	2		1	2	1				1	1	1			
AK BFT Bowhead FM 1 (29)	33	15	30	2	12	20	17	2	5	4	5	6	5	4		1																
Beaufort Spring Lead 1 (30)																	20	23	21	1	4	6	5	1	1	1	8	3	6	2		1
Utqiaġvik Feeding Aggregation (108)	46	27	44	3	17	27	24	3	8	6	9	10	8	7		2																
AK BFT Outer Shelf & Slope 10 (119)	44	72	55	2	12	25	19	2	5	3	26	13	21	8		3	4	7	6		2	3	3		1	1	3	2	2	1		1
East Chukchi Offshore (20)	15	28	22		3	9	6	1	2	1	15	6	11	4		2																
Chukchi Spring Lead 3 (54)																	8	12	8		2	3	2				5	1	4	1		
Pont Lay–Utqiaġvik BH GW SFF (61)	33	21	31	1	8	15	11	1	3	2	6	4	5	2		1	3	2	3		1	2	2				1		1			
Hanna Shoal Area (56)	18	34	24		3	9	6		1		20	4	14	3	4	2	1	1	1								1		1			
Chukchi Spring Lead 2 (53)																	1	2	1								1					
North Central Chukchi (70)	4	8	5		1	2	1				4		3		2			1	1													
Cape Lisburne–Pt. Hope (121)																		1	1								1					
Point Hope Offshore (107)																	1	1	1								1					
North Chukchi (63)	2	2	2								1		1		1																	
Offshore Herald Isl./Hope Sea Valley (101)	1	2	1								1																					
North Chukotka Nearshore 3 (83)																	1	2	1								1		1			
North Chukotka Nearshore 2 (82)	1	1	1														2	4	2		1	1	1				2		2		2	

Note: Resources with values <0.5% are not shown.

Figure 5-4 Percentage of Trajectories Contacting Whale Resource Areas (≥1% within 120 days Summer and 360 days Winter)

A Central Shelf VLOS could contact the most whale resource areas, while a Far Offshore VLOS could contact the least. The Utqiaġvik Feeding Aggregation area (108) and the adjacent Outer Shelf and Slope

(119) have the highest percentage of trajectories contacting from a Western Shelf VLOS (46–72 percent). A VLOS from specific subareas has the highest percentage of trajectories contacting Outer Shelf and Slope whale resource areas (Table 5-1).

Table 5-1 Highest Percentage of Trajectories Contacting each Whale Resource Area (Summer)

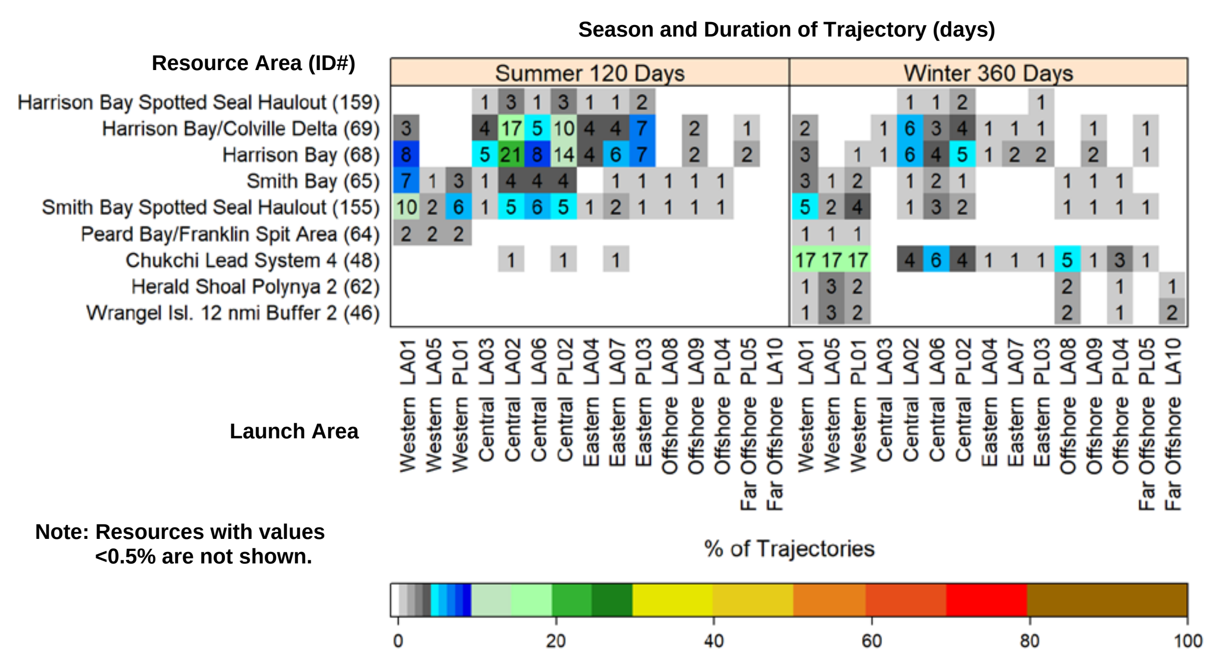
VLOS Area	Subarea	Whale Resource Area	Percentage of Trajectories
Western Shelf	LA5 (offshore portion)	BFT Outer Shelf & Slope (119)	72
Central Shelf	LA06	BFT Outer Shelf & Slope (115)	35
Eastern Shelf	LA7 (offshore portion)	BFT Outer Shelf & Slope (112)	44
Offshore	PL4	BFT Outer Shelf &Slope (116)	37
Far Offshore	PL5	BFT Outer Shelf & Slope (111)	32

Winter. Portions of the Beaufort Spring Leads (30–37) have the highest percentage of trajectories contacting regardless of the VLOS origin and are most vulnerable to a Western Shelf VLOS (Table 5-2). A Western Shelf VLOS has 5–31 percent of trajectories contacting Beaufort and Chukchi Spring Leads (30–32, 54). A Central Shelf VLOS has slightly lower (1–10 percent) percentages of trajectories contacting these same areas. An Eastern Shelf VLOS has <0.5–3 percent of trajectories contacting as it is the farthest removed from these whale resource areas. A VLOS in the Offshore and Far Offshore has <0.5–20 percent of trajectories contacting Beaufort Spring Leads (31–37, 45). An Offshore VLOS contacts the most whale resource areas when compared to the other areas during the winter (Figure 5-4).

Table 5-2 Highest Percentage of Trajectories Contacting each Whale Resource Area (Winter)

VLOS Area	Subarea	Whale Resource Area	Percentage of Trajectories
Western Shelf	PL1	Beaufort Spring Lead System (31)	31
Central Shelf	offshore portion (LA6)	Beaufort Spring Lead System (32)	10
Offshore	PL4	Beaufort Spring Lead System (33)	17
Far Offshore	PL5	Beaufort Spring Lead System (36)	20

Pinnipeds. BOEM identified 34 pinniped resource areas for the analysis (Appendix A, Tables A6 and A7, Figures A3a, A3c–g, A4a–b, and A5a–c). Most percentages of trajectories contacting ERAs or GLSs were below 10 percent, meaning over 90 percent of the time the OSRA model estimated trajectories do not contact a pinniped ERA or GLS (Figure 5-5 and Figure 5-6). Only resources contacted by 10 percent or more of the modeled trajectories are discussed.

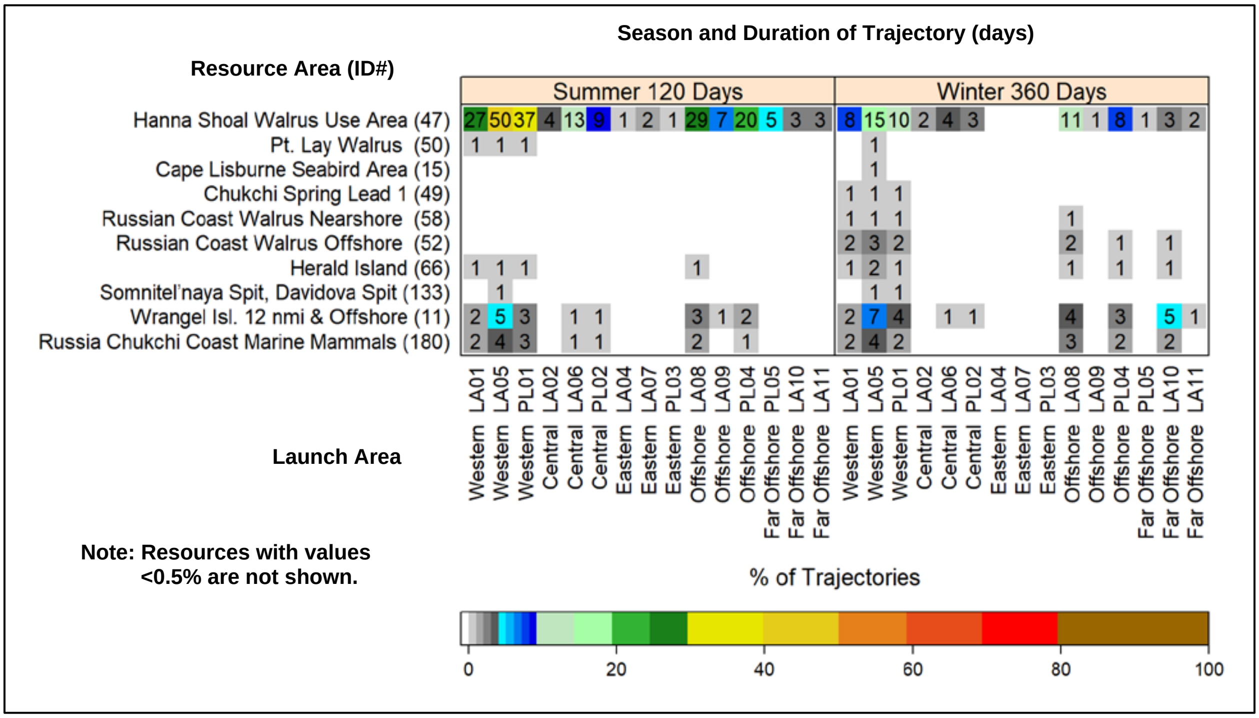


Season and Duration of Trajectory (days)

Resource Area (ID#)	Summer 120 Days															Winter 360 Days														
Launch Area	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10
Harrison Bay Spotted Seal Haulout (159)				1	3	1	3	1	1	2										1	1	2			1					
Harrison Bay/Colville Delta (69)	3			4	17	5	10	4	4	7		2		1		2			1	6	3	4	1	1	1		1		1	
Harrison Bay (68)	8			5	21	8	14	4	6	7		2		2		3		1	1	6	4	5	1	2	2		2		1	
Smith Bay (65)	7	1	3	1	4	4	4		1	1	1	1	1			3	1	2		1	2	1				1	1	1		
Smith Bay Spotted Seal Haulout (155)	10	2	6	1	5	6	5	1	2	1	1	1	1			5	2	4		1	3	2				1	1	1	1	
Peard Bay/Franklin Spit Area (64)	2	2	2													1	1	1												
Chukchi Lead System 4 (48)					1		1		1							17	17	17		4	6	4	1	1	1	5	1	3	1	
Herald Shoal Polynya 2 (62)																1	3	2								2		1		1
Wrangel Isl. 12 nmi Buffer 2 (46)																1	3	2								2		1		2

Note: Resources with values <0.5% are not shown.

Figure 5-5 Percentage of Trajectories Contacting Seal Resource Areas (≥1% within 120 days Summer and 360 days Winter)



Season and Duration of Trajectory (days)

Resource Area (ID#)	Summer 120 Days															Winter 360 Days														
Launch Area	Western LA01	Western LA05	Western PL01	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11	Western LA01	Western LA05	Western PL01	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Hanna Shoal Walrus Use Area (47)	27	50	37	4	13	9	1	2	1	29	7	20	5	3	3	8	15	10	2	4	3				11	1	8	1	3	2
Pt. Lay Walrus (50)	1	1	1														1													
Cape Lisburne Seabird Area (15)																	1													
Chukchi Spring Lead 1 (49)																1	1	1												
Russian Coast Walrus Nearshore (58)																1	1	1							1					
Russian Coast Walrus Offshore (52)																2	3	2							2		1		1	
Herald Island (66)	1	1	1							1						1	2	1							1		1		1	
Somnitel'naya Spit, Davidova Spit (133)		1															1	1												
Wrangel Isl. 12 nmi & Offshore (11)	2	5	3		1	1				3	1	2				2	7	4		1	1				4		3		5	1
Russia Chukchi Coast Marine Mammals (180)	2	4	3		1	1				2		1				2	4	2							3		2		2	

Note: Resources with values <0.5% are not shown.

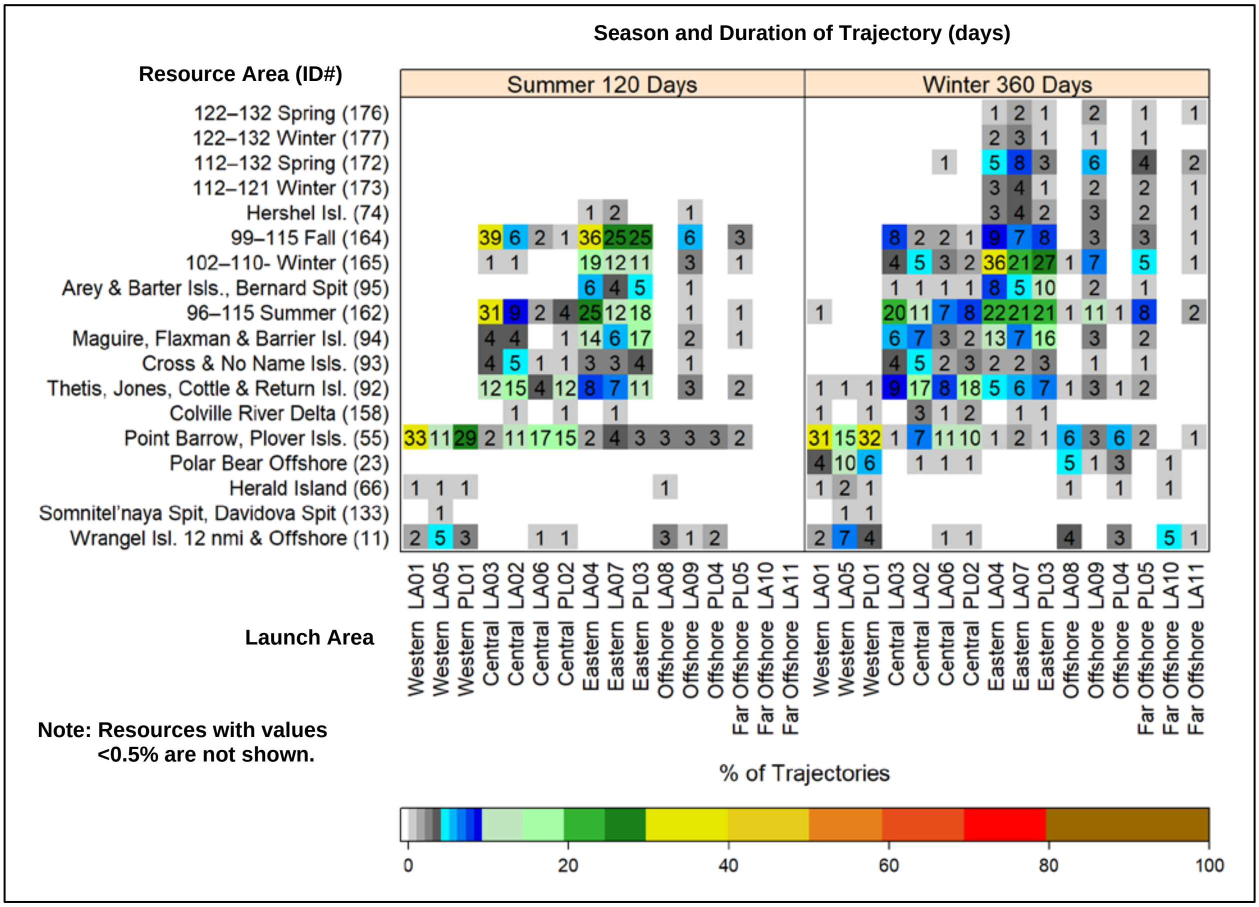
Figure 5-6 Percentage of Trajectories Contacting Walrus Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. Ice seal resource areas Harrison Bay (68) and Harrison Bay/Colville Delta (69) have 14–21 percent and 10–17 percent of trajectories contacting from a Central Shelf VLOS, respectively. Likewise, the Smith Bay Spotted Seal Haulout (155) has 10 percent of trajectories contacting from a Western Shelf

VLOS. All other percentages are <10 percent. A Western Shelf VLOS has 27–50 percent, a Central Shelf VLOS has 13 percent, and an Offshore VLOS has 20–29 percent of trajectories contacting Hanna Shoal Walrus Use Area (47). All other percentages for this area were <10 percent.

Winter. The percentage of trajectories contacting Chukchi Lead System 4 (48) is 17 percent from a Western Shelf VLOS while all others were below 10 percent for ice seal resource areas. A Western Shelf and Offshore VLOS has 10–15 percent and 11 percent of trajectories contacting Hanna Shoal Walrus Use Area (47), respectively. All other percentages of trajectories contacting Pacific walrus resource areas are <10 percent.

Polar Bears. BOEM identified 24 polar bear resource areas for the analysis (Appendix A, Table A5, Figures A3a–c, A3f–g, A4b–c, and A5a–c). Figure 5-7 shows 18 polar bear resource areas with ≥1 percent of trajectories contacting them within summer or winter. Within the Western, Central, and Eastern Shelves, launch areas adjacent to the coast (LA 01, 03, 04) have the highest percent of trajectories contacting coastal polar bear resource areas (55, 162, 164).



Season and Duration of Trajectory (days)

Resource Area (ID#)	Summer 120 Days																Winter 360 Days															
Launch Area	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
122–132 Spring (176)																								1	2	1		2		1		1
122–132 Winter (177)																								2	3	1		1		1		
112–132 Spring (172)																						1		5	8	3		6		4		2
112–121 Winter (173)																								3	4	1		2		2		1
Hershel Isl. (74)								1	2			1												3	4	2		3		2		1
99–115 Fall (164)				39	6	2	1	36	25	25		6		3						8	2	2	1	9	7	8		3		3		1
102–110- Winter (165)				1	1			19	12	11		3		1						4	5	3	2	36	21	27	1	7		5		1
Arey & Barter Isls., Bernard Spit (95)								6	4	5		1								1	1	1	1	8	5	10		2		1		
96–115 Summer (162)				31	9	2	4	25	12	18		1		1			1			20	11	7	8	22	21	21	1	11	1	8		2
Maguire, Flaxman & Barrier Isl. (94)				4	4		1	14	6	17		2		1						6	7	3	2	13	7	16		3		2		
Cross & No Name Isls. (93)				4	5	1	1	3	3	4		1								4	5	2	3	2	2	3		1		1		
Thetis, Jones, Cottle & Return Isl. (92)				12	15	4	12	8	7	11		3		2			1	1	1	9	17	8	18	5	6	7	1	3	1	2		
Colville River Delta (158)					1		1		1								1		1		3	1	2		1	1						
Point Barrow, Plover Isls. (55)	33	11	29	2	11	17	15	2	4	3	3	3	3	2			31	15	32	1	7	11	10	1	2	1	6	3	6	2		1
Polar Bear Offshore (23)																	4	10	6		1	1	1				5	1	3		1	
Herald Island (66)	1	1	1								1						1	2	1								1		1		1	
Somnitel'naya Spit, Davidova Spit (133)		1																1	1													
Wrangel Isl. 12 nmi & Offshore (11)	2	5	3			1	1				3	1	2				2	7	4			1	1				4		3		5	1

Note: Resources with values <0.5% are not shown.

Figure 5-7 Percentage of Trajectories Contacting Polar Bear Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. A Central or Eastern Shelf VLOS has some percentage of trajectories contacting Beaufort Sea coastal barrier islands (55, 92, 94) and portions of the coastline where the summer, fall, and winter habitat are located (11, 162, 164, 165). The highest percentages of trajectories contact 162 (31 percent) and 164 (36–39 percent) from a Central or Eastern Shelf VLOS. A Western Shelf VLOS contacts barrier islands near Point Barrow (55; 11–33 percent); it also contacts Davidova Spit along with Wrangel and Herald islands to a much lesser degree (1–5 percent). An Offshore VLOS has <0.5–11 percent of trajectories contacting coastal islands and summer bear habitat, which is lower than a Central or Eastern Shelf VLOS.

Winter. A Winter VLOS contacts polar bear resource areas similarly to what was described for a summer VLOS above; however, the percentage of trajectories contacting fall habitat (164) declines to <10 percent, while an Eastern Shelf VLOS has the highest percentage of trajectories contacting winter habitat (165; 36 percent). An Offshore or Eastern Shelf VLOS has an increased percentage of trajectories contacting summer habitat (162), while the percentage of trajectories decreases for a Central Shelf VLOS. A Western Shelf VLOS has the highest percentage of trajectories (32 percent) contacting Point Barrow (55). A nearshore Central Shelf VLOS has 20 percent of trajectories contacting the summer habitat (162). The highest percentage of trajectories contacting (36 percent) from a nearshore Eastern Shelf is to winter habitat (165). The percentage of trajectories contacting from an Offshore VLOS also increases in winter and has >10 percent of trajectories contacting summer habitat (162; 11 percent). Similarly, a far offshore VLOS increases from <0.5 percent with many trajectories contacting resource areas spanning a wide distribution within the planning area (1–8 percent) due to the longer travel time.

5.6.5 Conclusion

Whales. Oil on and in the water may be avoided depending on the timing, volume, contents, and duration of a VLOS. Whales generally could experience some loss of seasonal habitat, and reduction of and/or contamination of prey. Consumption of contaminated prey may also affect the distribution, abundance, and health of whales. A variety of effects on whales could result from contact with and exposure to a VLOS ranging from no effect, to avoidance, to mortality depending on the circumstances unique to a VLOS. Temporary and non-lethal effects are likely from the human activities associated with VLOS response, cleanup, remediation, and recovery. Whales would be expected to avoid vessel-supported response and cleanup activities at distances of several miles depending on the noise levels. Migrating whales would be expected to divert around relief well drilling operations and other vessel-based activities. This could lead to displacement or diversion away from prey aggregations and important feeding opportunities. Frequent encounters with VLOS activities and lost feeding opportunities could result in reduced body condition or reproductive performance, increased reproductive interval, decreased calf survival, and increased age of sexual maturation in some bowheads. These impacts are not expected to result in population-level effects.

Most VLOS trajectories would not produce population-level effects on whales in the Beaufort Sea, and most impacts would produce negligible to minor, temporary behavioral responses among a few whales and whale groups. However, a VLOS from the Central or Western Shelf could expose large numbers of whales to VOCs and oil for a prolonged period, particularly in the vicinity of the Utqiaġvik Feeding Aggregation Area (108), AK BFT Outer Shelf & Slope 10 (119), and AK BFT Bowhead FM 1 (29). If whales in these locations ingest large amounts of oil, injury and some mortalities could occur. A VLOS contacting Utqiaġvik Feeding Aggregation Area (108) during the bowhead whale fall migration, could injure or kill substantially large portions of the bowhead whale stock, with a major level of impact. Under most conditions, a VLOS would have negligible to minor impacts on cetacean populations; however, there could be situations where a VLOS from the Western Shelf could have major impacts on whale populations.

Pinnipeds. Since ringed seals overwinter in areas of solid fast ice, a large number of them could be affected by an under-ice winter VLOS. Some bearded seals could be immediately affected, but they prefer overwintering in lead systems and would most likely be spared from the immediate effects of an under-ice VLOS.

A winter VLOS occurring in or contacting a lead system could immediately impact large numbers of ringed or bearded seals perhaps into the hundreds or possibly thousands. The impacts from a VLOS contacting those leads would range from skin and eye irritation to ulcers and in some cases death. The OSRA estimates a winter VLOS from most LAs and PLs could contact Chukchi Lead System 4 (48) and the Hanna Shoal Walrus Use Area (47). Large amounts of oil in these habitat areas could impact several thousand Pacific walruses.

A summer VLOS contacting nearshore spotted seal habitat could injure or kill low numbers of spotted seals, particularly those using the Colville River Delta, Smith Bay, and Dease Inlet. Ringed and bearded seals remain near sea ice during the open-water season, so greater numbers could be contacted by a summer VLOS near the ice front and in deeper shelf waters. A summer VLOS could contact, injure, or kill a few hundred to a few thousand ringed or bearded seals if spilled oil were to contact areas where seals aggregate to feed or molt.

A summer VLOS could affect very few Pacific walruses in the Beaufort Sea due to their scarcity. The OSRA model estimates a VLOS consistently contacts Hanna Shoal Walrus Use Area (47) from every LA. The highest percentages of trajectories occurred from the Western Shelf (37–50 percent), while other areas had 1–29 percent of trajectories contacting it. If a VLOS were to contact Hanna Shoal Walrus Use Area (47), several thousand walruses could be directly impacted by contact, inhalation, or ingestion of crude oil possibly leading to death.

A winter VLOS would likely have moderate to major effects on ringed and bearded seal populations wintering in the Beaufort Sea. The effects on spotted seals and Pacific walruses would be negligible to minor since a winter spill would have weathered, become frozen in sea ice, and dispersed. A summer VLOS would produce behavioral responses and have physiological impacts on pinnipeds that could result in mortality. Due to the potential for mortalities, the range of impacts could be minor to major, with minor being widespread behavioral responses and major being widespread impairments or deaths among seals and/or walruses. Temporary and non-lethal effects are likely from the activities related to VLOS response including cleanup, remediation, and recovery. Seals and walrus would avoid oiled areas because of cleanup activities. This would reduce their chances of being exposed to crude oil and reduce the overall impacts to minor to moderate.

Polar Bears. VLOS effects on polar bears are expected to be regional. The most likely impacts to individual bears from contacting oil would involve dermal or eye irritation, irritation to the respiratory system, the digestive system, energetic losses, and increased stress. In more extreme cases some bears could die from prolonged or extensive oil contact. Oil spill response, cleanup, and remediation would produce short-term behavioral responses from bears. The extent of the impacts on polar bear stocks would be a function of the proportion of the stock contacted, spill trajectories, spill timing and duration, the extent of oil weathering, and spill response and cleanup effectiveness. Impacts would be greatest in areas where polar bears aggregate. For these reasons, impacts to the SBS and CBS polar bear stocks from a VLOS are expected to be minor to moderate.

5.7 Terrestrial Mammals

5.7.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Well Control Incident. An explosion from a LOWC incident during summer and fall would not affect terrestrial mammals, but an explosion during winter or spring could affect Arctic foxes and grizzly bears. Arctic foxes roam widely across sea ice during winter and spring, and grizzly bears may hunt seals on spring sea ice. Potential impacts could result from a pressure wave in the air, loud noises, and smoke from burning materials. Smoke has the greatest potential to harm Arctic foxes or grizzly bears because the other elements of an explosion would be brief, restricted to the immediate area, and unlikely to persist. The effect of severity from smoke inhalation would be proportional to the volume of smoke inhaled, duration of exposure, chemical constituents of the smoke, environmental conditions at the time of the incident, exposure duration, and numbers and physical condition of individuals present. Effects could range from behavioral responses to mortalities among a small number of Arctic foxes and/or grizzly bears who happen to be near the event.

If large volumes of smoke reach terrestrial mammals for extended periods of time, airborne contaminants would be inhaled. Effects from prolonged inhalation could include damage to respiratory and circulatory systems in individual animals. Large species, such as caribou, muskox, and grizzlies, may be affected more often and to a greater extent than foxes during summer, since smoke flows above the ground level where foxes breathe. Larger mammals, while potentially exposed to the smoke plume, would also be more capable of moving away from it. The larger size of caribou, muskoxen, and grizzly bears would also require greater quantities of inhaled toxins to affect them than foxes. Most likely, smoke from a well control incident would disperse well before reaching the Beaufort coast since leases would be a minimum of 3 mi offshore.

Offshore Spill. Caribou, grizzly bears, muskox, and Arctic foxes could come into contact with oil from a VLOS. During winter, Arctic foxes use sea ice to hunt and scavenge, and grizzly bears sometimes venture onto shorefast ice to hunt seals in early spring (Doupé, 2005; Doupé et al., 2007; Lindsay, 2009; Taylor, 1995; Struzik, 2003; Wolcow, 2005). Consequently, they could be exposed to offshore oil in winter and early spring. Contamination may then be passed on through the food web, potentially resulting in short- and/or long-term health impacts. Since Arctic foxes are present on sea ice and barrier islands, their ability to thermoregulate could be impaired if their fur becomes oiled, possibly leading to hypothermia or death. Winter spills contacting polynyas, leads, shear zones, and other areas important to Arctic foxes could lead to fox mortalities.

Section 4.2.7 describes the physiological effects from ingesting oiled food, grooming oiled fur, and prolonged skin contact with oil. The most likely means for a terrestrial mammal to contact spilled oil in the offshore environment involves accidentally oiling their fur, or by ingesting contaminated meat from a kill/carcass. Grizzly bears and foxes may not be particular about their foods. If salmon runs were contaminated, several grizzly bears could be affected. Likewise, bears or foxes eating oiled ringed seal pups or scavenging contaminated carrion could ingest some oil. Bears or foxes getting oil on their fur or skin would only be affected if the oiling was sufficient to compromise the insulating capabilities of their fur, or if skin lesions develop.

Occasionally, a few foxes, caribou, and muskoxen may temporarily visit barrier islands during summer. Caribou and muskox could be exposed to oil when they swim to barrier islands or when caribou enter the Beaufort Sea for insect relief. Caribou are the only terrestrial mammals that may aggregate in large numbers at coastal areas. Because they are highly mobile, the impacts on caribou would depend on their seasonal ranges and numbers present at the time of contact.

During winter, there would be no chance of offshore contact for caribou, muskox, or grizzly bears. Most caribou migrate south to or beyond the Brooks Range during winter and would not be affected at that time. Muskox prefer windswept upland areas during winter and spring, far removed from offshore areas. Hibernating grizzly bears remain in their inland dens from late fall through spring and would not be affected.

Onshore Contact. The greatest potential for a VLOS to impact several species of terrestrial mammals occurs if spilled oil contacts areas used by caribou, muskox, grizzly bears, or foxes during summer. With the exception of caribou, terrestrial mammals do not aggregate in numbers sufficient to permit population-level effects. The presence of landfast sea ice precludes onshore contact by a VLOS during winter.

Caribou populations that could be affected include the Teshekpuk Lake Caribou Herd (TCH), Central Arctic Caribou Herd (CAH), or the Porcupine Caribou Herd (PCH). These herds could be impacted if sufficient oil contaminates coastal insect relief areas during the peak insect harassment period (mid-July through late August), or to a lesser degree, if coastal feeding areas are contaminated. Muskox, grizzly bear, and Arctic fox populations should not experience severe impacts, though potentially a few individuals could die after contacting crude oil under certain conditions. Ingested oil can result in numerous health effects, depending on the quantity of oil consumed and the physical and chemical state of the oil at the time of ingestion. The effects of crude oil contact, inhalation, and ingestion are addressed in Section 4.2.7.

Direct contamination could arise from ingestion of oil while grooming oiled fur, inhalation of oil constituents in the air, and dermal oiling. Effects of such contacts could include skin/eye/mucus lining/ lung irritation, skin lesions, and biochemical effects such as injury to renal, respiratory, circulatory, and biliary systems, or elevated cortisol levels. Such effects on an affected animal’s health could be short- and/or long-term depending on the severity of contamination. Due to the noxious characteristics of crude oil, terrestrial mammals would probably attempt to rub oil off on vegetation, rocks, or in areas where they could wallow in bare soil.

Caribou are unlikely to ingest oiled vegetation since they are selective feeders (Kuropat and Bryant, 1980). They would likely detect and avoid oiled forage plants. In contrast, bears and foxes may not be as selective in the quality of their food. However, losses of foraging areas or food resources could result in animals having to switch to alternate foods or different feeding areas; or malnutrition if remaining foodstocks are insufficient to maintain an animal’s health or fitness. Furthermore, searching for replacement foods may force some animals into areas where their presence may conflict with resident animals, or where they may experience increased predation. Therefore, losses of food resources could compromise the nutritional status of some animals, impacting individual fitness and survival, though such changes would be unlikely to disrupt local populations.

5.7.2 Phase 2 (Spill Response and Cleanup)

Spill response activities could increase disturbance in the affected area, temporarily driving some animals into alternate and less suitable habitat, which could result in reduced nutrition, increased energy expended in foraging, increased predation, and increased competition over habitat and food resources. Spill response activities would involve the use of vessels and aircraft resulting in increased activity at shore bases and airports. Spill response activities may increase the possibility of encounters between cleanup crews and animals into whose habitat the cleanup crews intrude. Areas likely to be contacted by oil in summer include river deltas and beaches heavily used by caribou, brown bears, and Arctic foxes, while a winter VLOS would most likely affect the terrestrial mammals that inhabit or visit shorefast ice. The presence of cleanup crews in these areas may deny access to caribou, muskox, grizzlies, or Arctic foxes that rely on foods occurring in contaminated areas. Terrestrial mammals displaced from contaminated areas by spill response would have a reduced likelihood of direct effects from oiling.

Owing to the high nutritive value of resources such as carrion, bears and Arctic foxes may be unwilling to forsake the area. Actions such as hazing in the affected area would be taken to reduce bear-human interactions. This may include reduced access to bears, possible tranquilization, relocation, or killing of “problem animals” in defense of human life.

In-situ burning operations would primarily occur near the localized origination point of the VLOS and in prioritized nearshore areas. Effects on all terrestrial mammal species from these operations are likely to be minor since most burning would occur near the source of the spill; however, nearshore operations and noise could affect sensitive coastal sites important to terrestrial mammal species. Burning in nearshore areas would discourage any terrestrial mammal species from remaining in the immediate area.

Ground/on-ice cleanup activities and aircraft operations should have minimal effects on terrestrial mammal populations as long as minimum altitude flying restrictions (1,000 ft above ground level) are maintained (ADNR, 2016; NSB Code §19.70.050(I)(1)). Furthermore, any aircraft avoidance by terrestrial mammals would have the benefit of encouraging individual animals to avoid spill areas where aircraft would operate. Disposal of contaminated carcasses (if any), tissues, and oil contaminated materials (absorbent pads, protective gear, etc.) would be at an authorized disposal site onshore.

5.7.3 Phase 3 (Post-Spill, Long-Term Recovery)

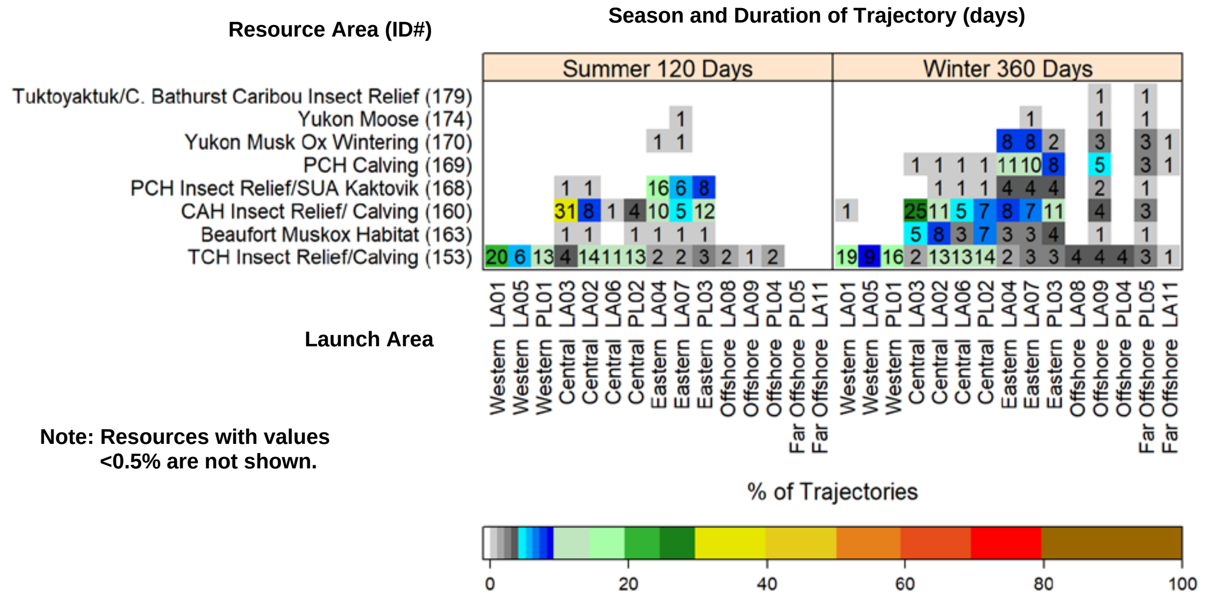
Soil and shoreline contamination may persist for years with toxins transferred to growing plants and on to animals feeding on these plants. Any contamination in the food web could have long-term ecologic and biologic effects on individual caribou, muskoxen, grizzlies, or Arctic foxes exposed to oil. Toxins sequestered in the sediments or prey, would likely be ingested by bears or Arctic foxes scavenging coastal food sources such as carrion or beach debris (Peterson et al., 2003).

Over the long-term, terrestrial mammals other than caribou should not experience population-level effects from a VLOS. The low numbers and widespread distribution of grizzly bears and muskox make any population-level effects improbable under the worst circumstances. Conversely, the numbers, distribution, and reproductive characteristics of caribou and Arctic fox populations would mostly buffer their populations from VLOS effects. However, an exception would occur if caribou insect relief areas were contacted when caribou are present or need to be in those areas (mid-July through late August). At such times, large numbers of caribou (into the thousands or tens of thousands) can enter coastal waters to escape biting insects. Such effects could take anywhere between one year to many years to recover, depending on the population size, number of individuals exposed, and the severity of exposures. Grizzly bears, muskox, and Arctic fox populations would probably recover within a year or two since they occur in low numbers and are widely dispersed (grizzly bears and muskox), or because they are extremely prolific (Arctic foxes).

It is reasonable to expect post-spill monitoring for terrestrial mammals as result of a VLOS. Over the long-term, terrestrial mammals would experience continued exposure to aircraft and vessel noise and traffic. Aircraft and vessel operations would support many long-term NRDA efforts for monitoring the recovery of resources, fate of oil and/or dispersants in the Arctic environment, and research and monitoring on the effectiveness of cleanup and restoration practices. Research monitoring and studies are subject to scientific research permits and authorizations issued by state and federal agencies. These permits and authorizations would provide stipulations, best practices, and enforcement measures to protect terrestrial mammals. Effects on terrestrial mammals from NRDA activities are expected to be little to none, or short-term and/or localized, and less than severe.

5.7.4 Oil Spill Trajectory Analysis

BOEM identified 11 terrestrial mammal resource areas for the OSRA analysis (Appendix A, Table A8, Figures A5a–c). Figure 5-8 shows 8 terrestrial mammal resource areas with ≥1 percent of trajectories contacting them in summer or winter. The OSRA model shows a general tendency for a VLOS to spread more westerly than easterly and an offshore or far offshore VLOS is unlikely to contact any important terrestrial mammal habitats. A VLOS starting adjacent to the coast had the most trajectories contacting terrestrial mammal habitat in the nearest coastal areas and those west of the release locations.



Summer 120 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
Tuktoyaktuk/C. Bathurst Caribou Insect Relief (179)															
Yukon Moose (174)									1						
Yukon Musk Ox Wintering (170)								1	1						
PCH Calving (169)															
PCH Insect Relief/SUA Kaktovik (168)				1	1			16	6	8					
CAH Insect Relief/ Calving (160)				31	8	1	4	10	5	12					
Beaufort Muskox Habitat (163)				1	1		1	1	1	1					
TCH Insect Relief/Calving (153)	20	6	13	4	14	11	13	2	2	3	2	1	2		

Winter 360 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
Tuktoyaktuk/C. Bathurst Caribou Insect Relief (179)												1		1	
Yukon Moose (174)									1			1		1	
Yukon Musk Ox Wintering (170)								8	8	2		3		3	1
PCH Calving (169)				1	1	1	1	11	10	8		5		3	1
PCH Insect Relief/SUA Kaktovik (168)					1	1	1	4	4	4		2		1	
CAH Insect Relief/ Calving (160)	1			25	11	5	7	8	7	11		4		3	
Beaufort Muskox Habitat (163)				5	8	3	7	3	3	4		1		1	
TCH Insect Relief/Calving (153)	19	9	16	2	13	13	14	2	3	3	4	4	4	3	1

Figure 5-8 Percentage of Trajectories Contacting Terrestrial Mammal Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. Three GLSs had percentages of trajectories contacting above 10 percent within 120 days during summer. Those GLSs were the TCH Insect Relief/Calving area (GLS 153), CAH Insect Relief/Calving (GLS 160), and PCH Insect Relief/SUA Kaktovik (GLS 168). GLS 153 had 6–20 percent and 4–14 percent of trajectories contacting from the Western and Central Shelf, respectively. GLS 160 had 1–31 percent and 5–12 percent of trajectories contacting from the Central and Eastern Shelf, respectively, while GLS 168 had 6–16 percent of trajectories contacting from the Eastern Shelf. Overall, there were no trajectories from Offshore or Far Offshore contacting GLSs, other than 1–2 percent of trajectories from Offshore contacting GLS 153.

Winter. Three GLSs had percentages of trajectories contacting above 10 percent within 360 days during winter. GLS 153 had 9–19 percent and 2–14 percent of trajectories contacting from the Western and Central Shelf, respectively. GLS 160 had 5–25 percent and 7–11 percent of trajectories from the Central and Eastern Shelf, respectively. GLS 169 had 8–11 percent of trajectories contacting from the Eastern Shelf. The remaining percentages of trajectories contacting were all below 10 percent; however, there were more contacts than from summer VLOS trajectories, and the values were up to 8 percent. The Beaufort Muskox Habitat (GLS 163) was contacted by 3–8 percent of trajectories from the Central Shelf, while Yukon Muskox Wintering (GLS 170) was contacted by 2–8 percent of trajectories from the Eastern Shelf. All remaining values were 5 percent or less.

5.7.5 Conclusion

A VLOS would affect a small number of Arctic foxes or grizzly bears hunting or scavenging on sea ice. This is due to the scarcity of grizzlies on spring sea ice and the dispersion of Arctic foxes over large geographic areas when ice is present, and the likelihood a VLOS would contact surface winter or spring ice over a restricted area. Caribou and muskoxen should not be affected by a VLOS unless it reaches coastal habitat areas used by these species. Muskox are widely scattered in small herds and would most likely remain unaffected by a VLOS unless some coastal feeding areas became contaminated. Under such circumstances limited numbers of muskoxen could die or be affected. For these reasons, population-level effects to grizzly bears, muskoxen, or Arctic foxes, from a VLOS would be unlikely and would most likely have a negligible to minor level of effects.

Caribou populations could only be affected if large volumes of oil contact an insect relief area during periods of high insect harassment, or if oil contaminates substantial amounts of nearshore calving areas. In these specific circumstances, thousands of caribou could be impacted. This level of impact could produce moderate to major population-level effects, depending on the extent and duration of contact, and herd population size. VLOS contacts outside of insect relief and caribou calving periods would have negligible effects on caribou herds.

5.8 Birds

A VLOS would be expected to impact birds, particularly via oiling of birds and response operations that impact forage or prey items and habitat. The level of impacts to bird forage and habitat depends on whether or not birds are present during a VLOS. Effects to shoreline wetlands, and invertebrate and fish prey populations can persist until birds are present, and up to several years beyond (see Sections 5.3, 5.4, and, 5.5 respectively).

5.8.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

A well control incident could happen during any season, including when birds are not present. If the blowout were to occur when and where birds are present, any birds immediately around the drilling unit could be killed from the initial explosion, including a large, high-density raft or staging flock that could occasionally occur near human activity. Because birds are acutely sensitive to methane poisoning, the ongoing release of natural gas into the atmosphere could potentially cause physiological effects to migrating birds, should they be seasonally present and fly directly through a gas cloud. Impacts of a gas release would likely be short-term because birds are known to recover after exposure to methane, as the ongoing gas release would often be dissipated or diluted by winds (Section 5.1.1), and the numbers of affected birds from any one population would be too low to have long-term (population-level) impacts.

Oiling of birds, prey, and habitat would be the primary source of VLOS impacts to birds. Bird oiling and oil-ingestion effects are described in Section 4.2.8. For purposes of this analysis, all birds contacted by oil are assumed to die. Contamination of invertebrates, fish, and wetland plants would be expected to result in ingestion of contaminated food and diminished food availability that could persist from one to several years. Birds also could be displaced to potentially less productive secondary foraging locations. Contamination of wetlands would also be expected to impact breeding, including nesting and brooding of young, of certain populations.

Offshore Spill. Large numbers of waterbirds, including seaducks, dabbling ducks, seabirds, loons, and phalaropes, initially appear when leads open in marine waters in spring, and are vulnerable throughout the open-water season. Bird populations are most vulnerable to a VLOS in the Beaufort Sea when they aggregate in dense flocks. Seaducks such as long-tailed duck, king eider, and scoters (spp) could experience mortality of hundreds or thousands via an explosion and oiling if exposure occurs between the barrier islands and mainland during peak use and flightless molting. While many are local breeders, the highest proportion would likely be migrants moving through from various breeding populations in Russia, the Chukchi Sea area, or Canada (Dickson, 2012; Quakenbush et al., 2009). Birds in Beaufort Sea marine waters are usually not exclusively rafted together according to local breeding populations. Their larger

Arctic populations may number in the hundreds of thousands, so losses in the thousands would not be expected to result in long-term impacts but would be considered widespread geographically. Depending on location, however, it is possible that over a breeding or molting season certain vulnerable local breeding populations could begin to experience longer-term effects. Sea ducks, such as barrier island-breeding common eiders, could experience high exposure rates and mortality to their local breeding populations. Additional numbers of sea ducks would be affected by the impacts on lower trophic and fish prey.

Besides seaducks, many species of seabirds and loons could experience widespread mortality in marine waters. Locally abundant foragers in pelagic waters and common breeders onshore in the Beaufort Sea Planning Area include glaucous gull and Arctic tern. The local populations of these species could incur high levels of mortality and sublethal effects through direct contact, contaminated food, and nest contamination. A VLOS could not only cause widespread mortality of adults, but of chicks as well if adults bring contaminated food or residual oil on their feathers back to nests. As with many of the waterfowl discussed above, Arctic tern’s wide-ranging and abundant overall population would prevent the species itself from incurring more than minor impacts. Owing to its overall large population, a VLOS would probably not have population-level effects. Ross’s gulls, ivory gulls, and black guillemot are ice-associated species, vulnerable if a VLOS contaminated ice edge habitat or prey. The circumpolar breeding populations of the gulls may not be impacted overall, but there are some indications that guillemots may be in decline (Joiris, 2016), and it is possible that they could sustain long-lasting impacts.

Hundreds or thousands of marine birds of other species including short-tailed shearwaters, jaegers, phalaropes, and loons could be contacted and killed by spilled oil. Most of these birds are found widely across the Beaufort Sea, foraging variously on patchily distributed zooplankton, euphausiids, or small fish in pelagic waters, and the non-uniform distribution of these birds could favor their survival during a VLOS or lead to extensive mortality. Populations are generally considered large, widespread, and stable, and impacts therefore considered temporary, even though large numbers of individuals could be contacted with oil or eat contaminated food. A few species that have specialized foraging and breeding niches and/or are possibly in decline, such as black guillemot and the red-throated loon, could incur longer term impacts.

Onshore Spill. If oil made onshore contact, other birds could be impacted. Large numbers of shorebirds and waterfowl could come into contact with spilled oil along shoreline areas and in estuaries and bays. Since many species stage and stop over in high density flocks in these coastal areas during migration, these birds could be affected through direct contact with oil, ingestion of contaminated food items, and mortality of prey resources. Given the high variability in abundance at migration stopover sites, a VLOS that contacted shoreline habitat could initially affect either a few birds or most birds using an area, depending on when the VLOS occurred. Between July and September, many coastal sites host migrating flocks of hundreds or thousands of shorebirds, ducks, and geese a day. Birds may stop over for only a few days, and with thousands more continually moving in and stopping while others attempt to move on, the sum of birds at risk at any one stopover site can climb to tens of thousands. Breeding and migration foraging habitat and food sources could be impacted or lost for years, impacting many more birds. The loss of thousands of several shorebird and waterfowl species, each at a migratory stopover, would be considered a widespread impact. Some species that are less abundant, declining, or have more restricted ranges such as buff-breasted sandpiper, could potentially incur longer lasting effects to a larger percentage of their population, and therefore severe impacts.

The locally nesting birds most vulnerable to onshore contact would be barrier island-dependent nesting waterbirds, and geese that nest and brood in colonies on river deltas like the Colville and Canning River area or north of Teshekpuk Lake. Oiling of coastal or other wetland habitats with concentrations of nesting birds would be expected to cause displacement of nesting birds in the oiled areas and contribute to reduced reproductive success of the birds, and possibly direct mortality of large numbers of eggs and chicks. Reproductive impacts are of particular significance in the short summer period of high northern latitudes, given the high energetic investment in egg laying and nesting. Geese vulnerable to a VLOS in the Beaufort Sea are greater white-front goose, Pacific black brant, lesser snow goose, and Canada goose. Snow geese are colonial nesters that nest in only a few places in Alaska, all on Arctic Coastal Plain coastal habitat. One of their largest colonies has been on the Sagavanirktok River Delta where they nest on Howe Island, and sometimes Duck Island. Brant nest colonially primarily in shoreline habitat between the Colville and Canning rivers, on the Central Beaufort Sea coast. Potentially thousands of geese would be vulnerable to VLOS contact while foraging or resting in nearshore waters during staging or breeding. Post-breeding geese move, often in large flocks, to protected deltas and inlets and on to nearby large lakes, including the lakes north of Teshekpuk Lake, to undergo a flightless molt. If oil contamination of geese molting habitat caused food resources to be depressed for several years, long-term impacts would be expected.

Other seabirds, raptors, and passerines could also be impacted by oil making onshore contact. For example, dozens of raptors, owls, and ravens might be killed if they were to scavenge on oiled carcasses. These birds typically have wide-ranging breeding populations so would therefore not incur long-term effects. In general, the species potentially impacted the most by offshore and onshore contact with a VLOS are the same as those for a large spill in the Beaufort (BOEM, 2018d).

5.8.2 Phase 2 (Spill Response and Cleanup)

Spill response activities could disturb and displace birds, and potentially directly cause lethal impacts to some nests. Specific types of impacts that birds may experience include contamination of food resources from chemical dispersant use; toxicity and loss of water-shedding capabilities from dispersant use or burn residue; loss and damage of food resources from mechanical spill response; loss of nests from cleanup worker disturbance or inadvertent crushing; and disturbance and displacement from foraging, nesting, brood-rearing, molting, or staging habitats. Humans intentionally or unintentionally may displace birds. Net beneficial effects may occur if birds can be displaced with low energetic costs from oiled to unoiled areas of similar habitat quality. For purposes of conservative analysis, however, BOEM assumes that the majority of birds displaced would be moved to inferior habitats, to other oiled areas, or with enough disturbance to incur high energetic costs, and therefore experience net negative impacts.

Depending on type, timing, location, and duration of response, as well as the quality of food resources affected, spill response and cleanup efforts could have long-lasting impacts on birds. Arctic wetlands are slow to naturally rehabilitate, so unmitigated tundra or wetland damage could cause decades-long habitat impacts. Such impacts would likely not be large in area relative to surrounding undisturbed habitat, however. Except if they occur in particularly unique or sensitive habitats, breeding impacts should be localized. If, however, worker or camp presence was situated on the only unoiled shoreline available for several miles, or otherwise blocked access to nesting common eider habitat, for example, impacts could be amplified. Similarly, disturbance to areas hosting large aggregations of disparate populations, such as staging shorebird roosts, could lead to widespread impacts. Expected repeated and substantial anchoring of response vessels and spill containment booms could lead to long-term degradation or loss of small but numerous areas of marine foraging habitat.

The long duration of VLOS cleanup activities would be expected to preclude birds from successfully using the area for an entire season or more, which could disrupt survivorship or productivity. Cleanup of the EVOS took more than four summers (USCG, 1993). If disturbance from either a summer or winter VLOS continued in an important habitat site for multiple years, these impacts could increase for certain birds such as nesting common eider. If response and cleanup impacts occurred for repeated years in the most vulnerable habitats when birds were present (common eider barrier island nest habitats and shorebird staging areas), response impacts alone could be long-lasting and widespread for certain vulnerable populations. As long as oil remained in the same environment, however, spill recovery efforts would have both negative and positive effects, in that they may keep some birds from additional contamination impacts.

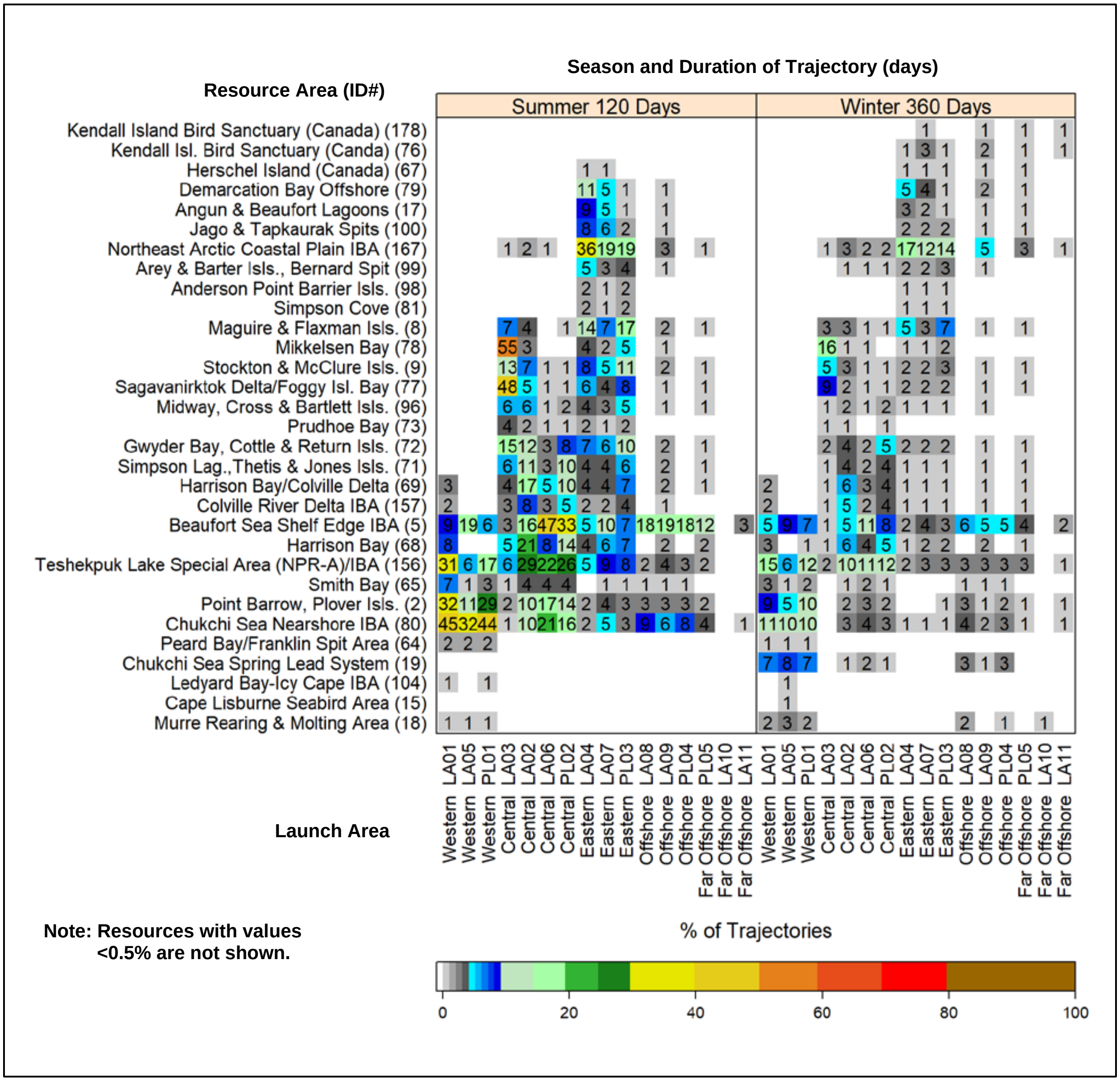
5.8.3 Phase 3 (Post-Spill, Long-Term Recovery)

A VLOS would cause long-term adverse effects (2 years or more in duration) to coastal and estuarine migratory bird habitats from lingering effects of oiled or damaged habitat, effects of post-spill damage assessment studies, or impacted reproductivity. Long-term loss of breeding and forage habitat would occur where shoreside camps and storage areas displace tundra. Contamination of food resources or nesting substrates could lead to reduced fitness and productivity. Sections 5.4.3 and 5.5.3 describe how a VLOS and spill response may have long-lasting impacts on shorezone and benthic lower trophic food resources and widespread and persistent impacts on fish prey resources, which could in turn have long-term consequences for many bird species, including benthic feeding sea ducks, staging shorebirds, piscivorous seabirds and loons, and others. After the EVOS, the extent and degree of oiling on shorelines decreased rapidly over the first few years, and it was assumed that remaining oil would be reduced to negligible amounts soon thereafter (Neff et al., 1995). However, long-term studies have raised concerns that the tiny fraction of largely unweathered lingering oil remaining for decades in intertidal sediments of some beaches may have exposed a few fish and wildlife populations as well as the nearshore ecosystem to chronic impacts (Esler et al., 2015). Most marine bird populations appear to have recovered from the EVOS, but in some cases have taken 10 years or longer (Esler and Iverson, 2010; Lance et al., 2001; McKnight et al., 2006; Stephensen et al., 2001; Wiens et al., 2004). Harlequin duck, for example, appears to have experienced such long-term impacts (Esler et al., 2015), and although it does not occur in the Beaufort Sea, its experience could indicate that other sea ducks with nearshore benthic feeding requirements may have similar vulnerabilities. Despite differences in species composition between the Gulf of Alaska and Beaufort Sea, Beaufort Sea birds would probably not have more resilience to VLOS impacts than Gulf of Alaska birds.

Post-spill avian impacts would also continue to be widespread because of the extreme migratory nature of Arctic-breeding birds. The DWH was reported to have potentially affected bird populations, depending on their migration patterns, as far away as Alaska and northern Canada, Central and South America, or the Caribbean (Corn and Copeland, 2010; DWH Trustees, 2016). In other words, almost all birds that could be impacted move to other places distant from the Beaufort Sea Planning Area to molt, winter, and in some cases breed. As described under effects for Phases 1 and 2 (Sections 5.8.1 and 5.8.2), the numbers of birds affected relative to overall population levels for most species would keep the long-term and widespread impacts from becoming severe. However, for some populations that are more limited in geographic scope or abundance or are potentially declining or increasingly vulnerable to climate change impacts (common eider), severe impacts could continue through the post-spill recovery period.

5.8.4 Oil Spill Trajectory Analysis

BOEM identified 35 bird resource areas for analysis (Appendix A, Table A9, Figures A3a, A3c–d, A3f–g, and A5a–c). The OSRA estimates that a VLOS occurring in the summer or winter, depending on where it occurs, has ≥1 percent of trajectories contacting 31 of the 35 resource areas (Figure 5-9). Whether or not the OSRA showed a greater or lesser percentage of trajectories contacting a given resource area is largely dependent on where a VLOS starts and season. A winter VLOS has ≥1 percent of trajectories contacting a few more ERAs and GLSs than a summer VLOS (31 vs 27), because of longer travel time and persistence due to freezing in sea ice, but there would also be fewer ERAs in winter with ≥10 percent of trajectories contacting (6 versus 14, Figure 5-9). In general, there is a lower percentage of trajectories contacting bird resource areas in the winter than in the summer when more habitat is seasonally occupied.



Note: Resources with values <0.5% are not shown.

Summer 120 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Kendall Island Bird Sanctuary (Canada) (178)																
Kendall Isl. Bird Sanctuary (Canda) (76)																
Herschel Island (Canada) (67)								1	1							
Demarcation Bay Offshore (79)								11	5	1		1				
Angun & Beaufort Lagoons (17)								9	5	1		1				
Jago & Tapkaurak Spits (100)								8	6	2		1				
Northeast Arctic Coastal Plain IBA (167)				1	2	1		36	19	19		3		1		
Arey & Barter Isls., Bernard Spit (99)								5	3	4		1				
Anderson Point Barrier Isls. (98)								2	1	2						
Simpson Cove (81)								2	1	2						
Maguire & Flaxman Isls. (8)				7	4		1	14	7	17		2		1		
Mikkelsen Bay (78)				55	3			4	2	5		1				
Stockton & McClure Isls. (9)				13	7	1	1	8	5	11		2		1		
Sagavanirktok Delta/Foggy Isl. Bay (77)				48	5	1	1	6	4	8		1		1		
Midway, Cross & Bartlett Isls. (96)				6	6	1	2	4	3	5		1		1		
Prudhoe Bay (73)				4	2	1	1	2	1	2						
Gwyder Bay, Cottle & Return Isls. (72)				15	12	3	8	7	6	10		2		1		
Simpson Lag.,Thetis & Jones Isls. (71)				6	11	3	10	4	4	6		2		1		
Harrison Bay/Colville Delta (69)	3			4	17	5	10	4	4	7		2		1		
Colville River Delta IBA (157)	2			3	8	3	5	2	2	4		1				
Beaufort Sea Shelf Edge IBA (5)	9	19	6	3	16	47	33	5	10	7	18	19	18	12		3
Harrison Bay (68)	8			5	21	8	14	4	6	7		2		2		
Teshekpuk Lake Special Area (NPR-A)/IBA (156)	31	6	17	6	29	22	26	5	9	8	2	4	3	2		
Smith Bay (65)	7	1	3	1	4	4	4		1	1	1	1	1			
Point Barrow, Plover Isls. (2)	32	11	29	2	10	17	14	2	4	3	3	3	3	2		
Chukchi Sea Nearshore IBA (80)	45	32	44	1	10	21	16	2	5	3	9	6	8	4		1
Peard Bay/Franklin Spit Area (64)	2	2	2													
Chukchi Sea Spring Lead System (19)																
Ledyard Bay-Icy Cape IBA (104)	1		1													
Cape Lisburne Seabird Area (15)																
Murre Rearing & Molting Area (18)	1	1	1													

Winter 360 Days

Resource Area (ID#)	Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA10	Far Offshore LA11
Kendall Island Bird Sanctuary (Canada) (178)									1			1		1		1
Kendall Isl. Bird Sanctuary (Canda) (76)								1	3	1		2		1		1
Herschel Island (Canada) (67)								1	1	1		1		1		
Demarcation Bay Offshore (79)								5	4	1		2		1		
Angun & Beaufort Lagoons (17)								3	2	1		1		1		
Jago & Tapkaurak Spits (100)								2	2	2		1		1		
Northeast Arctic Coastal Plain IBA (167)				1	3	2	2	17	12	14		5		3		1
Arey & Barter Isls., Bernard Spit (99)					1	1	1	2	2	3		1				
Anderson Point Barrier Isls. (98)								1	1	1						
Simpson Cove (81)								1	1	1						
Maguire & Flaxman Isls. (8)				3	3	1	1	5	3	7		1		1		
Mikkelsen Bay (78)				16	1	1		1	1	2						
Stockton & McClure Isls. (9)				5	3	1	1	2	2	3		1		1		
Sagavanirktok Delta/Foggy Isl. Bay (77)				9	2	1	1	2	2	2		1		1		
Midway, Cross & Bartlett Isls. (96)				1	2	1	2	1	1	1		1				
Prudhoe Bay (73)				1	1		1									
Gwyder Bay, Cottle & Return Isls. (72)				2	4	2	5	2	2	2		1		1		
Simpson Lag.,Thetis & Jones Isls. (71)				1	4	2	4	1	1	1		1		1		
Harrison Bay/Colville Delta (69)	2			1	6	3	4	1	1	1		1		1		
Colville River Delta IBA (157)	2			1	5	2	4	1	1	1		1		1		
Beaufort Sea Shelf Edge IBA (5)	5	9	7	1	5	11	8	2	4	3	6	5	5	4		2
Harrison Bay (68)	3		1	1	6	4	5	1	2	2		2		1		
Teshekpuk Lake Special Area (NPR-A)/IBA (156)	15	6	12	2	10	11	12	2	3	3	3	3	3	3		1
Smith Bay (65)	3	1	2		1	2	1				1	1	1			
Point Barrow, Plover Isls. (2)	9	5	10		2	3	2			1	3	1	2	1		1
Chukchi Sea Nearshore IBA (80)	11	10	10		3	4	3	1	1	1	4	2	3	1		1
Peard Bay/Franklin Spit Area (64)	1	1	1													
Chukchi Sea Spring Lead System (19)	7	8	7		1	2	1				3	1	3			
Ledyard Bay-Icy Cape IBA (104)		1														
Cape Lisburne Seabird Area (15)		1														
Murre Rearing & Molting Area (18)	2	3	2								2		1		1	

Figure 5-9 Percentage of Trajectories Contacting Bird Resource Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. Those ERAs that have the highest percentage of trajectories contacting (31–55 percent) are primarily pelagic bird habitat (Chukchi Sea Nearshore IBA (80) and Beaufort Sea Shelf Edge IBA (5)), and coastal brooding, molting, and migratory stopover areas on the West and Central Shelves (Mikkelsen Bay (78), Sagavanirktok Delta/Foggy Island Bay (77), Point Barrow and Plover Islands (2), and Teshekpuk Lake Special Area (NPR-A/IBA, 156). For pelagic bird habitat (80 and 5), and the Teshekpuk Lake coast (156), the percentage of trajectories contacting are ≥5 percent from all or most spill areas. More ERAs have ≥5 percent of trajectories contacting them from an Eastern shelf VLOS than a VLOS originating anywhere else. The Northeast Arctic Coastal Plain IBA (167) has the highest percentage of trajectories (19–36 percent) contacting it from an Eastern shelf VLOS.

Winter. The winter percentages of trajectories contacting follow roughly the same patterns as discussed above for a summer spill, with the following differences. The VLOS would have the opportunity to persist, travel longer, and contact distant resources. This would be true both to the west in Chukchi Sea ERAs such as Murre Rearing and Molting Area (18), and to the east in Canadian resource areas like Kendall Island Bird Sanctuary (76). The percentage of trajectories is notably less per area, however; none as much as 20 percent. Those ERAs with the highest percentage of trajectories contacting (10–17 percent), would still include Chukchi Sea Nearshore IBA (80) and Beaufort Sea Shelf Edge IBA (5), and coastal/barrier island habitat of Mikkelsen Bay (78), Point Barrow and Plover Islands (2), Teshekpuk Lake Special Area (NPRA-A/IBA, 156), and Northeast Arctic Coastal Plain IBA (167). For a Central Shelf VLOS, the OSRA model estimates less trajectories (9 versus 48 percent) contacting Sagavanirktok Delta/Foggy Island Bay (77) seaduck and loon habitat in winter versus summer. Finally, the Chukchi Sea spring leads (19), important to migrating birds, only form and are vulnerable to a VLOS in winter.

5.8.5 Conclusion

Large numbers of migrating birds are dependent on nearshore and coastal habitats of the Beaufort Sea. In particular, dense flocks of waterfowl and shorebirds are highly sensitive to contamination and disturbance, so long-term impacts could arise from all phases of a VLOS. Even if a VLOS were initiated at a time when birds were not present, persistence of impact to important habitats combined with seasonal response efforts are likely to lead to long-term, and therefore moderate, impacts to these widespread breeding populations. When impacts from all phases are combined, certain vulnerable bird populations may incur severe and therefore major impacts.

5.9 Economy

This analysis considers the cash-subsistence economy of the NSB. This section discusses SOA and NSB economic impacts from a VLOS in terms of traditional measures of employment, labor income, population, and revenues. Potential impacts to subsistence harvest patterns and sociocultural systems are discussed in Section 5.10.

Effects of a VLOS on the economy would depend on several factors, including seasonal conditions during the spill, the level of preparedness and training of response personnel, and the amount and distribution of compensation payments. A VLOS would adversely affect the economics of non-oil and gas activities such as recreation and tourism.

5.9.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Well Control Incident. Once the explosion is reported, response equipment and workers would be mobilized and sent to the site of the explosion. Employment and personal income level impacts would be minimal during this initial phase. This event would have limited impact on the economy and population as the initial mobilization of workers would be pulled from workers already in-place. This would result in a very minor influx of employment and earnings in the NSB economy.

Offshore Spill. Employment and personal income would begin to rapidly increase during the continuing release of an oil spill in offshore waters as response workers and equipment continue to mobilize and begin offshore cleanup operations. The number of cleanup workers and response vessels in Phase 1 would depend on the spatial extent of the thin liquid layer of oil on the water surface. In Phase 1, there could be increasing space/use conflicts for access to and use of shipping lanes, open water space, and dock/port space.

Onshore Oil. Onshore oiling impacts would include contamination and loss of access. Increased space/use conflicts from water traffic as well as loss of dock space may occur. With the increased vessel traffic, incoming barges may have difficulty navigating/docking and delivering goods not available in the immediate area. Income/profit losses could occur in oiled areas coinciding with recreation and tourism activities. A VLOS could also have impacts on economic activity that does not currently take place in the area (or that is currently not significant) but could exist in the future.

5.9.2 Phase 2 (Spill Response and Cleanup)

Impacts from spill response and cleanup with relevance to the economy include employment, labor income, population, and revenues. Employment and personal income would reach peak levels during this phase. Thousands of potential workers would be employed for response and cleanup operations in offshore federal and state waters as well as onshore federal, state, and private lands. Additional housing and infrastructure may be required to support the influx of a large number of workers described in Section 2.9.4. The numbers of workers and onshore infrastructure would begin to substantially increase during this phase as more workers are needed for onshore cleanup operations.

The discussion of employment for oil spill response is based on the most relevant historical experience of a spill in Alaskan waters, the EVOS, of 240,000 bbl in 1989. This event generated direct employment for up to 10,000 workers in relatively remote locations. The following years, from 1990 to 1992, generated a smaller number of workers returning in the warmer months. During the EVOS, many local residents quit their current jobs to work on the cleanup effort due to higher wages. This caused sudden and significant inflation in the local economy (Cohen, 1993). This type of inflationary response would be mitigated in the NSB’s case because the cleanup activities would be supported by existing enclave facilities. The local economy could benefit from workers outside the existing enclaves integrating into the community with goods and services they may require (i.e., lodging). However, the likelihood of citizens outside the NSB arriving in direct support of cleanup activities may not be as high as the EVOS due to limited transportation options to the community.

The effects of employment and labor income on the NSB economy would ultimately depend on the extent to which NSB residents are employed in the cleanup efforts. Given the relatively small size of the existing labor force in the NSB relative to the number of response and cleanup workers that could be employed, the incremental impacts to the NSB economy in totality would likely be severe, although employment and its marginal economic benefits would be short-term in nature.

A VLOS is expected to have minimal effects on Alaska employment and associated labor income. Response and cleanup workers would likely come from the NSB, other parts of Alaska, and then other states. It is expected to have little to no impact on the population of Alaska or the NSB due to its limited timeframe and a low likelihood of workers permanently relocating to the NSB.

Revenue impacts on the NSB and SOA from a VLOS would be in the form of property tax revenues. SOA levies an oil and gas property tax on the value of exploration, production, and pipeline transportation property in the state. The 4.6 MMbbl of oil lost would have a negative impact on royalties, production tax, and corporate income tax for the SOA.

5.9.3 Phase 3 (Post-Spill, Long-Term Recovery)

In Phase 3, potential impact-producing factors with relevance to the economy are the availability of environmental resources, contamination, perception of contamination (tainting), co-opting of human resources, and psychological distress. These impact-producing factors have the potential for long-term economic impacts related to tourism, guided recreational activities, and subsistence hunting activities. During this phase, response and cleanup employment would begin declining from peak levels.

In addition, a VLOS would result in a NRDA. The result of the NRDA process could have substantial revenue impacts as the population of interest is compensated for a range of natural resource service values damaged by the VLOS and come at a high cost to the responsible parties.

5.9.4 Conclusion

Table 5-3 presents conclusions on economic measures used to analyze the effects of a VLOS on the SOA and NSB economies. These conclusions are not based on potential impacts' marginal costs/benefits, but in their size and duration.

Table 5-3 VLOS Effects on Economic Measures

Economic Measure	State of Alaska	NSB
Employment/ Labor Income	Negligible	Minor
Revenue	Minor	Negligible
Population	Negligible	Negligible

A VLOS is expected to have minor beneficial effects on NSB employment and wages, and negligible effects on NSB revenues. A VLOS is likely to have little to no impact on the population base for Alaska and the NSB. Phase 2 and Phase 3 are the most relevant to analyzing economic effects. BOEM expects spill cleanup employment to increase rapidly during Phase 2. Short-term revenue impacts from a VLOS would be experienced with the SOA in the form of reduced royalties, production tax, and corporate income tax. However, the NSB may receive oil spill damage compensation as witnessed in the DWH event.

5.10 Subsistence Activities and Harvest Patterns

5.10.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

The initial explosion would have little to no effect on subsistence activities and harvest patterns because subsistence harvesters tend to avoid offshore industrial developments, staying 2 to 3 mi away. During the open-water season, impacts of an offshore VLOS to subsistence activities and harvest patterns could be immediate and widespread in the initial phases of the blowout event. This is because winds and currents from the northeast could push oil to shore relatively quickly.

Depending on the response time and extent of coverage of the initial incident by the news media and local social media, the initial impacts of a VLOS to residents of Kaktovik, Nuiqsut, and Utqiaġvik from hearing news and viewing images of the event would most likely be severely traumatic. This would likely produce long-lasting, widespread, and severe stress and anxiety because of fears of potential contamination of subsistence foods and communities not being able to harvest. There could be chronic psychological disruptions, especially if communities experienced losses of culturally preferred activities and foods (Morris et al., 2013).

Spilled oil contacting beaches, barrier islands, and sea ice would have impacts on marine mammal hunting because Iñupiaq whalers and seal hunters would be unwilling and/or unable to bring whales and seals ashore or onto the ice for butchering. Some harvest could cease until resources were determined to be safe for harvest, sharing, and eating. In the event of a VLOS, all whaling communities in Alaska would share concerns over the safety of whale products and the health of the bowhead whale stock.

Loss of opportunities to harvest whales would threaten a pivotal element of indigenous culture on the North Slope. Whaler avoidance of resources and harvest areas would most likely vary depending on the timing and volume of oil in harvest areas, persistence of oil in the environment, and community confidence that bowhead whales were once again safe to eat. Traditional practices of harvesting, processing, and sharing whales and other marine resources could be severely disrupted for one or more seasons. Disruptions would adversely affect social organization, cultural values, and local institutions (the sociocultural system). A VLOS could have long-lasting, widespread, and severe adverse effects on the sociocultural system because of reduced sharing of whale products in the region, and because the migratory nature of the species provides harvest opportunities for several communities (Galginaitis, 2014). All whaling communities could experience a loss of opportunities to harvest in the event of a VLOS.

A VLOS could cause seals to move away from normal habitats making them unavailable to subsistence harvesters for one or more seasons. Impacts to subsistence seal hunting could be widespread, long-lasting, and severe for Kaktovik, Nuiqsut, and Utqiaġvik. Many bird species, important for subsistence harvests by the Beaufort Sea communities, are associated with coastal areas and in sea ice leads. The loss of groups of waterfowl on the North Slope due to a VLOS would most likely cause severe harvest disruptions, because waterfowl hunts, harvests of birds, and sharing of waterfowl are of primary importance after a long winter. Depending on timing, extent, and persistence of a VLOS, migratory fishes could be reduced in numbers or eliminated. Some local fish stocks could become unavailable to subsistence fishers for one or more seasons. A VLOS could have long-lasting, widespread, and severe effects on subsistence fishing in coastal areas.

Kaktovik, Nuiqsut, and Utqiaġvik hunt for caribou along the coast in July and August. Hunters would be severely distressed by oiled caribou and oiled shorelines. If a VLOS occurred during the open-water season or during winter and subsequently melted out of the ice during spring, caribou at coastal habitats could be contaminated at the shoreline and in shallow waters. Contact and contamination would occur during periods of insect relief during summer months. During late winter and early spring, caribou move offshore to lick sea ice for salt and could be exposed to spilled oil on the ice. Impacts to subsistence caribou hunting could be long-lasting, widespread, and severe, especially in July and August.

Contamination of subsistence food resources as a result of a VLOS could severely curtail harvesting, processing, and sharing subsistence resources. These practices could be interrupted for one or more seasons. In addition, oiled subsistence use areas would not be available to subsistence hunters for one or more seasons. Hunters and fishers could avoid all harvest areas in the spill area due to potential contamination of subsistence resources. This would disrupt sharing networks and could lead to a decreased emphasis on the importance of the family, cooperation, and sharing. Multiyear disruptions of subsistence bowhead whaling could adversely affect whaling crew activities and the proper function of other task groups who are accustomed to working together on subsistence activities. Impacts of this nature could have long-lasting, widespread, and severe effects to sociocultural systems. As a result, people could decrease their normal emphasis on subsistence as a livelihood and focus on wage employment, individualism, and entrepreneurism, leading to loss of cultural identity (BOEM, 2015b).

5.10.2 Phase 2 (Spill Response and Cleanup)

During spill response and cleanup, disturbances to subsistence activities and harvest patterns would most likely occur from disruptions to daily life from an influx of outsiders coming to the area to work and possibly reside in communities. There would most likely be increased noise and physical habitat alterations associated with cleanup of a VLOS.

Spill cleanup could provide opportunities for local, high-paying wage work and could likely displace many local hunters from subsistence activities and harvest patterns. VLOS cleanup could disrupt subsistence activities and harvest patterns for an entire season or more. This disruption would be due to employment of local hunters during cleanup potentially causing them to be unable to take time for hunting, fishing, and other subsistence activities.

Cleanup methods could potentially reduce the amount of spilled oil in the environment and could reduce the effects of contact with crude oil and contamination of subsistence resources. Fewer subsistence harvesters would be present in winter, so spill response and cleanup would most likely have less effect to subsistence activities and harvest patterns than during open-water season. Winter response and cleanup could have short-term and localized effects to those hunting seals on the ice at breathing holes.

Equipment used during spill response and cleanup (vessels and skimmers) would make noises in the marine environment that could cause marine mammals to avoid the area or change behavior patterns. For example, whales and seals could become more wary and difficult to harvest. During migration periods, cleanup operations could cause marine mammals to change their movements in ways that make them unavailable to subsistence hunters. The presence of spill response and cleanup operations could reduce access to traditional hunting areas and alter timing of subsistence hunts for one or more seasons. For example, the EVOS cleanup took more than four summers (USCG, 1993).

Spill response crews may require local knowledge, experience, and vessels belonging to whaling captains in the community as expert resources. By utilizing these resources, cleanup crews could divert the whaling captains and their equipment to spill response and cleanup activities with the potential to affect subsistence whaling or other offshore subsistence activities.

The overall result would be a major adverse effect to subsistence activities and harvest patterns. North Slope residents and communities could experience adverse impacts to social organization and cultural values due to the loss of subsistence resources and harvest opportunities. Residents could experience a decrease in their nutritional health and mental well-being. Impacts from VLOS response and cleanup activities could be long-lasting and widespread and/or severe depending on their longevity.

5.10.3 Phase 3 (Post-Spill, Long-Term Recovery)

In this phase of a VLOS, the impacts to subsistence activities and harvest patterns would result from:

- Unavailability or increased difficulty in obtaining subsistence resources
- Long-term contamination of habitats and subsistence resources
- Altered subsistence harvest and sharing patterns
- Co-opting of human resources and equipment required to conduct assessment studies as part of the NRDA process
- Long-lasting and widespread psychological and social distress

On the North Slope, a well-functioning and healthy sociocultural system is related to subsistence activities and harvest patterns. Long-term adverse effects to subsistence activities and harvest patterns during VLOS recovery could create chronic disruptions to social organization, cultural values, and local institutions. Disruptions would result from long-term loss of ritualistic harvests and sharing of bowhead whales. Potential contamination of the whale mataaq and meat as bowhead whales pass through the VLOS area during migration could cause long-term disruptions to subsistence activities and harvest patterns, which could lead to a breakdown of kinship networks, sharing patterns, and increased social stressors in communities (BOEM, 2015b). Communities farther from the oil spill area would most likely share subsistence foods with those affected, potentially taxing the resources in these regions and communities (BOEM, 2015b).

If local subsistence harvesters were employed in long-term monitoring and assessment studies of VLOS impacts (during the NRDA process), their time, work force, and equipment may be diverted away from subsistence activities and community service jobs. Participation in long-term recovery work on the part of local people could cause non-participation in subsistence activities and fewer people to seek employment in the community services sectors if spill recovery jobs paid higher wages. Increased income could be beneficial to some families; having extra cash on hand could allow individuals to purchase fuel and equipment needed for effective subsistence harvests or give cash to family members who have more time for harvesting. On the other hand, rapid increases in income could have adverse effects. Extra cash could be used to buy less nutritional store-bought foods to replace lost subsistence foods. Families could quarrel over what to do with extra income or become jealous of families or communities whose incomes increased, resulting in increased interpersonal conflicts (Morris et al., 2013; Wooley, 1995).

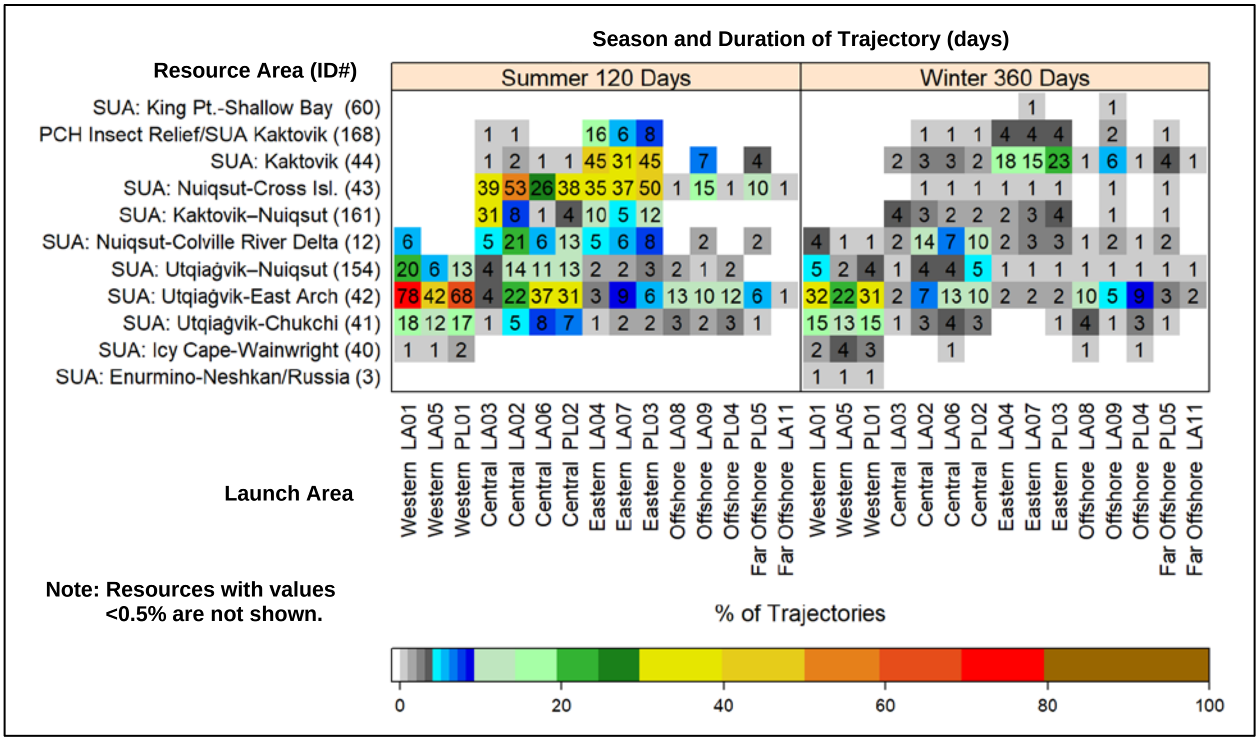
During long-term recovery, communities could experience severe stress and anxiety over the loss or reduction in subsistence activities, contamination of resources, and fear of eating contaminated wild foods. Communities could experience changes to harvest regulations and an over reliance on the knowledge of outside experts about levels of environmental contamination and when it would once again be safe to consume traditional foods (BOEM, 2015b). This over-reliance on outsiders can cause loss of control and loss of self-determination for the Iñupiat people.

Individuals and communities could be increasingly stressed as they modify subsistence harvest patterns and change to new harvest areas. If new harvest areas were farther away from communities in unfamiliar places, there would be increased safety risks and costs associated with travel and hunting. An affected community would most likely not be able to hunt or fish in another community’s territory without permission. Whaling crew structure and function could be adversely affected, and Iñupiaq cultural values central to the subsistence way of life could be severely disrupted for one or more seasons. Recovery could cause long-lasting, widespread, and severe impacts to subsistence activities across the North Slope.

5.10.4 Oil Spill Trajectory Analysis

BOEM identified 20 subsistence use areas (SUAs) for the analysis (Appendix A, Table A11, Figures A3b–g and A5a–b). BOEM discussed results in terms of percentage of trajectories contacting a geographical and temporal area important to coastal communities for subsistence hunting and fishing. Examples of SUAs include offshore areas where whaling crews scout for bowhead whales in fall.

Figure 5-10 shows 11 SUAs examined in this analysis with a ≥1 percent of trajectories contacting them in summer and winter. One percent of VLOS trajectories contacting a SUA is notable, because even if a small percentage of total trajectories contacted a SUA, there would most likely be severe impacts to subsistence harvesters in coastal communities.



Resource Area (ID#)	Summer 120 Days: Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
SUA: King Pt.-Shallow Bay (60)															
PCH Insect Relief/SUA Kaktovik (168)				1	1			16	6	8					
SUA: Kaktovik (44)				1	2	1	1	45	31	45		7		4	
SUA: Nuiqsut-Cross Isl. (43)				39	53	26	38	35	37	50	1	15	1	10	1
SUA: Kaktovik–Nuiqsut (161)				31	8	1	4	10	5	12					
SUA: Nuiqsut-Colville River Delta (12)	6			5	21	6	13	5	6	8		2		2	
SUA: Utqiaġvik–Nuiqsut (154)	20	6	13	4	14	11	13	2	2	3	2	1	2		
SUA: Utqiaġvik-East Arch (42)	78	42	68	4	22	37	31	3	9	6	13	10	12	6	1
SUA: Utqiaġvik-Chukchi (41)	18	12	17	1	5	8	7	1	2	2	3	2	3	1	
SUA: Icy Cape-Wainwright (40)	1	1	2												
SUA: Enurmino-Neshkan/Russia (3)															

Resource Area (ID#)	Winter 360 Days: Western LA01	Western LA05	Western PL01	Central LA03	Central LA02	Central LA06	Central PL02	Eastern LA04	Eastern LA07	Eastern PL03	Offshore LA08	Offshore LA09	Offshore PL04	Far Offshore PL05	Far Offshore LA11
SUA: King Pt.-Shallow Bay (60)									1			1			
PCH Insect Relief/SUA Kaktovik (168)					1	1	1	4	4	4		2		1	
SUA: Kaktovik (44)				2	3	3	2	18	15	23	1	6	1	4	1
SUA: Nuiqsut-Cross Isl. (43)					1	1	1	1	1	1		1		1	
SUA: Kaktovik–Nuiqsut (161)				4	3	2	2	2	3	4		1		1	
SUA: Nuiqsut-Colville River Delta (12)	4	1	1	2	14	7	10	2	3	3	1	2	1	2	
SUA: Utqiaġvik–Nuiqsut (154)	5	2	4	1	4	4	5	1	1	1	1	1	1	1	1
SUA: Utqiaġvik-East Arch (42)	32	22	31	2	7	13	10	2	2	2	10	5	9	3	2
SUA: Utqiaġvik-Chukchi (41)	15	13	15	1	3	4	3			1	4	1	3	1	
SUA: Icy Cape-Wainwright (40)	2	4	3			1					1		1		
SUA: Enurmino-Neshkan/Russia (3)	1	1	1												

Figure 5-10 Percentage of Trajectories Contacting Subsistence Use Areas (≥1% within 120 days Summer and 360 days Winter)

Summer. For a Western Shelf VLOS, three SUAs have a notable percentage of trajectories contacting. Utqiaġvik's offshore area (41) on the Chukchi side of Point Barrow has percentages of trajectories contacting ranging from 12–18 percent. For Utqiaġvik's offshore area on the Beaufort side of the point (42), the percentage is substantially greater (42–78 percent). These are notable because Utqiaġvik hunts whales, seals, walrus, waterfowl, and fish in SUA 42 during the open-water season and SUA 41 is of equal importance for subsistence hunting and fishing to the community of Utqiaġvik. For the eastern and offshore areas, the percentage of trajectories contacting SUAs 41 and 42 are notably less, ranging from 1–9 percent and 2–13 percent, respectively. However, for SUA 42, a Central Shelf VLOS is more notable than the eastern and offshore areas with a range of 4–37 percent trajectories contacting.

Residents of Wainwright use SUA 40 for hunting whales, seals, and waterfowl, and it has 1–2 percent of trajectories contacting it from a Western Shelf VLOS. A VLOS from other areas would most likely not contact SUA 40.

The Colville River Delta (SUA 12) is an important subsistence area for Nuiqsut residents because they harvest seals, waterfowl, caribou, moose, and ocean fish there. A Central Shelf VLOS could contact SUA 12 (5–21 percent of trajectories). For the western, eastern, and offshore areas, the percentage of trajectories contacting SUA 12 decreases (2–8 percent).

Nuiqsut hunts bowhead whales in SUA 43; the hunt is based at Cross Island in the central Beaufort Sea. For a Central Shelf VLOS, 26–53 percent of trajectories contact this whaling area, and 35–50 percent of trajectories contact it from the Eastern Shelf. If a VLOS from either one of these areas were to contact SUA 43, there would be long-lasting, widespread, and severe impacts to subsistence activities and harvest patterns. For the offshore areas, the percent of trajectories contacting SUA 43 is 1–15 percent.

Kaktovik’s whaling area (SUA 44) is vulnerable from an Eastern Shelf VLOS with contact by 31–45 percent of trajectories. For the Central Shelf, the range is 1–2 percent. For the offshore areas, 4–7 percent of trajectories contact SUA 44. If a VLOS were to contact SUA 44, there would be long-lasting, widespread, and severe impacts to subsistence activities and harvest patterns. In addition to bowhead whales, Kaktovik residents harvest seals, beluga whales, waterfowl, and ocean fish in SUA 44.

For the coastal caribou hunting area shared by Utqiaġvik and Nuiqsut (SUA 154), the range is 6–20 percent of trajectories contacting it from a Western Shelf VLOS and 4–14 percent of trajectories contacting it from the Central Shelf. For the Eastern Shelf and offshore area, 1–3 percent of trajectories contact SUA 154. There could be long-lasting, widespread, and severe impacts to coastal caribou hunting if a VLOS contacted SUA 154 in summer.

Nuiqsut and Kaktovik hunters use SUA 161 for coastal caribou harvest during summer. The OSRA model estimates 1–31 percent of trajectories contacting SUA 161 for the Central Shelf and 5–12 percent for an Eastern Shelf VLOS. Residents of Kaktovik use SUA 168 to harvest caribou. For the Central and Eastern Shelf areas combined, 1–16 percent of trajectories contact this caribou hunting area (SUA 168). If a VLOS were to contact these important caribou hunting areas, there would most likely be long-lasting, widespread, and severe impacts to subsistence activities and harvest patterns.

Winter. A Western Shelf VLOS could contact six SUAs (Figure 5-10). Both offshore areas used by Utqiaġvik (SUAs 41 and 42) have notably higher percentages of trajectories contacting than the other four SUAs at 13–15 percent and 22–32 percent, respectively. SUA 41 is used throughout the year and would be more vulnerable in winter than SUA 42, which is primarily used during the open-water season. If a VLOS contacted SUA 41 in winter, there could be long-lasting, widespread, and severe impacts to winter seal hunting, spring whaling, and spring waterfowl hunting. Residents of Utqiaġvik use coastal areas of SUA 42 for fishing in winter and geese hunting in spring; a VLOS contacting the coast in SUA 42 could have severe impacts to subsistence activities.

A Western Shelf VLOS could contact four other SUAs, including SUA 3 on the Russian coast (1 percent); SUA 40, used by Wainwright throughout the year (2–4 percent); SUA 12, used by Nuiqsut from March through October (1–4 percent); and SUA 154, used for coastal caribou hunting (2–5 percent). SUA 154 is not used in winter for coastal caribou hunting.

A Central Shelf VLOS could contact nine SUAs (Figure 5-10). Two of these have notably higher percentages of trajectories contacting than the other seven, including SUA 42 (2–13 percent) and SUA 12 (2–14 percent). Nuiqsut harvesters use coastal areas of SUA 12 for winter caribou hunting and fishing and geese hunting in spring. If SUA 12 were contacted by a winter VLOS, there could be long-lasting, widespread, and severe impacts to these subsistence activities.

The other seven SUAs in Alaska that could be contacted from a Central Shelf VLOS have percentages of trajectories contacting that range from 1–5 percent. SUA 3 in Russia and SUA 60 in Canada have <1 percent trajectories contacting from a Central Shelf VLOS.

For an Eastern Shelf VLOS, nine SUAs have a ≥1 percent of trajectories contacting them (Figure 5-10). SUA 44, used by Kaktovik from April through October, has the highest percentage of trajectories contacting it, ranging from 15–23 percent. If a VLOS contacted SUA 44 in winter, there could be long-lasting, widespread, and severe impacts to winter seal hunting. The other eight SUAs that could be contacted from the Eastern Shelf have combined percentages of trajectories contacting that range from 1–4 percent.

For the offshore and far offshore areas, 10 SUAs could be contacted, ranging from 1–10 percent trajectories. Of these, SUA 42 has the most notable range in percent of trajectories contacting (2–10 percent).

5.10.5 Conclusion

In Phase 1, coverage of the initial incident by the news and social media could cause severe stress and anxiety. Subsistence activities, particularly bowhead whale hunting, would be severely curtailed if an offshore VLOS contacted migrating or resident whales, seals, fish, caribou, and/or migratory waterfowl; contaminated traditional harvest areas; and persisted in subsistence use areas. This could create major reductions in access to traditional nearshore and offshore harvest areas lasting one or more seasons. Impacts to subsistence activities, harvest patterns, and the overall sociocultural system could be major.

For Phase 2, overall impacts of VLOS response and cleanup activities to subsistence activities could be major for Nuiqsut, Kaktovik, and Utqiaġvik. This is because response and cleanup activities would most likely persist longer than one season on the North Slope, and substantial amounts of local resources and labor could be expended.

During Phase 3, long-term recovery could disrupt subsistence harvest patterns for one or more seasons and could cause major impacts to subsistence activities, harvest patterns, and the broader sociocultural system. Increased income from working on long-term recovery projects could have major effects in North Slope communities, both positive and adverse.

For the spill trajectory analysis, A VLOS in summer would most likely have greater impacts to subsistence activities and harvest patterns than a VLOS in winter. This is because more subsistence activities occur offshore in summer than winter. In summer and winter, the highest percentage of trajectories contacting subsistence use areas affect offshore and coastal areas used by communities for hunting and fishing (SUAs 12, 41, 42, 43, 44, 154, 161, 168). A VLOS contacting these areas would have major adverse impacts to subsistence activities and harvest patterns.

5.11 Community Health and Environmental Justice

5.11.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

The initial explosion would have little to no effect on community health because the offshore location of a blowout would be far from communities. An offshore VLOS could adversely affect community health in a number of ways (BOEM, 2015b, p. 606). For example, a VLOS could cause adverse impacts to air and water quality, which in turn could have long-lasting and widespread effects to community health related to respiratory illnesses and contaminated marine and freshwaters used for subsistence hunting and fishing.

There would be long-lasting, widespread, and possibly severe impacts to community health if a VLOS: directly contacted migrating or resident fish and wildlife used for subsistence purposes; contaminated traditional harvest areas; and/or persisted in subsistence harvest areas. Social organization, cultural values, and health and social services would most likely be disrupted for one or more seasons. This would lead to long-lasting and widespread or severe impacts to community health from food insecurity, poor nutritional status, increased metabolic disorders, and decreased cultural well-being.

5.11.2 Phase 2 (Spill Response and Cleanup)

The arrival and presence of hundreds of oil spill response and cleanup workers, support vessels, and aircraft would most likely exacerbate effects to community health. If local residents substantially participated in spill response and cleanup work, as local residents did in the EVOS, they could experience both adverse and beneficial effects to their health and well-being. Local employment in long-term recovery efforts could disrupt subsistence harvest patterns for one or more seasons. Some local institutions such as whaling captains' associations and kinship networks could be disrupted in structure and function, which could create stress and anxiety. Community healthcare systems could be severely stressed by drawing local workers away from village service jobs. Cash earnings from work on recovery projects could be used for healthcare and improved hunting and fishing equipment, which would have beneficial effects. Depending on the length of response and cleanup, both positive and adverse effects to community health could be long-lasting and widespread or severe if cleanup lasted for one or more subsistence seasons.

5.11.3 Phase 3 (Post-Spill, Long-Term Recovery)

During long-term recovery, there could be multiyear disruptions to community health due to loss of subsistence activities and harvest patterns, especially if one or more bowhead hunts failed. This could severely disrupt sharing networks, whaling crew structures, and the subsistence way of life. Mental health and cultural well-being could be severely affected in adverse ways. Increased social problems, breakdown in family ties, and a weakening of community cohesion could lead to long-lasting, widespread, and severe effects to community health. Damage assessment studies would occur as a part of the NRDA process. These could further disrupt the lives of residents and community well-being, depending on the extent to which residents participated in the studies.

5.11.4 Conclusion

There would be major effects to community health if an offshore VLOS contacted, contaminated, and persisted in subsistence harvest areas. This could result in major adverse impacts to community health from food insecurity and loss of cultural values. Adverse impacts to sociocultural systems would most likely lead to moderate to major impacts to community health from decreased social organization and cultural well-being. Impacts from response and cleanup activities to community health could be both positive and adverse and would most likely be moderate to major depending on how long cleanup would take and to what extent residents participated in the work or monitoring studies. Long-term recovery could severely disrupt community health for more than one year, resulting in major impacts. Overall, there could be moderate to major impacts to community health.

5.11.5 Environmental Justice Communities

BOEM considers Utqiaġvik, Nuiqsut, and Kaktovik to be Environmental Justice communities requiring analysis pursuant to Executive Order 12898. Major impacts to any resource upon which these communities rely would constitute disproportionately high and adverse impacts to these communities. As this report anticipates major impacts to subsistence activities and harvest patterns, community health, fish, and birds, it is concluded that a VLOS in the Beaufort Sea OCS would result in disproportionately high and adverse impacts to Utqiaġvik, Nuiqsut, and Kaktovik.

5.11.6 Conclusion

Disproportionately high and adverse environmental, social, and health impacts could occur from a VLOS.

5.12 Archaeological Resources

A VLOS could result in the loss of archaeological resources that may contain unique historic and prehistoric information. Although most of the Beaufort Sea and Chukchi Sea area has not been surveyed, historic records document both submerged shipwrecks and airplanes. The magnitude of impact from a VLOS would depend on the significance and uniqueness of the archaeological information lost.

The majority of documented shipwrecks in the Beaufort or Chukchi seas are losses of the nineteenth century Arctic whaling fleet. The exact locations and conditions of these ships are largely undetermined, but BOEM has identified lease blocks with the potential for archaeological resources (MMS, 1990b,c). The distribution of known shipwrecks indicates that most of the ships were trapped by ice or ran aground in very shallow coastal waters. Therefore, it is probable that most unreported shipwrecks are also located close to shore in shallow water (MMS, 1990b,c). In the case of the Beaufort Sea, there is sufficient evidence of the potential for shipwrecks and downed aircraft to warrant additional archaeological analysis prior to activities. A VLOS in the Beaufort Sea could also impact archaeological sites along the coast and barrier islands.

5.12.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Archaeological sites that are near a blowout could experience severe impacts possibly resulting in the loss of significant and unique information. If an archaeological site is near a blowout, the resource could be severely damaged by the high volume of escaping gas, buried by large amounts of dispersed sediments, crushed by the sinking of the rig or platform, destroyed during emergency relief well drilling, harmed by an explosion or fire, or contaminated by the spilled or dispersed oil. Resources in the vicinity, but not adjacent to a blowout, could also be severely impacted by the redistribution of sediments if it is at a scale large enough to substantially alter the seafloor and create movement. Adequate buffer zones based on archaeological surveys may mitigate severe impacts from a blowout. If these impacts are not mitigated, they would be long-lasting and severe.

There is a possibility that oil from a blowout could come in contact with wooden or iron shipwrecks and artifacts on the seafloor, as well as onshore archaeological resources, and accelerate their deterioration. An experimental study suggested that the biodegradation of wood in terrestrial environments is initially retarded by crude oil contamination but is accelerated in later stages of contamination (Ejechi, 2003). While there are different environmental constraints that affect the degradation of wood in terrestrial versus waterlogged environments, soft-rot fungal activity, one of the primary wood-degrading organisms in submerged environments, increased in the presence of crude oil (Ejechi, 2003). Any archaeological resource contacted by oil could be impacted; and as the spill moves into the intertidal zone, the chance of direct contact between the oil and archaeological resources increases. This could result in increased degradation of wooden or iron shipwrecks and artifacts. Preliminary results from ongoing studies indicate that the impact of a VLOS on archaeological sites is high, as oil is known to negatively impact benthic communities that inhabit wreck sites and protect structural integrity (Damour et al., 2016; White et al., 2012). Therefore, if oil from a VLOS causes a die-off of the organisms colonizing the site, the integrity and stability of the site could be harmed. In the case of a VLOS, heavy oiling of either an onshore or underwater archaeological resource could degrade it to the point that valuable data necessary to understand and interpret the site would be lost. If this occurs, the impact would be localized to an individual archaeological resource or resources, but long-lasting and severe.

5.12.2 Phase 2 (Spill Response and Cleanup)

The most significant damage to archaeological sites would likely be related to cleanup and response efforts (Dekin, 1993). Increased human presence and activity increases the potential for vandalism and looting, as well as inadvertent damage resulting in the loss of some resources. However, increased attention to archaeological resources during spill response and cleanup may also result in the discovery, reporting, documentation, and protection of archaeological sites. Cleanup activities such as high pressure washing, vehicle and foot traffic, and mechanized cleanup also may impact archaeological resources. Should important information about an archaeological resource be lost due to cleanup and response efforts either by looting or inadvertent damage, the impact would be localized, but long-lasting and severe.

Many lessons were learned about how to mitigate impacts from cleanup activities due to the loss of archaeological resources during the EVOS cleanup. Bittner (1996) reported that some sites were considerably damaged by vandalism associated with cleanup activities even if they were not contaminated by oil. As a result, archaeologists were included in the DWH spill's Shoreline Cleanup Assessment Teams and consulted with cleanup crews. Historic preservation representatives were also present at command sites and participated in oversight. Despite these efforts, some sites in the DWH cleanup area still suffered damage from looting or cleanup activities. The lessons from these two spills established an understanding of possible mitigation measures. First, avoidance measures could mitigate negative impacts by informing cleanup crews of culturally sensitive areas to avoid. This would require a cleanup crew supervisor to consult with archaeologists that inspected a site to advise on where planned cleanup could impact a cultural site. Second, artifact collection would mitigate overall impacts to archaeological resources by preventing them from being harmed by cleanup activities or removed by cleanup workers. The collection of artifacts would only be implemented when the material is on the surface and in potential danger of damage or removal. Third, education and training provided to cleanup crews could mitigate impacts by informing workers about the types of sites and artifacts to be aware of as well as instructing them on what to do and who to call should they find artifacts (Haggarty et al., 1991). Despite efforts to mitigate, the most common source of potential impacts from oil spills is the harm that could result from unmonitored shoreline cleanup activities including unauthorized collecting of artifacts or unintended damage from cleanup.

Though unlikely, there would be a severe impact to archaeological resources if anchoring occurs in deep water near a site because of the required number and size of anchors and the length of mooring chains needed to safely secure vessels. It is more likely that vessels in deep water would use dynamic positioning (a system that uses computers to automatically maintain a vessel's position using propellers and thrusters) and would not require anchors and mooring chains. However, if cleanup activities occur in shallow water, impacts to archaeological resources are more likely. Vessels in shallow water would have mooring for decontamination stations in areas where there is a potential to come in contact with shipwrecks. The potential to impact archaeological resources could increase as the density of anchoring activities increases. Should an archaeological resource be harmed by anchoring or mooring, the impact would be localized to an individual resource or resources but could be long-lasting and severe if important information is lost.

The use of dispersants would result in the settling of oil droplets to the seafloor that could have an impact on archaeological resources. If the use of dispersants results in more oil reaching the seafloor and negatively affecting the benthic communities that inhabit wreck sites, then the structural integrity of a shipwreck could be impacted (Damour et al., 2016; White et al., 2012). Historical information about a shipwreck could be lost if dispersants contribute to the deterioration of the shipwreck itself or harm the organisms colonizing it. If an archaeological resource is harmed by the settling of oil droplets through the use of dispersants, the impact would be localized, but could be long-lasting and severe if important information is lost.

Some archaeological sites could be irreparably damaged due to spill response and cleanup activities after a VLOS. Increased human activity, looting, vessel anchoring and mooring, and dispersants could all contribute to the loss of an archaeological resource. For the EVOS, researchers concluded that less than 3 percent of the archaeological resources within the spill area suffered any significant effects (Dekin, 1993).

Although cleanup activities can result in a loss of archaeological sites and historic information, impacts are localized and dependent on the significance and uniqueness of the loss. Researchers learned, especially from lessons from the EVOS, that one of the most effective ways to mitigate impacts on archaeological resources is to incorporate cultural resource concerns and integrate archaeologists in cleanup planning and onsite cleanup activities (Haggarty and Wooley, 2013).

5.12.3 Phase 3 (Post-Spill, Long-Term Recovery)

Archaeological sites, historic shipwrecks, and submerged aircraft are unique nonrenewable resources. Damage to archaeological resources from a VLOS and its cleanup activities would be irreversible, leading to the loss of important data and historical information. The most significant damage to archaeological sites would be related to cleanup and response efforts.

However, the Exxon Cultural Resource Program that was established after the EVOS is a good example of how post-spill activities, and spending or other investments related to the protection of archaeological sites, could also result in the discovery, documentation, or protection of sites. In several cases, the Cultural Resource Program enabled findings that made a contribution to understanding culture or "salvaged important data that would otherwise have been lost over time" (Haggarty and Wooley, 2013).

5.12.4 Oil Spill Trajectory Analysis

Archaeological resources such as historic shipwrecks, aircraft, and artifacts may be found anywhere within the OSRA study area or along the adjacent shoreline. Submerged shipwrecks, aircraft, and prehistoric sites located within the vicinity of the hypothetical LAs (Appendix A, Figure A1) would have the highest percentage of trajectories contacting (Appendix A, Figures A6–A9). BOEM identified 132 LSs (Appendix A, Table A11 and Figures A4a–c). Figure 5-1, in Section 5.3.4, displays LSs with ≥1 percent of trajectories contacting them from any individual LA within 120 or 360 days in summer or winter, respectively. The LAs closest to the shoreline result in ≥5 percent of trajectories contacting some individual LSs from Utqiaġvik (85) to Demarcation Bay (111).

5.12.5 Conclusion

Archaeological resources are finite, unique, and irreplaceable records of mankind's past, which, once destroyed, are gone forever. Furthermore, it is possible that, even if not destroyed, an archaeological resource could be damaged in such a way that all information of value is lost. A VLOS in the Beaufort Sea would likely impact archaeological resources, though the magnitude of the impact would depend on the location and trajectory of the spill, the significance of the impacted site, and the uniqueness of the information lost. Overall impacts would depend on the timing, size, location, and duration of the VLOS as well as the presence of archaeological resources in the affected area; however, it is assumed that impacts to archaeological sites contacted by oil or requiring cleanup activities could be major if important information is lost.

6 SUMMARY

This report describes the environmental effects of a VLOS to inform decision makers of potential impacts from a very low-probability LOWC event in the Beaufort Sea OCS. BOEM analyzed a VLOS of 4.6 MMbbl of oil and a release of 7.26 billion standard cubic feet of natural gas occurring over 90 days. These hypothetical VLOS volumes are conditioned on the assumption that all of the steps in the chain of events that would lead to a VLOS actually occur (appropriate geology, operational failures, escaping confinement measures, the spill reaching the environment, etc.). Therefore, the VLOS volumes do not consider the very low frequency of occurrence. Historical OCS data show that LOWC events escalating into blowouts and resulting in oil spills are infrequent, and those resulting in a VLOS are even rarer. BOEM estimates a very low VLOS frequency between 0.00001 and 0.0001 per well.

Analysis of the environmental impacts of a VLOS in the Beaufort Sea OCS is based on a hypothetical, yet feasible, scenario that provides a framework for identifying the impacts of an extended oil spill and gas release from an uncontrolled blowout. The scenario identifies the cause and timing of the spill, volume of oil and gas released, duration of the flow and oiling, volume of oil reaching shore, and length of shoreline contacted. The VLOS is analyzed in three phases: 1) well blowout incident, offshore spill, and onshore contact; 2) spill response and cleanup; and 3) post-spill, long-term recovery. These phases provide a logical structure for analyzing the different geographic and temporal impacts for each resource. The VLOS analysis is informed by the OSRA, which provides information about the likelihood of resource areas being contacted in both summer and winter from different portions of the Beaufort Sea OCS. Each conditional probability calculated by the OSRA estimates the percentage of oil spill trajectories, starting from a particular location, that contact a specific resource area within a given time period.

Once oil or gas enters the environment, it begins to change through physical, chemical, and biological processes. A summary of the general behavior and fate of spilled oil or released gas provides background for the impact analyses. The type of oil, time of year, location of the spill, environmental conditions, and characteristics of spill response efforts influence the magnitude and extent of spill impacts. The extent of effect depends on factors that differ across resources, such as the location and mobility of the resource, the nature and timing of the impacts, and aspects of the affected environment. A hypothetical VLOS could have up to major impacts on nearly all the resources analyzed, except for air quality, pinnipeds, polar bears, and economy (Table 6-1).

Table 6-1 VLOS Impact Conclusion for Each Resource

General Resource	VLOS Impact Conclusion
Air Quality	Minor
Water Quality	Moderate to Major
Vegetation and Wetlands	Major
Lower Trophic Organisms	Major
Fish	Major
Marine Mammals	
Whales	Negligible to Major
Pinnipeds	Minor to Moderate
Polar Bears	Minor to Moderate
Terrestrial Mammals	Negligible to Major
Birds	Major
Economy	Negligible to Minor
Subsistence Activities and Harvest Pattern	Major
Community Health	Moderate to Major
Environmental Justice Communities	Disproportionately high and adverse
Archaeology	Major

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Appendix A
Oil Spill Risk Analysis

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A1 OIL SPILL TRAJECTORY ANALYSIS

The Bureau of Ocean Energy Management (BOEM) Oil Spill Risk Analysis (OSRA) model simulates oil spill trajectories (Li and Smith, 2020). The OSRA model is a method for estimating where a very large oil spill (VLOS) may go. For this analysis, BOEM presumes a VLOS occurs and the model estimates the percentage of oil spill trajectories that could contact environmental resource areas, land segments, boundary segments, or grouped land segments. Uncertainty exists regarding every parameter of a hypothetical VLOS because this is a highly unlikely event for which location and environmental conditions (e.g. wind, ice, and currents) must be estimated based upon the best available data. Although some of the uncertainty reflects imperfect data, a considerable amount of uncertainty exists simply because it is difficult to predict events 4–55 years into the future. For purposes of analysis, BOEM estimates the source of the accidental VLOS, its size, where potential trajectories may travel to, and how it might weather. A consistent set of estimates about a VLOS is used to analyze the impacts to environmental, social, and economic resources. The source, size, and general weathering of a VLOS were addressed in Chapters 2 and 4. Here, BOEM further discusses the oil spill trajectory analysis.

The analysis used 11 launch areas (LAs) representing the places where a VLOS could originate from an exploration or development activity and considered a large study area (Figure A1 and Figure A2). The analysis also used 122 environmental resource areas (ERAs), 132 land segments (LSs), 40 boundary segments (BSs) and 52 grouped land segments (GLS) representing biological, economic, or social resources (Figure A3a-g, Figure A4a-c, Figure A5a-c and Table A1 through Table A13).

The OSRA model estimates where a hypothetical spill from a particular point would move over a specific period of time using model-simulated historical wind, sea ice, and ocean current information. It tracks each simulated oil spill trajectory versus the offshore and onshore coastal resources both geographically and temporally. It counts every time a simulated oil spill trajectory contacts offshore and onshore coastal resources. Finally, it estimates the contact based on the total number of simulated oil spill trajectories launched from a given point and the total number of contacts to each specific offshore and onshore coastal resource.

A long-duration VLOS would consist of a spill occurring continuously for up to 90 days. For the trajectory analysis, it should be considered as if a new spill was launched every day. In this case, there would be multiple trajectories over time with each trajectory launched regularly as the well continued to flow. Each trajectory would model how some fraction of the VLOS could spread to a specific resource or location. The multiple trajectories representing a VLOS would change how the conditional probabilities are interpreted. The conditional probabilities would represent how many trajectories come to that location, as described as percent trajectories (number of trajectories contacting a location/total number of trajectories launched). For example, if 1,000 trajectories are launched and 500 of the trajectories contact a specific location, then 50% of the trajectories would allow oil to be carried to that location. The terminology used hereafter is “percentage of trajectories contacting.”

BOEM conducted OSRA modeling to estimate the percent chance of a large spill contacting a particular resource within a particular time period (conditional probability) (Li and Smith, 2020). BOEM used the conditional probabilities to estimate the percentage of trajectories contacting resources from a hypothetical future blowout and high-volume, long-duration flow resulting in a VLOS. For purposes of this VLOS analysis, the conditional probabilities were considered to represent the estimated percentage of trajectories contacting an environmental resource area, land segment, boundary segment, or grouped land segment. Higher percentages of trajectories contacting a given location could mean more oil reached the location depending upon weathering and environmental factors.

The hypothetical scenario provided in Chapter 2 considers that a VLOS could begin at any point during either the open water season (July1 through October 31), or ice covered season (November 1 through June 30). BOEM assumed a VLOS discharged for 90 days. BOEM analyzed oil spill trajectories for 120 days during summer and 360 days during winter. During the open water season, BOEM considered that spilled oil remains on the surface of the water for a few weeks after Day 90 when the well stops flowing (S.L. Ross Environmental Research, 2003; Ramseur, 2010). Therefore, a 120-day contact period for the summer open water season is appropriate for a VLOS analysis. Trajectories launched from July 1 to October 30 are treated as summer spills. BOEM also considered that spilled oil could freeze into the sea ice, remain through the winter, and be released in the spring, a period of up to 360 days. Therefore, a 360-day contact period for the winter ice-covered season is appropriate for a VLOS analysis. Trajectories launched on or from November 1 to June 30 are treated as winter spills.

The percentage of trajectories contacting for summer (120 days) and for winter (360 days) are incorporated by reference from BOEM, (2020), shown in Table A14 through Table A21, and are summarized by resource in Chapter 5. BOEM also plotted the statistical analysis of trajectories by launch area contacting various grids of the ocean within the study area. Figure A6 through Figure A9 show the statistical trajectory patterns for individual LAs.

Within each resource for which these distinctions are meaningful, the subsection Oil Spill Trajectory Analysis considers the percentage of trajectories contacting the particular resource areas. The percentage of trajectories is the fraction of the total trajectories launched from a given location (launch area) that are estimated to contact a given resource area (ERA, LS, etc.). These percentages provide a relative estimate of how likely it is that oil from a VLOS will reach that resource area. In addition, these trajectories are estimated separately for winter and summer seasons. In this way, the trajectory analysis also helps BOEM evaluate how the location and timing (season) of a VLOS relates to potential impacts of a VLOS on each resource area. Below, a general summary is provided with respect to differences in location and timing as estimated by the model.

BOEM analyzed 11 launch areas (LAs 1 through 11) as the locations from where a VLOS could originate (Figure A1). The most notable differences in percentages of trajectories occur between LAs in the eastern Beaufort Sea versus LAs in the western Beaufort Sea, and between nearshore LAs versus offshore LAs. LAs in the western Beaufort contact resource areas in the Chukchi Sea. Oil originating from offshore spill locations takes longer to contact the coast and nearshore resource areas, if contact occurs at all.

In terms of timing, winter spills would contact a comparatively lesser extent of the coastline and nearshore coastal resource areas due to the landfast ice generally in place from December to April. However, for trajectory periods that cover the freezing and melting season of the landfast ice coastline, contact is similar for summer and winter.

A VLOS trajectory analysis was evaluated for all resources except economy, air quality, sociocultural, and public health. Specific ERAs and their vulnerability are not identified for these resources. However, the general results of the trajectory analysis were considered in estimating impacts on these resources.

A2 OSRA FIGURES

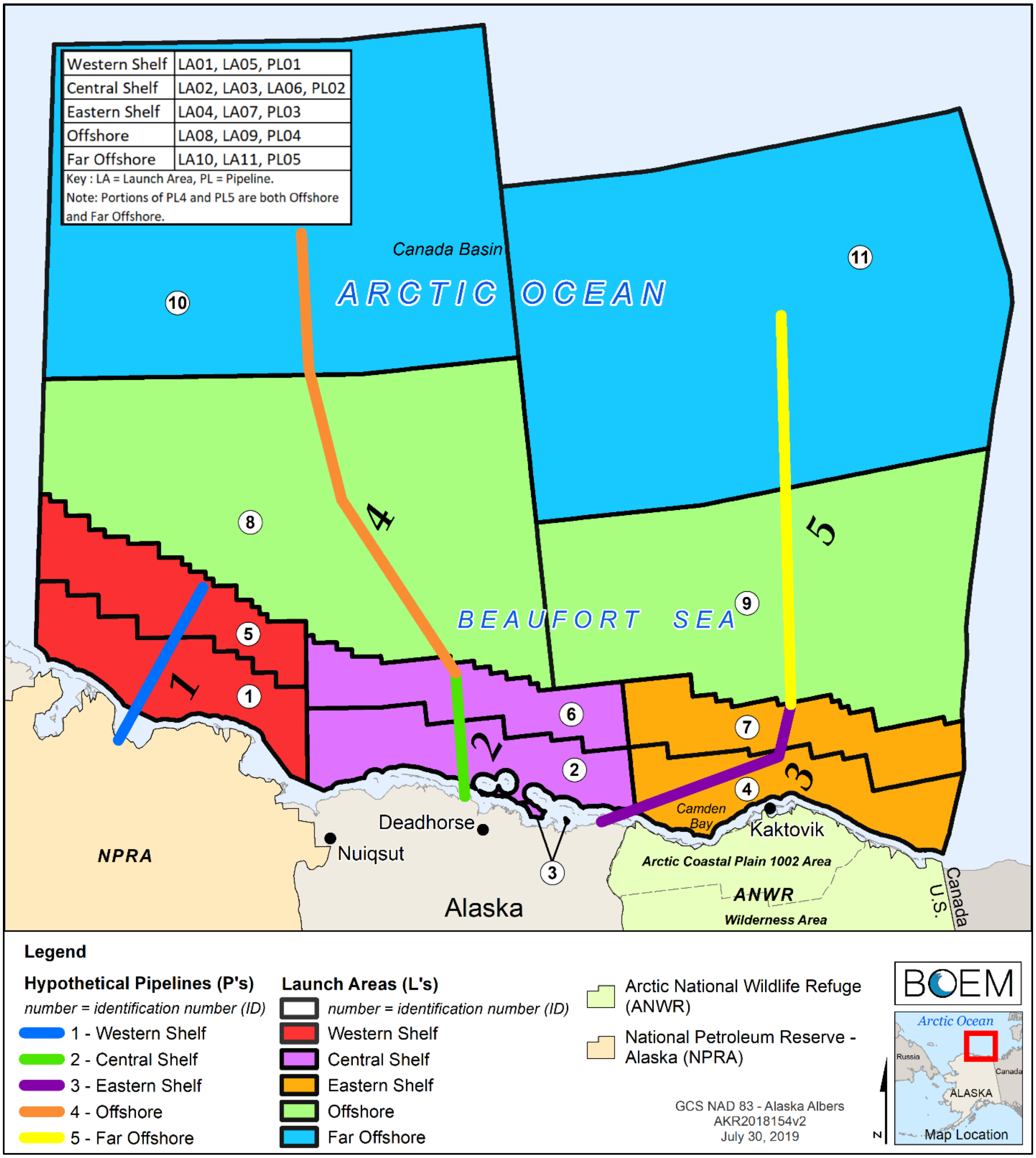


Figure A1 Hypothetical Launch Areas and Hypothetical Pipelines Used in the OSRA Model

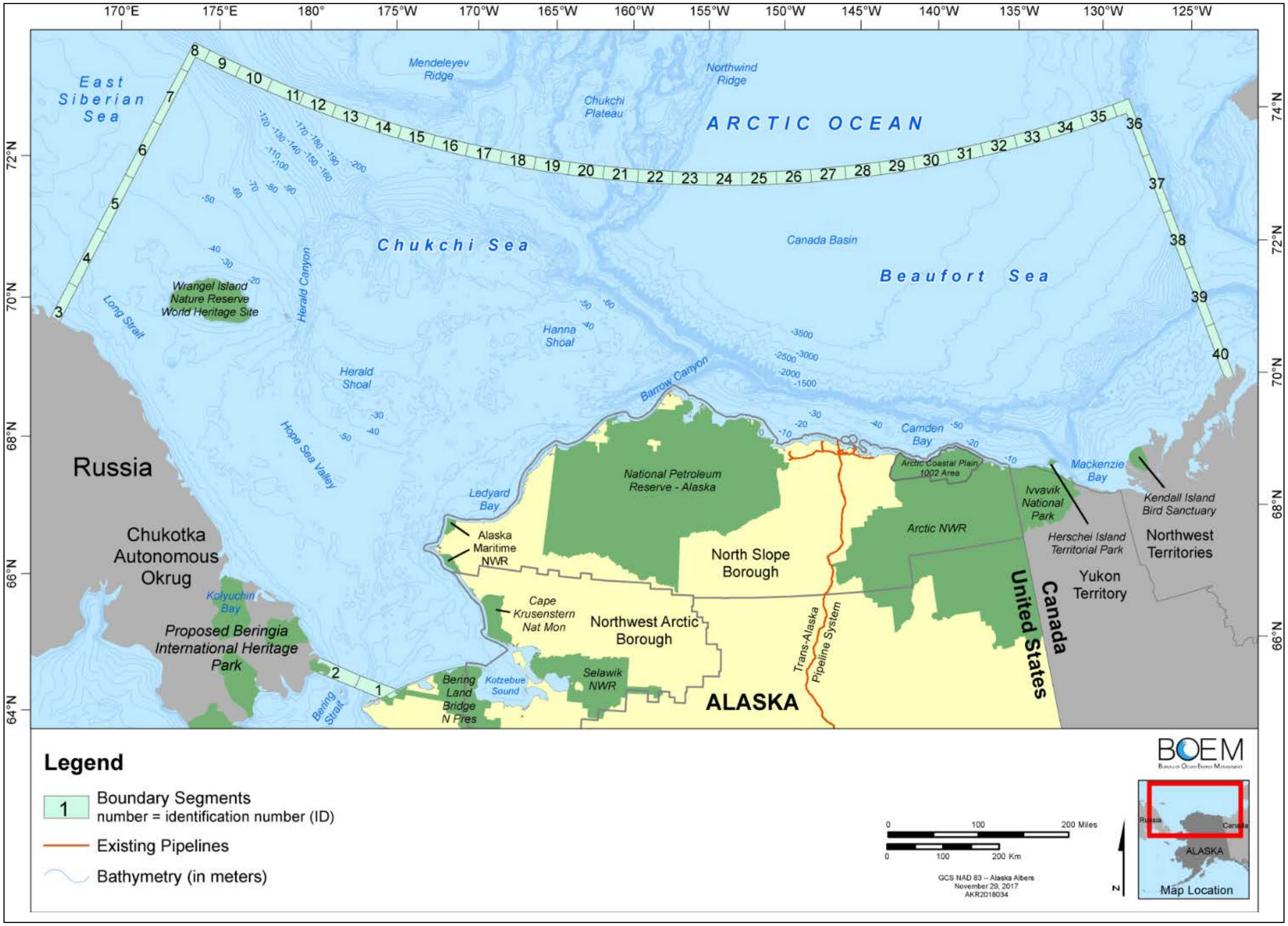


Figure A2 **Study Area and Boundary Segments Used in the OSRA Model**

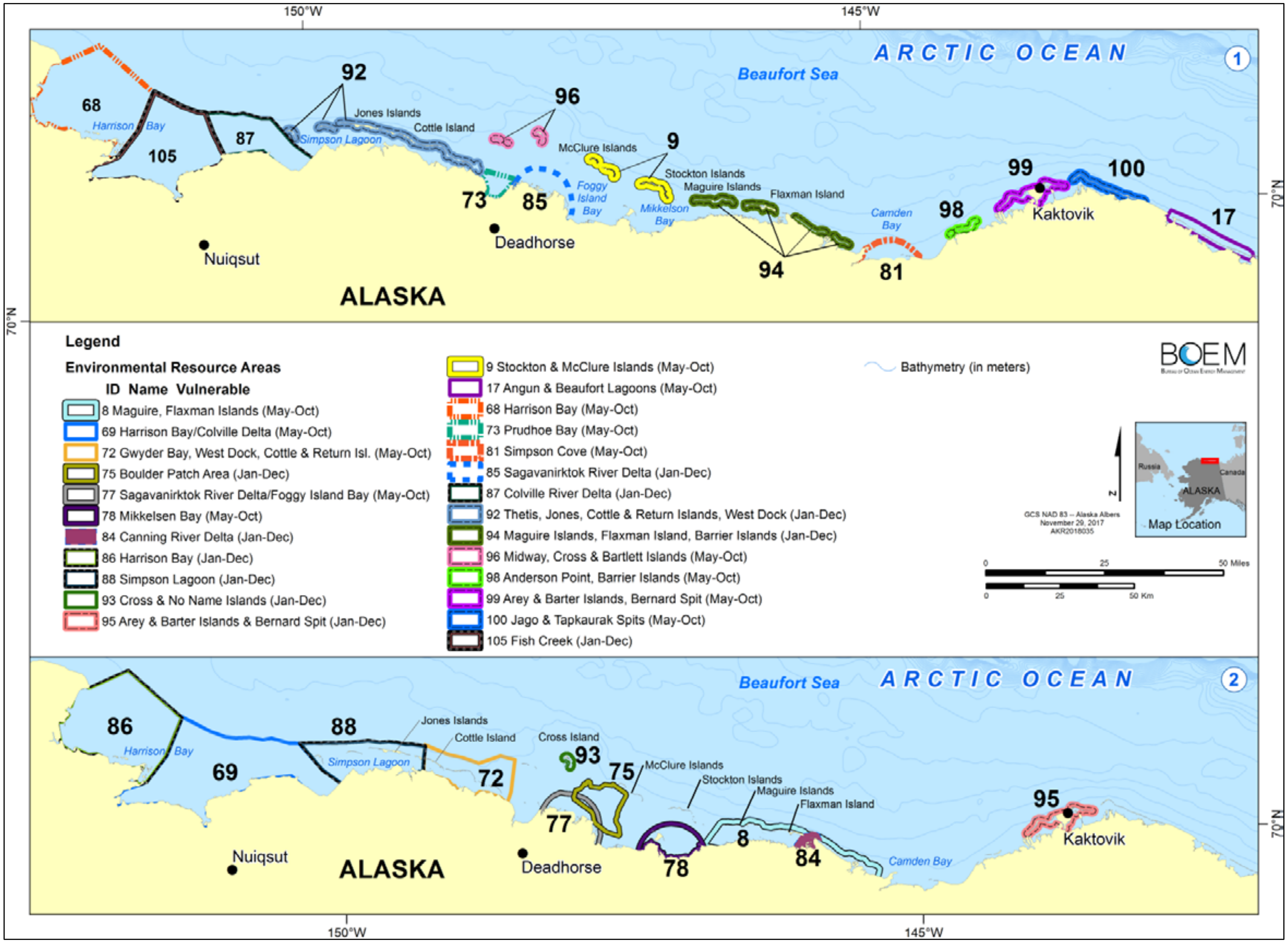


Figure A3a Environmental Resource Areas Used in the OSRA Model (Set 1 of 7)

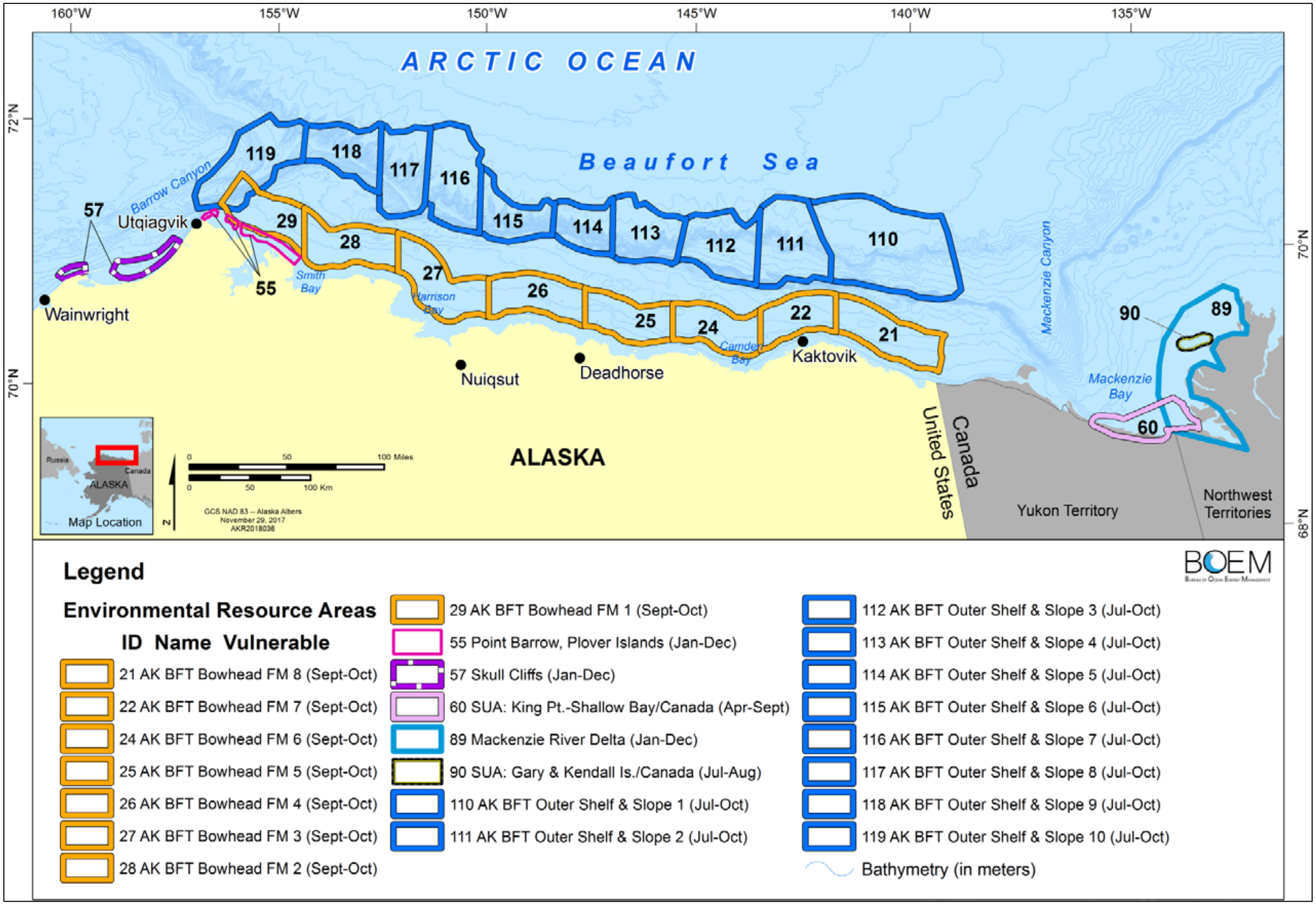


Figure A3b Environmental Resource Areas Used in the OSRA Model (Set 2 of 7)

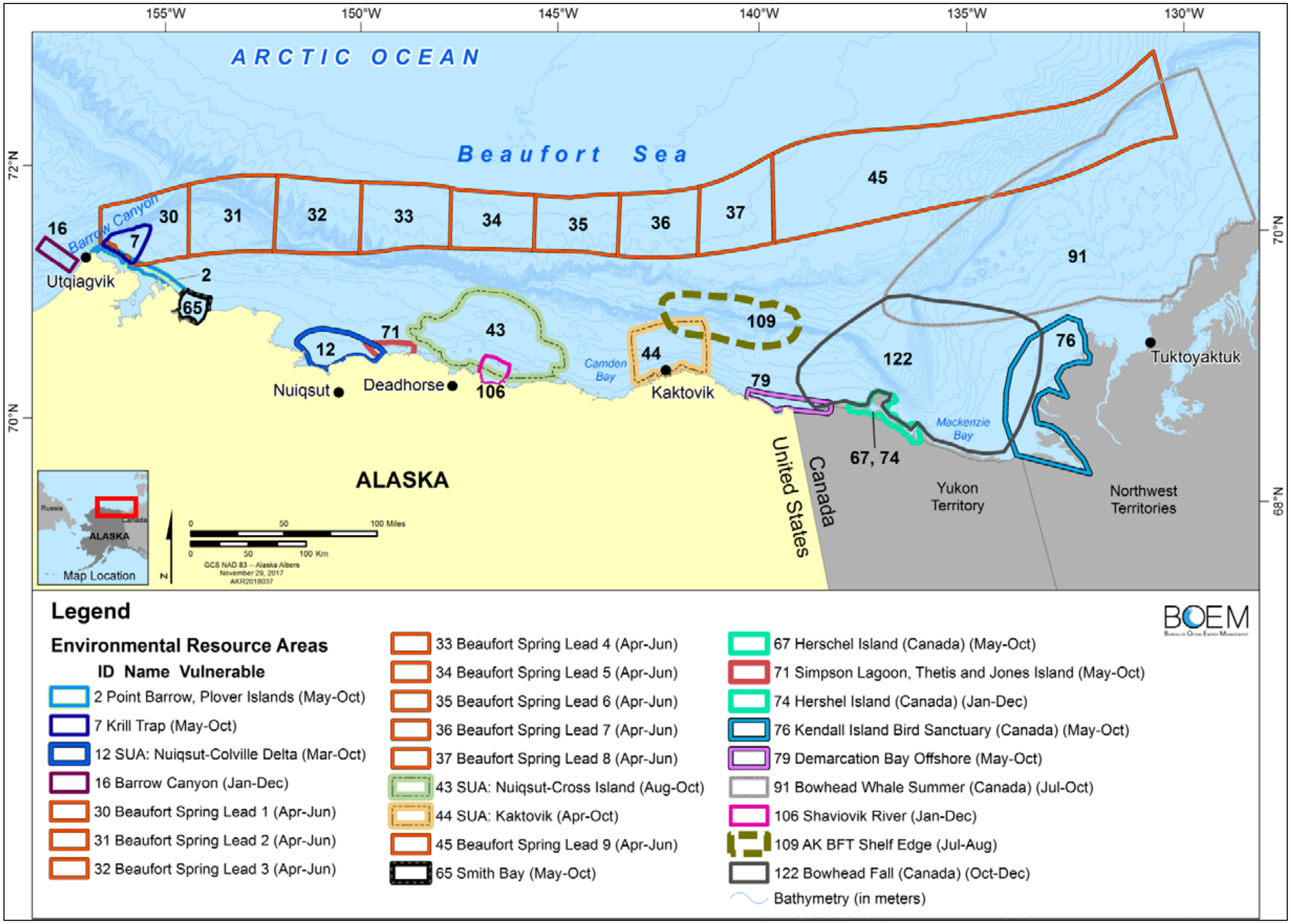


Figure A3c Environmental Resource Areas Used in the OSRA Model (Set 3 of 7)

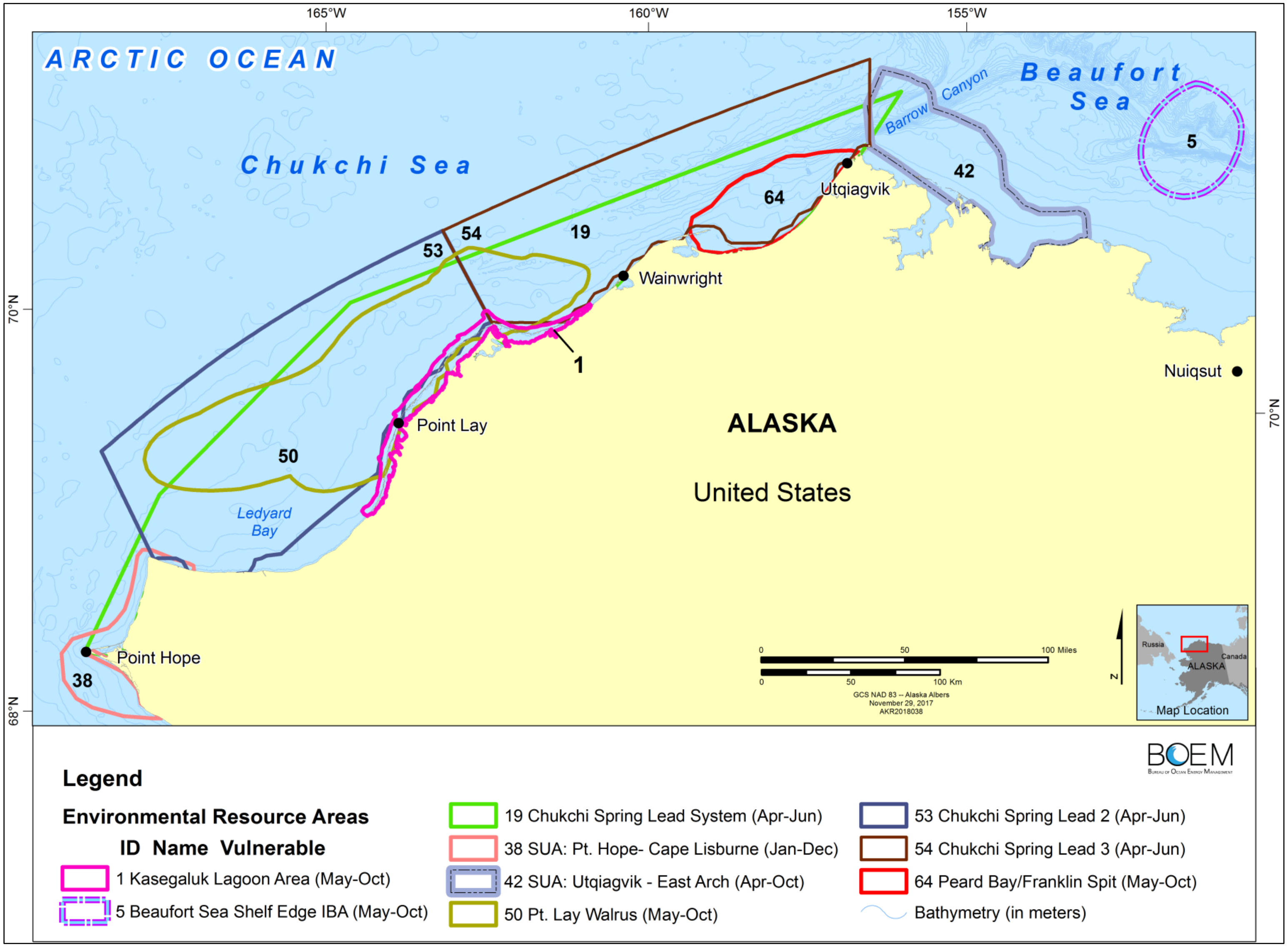


Figure A3d Environmental Resource Areas Used in the OSRA Model (Set 4 of 7)

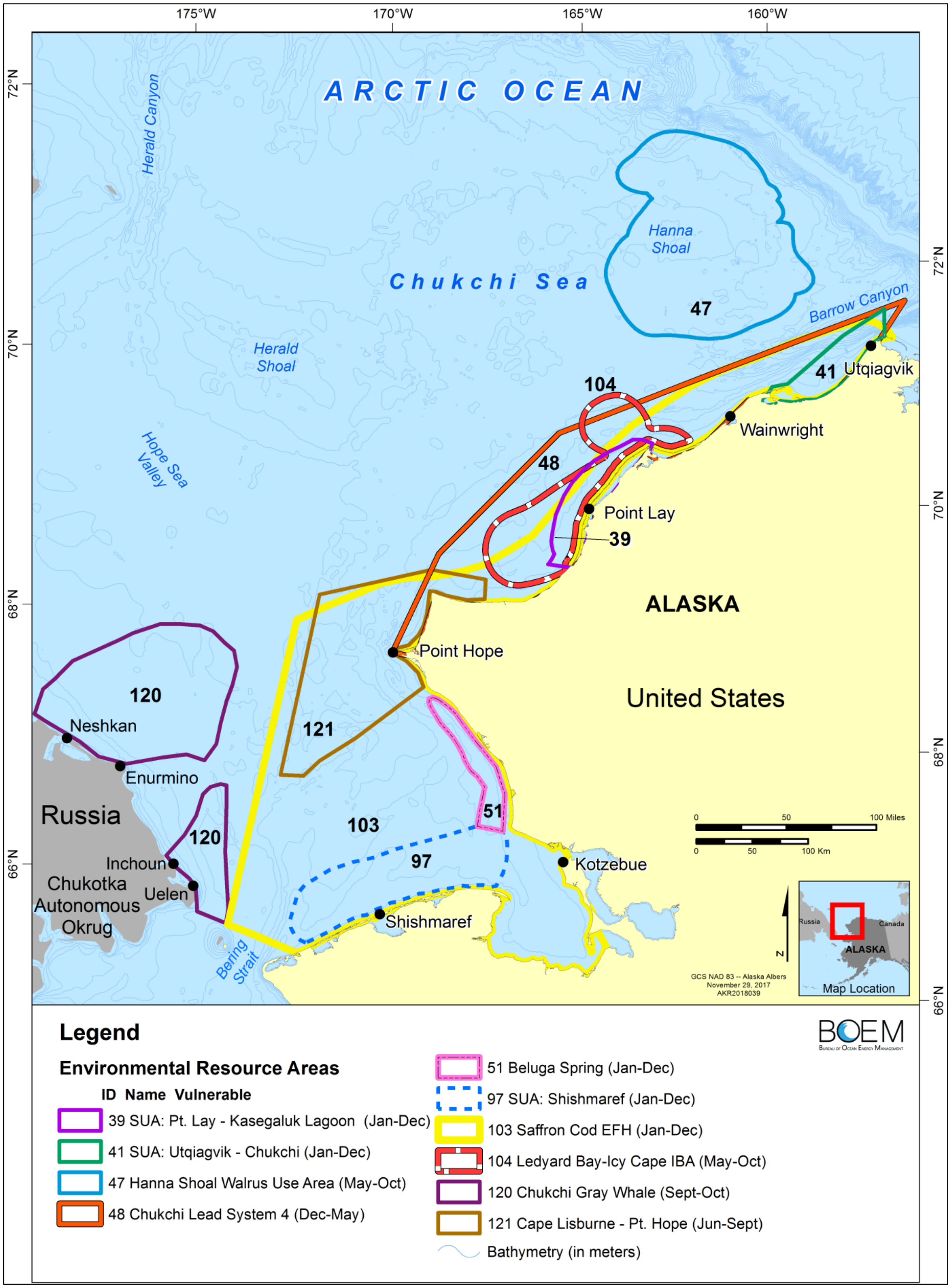


Figure A3e Environmental Resource Areas Used in the OSRA Model (Set 5 of 7)

Figure A3f Environmental Resource Areas Used in the OSRA Model (Set 6 of 7)

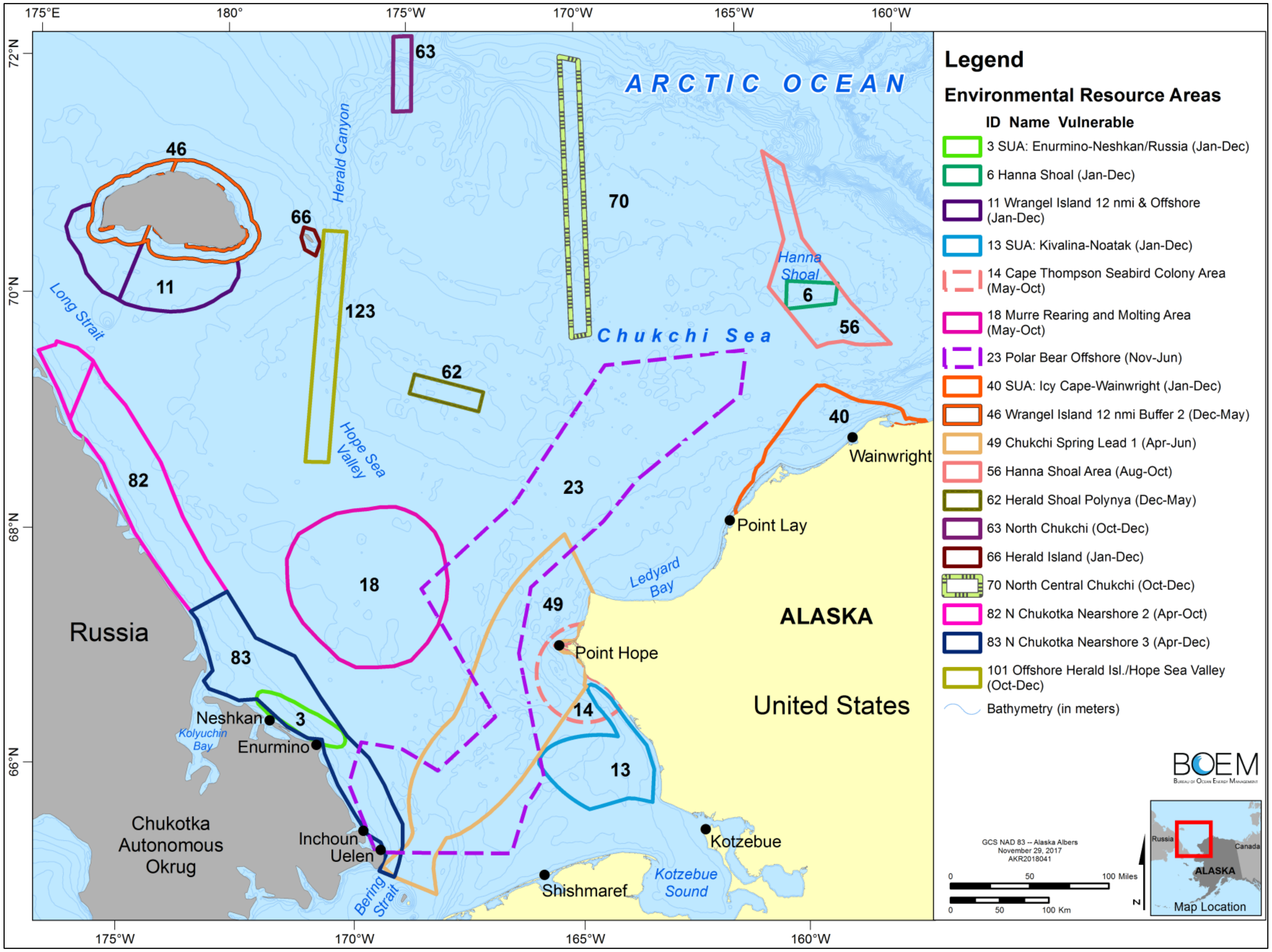


Figure A3g **Environmental Resource Areas Used in the OSRA Model (Set 7 of 7)**

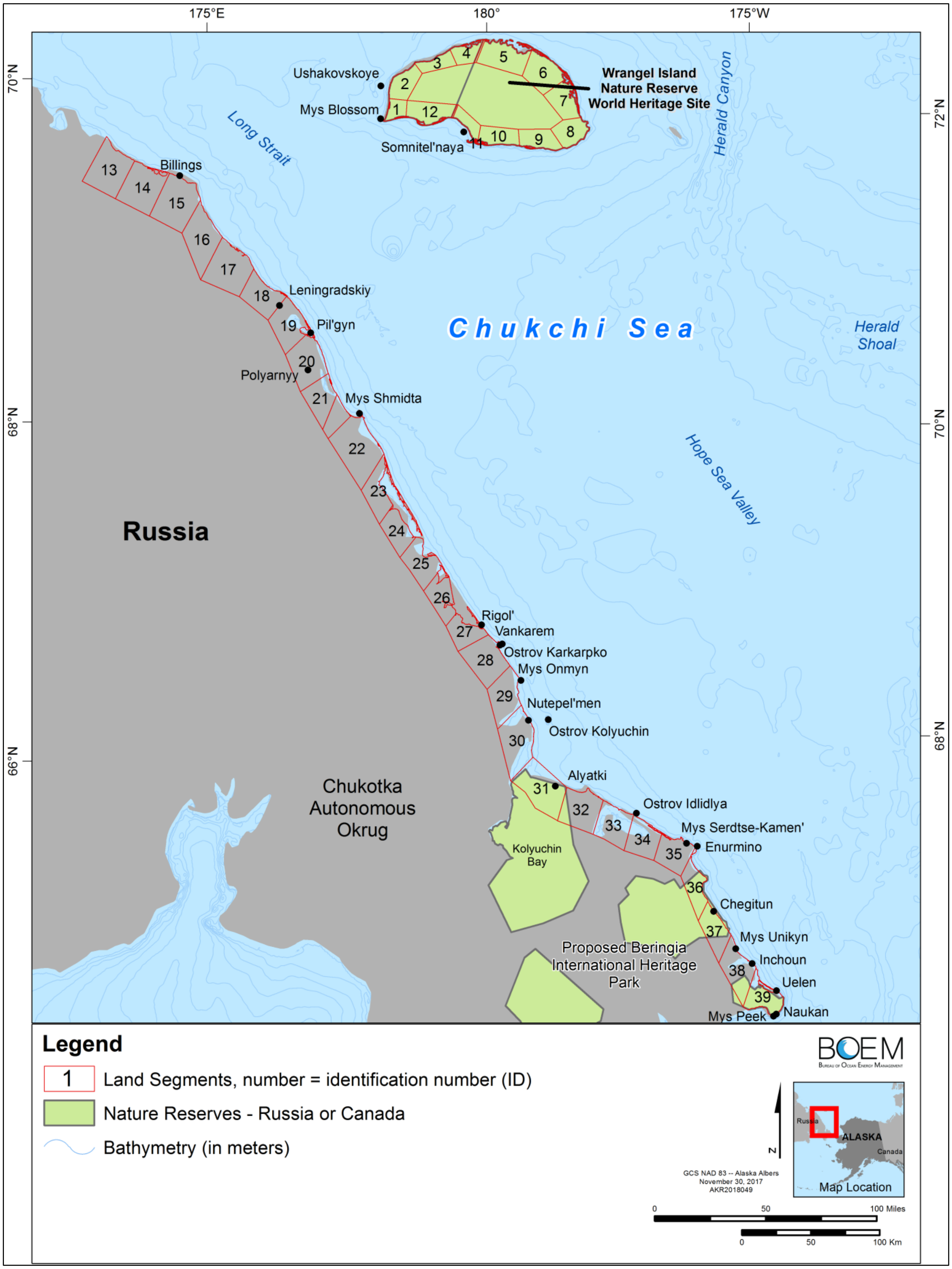


Figure A4a **Land Segments Used in the OSRA Model (Set 1 of 3)**

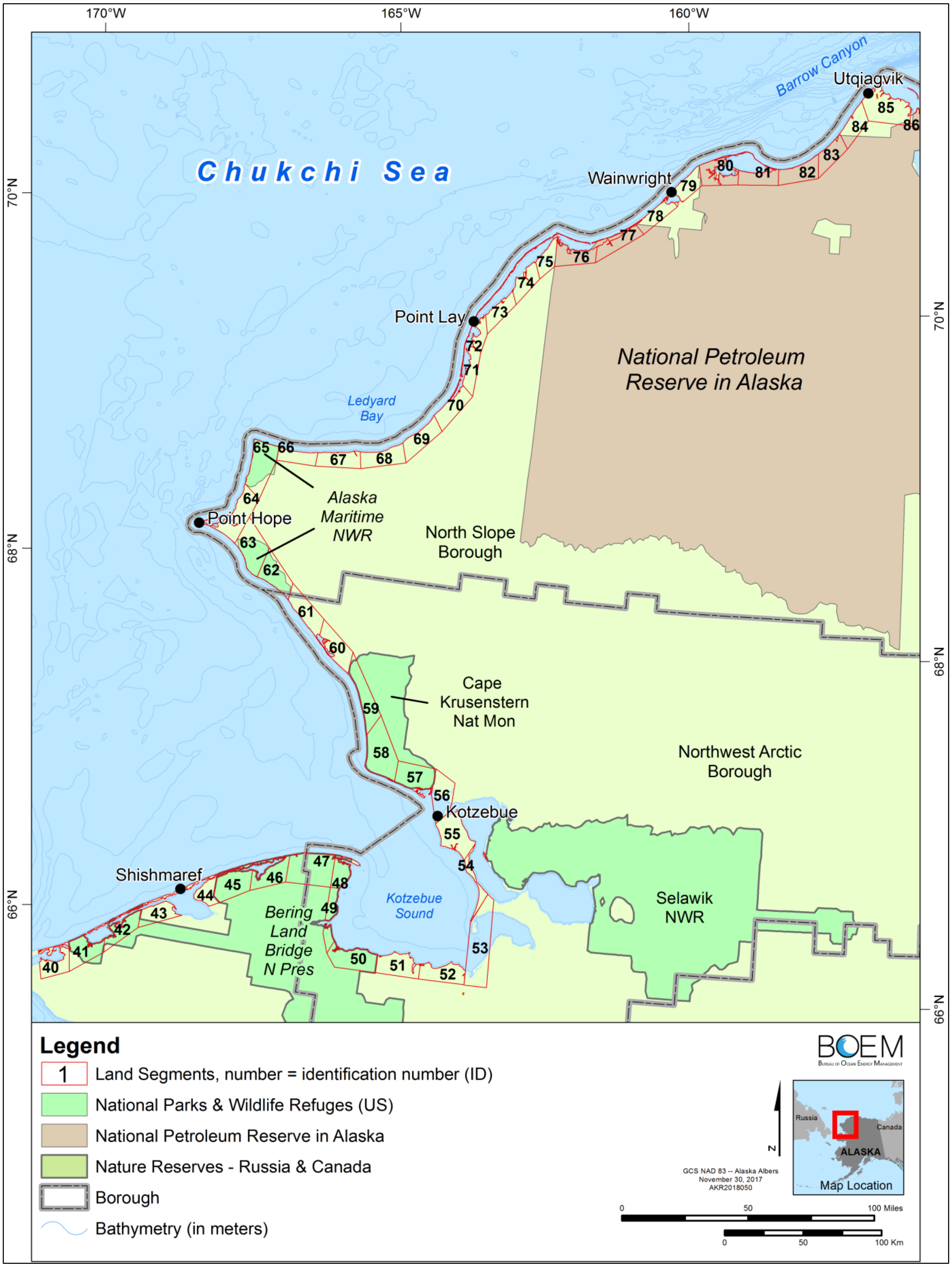


Figure A4b Land Segments Used in the OSRA Model (Set 2 of 3)

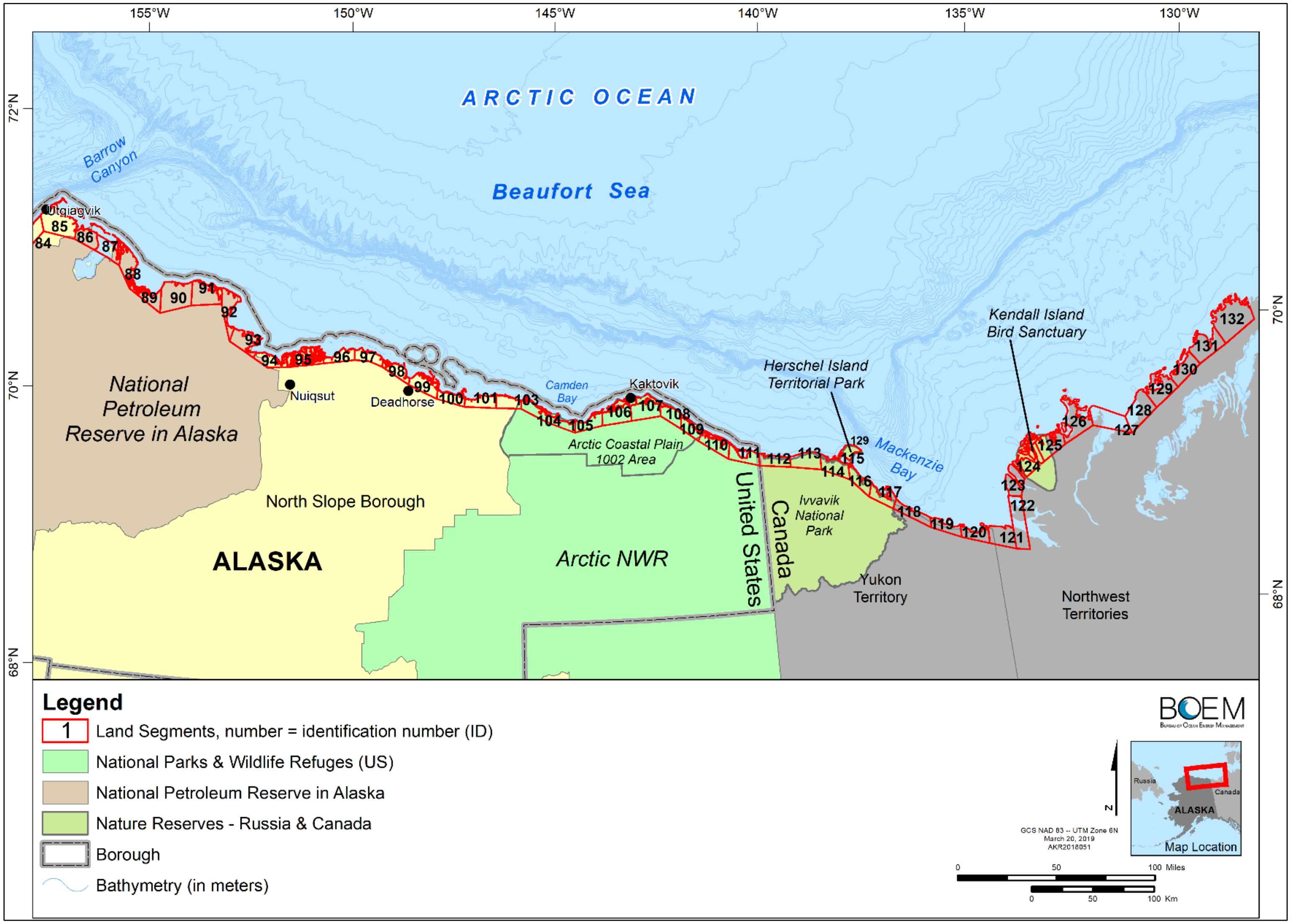


Figure A4c Land Segments Used in the OSRA Model (Set 3 of 3)

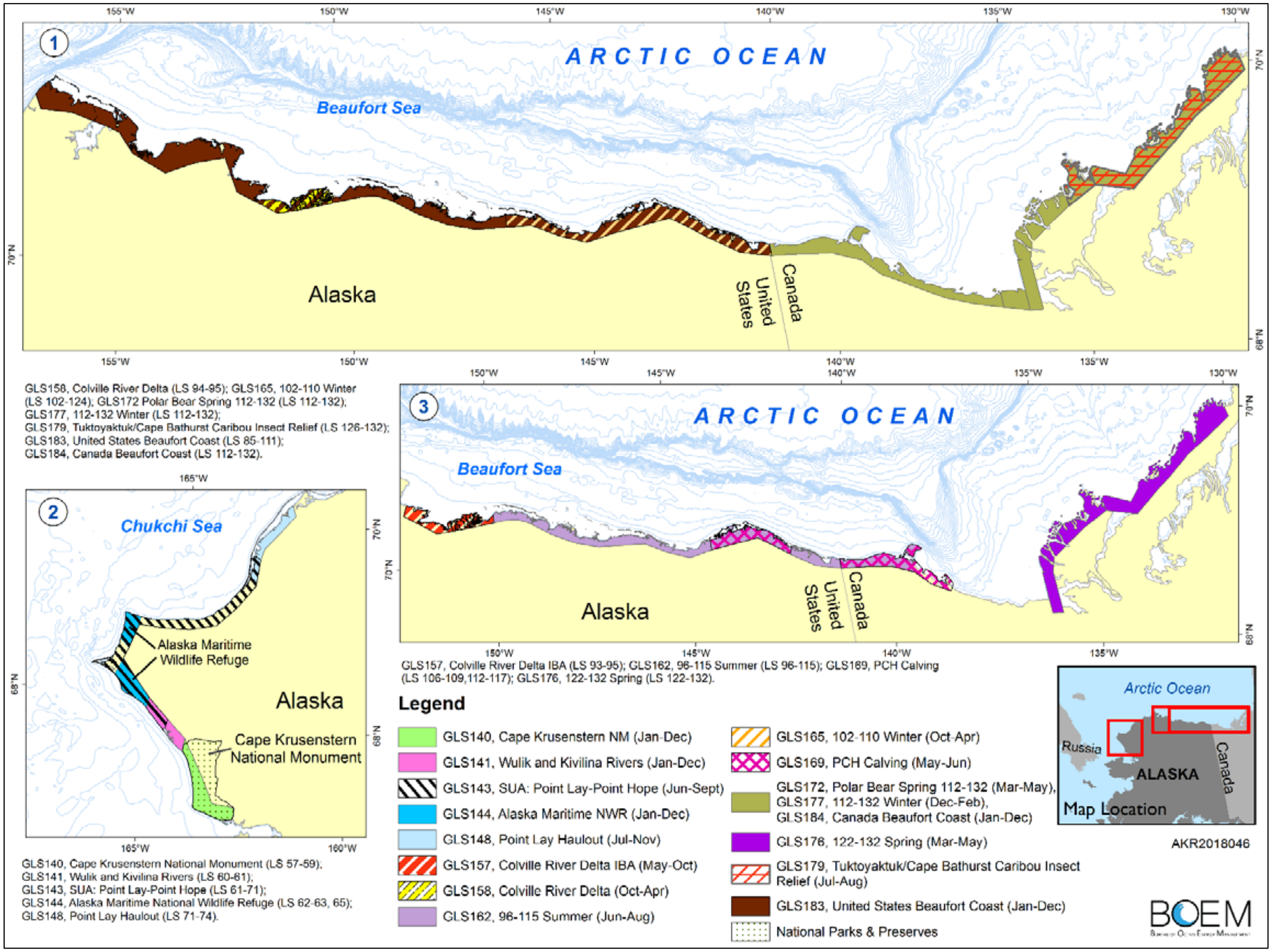
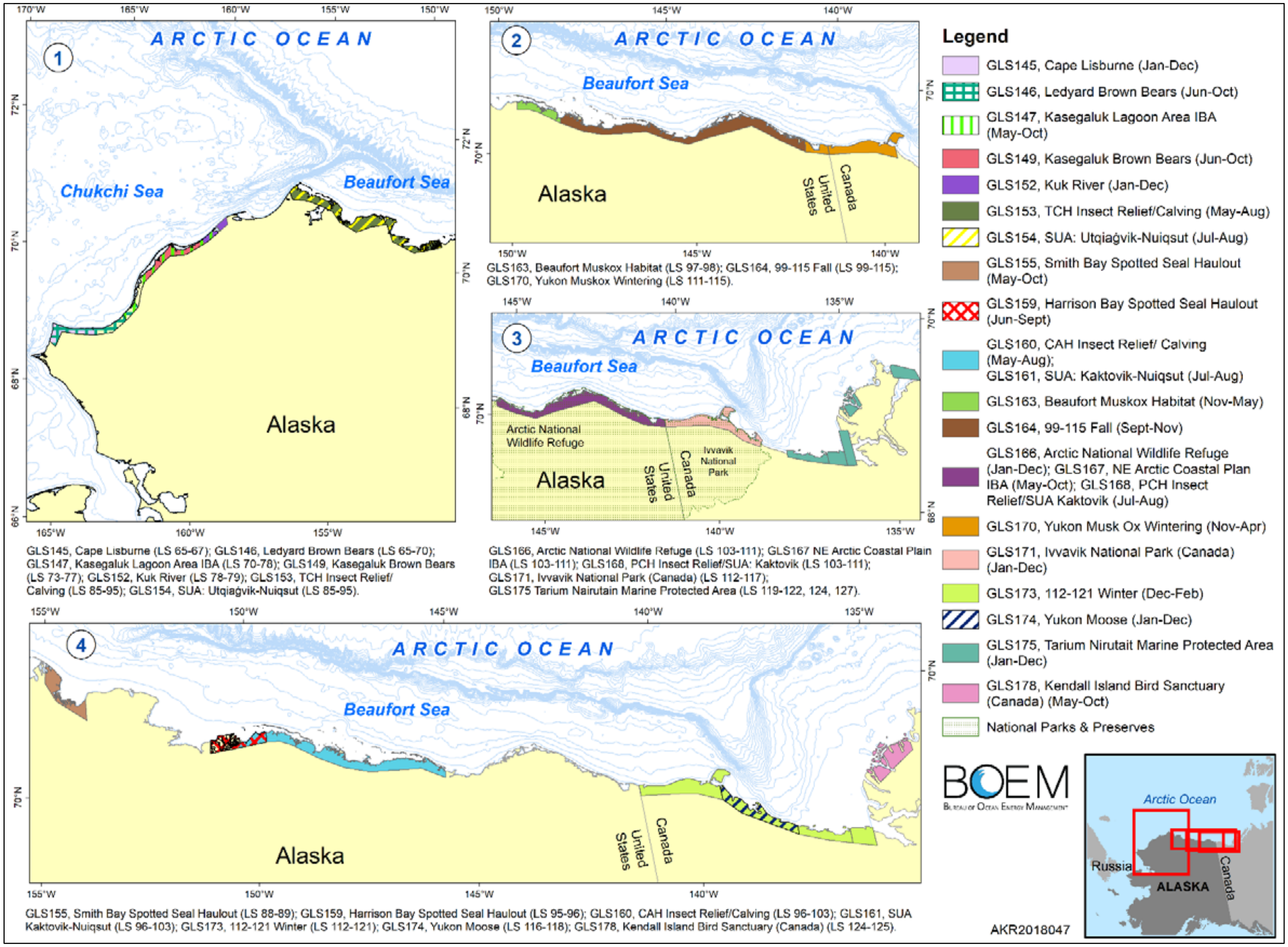


Figure A5a Grouped Land Segments Used in the OSRA Model (Set 1 of 3)



GLS145, Cape Lisburne (LS 65-67); GLS146, Ledyard Brown Bears (LS 65-70); GLS147, Kasegaluk Lagoon Area IBA (LS 70-78); GLS149, Kasegaluk Brown Bears (LS 73-77); GLS152, Kuk River (LS 78-79); GLS153, TCH Insect Relief/Calving (LS 85-95); GLS154, SUA: Utqiaġvik-Nuiqsut (LS 85-95).

GLS163, Beaufort Muskox Habitat (LS 97-98); GLS164, 99-115 Fall (LS 99-115); GLS170, Yukon Muskox Wintering (LS 111-115).

GLS166, Arctic National Wildlife Refuge (LS 103-111); GLS167 NE Arctic Coastal Plain IBA (LS 103-111); GLS168, PCH Insect Relief/SUA: Kaktovik (LS 103-111); GLS171, Ivvavik National Park (Canada) (LS 112-117); GLS175 Tarium Nairutain Marine Protected Area (LS 119-122, 124, 127).

GLS155, Smith Bay Spotted Seal Haulout (LS 88-89); GLS159, Harrison Bay Spotted Seal Haulout (LS 95-96); GLS160, CAH Insect Relief/Calving (LS 96-103); GLS161, SUA Kaktovik-Nuiqsut (LS 96-103); GLS173, 112-121 Winter (LS 112-121); GLS174, Yukon Moose (LS 116-118); GLS178, Kendall Island Bird Sanctuary (Canada) (LS 124-125).

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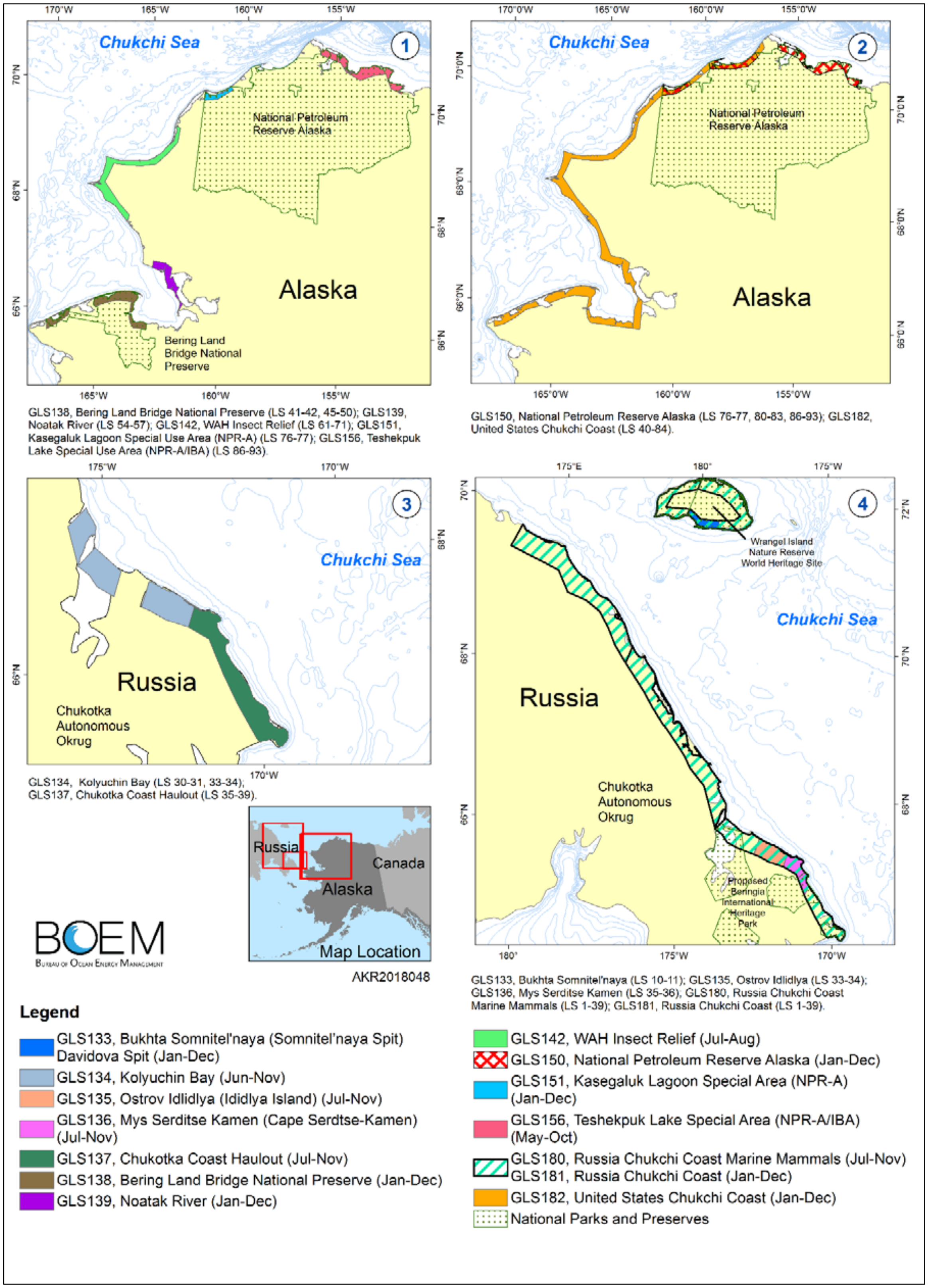
Figure A5b **Grouped Land Segments Used in the OSRA Model (Set 2 of 3)**



GLS138, Bering Land Bridge National Preserve (LS 41-42, 45-50); GLS139, Noatak River (LS 54-57); GLS142, WAH Insect Relief (LS 61-71); GLS151, Kasegaluk Lagoon Special Use Area (NPR-A) (LS 76-77); GLS156, Teshekpuk Lake Special Use Area (NPR-A/IBA) (LS 86-93).

GLS150, National Petroleum Reserve Alaska (LS 76-77, 80-83, 86-93); GLS182, United States Chukchi Coast (LS 40-84).

GLS134, Kolyuchin Bay (LS 30-31, 33-34); GLS137, Chukotka Coast Haulout (LS 35-39).

GLS133, Bukhta Somnitel'naya (LS 10-11); GLS135, Ostrov Idlidlya (LS 33-34); GLS136, Mys Serditse Kamen (LS 35-36); GLS180, Russia Chukchi Coast Marine Mammals (LS 1-39); GLS181, Russia Chukchi Coast (LS 1-39).

Figure A5c Grouped Land Segments Used in the OSRA Model (Set 3 of 3)

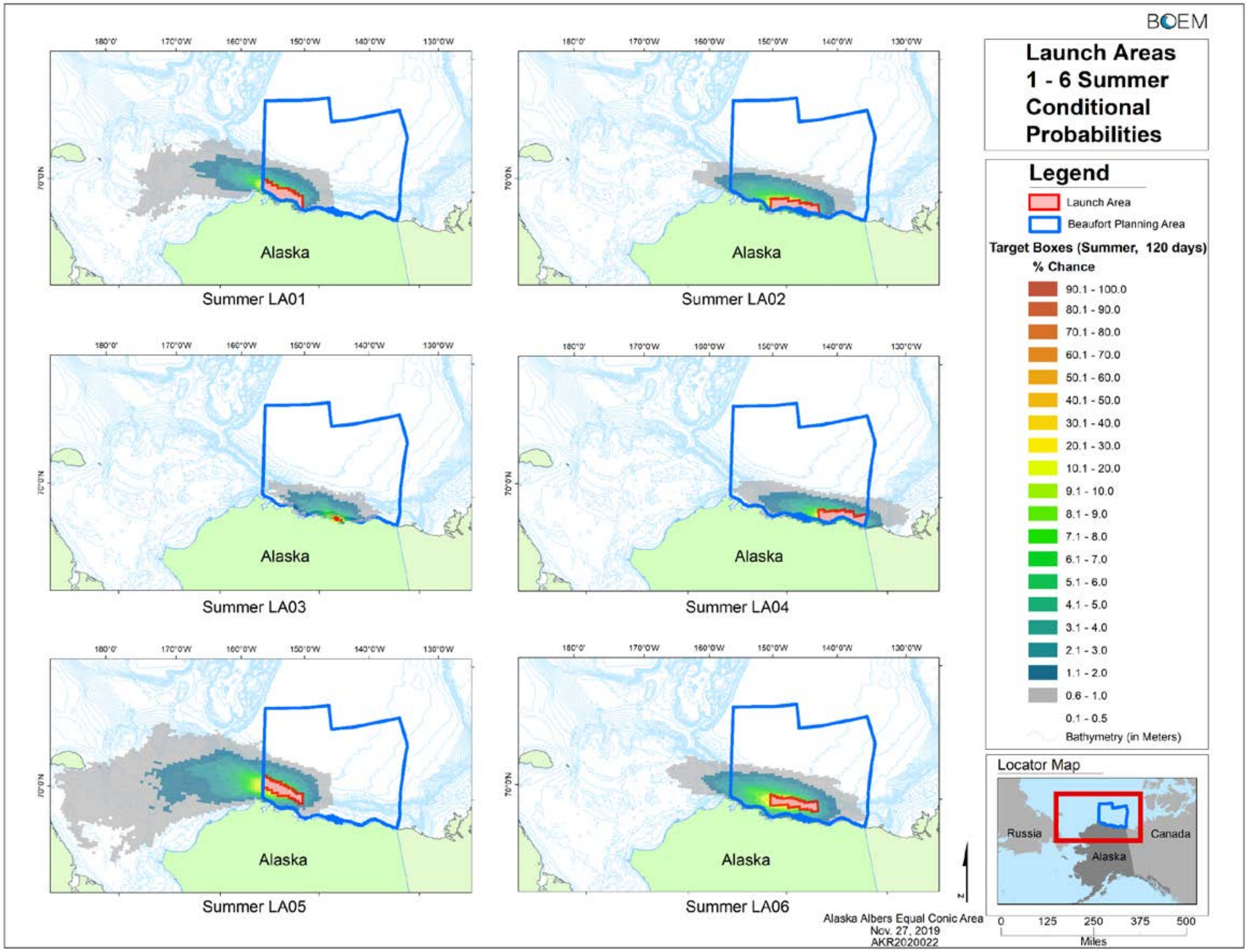


Figure A6 Launch Areas 1 through 6: Summer 120 days

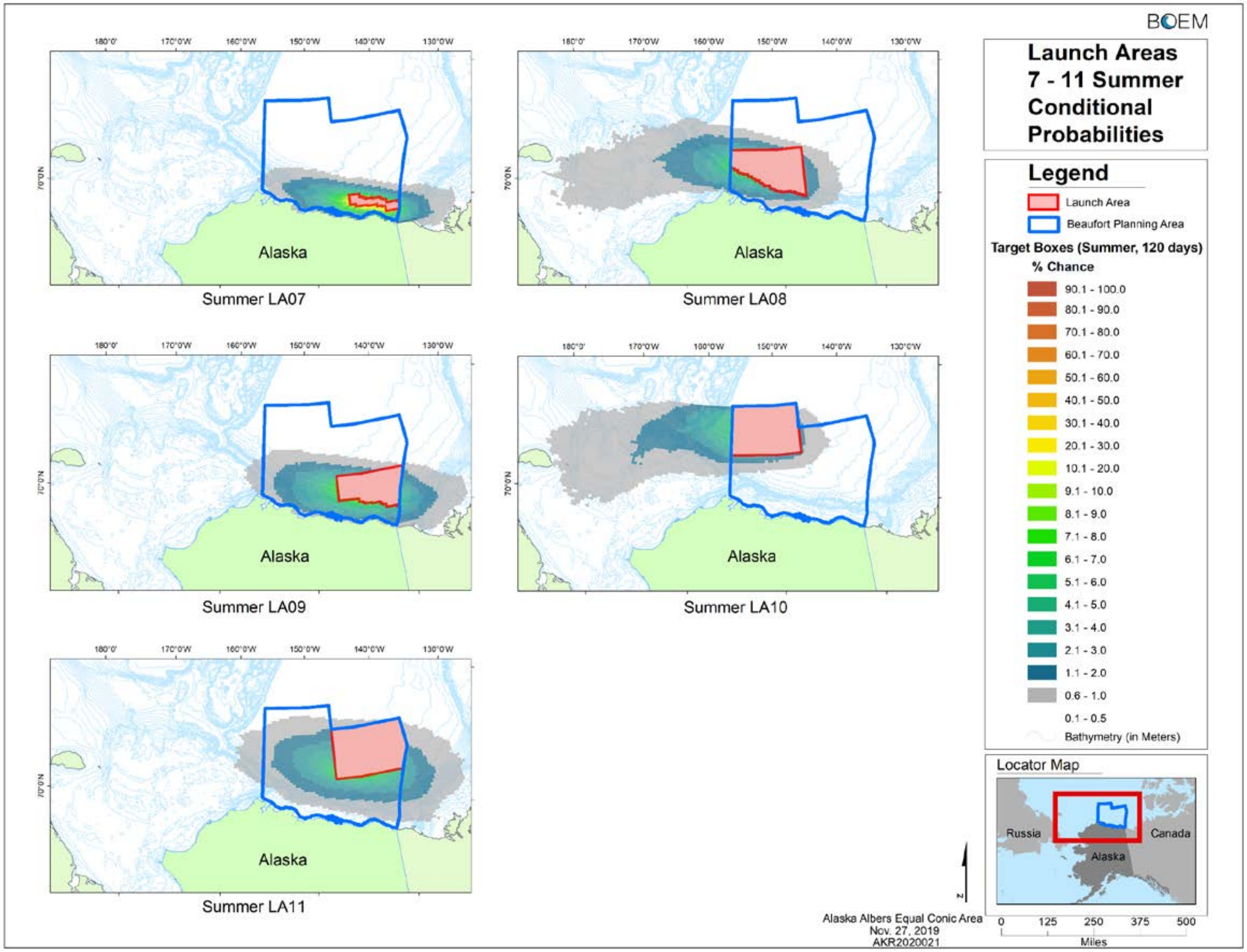


Figure A7 Launch Areas 7 through11: Summer 120 days

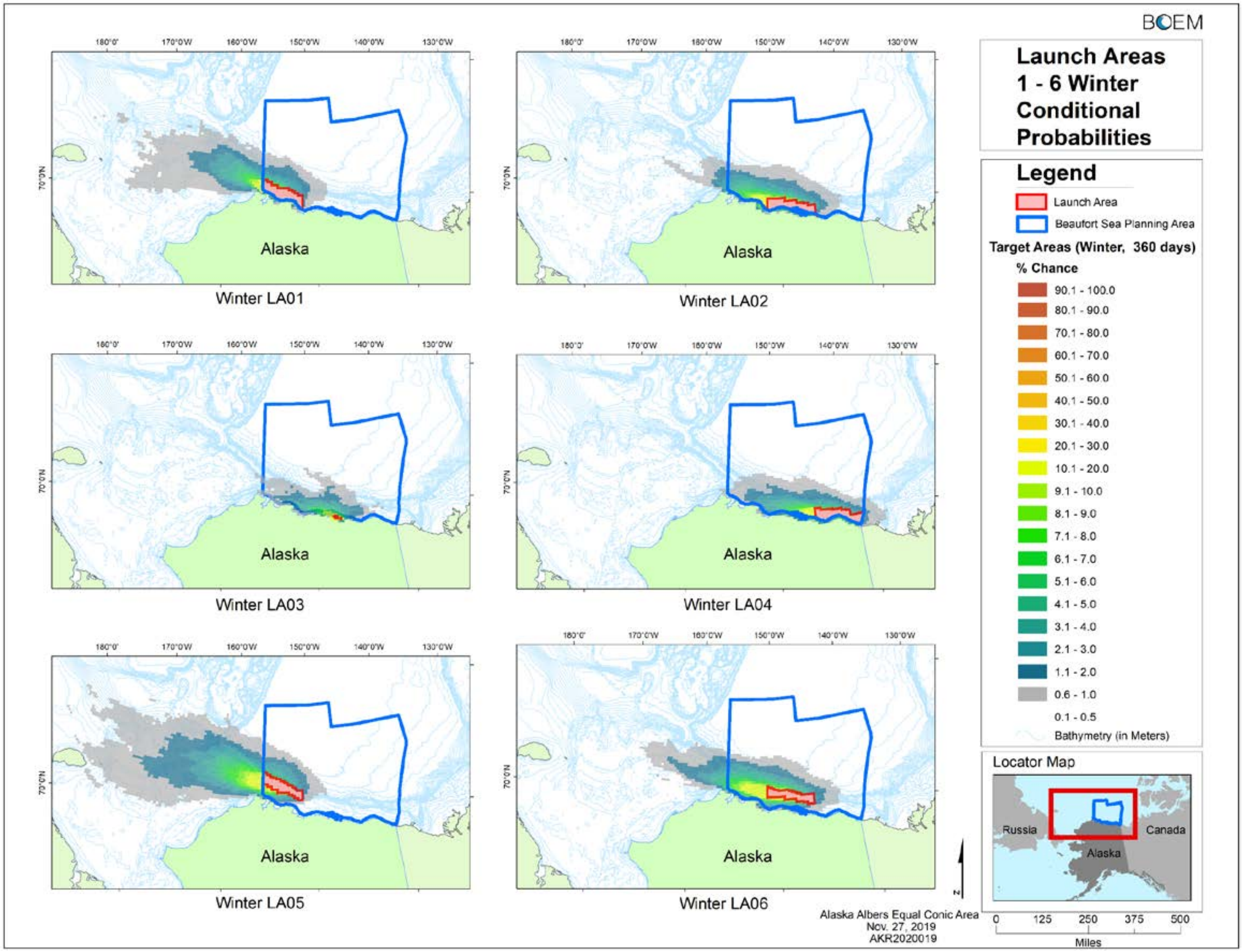


Figure A8 **Launch Areas 1 through 6: Winter 360 days**

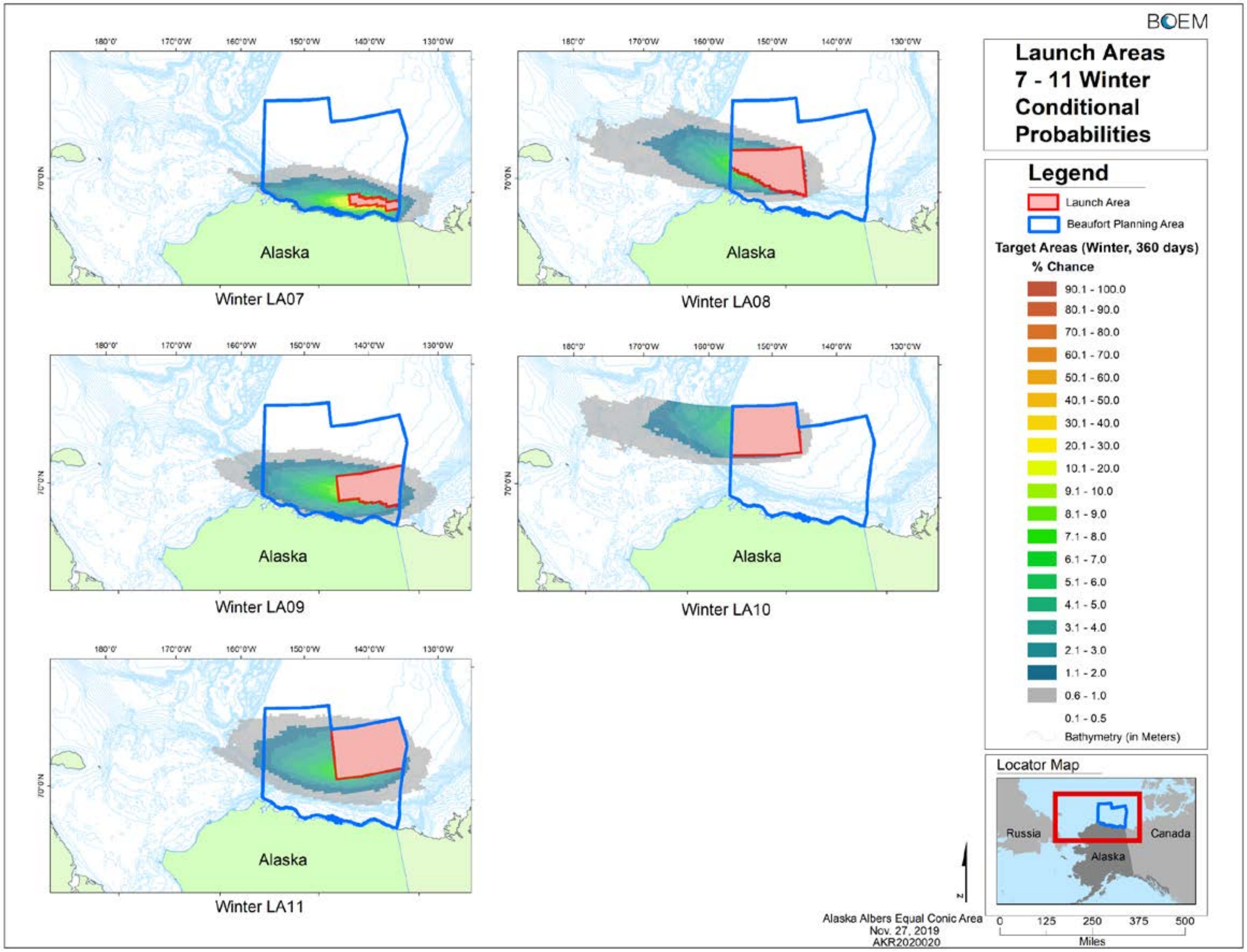


Figure A9 **Launch Areas 7 through 11: Winter 360 days**

A3 OSRA TABLES

Table A1 Environmental Resource Areas Used in the OSRA Model (Identification Number (ID), Name, General Resource, Months, and Map)

ID	Name	General Resource	Months	Figure
1	Kasegaluk Lagoon Area	Birds, Barrier Island, Seals, Whales	May-October	A3d
2	Point Barrow, Plover Isls.	Birds, Barrier Island	May-October	A3c
3	SUA: Enurmino-Neshkan/Russia	Subsistence	January-December	A3g
4	SUA: Inchoun-Uelen/Russia	Subsistence	January-December	A3f
5	Beaufort Sea Shelf Edge IBA	Birds	May-October	A3d
6	Hanna Shoal	Lower Trophic Level Organisms	January-December	A3g
7	Krill Trap	Lower Trophic Level Organisms	May-October	A3c
8	Maguire & Flaxman Isls.	Birds, Barrier Island	May-October	A3a-2
9	Stockton & McClure Isls.	Birds, Barrier Island	May-October	A3a-1
10	Ledyard Bay SPEI Critical Habitat Unit	Birds	July-November	A3f
11	Wrangel Isl. 12 nmi & Offshore	Marine Mammals	January-December	A3g
12	SUA: Nuiqsut-Colville River Delta	Subsistence	March-October	A3c
13	SUA: Kivalina-Noatak	Subsistence	January-December	A3g
14	Cape Thompson Seabird Colony Area	Birds	May-October	A3g
15	Cape Lisburne Seabird Colony Area	Birds, Marine Mammals	May-October	A3f
16	Barrow Canyon	Lower Trophic Level Organisms	January-December	A3c
17	Angun & Beaufort Lagoons	Birds, Barrier Island	May-October	A3a-1
18	Murre Rearing & Molting Area	Birds	May-October	A3g
19	Chukchi Sea Spring Lead System	Birds	April-June	A3d
20	East Chukchi Offshore	Whales	September-October	A3f
21	AK BFT Bowhead FM 8	Whales	September-October	A3b
22	AK BFT Bowhead FM 7	Whales	September-October	A3b
23	Polar Bear Offshore	Marine Mammals	November-June	A3g
24	AK BFT Bowhead FM 6	Whales	September-October	A3b
25	AK BFT Bowhead FM 5	Whales	September-October	A3b
26	AK BFT Bowhead FM 4	Whales	September-October	A3b
27	AK BFT Bowhead FM 3	Whales	September-October	A3b
28	AK BFT Bowhead FM 2	Whales	September-October	A3b
29	AK BFT Bowhead FM 1	Whales	September-October	A3b
30	Beaufort Spring Lead 1	Whales	April-June	A3c
31	Beaufort Spring Lead 2	Whales	April-June	A3c
32	Beaufort Spring Lead 3	Whales	April-June	A3c
33	Beaufort Spring Lead 4	Whales	April-June	A3c
34	Beaufort Spring Lead 5	Whales	April-June	A3c
35	Beaufort Spring Lead 6	Whales	April-June	A3c
36	Beaufort Spring Lead 7	Whales	April-June	A3c
37	Beaufort Spring Lead 8	Whales	April-June	A3c
38	SUA: Pt. Hope-Cape Lisburne	Subsistence	January-December	A3d
39	SUA: Pt. Lay-Kasegaluk Lagoon	Subsistence	January-December	A3e
40	SUA: Icy Cape-Wainwright	Subsistence	January-December	A3g
41	SUA: Utqiaġvik-Chukchi	Subsistence	January-December	A3e
42	SUA: Utqiaġvik-East Arch	Subsistence	April-October	A3d
43	SUA: Nuiqsut-Cross Isl.	Subsistence	August-October	A3c
44	SUA: Kaktovik	Subsistence	April-October	A3c
45	Beaufort Spring Lead 9	Whales	April-June	A3c
46	Wrangel Isl. 12 nmi Buffer 2	Marine Mammals	December-May	A3g
47	Hanna Shoal Walrus Use Area	Marine Mammals	May-October	A3e
48	Chukchi Lead System 4	Marine Mammals	December-May	A3e
49	Chukchi Spring Lead 1	Whales	April-June	A3g
50	Pt. Lay Walrus	Marine Mammals	May-October	A3d
51	Beluga Spring	Whales	January-December	A3e
52	Russian Coast Walrus Offshore	Marine Mammals	May-November	A3f

ID	Name	General Resource	Months	Figure
53	Chukchi Spring Lead 2	Whales	April-June	A3d
54	Chukchi Spring Lead 3	Whales	April-June	A3d
55	Point Barrow, Plover Isls.	Marine Mammals	January-December	A3b
56	Hanna Shoal Area	Whales	August-October	A3g
57	Skull Cliffs	Lower Trophic Level Organisms	January-December	A3b
58	Russian Coast Walrus Nearshore	Marine Mammals	May-November	A3f
59	Ostrov Kolyuchin	Marine Mammals	July -November	A3f
60	SUA: King Pt.-Shallow Bay (Canada)	Subsistence, Whales	April-September	A3b
61	Pont Lay–Utqiaġvik BH GW SFF	Whales	July-October	A3f
62	Herald Shoal Polynya 2	Marine Mammals	December-May	A3g
63	North Chukchi	Whales	October-December	A3g
64	Peard Bay/Franklin Spit Area	Birds, Marine Mammals	May-October	A3d
65	Smith Bay	Whales, Birds, Marine Mammals	May-October	A3c
66	Herald Island	Marine Mammals	January-December	A3g
67	Herschel Island (Canada)	Birds	May-October	A3c
68	Harrison Bay	Birds, Marine Mammals	May-October	A3a-1
69	Harrison Bay/Colville Delta	Birds, Marine Mammals	May-October	A3a-2
70	North Central Chukchi	Whales	October-December	A3g
71	Simpson Lagoon, Thetis & Jones Isls.	Birds	May-October	A3c
72	Gwyder Bay, W. Dock, Cottle & Return Isls.	Birds	May-October	A3a-2
73	Prudhoe Bay	Birds	May-October	A3a-1
74	Hershel Isl.	Marine Mammals	January-December	A3c
75	Boulder Patch Area	Lower Trophic Level Organisms	January-December	A3a-2
76	Kendall Isl. Bird Sanctuary (Canada)	Birds	May-October	A3c
77	Sagavanirktok River Delta/Foggy Isl. Bay	Birds	May-October	A3a-2
78	Mikkelsen Bay	Birds	May-October	A3a-2
79	DeMarcation Bay Offshore	Birds	May-October	A3c
80	Chukchi Sea Nearshore IBA	Birds	May-October	A3f
81	Simpson Cove	Birds	May-October	A3a-1
82	North Chukotka Nearshore 2	Whales	April-October	A3g
83	North Chukotka Nearshore 3	Whales	April-December	A3g
84	Canning River Delta	Anadromous & Marine Nearshore Fish	January-December	A3a-2
85	Sagavanirktok River Delta	Anadromous & Marine Nearshore Fish	January-December	A3a-1
86	Harrison Bay	Marine Nearshore Fish	January-December	A3a-2
87	Colville River Delta	Anadromous & Marine Nearshore Fish	January-December	A3a-1
88	Simpson Lagoon	Marine Nearshore Fish	January-December	A3a-2
89	Mackenzie River Delta	Anadromous & Marine Nearshore Fish	January-December	A3b
90	SUA: Garry & Kendall Isls./ Canada	Subsistence	July-August	A3b
91	Bowhead Whale Summer (Canada)	Whales	July-October	A3c
92	Thetis, Jones, Cottle & Return Isl.	Marine Mammals	January-December	A3a-1
93	Cross & No Name Isls.	Marine Mammals	January-December	A3a-2
94	Maguire, Flaxman & Barrier Isl.	Marine Mammals	January-December	A3a-1
95	Arey & Barter Isls., Bernard Spit	Marine Mammals	January-December	A3a-2
96	Midway, Cross & Bartlett Isls.	Birds, Barrier Islands	May-October	A3a-1
97	SUA: Shishmaref	Subsistence	January-December	A3e
98	Anderson Point Barrier Isls.	Birds, Barrier Islands	May-October	A3a-1
99	Arey & Barter Isls., Bernard Spit	Birds, Barrier Islands	May-October	A3a-1
100	Jago & Tapkaurak Spits	Birds, Barrier Islands	May-October	A3a-1
101	Offshore Herald Isl./Hope Sea Valley	Whales	October-December	A3g
102	Opilio Crab EFH	Opilio Crab Habitat (EFH)	January-December	A3f
103	Saffron Cod EFH	Saffron Cod Habitat (EFH)	January-December	A3e
104	Ledyard Bay-Icy Cape IBA	Birds	May-October	A3e
105	Fish Creek	Anadromous Fish	January-December	A3a-1
106	Shaviovik River	Anadromous & Marine Nearshore Fish	January-December	A3c
107	Point Hope Offshore	Whales	June-September	A3f
108	Utqiaġvik Feeding Aggregation	Whales	September-October	A3f
109	AK BFT Shelf Edge	Whales	July-August	A3c
110	AK BFT Outer Shelf & Slope 1	Whales	July-October	A3b
111	AK BFT Outer Shelf & Slope 2	Whales	July-October	A3b

ID	Name	General Resource	Months	Figure
112	AK BFT Outer Shelf & Slope 3	Whales	July-October	A3b
113	AK BFT Outer Shelf & Slope 4	Whales	July-October	A3b
114	AK BFT Outer Shelf & Slope 5	Whales	July-October	A3b
115	AK BFT Outer Shelf & Slope 6	Whales	July-October	A3b
116	AK BFT Outer Shelf & Slope 7	Whales	July-October	A3b
117	AK BFT Outer Shelf & Slope 8	Whales	July-October	A3b
118	AK BFT Outer Shelf & Slope 9	Whales	July-October	A3b
119	AK BFT Outer Shelf & Slope 10	Whales	July-October	A3b
120	Chukchi Gray Whale Fall (Russia)	Whales	September-October	A3e
121	Cape Lisburne–Pt. Hope	Whales	June-September	A3e
122	Bowhead Fall (Canada)	Whales	October-December	A3c

Key:
AK = Alaska
FM = Fall migration
Isl. = Island
SUA = Subsistence Use Area
BFT = Beaufort
GW = Gray Whale
Pt. = Point
BH = Bowhead
IBA = Important Bird Area
SFF = Summer Fall Feeding
EFH = Essential Fish Habitat
ID = Identification (number)
SPEI = Spectacled Eider

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A2 Environmental Resource Areas Used in the Analysis of Lower Trophic Level Organisms

ERA ID	Name	Figure	Months	Specific Resource	Reference
6	Hanna Shoal	A3g	Jan-Dec	Invertebrates	Dunton, Grebmeier and Trefry, 2014; Grebemier, 2012; Moore and Grebmeier, 2013.
7	Krill Trap	A3c	May-Oct	Invertebrates	Ashjian et al., 2010 (Figures 8 and 14, pp.187–189); Okkonen et al., 2011.
16	Barrow Canyon	A3c	Jan-Dec	Invertebrates	Moore and Grebmeier, 2013.
57	Skull Cliffs	A3b	Jan-Dec	Kelp/Invertebrates	Philips et al., 1984. (pp. 13-14 and 16-19).
75	Boulder Patch Area	A3a-2	Jan-Dec	Kelp/Invertebrates	Dunton and Schonberg, 2000 (p. 383, Fig 4. pp.388-392, Table 5. p. 393, Figure 6); Dunton et. al., 2009 (p. 17, Figure 1.3. p. 27, Table 2.1).

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A3 Environmental Resource Areas, Grouped Land Segments, and Land Segments Used in the Analysis of Fish

ID	Name	Figure	Months	General Resource	Specific Resource	Reference
ERAs Marine Waters						
84	Canning River Delta	A3a-2	Jan-Dec	Anadromous & Marine Nearshore Fish	Pp, DVpr, CHp, Wp, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017.
85	Sagavanirktok River Delta	A3a-1	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp, Pp, DVpr, Wp Arctic char, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017.
86	Harrison Bay	A3a-2	Jan-Dec	Marine Fish – nearshore	Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Wp	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017.
87	Colville River Delta	A3a-1	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp, Pp, DVp, Wp, Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Arctic cisco, Arctic char	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017; MBC Applied Environmental Sciences, 2004.
88	Simpson Lagoon	A3a-2	Jan-Dec	Marine Fish – nearshore	Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Wp, Arctic char	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017.
89	Mackenzie River Delta	A3b	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp, OMp, Wp, Sheefish, Saffron cod, Arctic cod, Arctic char, Arctic Cisco, Pacific herring, prickleback spp., sculpin spp.	Craig, 1984; MBC Applied Environmental Sciences, 2004; Sawatzky et.al, 2007; Wong et al., 2013.
102	Opilio Crab EFH	A3f	Jan-Dec	Opilio Crab Habitat (EFH)	Opilio Crab	NMFS, 2009.
103	Saffron Cod EFH	A3e	Jan-Dec	Saffron Cod Habitat (EFH)	Saffron Cod	NMFS, 2009.
105	Fish Creek	A3a-1	Jan-Dec	Anadromous Fish	CHp, Kp, Pp,DVp, HWp, Wp	Johnson and Blossom, 2017.

ID	Name	Figure	Months	General Resource	Specific Resource	Reference
106	Shaviovik River	A3c	Jan-Dec	Anadromous & Marine Nearshore Fish	Ps, DVp, Arctic char, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Craig and Poulin, 1975; Jarvela and Thorsteinson, 1998; Johnson and Blossom, 2017.
GLSs Marine Waters						
139	Noatak River	A5c	Jan-Dec	Anadromous & Marine Nearshore Fish	CHs,Kp,Pp,COp,Sp,DVp, Wp, SF	Johnson and Blossom, 2017.
140	Cape Krusenstern	A5a	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp.Sp,Pp,COp,Sp,DVp,Wp	Johnson and Blossom, 2017.
141	Wulik and Kivalina Rivers	A5a	Jan-Dec	Anadromous & Marine Nearshore Fish	CHs,COp,Ks,Pp,Ss,DVs,Wp	Johnson and Blossom, 2017.
152	Kuk River	A5b	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp,Pp,BWp,LCp, OMp	Johnson and Blossom, 2017.
166	Arctic National Wildlife Refuge	A5b	Jan-Dec	Anadromous & Marine Nearshore Fish	CHp,Pp,DVr,Wp,Kp,COp,OMp, Arctic char, least cisco, herring, capelin, Arctic cod, saffron cod, sculpin species, eelpout species, Arctic flounder, starry flounder, sand lance	Johnson and Blossom, 2017; U.S. Fish and Wildlife Service, 2013.
LSs Russia						
25	Amguema R.	A-4a	May-Oct	Anadromous Fish	CHs, Ps, ALp, DVs, ACs, Kp, Sp, COp, Ws, OMp	Andreev, 2001.
31	Kolyuchinskaya Bay	A-4a	May-Oct	Anadromous Fish	Ps, Ks, DVs, ACs, Wp, OMp	Andreev, 2001.
37	Chegitun R.	A-4a	May-Oct	Anadromous Fish	Bering Cisco, ACs, DVs, Ps, Ks, CHs, Ss, OMp	Andreev, 2001.
38	Inchoun Lagoon	A-4a	May-Oct	Anadromous Fish	CHp, Pp, Kp, COp, Sp, Bering Cisco, Least Cisco	Andreev, 2001.
39	Uelen Lagoon	A-4a	May-Oct	Anadromous Fish	CHp, Pp, Kp, COp, Sp, Bering Cisco, Least Cisco	Andreev, 2001.
LSs United States						
40	Mint R.	A-4b	May-Oct	Anadromous Fish	CHs, Ps, Sp, DVpr	Johnson and Blossom, 2017.
41	Pinguk R.	A-4b	May-Oct	Anadromous Fish	CHs, Pp, DVp, Wp	Johnson and Blossom, 2017.
42	Upkuarok C., Nuluk R., Kugrupaga R., Trout C.	A-4b	May-Oct	Anadromous Fish	DVpr, CHs, Ps, DVp, Wp, DVp, DVpr, Wp	Johnson and Blossom, 2017.
43	Shishmaref Airport	A-4b	May-Oct	Anadromous Fish	DVp	Johnson and Blossom, 2017.
44	Shishmaref Inlet, Arctic R., Sanaguich R., Serpentine R.	A-4b	May-Oct	Anadromous Fish	DVp, SFp, Wp, CHp	Johnson and Blossom, 2017.
47	Kitluk R.	A-4b	May-Oct	Anadromous Fish	Pp	Johnson and Blossom, 2017.
49	Kougachuk C.	A-4b	May-Oct	Anadromous Fish	Pp	Johnson and Blossom, 2017.
51	Inmachuk R., Kugruk R.	A-4b	May-Oct	Anadromous Fish	CHs, Ps, DVp, CHp, Pp, DVp	Johnson and Blossom, 2017.
53	Kiwalik R., Buckland R.	A-4b	May-Oct	Anadromous Fish	CHp, Pp, DVp, CHp, COp, Kp, Pp, DVp, Wp	Johnson and Blossom, 2017.
54	Baldwin Penn Kobuk R., & Channels	A-4b	May-Oct	Anadromous Fish	DVp, DVs, CHp, Kp, Pp, DVs, SFp, Wp	Johnson and Blossom, 2017.
55	Hotham Inlet Ogriveg R.	A-4b	May-Oct	Anadromous Fish	CHp, Pp, DVs, Wp CHp, Pp, DVp	Johnson and Blossom, 2017.
56	Noatak R.	A-4b	May-Oct	Anadromous Fish	CHp, COp, Kp, Pp, Sp, DVp, SFp, Wpr	Johnson and Blossom, 2017.
57	Aukulak Lagoon	A-4b	May-Oct	Anadromous Fish	Wp	Johnson and Blossom, 2017.
58	Tasaychek Lagoon	A-4b	May-Oct	Anadromous Fish	Pp	Johnson and Blossom, 2017.

ID	Name	Figure	Months	General Resource	Specific Resource	Reference
59	Kiligmak Inlet Jade C., Rabbit C., Imik Lagoon New Heart C., Omikviorok R.	A-4b	May-Oct	Anadromous Fish	DVp, Wp DVp CHp, Sp, DVp Wp DVr DVp, Wp	Johnson and Blossom, 2017.
60	Imikruk Lagoon Wulik R., Kivalina R.	A-4b	May-Oct	Anadromous Fish	Wp, CHp, COp, Kp, Pp, Sp, DVs, Wp CHp, CHs, Pp, DVp	Johnson and Blossom, 2017.
64	Sulupoaktak Chnl	A-4b	May-Oct	Anadromous Fish	Pp, DVp	Johnson and Blossom, 2017.
67	Pitmegea R.	A-4b	May-Oct	Anadromous Fish	CHp, Pp, DVp	Johnson and Blossom, 2017.
70	Kuchiak C.	A-4b	May-Oct	Anadromous Fish	CHs, COs	Johnson and Blossom, 2017.
71	Kukpowruk R.	A-4b	May-Oct	Anadromous Fish	CHp, Pp, DVp	Johnson and Blossom, 2017.
72	Pt Lay, Kokolik R.	A-4b	Jun-Oct	Anadromous Fish	CHp, Pp, DVp	Johnson and Blossom, 2017.
74	Utukok R.	A-4b	Jun-Oct	Anadromous Fish	CHp, Pp, DVp	Johnson and Blossom, 2017.
80	Kugrua R.	A-4b	Jun-Oct	Anadromous Fish	CHs,Ps	Johnson and Blossom, 2017.
87	Inaru R., Meade R., Topagoruk R., Chipp R.	A-4c	Jun-Oct	Anadromous Fish	Wsr CHs,Wp Wsr Ps,Wsr	Johnson and Blossom, 2017.
89	Ikpikpuk R.	A-4c	Jun-Oct	Anadromous Fish	Psr,Wsr	Johnson and Blossom, 2017.
91	Smith R.	A-4c	Jun-Oct	Anadromous Fish	DVp,Wp	Johnson and Blossom, 2017.
93	Kalikpik R.	A-4c	Jun-Oct	Anadromous Fish	Wp	Johnson and Blossom, 2017.
94	Fish C., Nechelik Channel	A-4c	Jun-Oct	Anadromous Fish	CHp,Kp,Pp,DVp,Wp Wp	Johnson and Blossom, 2017
95	Colville R. & Delta	A-4c	Jun-Oct	Anadromous Fish	CHp,Pp,DVp,Wp	Johnson and Blossom, 2017.
96	Kalubik R., Ugnuravik R.	A-4c	Jun-Oct	Anadromous Fish	DVp,Wp Wr	Johnson and Blossom, 2017.
97	Oogrukpuk R., Sakonowyak R.	A-4c	Jun-Oct	Anadromous Fish	Wpr Wr	Johnson and Blossom, 2017.
98	Kuparuk R., Fawn C., Unnamed 10435,	A-4c	Jun-Oct	Anadromous Fish	DVr,DVp,Wp,OMp,Wr	Johnson and Blossom, 2017.
99	W. Channel Sagavanirktok R., Sagavanirktok R., E. Sagavanirktok C.	A-4c	Jun-Oct	Anadromous Fish	ACp,Chp,Pp,DVr,Wp DVr	Johnson and Blossom, 2017.
100	E. Sagavanirktok C., Kadleroshilik R., Kavik R., Shaviovik R., 10300 (AWC#)	A-4c	Jun-Oct	Anadromous Fish	DVr, DVp, Ps	Johnson and Blossom, 2017.
101	E Badami C., 10300 (AWC#), 10280 (AWC#)	A-4c	Jun-Oct	Anadromous Fish	DVr	Johnson and Blossom, 2017.
102	10246 (AWC#), 10238 (AWC#) 10234 (AWC#) Staines R.	A-4c	Jun-Oct	Anadromous Fish	DVr Pp,DVp,Wp	Johnson and Blossom, 2017.
103	W. Canning R., Canning R., Canning R., Tamayariak R.	A-4c	Jun-Oct	Anadromous Fish	DVs , Pp,DVp,Wp CHp,Pp,DVp,Wp DVr	Johnson and Blossom, 2017.
104	Katakturik R., 10193 (AWC#)	A-4c	Jun-Oct	Anadromous Fish	DVp DVr	Johnson and Blossom, 2017.
105	Marsh C., Carter C.	A-4c	Jun-Oct	Anadromous Fish	DVr DVr	Johnson and Blossom, 2017.
106	Nataroarok C., Hulahula R., Okpilak R., 10173 (AWC#)	A-4c	Jun-Oct	Anadromous Fish	DVr DVp DVp DVr	Johnson and Blossom, 2017.
107	Jago R., Kimikpaurauk R.	A-4c	Jun-Oct	Anadromous Fish	DVp DVr	Johnson and Blossom, 2017.

ID	Name	Figure	Months	General Resource	Specific Resource	Reference
109	Siksik R., Sikrelurak R., Angun R., 10150-2004 (AWC#) Kogotpak 10140-2006 (AWC#)	A-4c	Jun-Oct	Anadromous Fish	DVr DVr DVr DVr DVp DVr	Johnson and Blossom, 2017.
110	Aichilik R., Egaksrak R., Kongakut R.	A-4c	Jun-Oct	Anadromous Fish	DVp DVp DVp	Johnson and Blossom, 2017.
LSs Canada						
112	Fish R.	A-4c	Jun-Oct	Anadromous Fish	ACp, Wp	Craig, 1984; Kendel et al., 1974.
113	Malcolm R.	A-4c	Jun-Oct	Anadromous Fish	ACp, OMp	Craig, 1984.
114	Firth R.	A-4c	Jun-Oct	Anadromous Fish	ACp,OMp	Craig, 1984.
116	Spring R.	A-4c	Jun-Oct	Anadromous Fish	ACp, Wp, SFp, OMp, sculpin spp.	Craig, 1984; Majewski et al, 2013.
117	Babbage R.	A-4c	Jun-Oct	Anadromous Fish	ACp, Wp	Craig, 1984.
119	Blow R.	A-4c	Jun-Oct	Anadromous Fish	ACp, Wp, SFp	Craig, 1984.
122-126	Mackenzie R.	A-4c	Jun-Oct	Anadromous Fish	ACp, Wp, CHp, OMp, SFp	Craig, 1984.
127-132	Kugmallit Bay Tuktoyaktuk Peninsula	A-4c	Jun-Oct	Anadromous & Marine Nearshore Fish	AC, DV, OM, Arctic cisco, Least Cisco, Whitefish spp., Arctic cod, Saffron cod, Pacific herring, Arctic flounder, Starry flounder, Sculpin spp.	Niemi, et al., 2012

Key: LS Name = Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes AC = Arctic Char AL = Arctic lamprey
CH = Chum salmon CO = Coho salmon DV = Dolly Varden K = Chinook salmon OM = Rainbow smelt P = Pink salmon
p = present r = rearing s = spawning SF = Sheefish S = Sockeye salmon W = Whitefish (undifferentiated)

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A4 Environmental Resource Areas and Boundary Segments Used in the Analysis of Marine Mammals (Whales)

ID	Name	Figure	Months	Specific Resource	Reference
ERAs					
1	Kasegaluk Lagoon Area	A3d	May-Oct	Beluga Whales	Frost and Lowry, 1990; Frost, Lowry, and Carroll, 1993; Suydam et al., 2001; Suydam, Lowry, and Frost, 2005; Citta et al., 2013.
20	East Chukchi Offshore	A3f	Sept-Oct	Bowhead Whales, Beluga Whales – fall migration, feeding	Clarke, Christman, et al., 2013; Clarke, Brower, et al., 2014; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Hauser et al., 2014; Ljungblad et al., 1988; Martell, Dickinson, and Casselman, 1984; Melnikov and Bobkov, 1993; Quakenbush and Citta, 2013; Quakenbush, Small and Citta, 2013.
21	AK BFT Bowhead FM 8	A3b	Sept-Oct	Bowhead Whales, Beluga Whales – fall migration	Clarke, Christman, et al., 2013; Clarke, Brower, et al., 2014; Hauser et al., 2014; Ljungblad et al., 1988; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.

ID	Name	Figure	Months	Specific Resource	Reference
22	AK BFT Bowhead FM 7	A3b	Sept-Oct	Bowhead Whales – fall migration	Clarke, Brower, Ferguson, and Willoughby, 2017a,b; Clarke, Brower, Ferguson, and Kennedy, 2015a; Clarke, Brower, et al., 2014; Clarke, Christman, Brower, and Ferguson, 2012, 2013; Clarke, Christman, Brower, Ferguson, and Grassia, 2011a; Clarke, Christman, Ferguson, and Grassia, 2011b; Clarke, Christman, Ferguson, Grassia, and Brower, 2011c; Clarke, Ferguson, Christman, Grassia, Brower, and Morse, 2011d; Ljungblad et al., 1988; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
24	AK BFT Bowhead FM 6	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
25	AK BFT Bowhead FM 5	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
26	AK BFT Bowhead FM 4	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
27	AK BFT Bowhead FM 3	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
28	AK BFT Bowhead FM 2	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
29	AK BFT Bowhead FM 1	A3b	Sept-Oct	Same as ERA22.	Same as ERA22.
30	Beaufort Spring Lead 1	A3c	Apr-Jun	Bowhead Whales, Beluga Whales – spring migration	Clarke, Christman, Brower, and Ferguson, 2013; Ljungblad et al., 1988; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
31	Beaufort Spring Lead 2	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
32	Beaufort Spring Lead 3	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
33	Beaufort Spring Lead 4	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
34	Beaufort Spring Lead 5	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
35	Beaufort Spring Lead 6	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
36	Beaufort Spring Lead 7	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
37	Beaufort Spring Lead 8	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
45	Beaufort Spring Lead 9	A3c	Apr-Jun	Same as ERA30.	Same as ERA30.
49	Chukchi Spring Lead 1	A3g	Apr-Jun	Bowhead Whales, Gray Whales, Beluga Whales – spring migration – spring leads – Chukchi	Bogoslovskaya, Votrogov, and Krupnik, 1982; Clarke, Christman, Brower, and Ferguson, 2013; Doroshenko, and Kolesnikov, 1984; George et al., 2012; Ljungblad et al., 1986, 1988; Miller, Rugh, and Johnson, 1986; Melnikov, Zelensky, and Ainana, 1997; Melnikov, Litovka, et al., 2004; Melnikov and Zeh, 2007; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Stringer and Groves, 1991.
51	Kotzebue Sound	A3e	Jan-Dec	Beluga Whales	Suydam et al., 2001; Suydam, Lowry, and Frost, 2005.
53	Chukchi Spring Lead 2	A3d	Apr-Jun	Same as ERA49	Same as ERA49.
54	Chukchi Spring Lead 3	A3d	Apr-Jun	Same as ERA49	Same as ERA49.
56	Hanna Shoal Area	A3g	Aug-Oct	Bowhead Whales, historically Gray Whales (Hanna Shoal)	Clarke, Christman, Brower, and Ferguson, 2013; Ljungblad et al., 1986; Moore, DeMaster and Dayton. 2000; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
60	King Point-Shallow Bay (Canada)	A3b	Apr-Sept	Beluga Whales	Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Harwood et al., 1996, 2010; Martell, Dickinson, and Casselman, 1984.

ID	Name	Figure	Months	Specific Resource	Reference
61	Pont Lay–Utqiaġvik BH GW SFF	A3f	Jul-Oct	Bowhead Whales, Gray Whales; summer-fall feeding, Gray and Bowhead Whale cow/calf aggregations and bowhead fall migration	Bogoslovskaya, Votrogov, and Krupnik, 1982; Clarke, Brower, Ferguson, and Willoughby, 2017a,b; Clarke, Brower, Ferguson, and Kennedy, 2015a; Clarke, Brower, Christman, and Ferguson, 2014; Clarke, Christman, Brower, and Ferguson, 2012, 2013; Clarke, Christman, Brower, Ferguson, and Grassia, 2011a; Clarke, Christman, Ferguson, and Grassia, 2011b; Clarke, Christman, Ferguson, Grassia, and Brower, 2011c; Clarke, Ferguson, Christman, Grassia, Brower, and Morse, 2011d; George et al., 2012; Ljungblad et al., 1988; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Moore and DeMaster, 1997; Moore, George, et al., 1995; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
63	North Chukchi	A3g	Oct-Dec	Bowhead Whales	Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
65	Smith Bay	A3c	May-Oct	Bowhead Whales	Clarke, Brower, Ferguson, and Kennedy, 2015a; Clarke, Ferguson, Curtice, and Harrison, 2015b.
70	North Central Chukchi	A3g	Oct-Dec	Bowhead Whales	Ainana, Zelenski, and Bychkov, 2001; Bogoslovskaya, Votrogov, and Krupnik, 1982; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
82	North Chukotka Nearshore 2	A3g	Jul-Oct	Bowhead Whales: Chukotka coast spring migration; Bowhead Whales, Gray Whales; summer-fall feeding and bowhead fall migration	Bogoslovskaya et al., 2016; Bogoslovskaya, Votrogov, and Krupnik, 1982; George et al., 2012; Heide-Jorgensen et al., 2012; Ljungblad et al., 1988; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Moore and DeMaster, 1997; Moore et al., 1995; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
83	North Chukotka Nearshore 3	A3g	Jul-Dec	Same as ERA82.	Same as ERA82.
91	Bowhead Whale Summer (Canada)	A3c	Jul-Oct	Bowhead Whale – summer concentration	Braham, Fraker, and Krogman. 1980; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Harwood, Auld and Moore, 2010; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small and Citta. 2013.
101	Offshore Herald Island/Hope Sea Valley	A3g	Oct - Dec	Bowhead Whales	Bogoslovskaya, Votrogov, and Krupnik, 1982; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
107	Point Hope Offshore	A3f	Jun-Sept	Gray Whales, Fin Whales, Humpback Whales summer fall aggregation	Clarke, Christman, Brower, and Ferguson, 2013 (Maps 6, 13); Friday et al., 2014; George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
108	Utqiaġvik Feeding Aggregation	A3f	Sept-Oct	Bowhead Whales, Gray Whales – feeding aggregation – fall	Clarke, Christman, Brower, and Ferguson, 2012, 2013; Ljungblad et al., 1988; Monnett and Treacy, 2005; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
109	AK BFT Shelf Edge	A3c	Jul-Aug	Bowhead Whales-cow/calf and feeding aggregation	Christman et al., 2013; Clarke, Christman, Brower, and Ferguson, 2012, 2013.
110	AK BFT Outer Shelf & Slope 1	A3b	Jul-Oct	Beluga Whales – summer-fall feeding concentration and movement corridor	Clarke Christman, Brower, and Ferguson, 2012, 2013; Clarke, Brower, Ferguson, and Willoughby, 2017a,b; Clarke, Brower, Ferguson, and Kennedy, 2015a; Clarke, Brower, Christman, and Ferguson, 2014; Clarke, Christman, Brower, Ferguson, and Grassia, 2011a; Clarke, Christman, Ferguson, and Grassia, 2011b; Clarke, Christman, Ferguson, Grassia, and Brower, 2011c; Clarke, Ferguson, Christman, Grassia, Brower, and Morse, 2011d; Richard, Martin and Orr, 1998, 2001.

ID	Name	Figure	Months	Specific Resource	Reference
111	AK BFT Outer Shelf & Slope 2	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
112	AK BFT Outer Shelf & Slope 3	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
113	AK BFT Outer Shelf & Slope 4	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
114	AK BFT Outer Shelf & Slope 5	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
115	AK BFT Outer Shelf & Slope 6	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
116	AK BFT Outer Shelf & Slope 7	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
117	AK BFT Outer Shelf & Slope 8	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
118	AK BFT Outer Shelf & Slope 9	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
119	AK BFT Outer Shelf & Slope 10	A3b	Jul-Oct	Same as ERA110.	Same as ERA110.
120	Chukchi Gray Whale Fall (Russia)	A3e	Sept-Oct	Gray Whales – fall feeding aggregation	Bogoslovskaya, Votrogov, and Krupnik, 1982; Doroshenko and Kolesnikov, 1983; George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
121	Cape Lisburne–Pt Hope	A3e	Jun-Sept	Gray Whale-cow/calf aggregation	Ljungblad et al., 1988.
122	Bowhead Fall (Canada)	A3c	Oct-Dec	Bowhead Whale – fall migration & feeding	Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small and Citta. 2013;
BSs					
2	RusCh C Dezhnev	A-1	May-Oct	Gray Whales, Beluga Whales, Humpback Whales, Bowhead Whales	Clarke, Christman, Brower, and Ferguson, 2013 (Maps 6, 13); George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
39-40	Amundsen Gulf BH Spring	A-1	May-Jul	Bowhead Whale – spring aggregation	Braham, Fraker, and Krogman, 1980; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.

Key: AK = Alaska BFT = Beaufort BH = Bowhead ERA = Environmental Resource Area FM = Fall Migration GW = Gray Whale
ID = identification (number) Isl. = Island Pt. = Point SFF = Summer Fall Feeding

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A5 Environmental Resource Areas, Land Segments and Grouped Land Segments Used in the Analysis of Marine Mammals (Polar Bears)

ID	Name	Figure	Months	Specific Resource	Reference
ERAs					
11	Wrangel Island 12 nmi & Offshore	A3g	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr),	Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Durner et al., 2006; Federal State Budget Institution, 2014; Kochnev, 2006; Ovsyanikov, 2012; Solovyev et al., 2012; Stishov, 1991; Upenski and Kistchinski, 1972; Wilson et al., 2014.
23	Polar Bear Offshore	A3g	Nov-Jun	Polar Bears	Wilson et al., 2014, 2016.
55	Point Barrow, Plover Islands	A3b	Jan-Dec	Polar Bears	Kalxdorff et al., 2002.
59	Ostrov Kolyuchin	A3f	Jul-Nov	Polar Bears	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Kochnev, 2006,

ID	Name	Figure	Months	Specific Resource	Reference
66	Herald Island	A3g	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	Amstrup and Gardner, 1994; Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Durner et al., 2006; Federal State Budget Institution, 2014; Ovsyanikov, 1998; Ovsyanikov and Menyushina, 2012; Rode et al., 2015; Stishov, 1991.
74	Hershel Island	A3c	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	Durner et al., 2004; Stirling and Andriashek, 1992.
92	Thetis, Jones, Cottle & Return Isl.	A3a-1	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	ACS, 2017; Durner, Amstrup, and Fischbach, 2003; Durner et al., 2004; Kalxdorff et al., 2002.
93	Cross and No Name Islands	A3a-2	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	ACS, 2017; Durner et al., 2004; Kalxdorff et al., 2002; Miller, Schliebe, and Proffitt, 2006.
94	Maguire, Flaxman & Barrier Isl.	A3a-1	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	ACS, 2017; Amstrup and Gardner, 1994; Durner 2005; Durner, Amstrup, and Fischbach, 2003; Durner et al., 2004; Kalxdorff et al., 2002.
95	Arey & Barter Isls. & Bernard Spit	A3a-2	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	ACS, 2017; Amstrup and Gardner, 1994; Durner et al., 2004; Kalxdorff et al., 2002; Miller, Schliebe, and Proffitt, 2006.
LSs					
65	Buckland, Cape Dyer, Cape Lewis, Cape Lisburne	A4b	Jan-Dec	Polar Bear denning (Oct-Apr)	ACS, 2017; Voorhees and Sparks, 2012.
85	Utqiaġvik, Browerville, Elson Lag.	A4b	Jan-Dec	Polar Bears (August-November)	ACS, 2017; Durner et al., 2006; Kalxdorff et al., 2002.
100	Foggy Island Bay	A4c	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	Durner, 2005; Hilcorp Alaska, LLC, 2015, Figure 3.12.1-1; Schliebe et al., 2008; Streever and Bishop, 2014.
GLSs					
133	Bukhta Somnitel'naya (Somnitel'naya Spit), Davidova Spit	A5c	Jan-Dec	Polar Bears, Polar Bear denning (Oct-Apr)	Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, Semenova, 2012; Durner et al., 2006; Kochnev, 2006; Ovsyanikov, 2003, 2012; Rode et al., 2015; Solovyev et al., 2012.
145	Cape Lisburne	A5b	Jan-Dec	Polar Bear denning (Oct-Apr)	ACS, 2017.
158	Colville River Delta	A5a	Oct-Apr	Polar Bear denning	ACS, 2017; Blank, 2013.
162	96 -115 Summer	A5a	Jun-Aug	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59), Durner et al., 2004.
164	99-115 Fall	A5b	Sept-Nov	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59) Durner et al., 2004.
165	102-110 Winter	A5a	Oct-Apr	Polar Bear denning	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner, 2005; Durner, Amstrup, and Ambrosius, 2005; Durner, Amstrup, and Fischbach, 2003.
172	112-132 Spring	A-5a	Mar-May	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004; Pilford, 2014.
173	112-121 Winter	A-5b	Dec-Feb	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004.
176	122-132 Spring	A5a	Mar-May	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004; Pilford, 2014.
177	122-132 Winter	A5a	Dec-Feb	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004.
180	Russia Chukchi Coast Marine Mammals	A5c	Jul-Nov	Polar Bears	Belikov, Boltunov, and Gorbunov, 1996; Boltunov,Nikiforov, and Semenova, 2012; Durner et al., 2006; Kochnev, 2006; Ovsyanikov, 2012; Stishov, 1991.

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A6 Environmental Resource Areas, Land Segments, and Grouped Land Segments Used in the Analysis of Marine Mammals (Walrus)

ID	Name	Figure	Months	Specific Resource	Reference
ERAs					
11	Wrangel Island 12 nmi & Offshore	A3g	Jan-Dec	Walrus (Jul-Nov)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov,Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Federal State Budget Institution, 2014; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004a,b; Ovsyanikov, 2013.
15	Cape Lisburne Seabird Colony Area	A3f	May-Oct	Walrus	ACS, 2017; Christman, 2013; Fay, 1982; Huntington and Quakenbush, 2013; Robards, 2013.
47	Hanna Shoal Walrus Use Area	A3e	May-Oct	Walrus	Jay, Fischbach, and Kochnev and Kozlov, 2012, Figures 4 & 5, pp. 8-9; Kuletz et al., 2015.
50	Pt Lay Walrus	A3d	May-Oct	Walrus	ACS, 2015; Fay et al., 1984; Huntington, Nelson, and Quakenbush, 2012; Huntington, Quakenbush, and Nelson, 2017; Jay, Fischbach, and Kochnev and Kozlov, 2012, Figures 4 & 5, pp. 8-9; Kuletz et al., 2015; Quakenbush, Crawford, et al., 2016..
52	Russian Coast Walrus Offshore	A3f	May-Nov	Walrus	Jay, Fischbach, and Kochnev and Kozlov, 2012, Figures 4 & 5, pp. 8-9.
58	Russian Coast Walrus Nearshore	A3f	May-Nov	Walrus	Fay et al., 1984; Jay, Fischbach, and Kochnev and Kozlov, 2012, Figures 4 & 5, pp. 8-9.
59	Ostrov Kolyuchin	A3f	July-Nov	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Gilbert et al., 1992; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2013a, 2013b; Kochnev and Kozlov, 2012; Kochnev et al., 2003; Pereverez and Kochnev, 2012.
66	Herald Island	A3g	Jan-Dec	Walrus (Jul-Nov)	Belikov, Boltunov, and Gorbunov, 1996; Fay, 1982; Federal State Budget Institution, 2014; Gilbert et al., 1992.
LSs					
22	Mys Shmidta (Cape Schmidt), Cape Kozhevnikov, Ryrkaipii	A-4a	Jan-Dec	Walrus (Jul-Nov)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Gilbert et al., 1992; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2013a,b; Robards, 2013.
28	Ostrov Karkarpko, Mys Vankarem (Cape Vankarem)	A-4a	Jan-Dec	Walrus (Jul-Nov)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2004a,b, 2013a, 2013b; Kryukova and Kochnev, 2012.
29	Mys Onmyn (Cape Onmyn)	A-4a	Jan-Dec	Walrus (Jul-Nov)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Kochnev, 2004a,b; Kryukova and Kochnev, 2012.
31	Kosa Belyaka (Belyaka Spit)	A-4a	Jan-Dec	Walrus (Jul-Nov)	Robards, 2013.
38	Mys Unikin (Cape Unikyn)	A-4a	Jan-Dec	Walrus (Jul-Nov)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Kochnev, 2004a,b, 2013a.
39	Mys Dezhnev, Mys Peek (Cape Dehznev, Cape Peek	A-4a	Jan-Dec	Walrus (Jul-Nov)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Fedoseev, 1981; Kochnev, 2004a,b, 2013a.
75	Icy Cape	A-4b	Jan-Dec	Walrus (July- Nov)	Christman, 2013; Fischbach, Monson, and Jay, 2009; Huntington, Quakenbush, and Nelson, 2017; Huntington, Nelson, and Quakenbush, 2012; Robards, 2013.

ID	Name	Figure	Months	Specific Resource	Reference
GLSs					
133	Bukhta Somnitel'naya (Somnitel’naya Spit), Davidova Spit	A5c	Jan-Dec	Walrus (Jul-Nov)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, Semenova, 2012; Fay, 1982; Gilbert et al., 1992; Kochnev, 2004a,b; 2013b.
135	Ostrov Idlidlya (Ididlya Island)	A5c	Jul-Nov	Walrus	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004a,b.
136	Mys Serditse Kamen (Cape Serdtse-Kamen)	A5c	Jul-Nov	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Chakilev, Dondua, and Kochnev , 2012; Fay, 1982; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004a,b, 2013a.
137	Chukotka Coast Haulout	A5c	Jul-Nov	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992; Jay, Fischbach, and Kochnev and Kozlov, 2012, Figures 4 & 5, pp. 8-9; Kochnev, 2013a.
145	Cape Lisburne	A5b	Jan-Dec	Walrus (Aug-Nov)	ACS, 2015; Christman, 2013; Fay, 1982; Fay et al., 1984; Huntington and Quakenbush, 2013; Robards, 2013.
148	Point Lay Haulout	A5a	Jul-Nov	Walrus	Christman, 2013; Fischbach, Monson, and Jay, 2009; Huntington, Quakenbush, and Nelson, 2017; Huntington, Nelson, and Quakenbush, 2012; Robards, 2013.
180	Russia Chukchi Coast Marine Mammals	A5c	Jul-Nov	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov,Nikiforov, and Semenova, 2012; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992.

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A7 Environmental Resource Areas, Grouped Land Segments, and Land Segments Used in the Analysis of Marine Mammals (Ice Seals)

ID	Name	Figure	Months	Specific Resource	Reference
ERAs					
1	Kasegaluk Lagoon Area	A3d	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
46	Wrangel Island 12 nmi Buffer 2	A3g	Dec-May	Bearded & Ringed Seals	Cameron, Bengtson, et al., 2010; Kelly et al., 2010.
48	Chukchi Lead System 4	A3e	Dec-May	Bearded & Ringed Seals	Cameron, Bengtson, et al., 2010; Kelly et al., 2010.
62	Herald Shoal Polynya 2	A3g	Dec-May	Ringed & Bearded Seals	Cameron, Bengtson, et al., 2010; Kelly et al., 2010.
64	Peard Bay Area/Franklin Spit Area	A3d	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
65	Smith Bay: Spotted Seal Haulout	A3c	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
68	Harrison Bay	A3a-1	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
69	Harrison Bay/Colville Delta	A3a-2	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
GLSs					
134	Kolyuchin Bay	A5c	Jun-Nov	Spotted & Ringed Seals	Boveng et al., 2009; Heptner et al., 1996; Kelly et al., 2010.
155	Smith Bay Spotted Seal Haulout	A5b	May-Oct	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
159	Harrison Bay Spotted Seal Haulout	A5b	Jun-Sept	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A8 Grouped Land Segments Used in the Analysis of Terrestrial Mammals.

GLS ID	Name	Map	Months	Specific Resource	Reference
142	WAH Insect Relief	A5c	Jul-Aug	Caribou	ADF&G, 2001; Person et al., 2007.
146	Ledyard Brown Bears	A5b	Jun-Oct	Brown Bears	ADF&G, 1986; ADF&G, 2001.
149	Kasegaluk Brown Bears	A5b	Jun-Oct	Brown Bears	ADF&G, 1986; ADF&G, 2001.
153	TCH Insect Relief/Calving	A5b	May-Aug	Caribou	ADF&G, 1986; ADF&G, 2001; Carroll et al., 2011; Person et al., 2007.
160	CAH Insect Relief/Calving	A5b	May-Aug	Caribou	ADF&G, 1986; ADF&G, 2001; Arthur and Del Vecchio, 2009; Cameron, Smith, et al., 2002; 2005; Lawhead and Prichard, 2007; Wolfe, 2000.
163	Beaufort Muskox	A5b	Nov-May	Muskox	ADF&G, 2001; Environment Yukon, 2009; Lawhead and Prichard, 2007; Reynolds, Wilson, and Klein, 2002.
168	PCH Insect Relief	A5b	Jul-Aug	Caribou	ADF&G, 2001; Environment Yukon, 2009; Nixon and Russell, 1990.
169	PCH Calving	A5a	May-Jun	Caribou	ADF&G, 2001; Environment Yukon, 2009; Fancy et al., 1989; Griffith et al., 2002.
170	Yukon Muskox Wintering	A5b	Nov-Apr	Muskox	Environment Yukon, 2009.
174	Yukon Moose	A5b	Jan-Dec	Moose	Environment Yukon, 2009.
179	Tuktoyaktuk & Cape Bathurst Caribou Insect Relief	A-5a	Jul-Aug	Caribou	Gunn, Russell, and Eamer, 2011; Nagy et al., 2005.

Key: CAH = Central Arctic Herd PCH = Porcupine Caribou Herd TCH = Teshekpuk Caribou Herd WAH = Western Arctic Herd

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A9 Environmental Resource Areas and Grouped Land Segments Used in the Analysis of Birds

ID	Name	Map	Months	Specific Resource	Reference
ERAs					
1	Kasegaluk Lagoon Area	A3d	May-Oct	Birds: BLBR, LTDU, eiders (STEI, COEI), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Johnson, 1993; Johnson, Wiggins, and Wainwright, 1993; Laing and Platte, 1994; Lehnhausen and Quinlan, 1981; Morgan, Day, and Gall, 2012; Seabird Information Network, 2015.
2	Point Barrow, Plover Islands	A3c	May-Oct	Birds: SPEI, LTDU, BLBR, BLGU	Dau and Bollinger, 2009; Fischer and Larned, 2004; Ritchie et al, 2013; Seabird Information Network, 2015; Troy, 2003.
5	Beaufort Sea Shelf Edge IBA	A3d	May-Oct	Birds: GLGU; POJA	Audubon Alaska, 2015; Smith et al., 2012 (p. 31).
8	Maguire and Flaxman Islands	A3a-2	May-Oct	Birds: nesting COEI, molting LTDU, PALO	Dau and Bollinger, 2009, 2012, Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000; Johnson, Noel, Gazey, and Hawkes, 2005; Noel et al., 2005; Seabird Information Network, 2015.
9	Stockton and McClure Islands	A3a-1	May-Oct	Birds: nesting COEI, molting LTDU, staging SPEI	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000, (Table 2); Johnson, Noel, Gazey, and Hawkes, 2005; Noel et al., 2005; Seabird Information Network, 2015; Troy, 2003.

ID	Name	Map	Months	Specific Resource	Reference
10	Ledyard Bay SPEI Critical Habitat Unit	A3f	July-Nov	Birds: seabirds, molting/staging SPEI, staging YBLO	66 FR 9146-9185; Laing and Platte, 1994; Morgan, Day, and Gall, 2012; Petersen, Larned, and Douglas, 1999; Piatt and Springer, 2003.
14	Cape Thompson Seabird Colony Area	A3g	May-Oct	Birds: seabirds, gulls, shorebirds, waterfowl, staging YBLO	Morgan, Day, and Gall, 2012; Piatt et al., 1991; Piatt and Springer, 2003; Seabird Information Network, 2015; Springer et al., 1984; Stephensen and Irons, 2003.
15	Cape Lisburne Seabird Colony Area	A3f	May-Oct	Birds: seabird breeding colony, staging YBLO	Dragoo and Balland, 2014; Dragoo, Thomson and Romano, 2017; Morgan, Day, and Gall, 2012; Oppel, Dickson, and Powell, 2009; Piatt et al., 1991; Piatt and Springer, 2003; Roseneau et al., 2000; Seabird Information Network, 2015; Springer et al., 1984; Stephensen and Irons, 2003.
17	Angun and Beaufort Lagoons	A3a-1	May-Oct	Birds: molting LTDU, scoters, staging shorebirds	Dau and Bollinger, 2009, 2012; Johnson and Herter, 1989.
18	Murre Rearing and Molting Area	A3g	May-Oct	Birds: murre foraging, rearing, and molting area	Piatt and Springer, 2003; Springer et al., 1984.
19	Chukchi Sea Spring Lead System	A3d	Apr-Jun	Birds: seabird foraging area; spring migration area for LTDU, eiders (KIEI, COEI), loons	Connors, Myers, and Pitelka, 1979; Piatt et al., 1991; Piatt and Springer, 2003; Sexson, Pearce, and Petersen, 2014.
64	Peard Bay/ Franklin Spit Area	A3d	May-Oct	Birds: eiders (all 4 species), loons (all 3 species)	Fischer and Larned, 2004; Gill, Handel, and Connors, 1985; Laing and Platte, 1994.
65	Smith Bay	A3c	May-Oct	Birds: eiders (SPEI, KIEI), YBLO	Dau and Bollinger, 2009, 2012; Earnst et al., 2005; Powell et al., 2005; Ritchie, Burgess, and Suydam, 2000; Ritchie et al., 2004; Troy, 2003.
67	Herschel Island (Canada)	A3c	May-Oct	Birds: LTDU, BLBR, scoters, eiders, loons, shorebirds	Johnson and Richardson, 1982; Richardson and Johnson, 1981.
68	Harrison Bay	A3a-1	May-Oct	Birds: eiders (KIEI, COEI), scoters (BLSC, SUSC), geese (BLBR, CANG, GWFG), loons, shorebirds	Connors, Connors, and Smith, 1984; Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004.
69	Harrison Bay/Colville Delta	A3a-2	May-Oct	Birds: geese (BLBR), eiders (KIEI, COEI), LTDU, scoters (BLSC, SUSC), loons (all 3 species)	Bergman et al., 1977; Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Herter, 1989.
71	Simpson Lagoon, Thetis and Jones Islands	A3c	May-Oct	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Connors, Connors, and Smith, 1984; Divoky, 1984; Johnson, 2000; Johnson, Herter, and Bradstreet, 1987; Johnson and Herter, 1989; Noel and Johnson, 1997; Richardson and Johnson, 1981; Stickney and Ritchie, 1996; Truett, Miller, and Kertell, 1997.
72	Gwyder Bay, West Dock, Cottle and Return Islands	A3a-2	May-Oct	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson, 2000; Noel et al., 2005; Noel and Johnson, 1997; Powell et al., 2005; Stickney and Ritchie, 1996; Troy, 2003; Truett, Miller, and Kertell, 1997.
73	Prudhoe Bay	A3a-1	May-Oct	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Richardson, 1982; Noel and Johnson, 1997; Noel et al., 2005; Powell et al., 2005; Richardson and Johnson, 1981; Stickney and Ritchie, 1996; Troy, 2003; Truett, Miller, and Kertell, 1997.

ID	Name	Map	Months	Specific Resource	Reference
76	Kendall Island Bird Sanctuary (Canada)	A3c	May-Oct	Birds: eiders (KIEI, COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Alexander, Dickson, and Westover, 1997; Dickson et al., 1997; Divoky, 1984; Johnson and Richardson, 1982; Richardson and Johnson, 1981.
77	Sagavanirktok River Delta/Foggy Island Bay	A3a-2	May-Oct	Birds: eiders (SPEI, COE), LTDU, scoters (all 3 species), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Johnson, 2000; Johnson, Wiggins, and Wainwright, 1993; Sexson, Pearce, and Petersen, 2014; Troy, 2003.
78	Mikkelsen Bay	A3a-2	May-Oct	Birds: eiders (KIEI, COEI), LTDU, scoters, loons (PALO, RTLO)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000; Noel et al., 2005.
79	Demarcation Bay Offshore	A3c	May-Oct	Birds: eiders (KIEI, COEI), LTDU, scoters (SUSC, WWSC), loons, molting LTDU, staging shorebirds	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Richardson, 1982; Johnson and Herter, 1989; Richardson and Johnson, 1981.
80	Chukchi Sea Nearshore IBA	A3f	May-Oct	Birds: ARTE; BLKI; GLGU; LTDU; POJA; REPH; SAGU	Audubon Alaska, 2015, Smith et al., 2012 (p. 31)
81	Simpson Cove	A3a-1	May-Oct	Birds: COEI, LTDU, PALO, scoters (SUSC, WWSC)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Herter, 1989.
96	Midway, Cross and Bartlett Islands	A3a-1	May-Oct	Birds: eiders (SPEI,COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Johnson, 2000; Troy, 2003, (Figure 3).
98	Anderson Point Barrier Islands	A3a-1	May-Oct	Same as ERA96	Same as ERA96
99	Arey and Barter Islands, Bernard Spit	A3a-1	May-Oct	Same as ERA96	Same as ERA96
100	Jago and Tapkaurak Spits	A3a-1	May-Oct	Same as ERA96	Same as ERA96
104	Ledyard Bay-Icy Cape IBA	A3e	May-Oct	Birds: staging molting SPEI, BLKI; GLGU; POJA	Audubon Alaska, 2015; Smith et al., 2012 (p. 31).
GLSs					
147	Kasegaluk Lagoon Area IBA	A5b	May-Oct	Birds: ALTE; BLBR; COEI; DUNL; GLGU; GWFG; LTDU; RTLO; SPEI	Audubon Alaska, 2015 (Report 991).
156	Teshekpuk Lake Special Area (NPR-) IBA	A5c	May-Oct	Birds: AMGP; ARTE; BBPL; BBSA; BLBR; BLSC; BTGO; CACG; CAGO; DUNL; EMGO; GLGU; GOEA; GWFG; LBDO; LTDU; NOPI; PALO; PESA; REPH; RNPH; RTLO; SAGU; SEOW; SESA; SNGO; SPEI; STEI; STSA; TUSW; YBLO	Audubon Alaska, 2015 (Report 2781).
157	Colville River Delta IBA	A5a	May-Oct	Birds: GLGU	Audubon Alaska, 2015, Brown et al., 2007; Smith et al., 2012 (p. 31).
167	Northeast Arctic Coastal Plain IBA	A5b	May-Oct	Birds: AMGP; BBSA; DUNL; GOEA; PESA; REPH; RNPH; RTLO; RUTU; SEPL; SESA; SNGO; STSA; WHIM	Audubon Alaska, 2015 (Report 2816).

ID	Name	Map	Months	Specific Resource	Reference
178	Kendall Island Bird Sanctuary (Canada)	A5b	May-Oct	Birds:	Rausch and Johnston, 2012.

Key: ALTE = Aleutian Tern
AMGP = American Golden-Plover
ARTE = Arctic Tern
BBPL = Black-bellied Plover
BBSA = Buff-breasted Sandpiper
BLBR = Black Brant
BLKI = Black-legged Kittiwake
BLSC = Black Scoter
BTGO = Bar-tailed Godwit
CACG = Cackling Goose
CANG = Canada Goose
COEI = Common Eider
DUNL = Dunlin
EMGO = Emperor Goose
GLGU = Glaucous Gull
GOEA = Golden Eagle
GWFG = Greater White-fronted Goose
KIEI = King Eider
LBDO = Long-billed Dowitcher
LSGO = Lesser Snow Goose
LTDU = Long-tailed Duck
NOPI = Northern Pintail
PESA = Pectoral Sandpiper
PALO = Pacific Loon
POJA = Pomarine Jaeger
REPH = Red Phalarope
RNPH = Red-necked Phalarope
RTLO = Red-throated Loon
RUTU = Ruddy Turnstone
SAGU = Sabine's Gull
SEOW = Short-eared Owl
SEPL = Semipalmated Plover
SESA = Semipalmated Sandpiper
SNGO = Snow Goose
SPEI = Spectacled Eider
STEI = Steller's Eider
STSA = Stilt Sandpiper
SUSC = Surf Scoter
TUSW = Tundra Swan
WHIM = Whimbrel
WWSC = White-winged Scoter
YBLO = Yellow-billed Loon
http://www.birdpop.org/DownloadDocuments/Alpha_codes_eng.pdf

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A10 Environmental Resource Areas, Grouped Land Segments, and Boundary Segments Used in the Analysis of Subsistence Resources

ID	Name	Figure	Months	Specific Resource	Reference
ERAs					
3	SUA: Enurmino-Neshkan /Russia	A3g	Jan-Dec	Bowhead Whales, Grey Whales, Walrus, Polar Bears, Ocean Fish, Birds	Ainana, Zelensky, and Bychkov, 2001; Kochnev, Etylin, et al., 2003; Melnikov and Bobkov, 1993; Zdor, Zdor, and Ainana, 2010.
4	SUA: Inchoun-Uelen/Russia	A3f	Jan-Dec	Bowhead Whales, Grey Whales, Walrus, Beluga, Polar Bears, Ocean Fish, Birds	Ainana, Zelensky, and Bychkov, 2001; Huntington and Mymrin, 1996; Kochnev et al., 2003; Melnikov and Bobkov, 1993; Mymrin et al., 1999; Zdor, Zdor, and Ainana, 2010.
12	SUA: Nuiqsut-Colville River Delta	A3c	Mar-Oct	Seals, Waterfowl, Ocean Fish, Moose, Caribou	ADF&G, 2017; S.R. Braund and Associates (SRB&A), 2010; USDOI, BLM and MMS, 2003.
13	SUA: Kivalina-Noatak	A3g	Jan-Dec	Walrus, Seals, Bowhead Whales, Beluga Whales, Polar Bears, Ocean Fish, King Crabs	Burch, 1985; Huntington, Quakenbush and Nelson, 2017; Magdanz et al., 2010.
38	SUA: Pt. Hope-Cape Lisburne	A3d	Jan-Dec	Beluga Whales, Bowhead Whales, Walrus, Seals	Bacon et al., 2009; Braund and Burnham, 1984; Frost and Suydam, 2010.
39	SUA: Pt. Lay-Kasegaluk Lagoon	A3e	Jan-Dec	Ocean Fish, Seals, Waterfowl, Beluga Whales	Bacon et al., 2009; Braund and Burnham, 1984; Frost and Suydam, 2010; Galginaitis and Impact Assessment, 1989; Huntington and Mymrin, 1996; S.R. Braund and Associates (SRB&A), 2013, 2014; USDOI, BLM and MMS, 2003.
40	SUA: Icy Cape-Wainwright	A3g	Jan-Dec	Bowhead Whales, Beluga Whales, Seals, Waterfowl	Bacon et al., 2009; Braund and Burnham, 1984; Frost and Suydam, 2010; Kassam and Wainwright Traditional Council, 2001; Kofinas et al., 2016; USDOI, BLM and MMS, 2003; S.R. Braund and Associates and University of Alaska Anchorage, ISER, 1993a; S.R. Braund and Associates, 2013.

ID	Name	Figure	Months	Specific Resource	Reference
41	SUA: Utqiaġvik-Chukchi	A3e	Jan-Dec	Bowhead Whales, Beluga Whales, Walrus, Waterfowl, Seals, Ocean Fish	ADF&G, 2016; Braund and Burnham, 1984; Frost and Suydam, 2010; Pedersen, 1979; S.R. Braund and Associates, 2010; S.R. Braund and Associates and University of Alaska Anchorage, ISER, 1993b; USDOI, BLM and MMS, 2003.
42	SUA: Utqiaġvik-East Arch	A3d	Apr-Oct	Bowhead Whales, Beluga Whales, Walrus, Waterfowl, Seals, Ocean Fish	ADF&G, 2016; Braund and Burnham, 1984; Frost and Suydam, 2010; Pedersen, 1979; S.R. Braund and Associates, 2010; S.R. Braund and Associates and University of Alaska Anchorage, ISER, 1993b; USDOI, BLM and USDOI, MMS, 2003.
43	SUA: Nuiqsut-Cross Island	A3c	Aug-Oct	Bowhead Whales, Seals, Waterfowl, Ocean Fish	Galginaitis, 2009, 2014a,b, 2016; Impact Assessment, 1990a; S.R Braund and Associates, 2010.
44	SUA: Kaktovik	A3c	Apr-Oct	Bowhead Whales, Seals, Walrus, Beluga Whales, Waterfowl, Ocean Fish	Frost and Suydam, 2010; Impact Assessment, 1990b; Kofinas et al., 2016; North Slope Borough, 2001; S.R. Braund and Associates, 2010.
60	SUA: King Pt.-Shallow Bay (Canada)	A3b	Apr-Sep	Polar Bears, Seals, Fish, Bowhead Whales, Beluga Whales, Migratory Waterfowl	Environment Canada, 2000; Fisheries and Oceans Canada 2002, 2009; Harwood et al., 2002, 2014; North/South Consultants, Inc., 2005.
90	SUA: Garry and Kendall Islands/ Canada	A3b	Jul-Aug	Beluga Whales	Environment Canada, 2000: Fisheries and Oceans Canada 2002, 2009; Harwood et al., 2002, 2014; North/South Consultants, Inc., 2005.
97	SUA: Shishmaref	A3e	Jan-Dec	Marine Mammals, Fish, Marine Invertebrates	Huntington, Quakenbush, and Nelson, 2017; Oceana and Kawerak, 2014; Wisniewski, 2005.
			BSs and GLSs		
1	SUA: Shishmaref-Wales	A-1	Jan-Dec	Marine Mammals, Fish, Marine Invertebrates	Huntington, Quakenbush, and Nelson, 2017; Oceana and Kawerak, 2014.
2	SUA: Bering Strait-West	A-1	Jan-Dec	Marine Mammals, Fish, Marine Invertebrates	Oceana and Kawerak, 2014.
143	SUA: Point Lay, Point Hope	A5a	Jun-Sept	Caribou	S.R. Braund and Associates, 2014; Wolfe, 2013.
154	SUA: Utqiaġvik, Nuiqsut	A5b	Jul-Aug	Caribou	S.R. Braund and Associates, 2010.
161	SUA: Kaktovik, Nuiqsut	A5b	Jul-Aug	Caribou	S.R. Braund and Associates, 2010.
168	PCH Insect Relief/SUA: Kaktovik	A5b	Jul-Aug	Caribou	Brower, Olemaun, and Hepa, 2000; Galginatis, 2014b; Jacobson and Wentworth, 1982: S.R. Braund and Associates, 2010.

Key: SUA = Subsistence Use Area PCH = Porcupine Caribou Herd

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A11 Land Segments Used in the OSRA Model (ID and Geographic Place Names)

ID	Geographic Place Names	ID	Geographic Place Names
1	Mys Blossom, Mys Fomy, Khishchnikov, Neozhidannaya, Laguna Vaygan	32	Mys Dzhenretlen, Eynenekvyk, Lit'khekay-Polar Station
2	Mys Gil'der, Ushakovskiy, Mys Zapadnyy	33	Neskan, Laguna Neskan, Mys Neskan
3	Mys Florens, Gusinaya	34	Emelin, Ostrov Idlidlya, I, Memino, Tepken,
4	Mys Ushakova, Laguna Drem-Khed	35	Enurmino, Mys Keylu, Netakeniskhvin, Mys Neten,
5	Mys Evans, Neizvestnaya, Bukhta Pestsonaya	36	Mys Chechan, Mys Ikigur, Keniskhvik, Mys Serditse Kamen
6	Ostrov Mushtakova	37	Chegitun, Utkan, Mys Volnistyy
7	Kosa Bruch	38	Enmytagyn, Inchoun, Inchoun, Laguna Inchoun, Mitkulino, Uellen, Mys Unikyn
8	Klark, Mys Litke, Mys Pillar, Skeletov, Mys Uering	39	Cape Dezhnev, Mys Inchoun, Naukan, Mys Peek, Uelen, Laguna Uelen, Mys Uelen
9	Nasha, Mys Proletarskiy, Bukhta Rodzhers	40	Ah-Gude-Le-Rock, Dry Creek, Lopp Lagoon, Mint River
10	Reka Berri, Bukhta Davidova, , Khishchnika, Reka Khishchniki	41	Ikpek, Ikpek Lagoon, Pinguk River, Yankee River
11	Bukhta Somnitel'naya	42	Arctic Lagoon, Kugrupaga Inlet, Nuluk River
12	Zaliv Krasika, Mamontovaya, Bukhta Predatel'skaya	43	Sarichef Island, Shishmaref Airport
13	Mys Kanayen, Mys Kekurnyy, Mys Shalaurova, Veyeman	44	Cape Lowenstern, Egg Island, Shishmaref, Shishmaref Inlet
14	Innukay, Laguna Innukay, Umkuveyem, Mys Veuman	45	No place names
15	Laguna Adtaynung, Mys Billingsa, Ettam, Gytkhelen, Laguna Uvargina	46	Cowpack Inlet, Cowpack River, Kalik River, Kividlo, Singeak, Singeakpuk River, White Fish Lake
16	Mys Emmatagen, Mys Enmytagyn, Uvargin	47	Kitluk River, Northwest Corner Light, West Fork Espenberg River
17	Enmaat'khyr, Kenmankautir, Mys Olennyy, Mys Yakan, Yakanvaam, Yakan	48	Cape Espenberg, Espenberg, Espenberg River
18	Mys Enmykay, Laguna Olennaya, Pil'khikay, Ren, Rovaam, Laguna Rypil'khin	49	Kungealoruk Creek, Kougachuk Creek, Pish River
19	Laguna Kuepil'khin, Leningradskiy	50	Clifford Point, Cripple River, Goodhope Bay, Goodhope River, Rex Point, Sullivan Bluffs
20	Polyarnyy, Kuekvun', Notakatryn, Pil'gyn, Tynupytku	51	Cape Deceit, Deering, Kugruk Lagoon, Kugruk River, Sullivan Lake, Toawlevic Point
21	Laguna Kinmanyakicha, Laguna Pil'khikay, Amen, Pil'khikay, Bukhta Severnaya, Val'korkey	52	Motherwood Point, Ninemile Point, Willow Bay
22	Ekiatan', Laguna Ekiatan, Kelyun'ya, Mys Shmidta, Rypkarpyy	53	Kiwalik, Kiwalik Lagoon, Middle Channel Kiwalik River, Minnehaha Creek, Mud Channel Creek, Mud Creek
23	Emuem, Kemuem, Koyvel'khveyergin, Laguna Tengergin, Tenkergin	54	Baldwin Peninsula, Lewis Rich Chan
24	No Place Name	55	Cape Blossom, Pipe Spit
25	Laguna Amguema, Ostrov Leny, Yulinu	56	Kinuk Island, Kotzebue, Noatak River
26	Ekugvaam, Reka Ekugvam, Kepin, Pil'khin	57	Aukulak Lagoon, Igisukruk Mountain, Noak, Mount, Sheshalik, Sheshalik Spit
27	Laguna Nut, Rigol'	58	Cape Krusenstern, Eigaloruk, Evelukpalik River, Kasik Lagoon, Krusenstern Lagoon
28	Kamynga, Ostrov Kardkarpko, Kovlyuneskin, Mys Vankarem, Vankarema, Laguna Vankarem	59	Imik Lagoon, Ipiavik Lagoon, Kotlik Lagoon, Omikviorok River
29	Akanatkhyrgyn, Nutpel’men, Mys Onman, Vel'may	60	Imikruk Lagoon, Imnakuk Bluff, Kivalina, Kivalina Lagoon, Singigrak Spit, Kivalina River, Wulik River
30	Laguna Kunergin, Nutepynmyn, Pyngopil'khin, Laguna Pyngopil'khin	62	Atosik Lagoon,Chariot,Ikaknak Pond,Kisimilok Mountain,Kuropak Creek,Mad Hill
31	Alyatki, Zaliv Tasytkhin, Kolyuchin Bay	62	Atosik Lagoon,Chariot,Ikaknak Pond,Kisimilok Mountain,Kuropak Creek,Mad Hill

ID	Geographic Place Names	ID	Geographic Place Names
63	Akoviknak Lagoon, Cape Thompson, Crowbill Point, Igilerak Hill, Kemegrak Lagoon	98	Beechey Point, Bertoncini , Bodfish, Cottle and, Jones Islands, Milne Point, Simpson Lagoon
64	Aiautak Lagoon, Ipiutak Lagoon, Kowtuk Point, Kukpuk River, Pingu Bluff, Point Hope, Sinigrok Point, Sinuk	99	Duck Island, Foggy Island, Gull Island, Heald Point, Howe Island, Niakuk Islands, Point Brower
65	Buckland, Cape Dyer, Cape Lewis, Cape Lisburne	100	Foggy Island Bay, Kadleroshilik River, Lion Point, Shaviovik River, Tigvariak Island
66	Ayugatak Lagoon	101	Bullen Point, Point Gordon, Reliance Point
67	Cape Sabine, Pitmegea River	102	Flaxman Island, Maguire Islands, North Star Island, Point Hopson, Point Sweeney, Point Thomson, Staines River
68	Agiak Lagoon, Punuk Lagoon	103	Brownlow Point, Canning River, Tamayariak River
69	Cape Beaufort, Omalik Lago	104	Camden Bay, Collinson Point, Katakturuk River, Konganevik Point, Simpson Cove
70	Kuchaurak Creek, Kuchiak Creek	105	Anderson Point, Carter Creek, Itkilyariak Creek, Kajutakrok Creek, Marsh Creek, Sadlerochit River
71	Kukpowruk River, Naokok, Naokok Pass, Sitkok Point	106	Arey Island, Arey Lagoon, Barter Island, Hulahula River, Okpilak River
72	Epizetka River, Kokolik River, Point Lay, Siksrikpak Point	107	Bernard Harbor, Jago Lagoon, Kaktovik, Kaktovik Lagoon
73	Akunik Pass, Tungaich Point, Tungak Creek	108	Griffin Point, Oruktalik Lagoon, Pokok Lagoon
74	Kasegaluk Lagoon, , Solivik Island, Utukok River	109	Angun Lagoon, Beaufort Lagoon, Nuvagapak Lagoon
75	Akeonik, Icy Cape, Icy Cape Pass	110	Aichilik River, Egaksrak Lagoon, Egaksrak River, Icy Reef, Kongakut R., Siku Lag.
76	Akoliakatat Pass, Avak Inlet, Tunalik River	111	Demarcation Bay, Demarcation Point, Gordon, Pingokraluk Lagoon
77	Mitliktavik, Nivat Point, Nokotlek Point, Ongorakvik River	112	Clarence Lagoon, Backhouse River
78	Kilmantavi, Kuk River, Point Collie, Sigeakruk Point,	113	Clarence Lagoon, Backhouse River
79	Point Belcher, Wainwright, Wainwright Inlet	114	Nunaluk Spit
80	Eluksingiak Point, Igklo River, Kugrua Bay	115	Herschel Island
81	Peard Bay, Point Franklin, Seahorse Islands, Tachinisok Inlet	116	Ptarmagin Bay
82	Skull Cliff	117	Roland & Phillips Bay, Kay Point
83	Nulavik, Loran Radio Station	118	Sabine Point
84	Walakpa River, Will Rogers and Wiley Post Memorial	119	Shingle Point
85	Utqiaġvik, Browerville, Elson Lagoon	120	Trent and Shoalwater Bays
86	Dease Inlet, Plover Islands, Sanigaruak Island	121	Shallow Bay, West Channel
87	Igalik Island, Kulgurak Island, Kurgorak Bay, Tangent Point	122	No Place Names
88	Cape Simpson, Piasuk River, Sinclair River, Tulimanik Island	123	Outer Shallow Bay, Olivier Islands
89	Ikpikpuk River, Point Poleakoon, Smith Bay	124	Middle Channel, Gary Island
90	Drew Point, Kolovik, McLeod Point,	125	Kendall Island
91	Lonely AFS Airport, Pitt Point, Pogik Bay, Smith River	126	North Point, Pullen Island
92	Cape Halkett, Esook Trading Post, Garry Creek	127	Hendrickson Island, Kugmallit Bay
93	Atigaru Point, Eskimo Islands, Harrison Bay, Kalikpik River, Saktuina Point	128	Tuktoyaktuk, Tuktoyaktuk Harbour
94	Fish Creek, Tingmeachsiovik River	129	Warren Point
95	Kalubik Creek, Oliktok Point, Thetis Mound	130	Hutchison Bay
96	Gwydyr Bay, Kuparuk River, Long Island	131	McKinley Bay, Atkinson Point
97	Beechey Point, Bertoncini , Bodfish, Cottle and, Jones Islands, Milne Point, Simpson Lagoon	132	Kidney Lake, Nuvorak Point

Key: ID = Identification (number)

Compiled: USDOI, BOEM, Alaska OCS Region (2018).

Table A12 Land Segment (LS) ID and the Percent Type of Environmental Sensitivity Index Shoreline Closest to the Ocean for United States, Alaska Shoreline

ID	Geographic Place Names	1A	1B	1C	3A	3B	3C	4	5	6A	6B	6C	7	8A	8B	8C	8E	9A	9B	10A	10B	10E	U
40	Lopp Lagoon, Mint River	-	-	-	21	-	3	1	23	-	-	-	6	-	-	-	21	7	1	2	-	15	-
41	Ikpek, Ikpek Lagoon	-	-	-	16	-	6	-	-	-	-	-	12	-	-	-	21	7	2	16	-	19	2
42	Arctic Lagoon, Nuluk River	-	-	-	1	-	3	1	7	-	-	-	1	-	-	-	30	6	14	2	-	34	1
43	Sarichef Island	-	-	-	-	-	13	4	1	-	-	-	12	-	-	-	27	7	1	4	-	32	-
44	Cape Lowenstern, Shishmaref	-	-	-	6	-	8	-	-	-	-	1	7	-	-	-	32	6	4	6	-	31	-
45	LS45	-	-	-	17	-	-	-	-	-	-	-	1	-	-	-	25	7	9	-	-	40	2
46	Kalik & Singeakpuk River	-	-	-	13	-	2	-	-	-	-	-	4	-	-	-	38	7	12	-	-	24	-
47	Kitluk River	-	-	-	13	-	1	-	-	-	-	-	32	-	-	-	20	2	24	-	-	-	7
48	Cape Espenberg	-	-	-	13	-	1	-	10	-	-	-	2	-	-	-	7	8	-	25	-	20	14
49	Pish River	-	-	-	19	-	-	-	15	-	-	-	-	-	-	-	14	5	3	20	-	24	-
50	Goodhope Bay & River	1	-	3	4	-	-	4	22	4	12	-	-	-	-	-	12	-	-	4	-	35	-
51	Deering	1	-	11	15	-	-	-	23	6	4	-	-	-	-	-	12	2	1	24	-	-	1
52	Willow Bay	2	5	4	9	-	-	-	35	1	1	-	-	-	1	-	1	-	-	32	-	7	-
53	Kiwalik	-	-	-	3	-	-	-	18	-	-	-	-	2	1	-	-	3	-	13	-	43	15
54	Baldwin Peninsula	-	-	-	15	-	8	-	68	-	-	-	-	1	-	-	2	-	-	-	-	6	-
55	Cape Blossom, Pipe Spit	-	-	-	1	-	6	-	78	1	1	-	-	-	-	-	4	-	-	7	-	1	-
56	Kotzebue, Noatak River	-	1	-	-	-	3	-	13	-	-	1	-	-	-	-	8	9	1	5	-	23	38
57	Aukulak Lagoon	-	-	-	4	-	2	-	18	-	-	-	-	-	-	-	19	7	3	5	-	28	14
58	Cape Krusenstern	-	-	-	-	-	1	-	32	-	1	-	-	-	-	-	17	-	1	22	-	26	-
59	Imik, Ipiavik & Kotlik Lagoon	-	-	-	1	-	-	-	48	4	-	-	-	-	-	-	6	4	-	35	-	2	-
60	Kivalina, Kivalina & Wulik River	-	-	-	-	-	2	1	46	3	-	1	-	-	-	1	19	5	7	9	-	6	-
61	Cape Seppings	-	-	-	-	-	-	-	54	-	-	-	-	-	-	-	9	-	11	6	-	19	-
62	Atosik Lagoon	-	-	-	-	-	-	-	76	-	-	-	-	-	-	-	1	-	17	5	-	1	-
63	Asikpak Lag., Cape Seppings	-	-	1	5	-	1	1	46	11	-	-	19	-	-	-	10	3	1	1	-	-	-
64	Kukpuk River, Point Hope	1	-	2	8	-	1	2	42	4	-	-	12	-	-	-	16	4	6	-	-	1	-
65	Buckland, Cape Lisburne	13	-	2	-	-	-	-	71	10	3	-	-	-	-	-	-	-	-	1	-	-	-
66	Ayugatak Lagoon	54	-	-	-	-	-	-	32	1	-	-	-	-	-	-	-	-	-	12	-	-	-
67	Cape Sabine, Pitmegea River	38	-	3	-	-	15	-	22	1	-	-	-	-	-	-	-	-	-	19	-	-	-
68	Agiak Lagoon, Punuk Lagoon	-	-	-	-	-	11	-	76	11	-	-	-	-	-	-	-	-	-	1	-	-	-
69	Cape Beaufort, Omalik Lagoon	-	-	-	-	-	-	-	44	47	-	-	-	-	-	-	-	-	-	2	-	6	-
70	Kuchaurak and Kuchiak Creek	-	-	-	-	-	-	-	20	-	-	-	20	-	-	-	14	1	21	2	-	19	2
71	Kukpowruk River, Sitkok Point	-	-	-	4	-	9	-	35	-	-	-	21	-	-	-	5	19	4	-	-	2	1
72	Point Lay, Siksrikpak Point	-	-	-	4	-	2	-	49	-	-	-	8	-	-	-	12	15	-	5	-	3	-
73	Tungaich Point, Tungak Creek	-	-	-	-	-	8	-	52	-	-	-	-	-	-	1	4	15	5	10	-	4	-
74	Kasegaluk Lagoon, Solivik Isl.	-	-	-	15	-	-	-	28	1	-	-	1	-	-	-	5	41	2	5	-	-	1
75	Akeonik, Icy Cape	-	-	-	13	-	4	1	34	-	-	-	2	-	-	-	14	14	11	5	1	1	-
76	Avak Inlet, Tunalik River	-	-	-	2	-	8	3	40	-	-	-	1	-	-	-	13	11	8	1	-	13	-
77	Nivat Point, Nokotlek Point	-	-	-	13	-	3	6	42	-	-	-	9	-	-	-	12	9	4	-	-	1	-
78	Point Collie, Sigeakruk Point	-	-	-	15	-	5	-	38	-	-	-	19	-	-	-	-	4	7	-	-	5	8
79	Point Belcher, Wainwright	-	-	-	22	-	1	-	33	2	1	-	32	-	-	-	2	-	-	1	-	5	-

ID	Geographic Place Names	1A	1B	1C	3A	3B	3C	4	5	6A	6B	6C	7	8A	8B	8C	8E	9A	9B	10A	10B	10E	U
80	Eluksingiak Point, Kugrua Bay	-	-	-	13	-	35	-	10	-	-	-	12	-	-	-	14	9	-	1	-	5	1
81	Peard Bay, Point Franklin	-	-	-	3	-	21	-	37	1	-	-	25	-	-	-	3	9	-	-	-	-	-
82	Skull Cliff	-	-	-	-	-	76	2	12	9	-	-	1	-	-	-	-	-	1	-	-	-	-
83	Nulavik, Loran Radio Station	-	-	-	-	-	73	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	Will Rogers & Wiley Post Mem.	-	-	-	1	-	8	-	82	-	-	-	-	-	-	-	-	-	8	-	-	-	-
85	Barrow, Browerville, Elson Lag.	-	-	-	11	-	14	-	37	-	-	-	1	-	-	-	17	2	2	3	-	7	7
86	Dease Inlet, Plover Islands	-	-	-	30	3	5	-	3	-	-	-	2	-	-	-	19	15	3	11	-	9	-
87	Igalik & Kulgurak Island	-	-	-	17	-	4	-	3	-	-	-	-	-	-	-	25	7	-	9	-	34	1
88	Cape Simpson, Piasuk River	-	-	-	6	-	5	6	-	-	-	-	-	-	-	-	14	-	-	-	-	25	44
89	Ikpikpuk River Point Poleakoon	-	-	-	2	-	4	-	-	-	-	-	-	-	-	-	4	57	-	-	-	13	20
90	Drew & McLeod Point, Kolovik	-	-	-	5	-	19	7	-	-	-	-	-	-	-	-	14	16	-	11	-	27	-
91	Lonely, Pitt Pt., Pogik Bay, Smith R	-	-	-	-	-	4	9	7	-	-	-	-	-	-	-	12	5	-	6	-	38	18
92	Cape Halkett, Garry Creek	-	-	-	1	-	20	3	-	-	-	-	-	-	-	-	26	2	-	-	-	31	18
93	Atigaru Pt, Eskimo Isl., Kogru R.	-	-	-	9	-	30	2	1	-	-	-	-	-	-	-	20	1	3	1	-	34	-
94	Fish Creek, Tingmeachsiovik River	-	-	-	1	-	4	-	1	-	-	-	-	-	-	-	6	34	-	1	-	38	16
95	Colville River	-	-	-	5	-	1	-	-	-	-	-	-	-	-	-	10	31	-	1	-	2	50
96	Oliktok Point	-	-	-	4	-	8	12	10	3	-	-	-	-	-	-	11	10	-	9	-	32	1
97	Milne Point, Simpson Lagoon	-	-	-	6	-	2	37	19	-	-	-	-	-	-	-	17	1	5	4	-	8	2
98	Kuparuk River	-	-	-	1	-	1	-	36	-	-	-	-	1	-	-	7	21	3	1	-	16	11
99	Point Brower, Prudhoe Bay	-	-	-	2	-	5	-	1	-	-	-	-	-	1	-	12	55	-	11	-	7	4
100	Foggy Island Bay, Kadleroshilik R.	-	-	-	6	-	4	4	15	1	-	-	-	-	-	-	7	31	-	5	-	22	4
101	Bullen, Gordon & Reliance Points	-	-	-	7	-	4	3	44	-	-	-	-	-	-	-	2	2	-	12	-	22	3
102	Pt. Hopson & Sweeney, Staines R	-	-	-	2	-	4	12	35	3	-	-	4	-	-	-	16	6	-	3	-	17	-
103	Brownlow Point, Canning River	-	-	-	21	-	6	3	7	-	-	-	-	-	-	-	5	43	-	-	-	8	8
104	Collinson Point, Konganevik Point	-	-	-	21	-	13	-	21	-	-	-	2	-	-	-	10	11	6	-	-	15	-
105	Anderson Point, Sadlerochit River	-	-	-	18	-	3	-	24	-	-	-	22	-	-	-	1	13	4	1	-	14	-
106	Arey Island, Barter Island,	-	-	-	11	-	3	1	13	-	-	-	-	-	-	-	9	45	-	-	-	14	1
107	Kaktovik	-	-	-	-	-	10	3	45	-	-	-	-	-	1	-	7	17	1	-	-	4	11
108	Griffin Point, Oruktalik Lagoon	-	-	-	-	-	20	2	43	-	-	-	-	-	-	-	13	2	2	1	-	16	-
109	Angun Point, Beaufort Lagoon	-	-	-	-	-	18	30	23	-	-	-	-	-	-	-	14	4	1	-	-	7	3
110	Icy Reef, Kongakut R., Siku Lag.	-	-	-	-	-	-	3	26	-	-	-	-	-	-	-	2	28	1	-	-	38	3
111	Demarcation Bay & Point	-	-	-	1	-	15	3	54	-	-	-	-	-	-	-	6	7	3	-	-	5	5

ID = Identification (number). Number Description

1A Exposed rocky shores; exposed rocky banks
1B Exposed, solid man-made structures
1C Exposed rocky cliffs with boulder talus base
3A Fine- to medium-grained sand beaches
3B Scarps and steep slopes in sand
3C Tundra cliffs
4 Coarse-grained sand beaches
5 Mixed sand and gravel beaches
6A Gravel beaches; Gravel beaches (granules and pebbles) *
6B Gravel beaches (cobbles and boulders) *
6C Rip rap (man-made) *
7 Exposed tidal flats
8A Sheltered scarps in bedrock, mud, or clay; Sheltered rocky shores (impermeable) *
8B Sheltered, solid man-made structures; Sheltered rocky shores (permeable) *
8C Sheltered rip rap
8D Sheltered rocky rubble shores
8E Peat shorelines
9A Sheltered tidal flats
9B Vegetated low banks
10A Salt- and brackish-water marshes
10B Freshwater marshes
10E Inundated low-lying tundra
U Unknown

Compiled: USDOI, BOEM, Alaska OCS Region (2016)) from Harper and Morris (2014).

Table A13 Grouped Land Segments Used in the OSRA Model (ID, Geographic Names, Land Segments ID, Vulnerability, and Map)

GLS ID	Grouped Land Segment Name	Land Segment IDs	Vulnerability	Figure
133	Bukhta Somnitel'naya (Somnitel’naya Spit), Davidova Spit	10–11	Jan–Dec	A5c
134	Kolyuchin Bay	30–31, 33–34	Jun–Nov	A5c
135	Ostrov Idlidlya (Ididlya Island)	33–34	Jul–Nov	A5c
136	Mys Serditse Kamen (Cape Serdtse-Kamen)	35–36	Jul–Nov	A5c
137	Chukotka Coast Haulout	35–39	Jul–Nov	A5c
138	Bering Land Bridge National Preserve	41–42, 45–50	Jan–Dec	A5c
139	Noatak River	54–57	Jan–Dec	A5c
140	Cape Krusenstern National Monument	57–59	Jan–Dec	A5a
141	Wulik and Kivalina Rivers	60–61	Jan–Dec	A5a
142	WAH Insect Relief	61–71	Jul–Aug	A5c
143	SUA: Point Lay–Point Hope	61–71	Jun–Sept	A5a
144	Alaska Maritime National Wildlife Refuge	62–63, 65	Jan–Dec	A5a
145	Cape Lisburne	65–66, 67	Jan–Dec	A5b
146	Ledyard Brown Bears	65–70	Jun–Oct	A5b
147	Kasegaluk Lagoon Area IBA	70–78	May–Oct	A5b
148	Point Lay Haulout	71–74	Jul–Nov	A5a
149	Kasegaluk Brown Bears	73–77	Jun–Oct	A5b
150	National Petroleum Reserve-Alaska	76–77, 80–83, 86–93	Jan–Dec	A5c
151	Kasegaluk Lagoon Special Area (NPR-A)	76–77	Jan–Dec	A5c
152	Kuk River	78–79	Jan–Dec	A5b
153	TCH Insect Relief/Calving	85–95	May–Aug	A5b
154	SUA: Utqiaġvik–Nuiqsut	85–95	Jul–Aug	A5b
155	Smith Bay Spotted Seal Haulout	88–89	May–Oct	A5b
156	Teshekpuk Lake Special Area/IBA	86–93	May–Oct	A5c
157	Colville River Delta IBA	93–95	May–Oct	A5a
158	Colville River Delta	94–95	Oct–Apr	A5a
159	Harrison Bay Spotted Seal Haulout	95–96	Jun–Sept	A5b
160	CAH Insect Relief/ Calving	96–103	May–Aug	A5b
161	SUA: Kaktovik–Nuiqsut	96–103	Jul–Aug	A5b
162	96–115 Summer	96–115	Jun–Aug	A5a
163	Beaufort Muskox Habitat	97–98	Nov–May	A5b
164	99–115 Fall	99–115	Sept–Nov	A5b
165	102–110- Winter	102–110	Oct–Apr	A5a
166	Arctic National Wildlife Refuge	103–111	Jan–Dec	A5b
167	Northeast Arctic Coastal Plain IBA	103–111	May–Oct	A5b
168	PCH Insect Relief/SUA Kaktovik	103–111	Jul–Aug	A5b
169	PCH Calving	106–109, 112–117	May–Jun	A5a
170	Yukon Musk Ox Wintering	111–115	Nov–Apr	A5b
171	Ivvavik National Park (Canada)	112–117	Jan–Dec	A5b
172	112–132 Spring	112–132	Mar–May	A5a
173	112–121 Winter	112–121	Dec–Feb	A5b
174	Yukon Moose	116–118	Jan–Dec	A5b
175	Tarium Nirutait MPA	119–122,124, 127	Jan–Dec	A5b
176	122–132 Spring	122–132	Mar–May	A5a
177	122–132 Winter	122–132	Dec–Feb	A5a
178	Kendall Island Bird Sanctuary (Canada)	124–125	May–Oct	A5b
179	Tuktoyaktuk/Cape Bathurst Caribou Insect Relief	126–132	Jul–Aug	A5a
180	Russia Chukchi Coast Marine Mammals	1–39	Jul–Nov	A5c
181	Russia Chukchi Coast	1–39	Jan–Dec	A5c
182	United States Chukchi Coast	40–84	Jan–Dec	A5c
183	United States Beaufort Coast	85–111	Jan–Dec	A5a
184	Canada Beaufort Coast	112–132	Jan–Dec	A5a

Key: CAH = Central Arctic Herd
IBA = Important Bird Area
ID = Identification Number
MPA = Marine Protected Area
NPR-A = National Petroleum Reserve-Alaska
PCH = Porcupine Caribou Herd
SUA = Subsistence Use Area
TCH = Teshekpuk Caribou Herd
WAH = Western Arctic Herd

Table A14 through Table A17 represent summer conditional probabilities (expressed as percent chance) that a very large oil spill starting at a particular location will contact a resource type within:

Table A14 120 Days (Summer ERA)

ID	Environmental Resource Area Name	LA										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0	Land	53	63	87	76	18	39	56	7	17	-	1
2	Point Barrow, Plover Isls.	32	10	2	2	11	17	4	3	3	-	-
5	Beaufort Sea Shelf Edge IBA	9	16	3	5	19	47	10	18	19	-	3
6	Hanna Shoal	9	2	-	-	14	5	1	5	1	-	-
7	Krill Trap	34	9	1	1	17	17	4	5	4	-	1
8	Maguire & Flaxman Isls.	-	4	7	14	-	-	7	-	2	-	-
9	Stockton & McClure Isls.	-	7	13	8	-	1	5	-	2	-	-
11	Wrangel Isl. 12 nmi & Offshore	2	-	-	-	5	1	-	3	1	-	-
12	SUA: Nuiqsut-Colville River Delta	6	21	5	5	-	6	6	-	2	-	-
16	Barrow Canyon	3	1	-	-	3	1	-	1	-	-	-
17	Angun & Beaufort Lagoons	-	-	-	9	-	-	5	-	1	-	-
18	Murre Rearing & Molting Area	1	-	-	-	1	-	-	-	-	-	-
20	East Chukchi Offshore	15	3	-	1	28	9	2	15	6	-	2
21	AK BFT Bowhead FM 8	-	-	-	21	-	-	18	-	4	-	-
22	AK BFT Bowhead FM 7	-	1	1	25	-	1	16	-	4	-	-
24	AK BFT Bowhead FM 6	-	8	3	29	-	1	14	-	5	-	-
25	AK BFT Bowhead FM 5	-	23	14	17	-	5	13	-	6	-	-
26	AK BFT Bowhead FM 4	1	33	13	11	-	11	12	1	7	-	-
27	AK BFT Bowhead FM 3	12	32	8	7	3	22	11	2	8	-	1
28	AK BFT Bowhead FM 2	28	17	4	3	6	20	6	3	6	-	1
29	AK BFT Bowhead FM 1	33	12	2	2	15	20	5	5	6	-	1
40	SUA: Icy Cape-Wainwright	1	-	-	-	1	-	-	-	-	-	-
41	SUA: Utqiaġvik-Chukchi	18	5	1	1	12	8	2	3	2	-	-
42	SUA: Utqiaġvik-East Arch	78	22	4	3	42	37	9	13	10	-	1
43	SUA: Nuiqsut-Cross Isl.	-	53	39	35	-	26	37	1	15	-	1
44	SUA: Kaktovik	-	2	1	45	-	1	31	-	7	-	-
47	Hanna Shoal Walrus Use Area	27	4	-	1	50	13	2	29	7	3	3
48	Chukchi Lead System 4	-	1	-	-	-	-	1	-	-	-	-
50	Pt. Lay Walrus	1	-	-	-	1	-	-	-	-	-	-
55	Point Barrow, Plover Isls.	33	11	2	2	11	17	4	3	3	-	-
56	Hanna Shoal Area	18	3	-	-	34	9	1	20	4	4	2
61	Pont Lay–Utqiaġvik BH GW SFF	33	8	1	1	21	15	3	6	4	-	1
63	North Chukchi	2	-	-	-	2	-	-	1	-	1	-
64	Peard Bay/Franklin Spit Area	2	-	-	-	2	-	-	-	-	-	-
65	Smith Bay	7	4	1	-	1	4	1	1	1	-	-
66	Herald Island	1	-	-	-	1	-	-	1	-	-	-
67	Herschel Island (Canada)	-	-	-	1	-	-	1	-	-	-	-
68	Harrison Bay	8	21	5	4	-	8	6	-	2	-	-
69	Harrison Bay/Colville Delta	3	17	4	4	-	5	4	-	2	-	-
70	North Central Chukchi	4	1	-	-	8	2	-	4	-	2	-
71	Simpson Lag., Thetis & Jones Isls.	-	11	6	4	-	3	4	-	2	-	-
72	Gwyder Bay, Cottle & Return Isls.	-	12	15	7	-	3	6	-	2	-	-
73	Prudhoe Bay	-	2	4	2	-	1	1	-	-	-	-
74	Hershel Isl.	-	-	-	1	-	-	2	-	1	-	-
75	Boulder Patch Area	-	7	59	8	-	1	5	-	2	-	-
77	Sagavanirktok Delta/Foggy Isl. Bay	-	5	48	6	-	1	4	-	1	-	-
78	Mikkelsen Bay	-	3	55	4	-	-	2	-	1	-	-
79	Demarcation Bay Offshore	-	-	-	11	-	-	5	-	1	-	-
80	Chukchi Sea Nearshore IBA	45	10	1	2	32	21	5	9	6	-	1
81	Simpson Cove	-	-	-	2	-	-	1	-	-	-	-
82	North Chukotka Nearshore 2	1	-	-	-	1	-	-	-	-	-	-
84	Canning River Delta	-	1	1	3	-	-	1	-	-	-	-
85	Sagavanirktok River Delta	-	6	49	7	-	1	4	-	1	-	-
86	Harrison Bay	8	22	5	5	-	8	6	1	3	-	-

ID	Environmental Resource Area Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
87	Colville River Delta	1	11	3	3	-	3	3	-	1	-	-
88	Simpson Lagoon	-	11	7	5	-	4	5	-	2	-	-
89	Mackenzie River Delta	-	-	-	-	-	-	1	-	-	-	-
91	Bowhead Whale Summer (Ca)	-	-	-	1	-	-	3	-	3	-	1
92	Thetis, Jones, Cottle & Return Isl.	-	15	12	8	-	4	7	-	3	-	-
93	Cross & No Name Isls.	-	5	4	3	-	1	3	-	1	-	-
94	Maguire, Flaxman & Barrier Isl.	-	4	4	14	-	-	6	-	2	-	-
95	Arey & Barter Isls., Bernard Spit	-	-	-	6	-	-	4	-	1	-	-
96	Midway, Cross & Bartlett Isls.	-	6	6	4	-	1	3	-	1	-	-
98	Anderson Point Barrier Isls.	-	-	-	2	-	-	1	-	-	-	-
99	Arey & Barter Isls., Bernard Spit	-	-	-	5	-	-	3	-	1	-	-
100	Jago & Tapkaurak Spits	-	-	-	8	-	-	6	-	1	-	-
101	Offshore Herald Isl./Hope Sea Vly.	1	-	-	-	2	-	-	1	-	-	-
103	Saffron Cod EFH	14	4	1	1	10	6	1	3	1	-	-
104	Ledyard Bay-Icy Cape IBA	1	-	-	-	-	-	-	-	-	-	-
105	Fish Creek	3	14	3	3	-	4	4	-	1	-	-
106	Shaviovik River	-	9	79	11	-	2	7	-	2	-	-
108	Utqiaġvik Feeding Aggregation	46	17	3	3	27	27	8	9	10	-	2
109	AK BFT Shelf Edge	-	-	-	8	-	1	28	-	5	-	-
110	AK BFT Outer Shelf & Slope 1	-	1	1	7	-	1	41	-	29	-	3
111	AK BFT Outer Shelf & Slope 2	-	2	1	11	-	3	41	1	32	-	3
112	AK BFT Outer Shelf & Slope 3	-	4	2	11	-	7	44	1	31	-	2
113	AK BFT Outer Shelf & Slope 4	-	6	4	8	-	18	22	5	31	-	3
114	AK BFT Outer Shelf & Slope 5	1	8	4	6	1	28	14	7	23	-	3
115	AK BFT Outer Shelf & Slope 6	3	11	3	5	3	35	10	16	22	-	4
116	AK BFT Outer Shelf & Slope 7	6	10	2	5	8	34	9	33	26	-	8
117	AK BFT Outer Shelf & Slope 8	9	9	3	4	25	28	6	32	20	-	6
118	AK BFT Outer Shelf & Slope 9	9	6	2	2	37	15	3	29	13	-	5
119	AK BFT Outer Shelf & Slope 10	44	12	2	2	72	25	5	26	13	-	3
122	Bowhead Fall (Canada)	-	-	-	4	-	-	5	-	2	-	-

Table A15 120 Days (Summer LS)

ID	Land Segment Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
7	Kosa Bruch	-	-	-	-	1	-	-	1	-	-	-
8	E. Wrangel Island, Skeletov	-	-	-	-	1	-	-	1	-	-	-
85	Barrow, Browerville, Elson Lag.	14	4	1	1	7	7	1	2	1	-	-
86	Dease Inlet, Plover Islands	5	1	-	-	2	3	1	1	-	-	-
87	Igalik & Kulgurak Island	6	2	-	-	2	3	1	-	1	-	-
88	Cape Simpson, Piasuk River	10	5	1	1	2	6	2	1	1	-	-
89	Ikpikpuk River Point Poleakoon	1	1	1	-	-	1	-	-	-	-	-
90	Drew & McLeod Point, Kolovik	2	1	-	-	-	1	-	-	-	-	-
91	Lonely, Pitt Pt., Pogik Bay, Smith R	2	2	1	1	-	2	1	-	-	-	-
92	Cape Halkett, Garry Creek	6	16	3	4	-	7	5	1	2	-	-
93	Atigaru Pt, Eskimo Isl., Kogru R.	1	4	2	1	-	2	1	-	-	-	-
94	Fish Creek, Tingmeachsiovik River	-	1	-	-	-	1	-	-	-	-	-
95	Colville River	-	2	1	1	-	1	1	-	-	-	-
96	Oliktok Point	-	2	1	1	-	1	1	-	-	-	-
97	Milne Point, Simpson Lagoon	-	5	4	3	-	1	2	-	1	-	-
98	Kuparuk River	-	4	5	3	-	1	3	-	1	-	-
99	Point Brower, Prudhoe Bay	-	4	26	4	-	1	3	-	1	-	-
100	Foggy Island Bay, Kadleroshilik R.	-	2	28	3	-	-	2	-	1	-	-
101	Bullen, Gordon & Reliance Points	-	2	11	2	-	-	1	-	-	-	-
102	Pt. Hopson & Sweeney, Staines R	-	1	1	4	-	-	2	-	1	-	-
103	Brownlow Point, Canning River	-	1	1	7	-	-	3	-	1	-	-
104	Collinson Point, Konganevik Point	-	-	-	3	-	-	1	-	-	-	-
105	Anderson Point, Sadlerochit River	-	-	-	2	-	-	1	-	-	-	-

ID	Land Segment Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
106	Arey Island, Barter Island,	-	-	-	4	-	-	2	-	-	-	-
107	Kaktovik	-	-	-	6	-	-	4	-	1	-	-
108	Griffin Point, Oruktalik Lagoon	-	-	-	6	-	-	4	-	1	-	-
109	Angun Point, Beaufort Lagoon	-	-	-	7	-	-	4	-	1	-	-
110	Icy Reef, Kongakut R., Siku Lag.	-	-	-	6	-	-	3	-	-	-	-
111	Demarcation Bay & Point	-	-	-	4	-	-	2	-	-	-	-
112	Clarence Lagoon, Backhouse River	-	-	-	2	-	-	1	-	-	-	-
113	Komakuk Beach, Fish Creek	-	-	-	1	-	-	1	-	-	-	-
115	Herschel Island	-	-	-	1	-	-	1	-	-	-	-

Table A16 120 Days (Summer GLS)

ID	Grouped Land Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
133	Somnitel’naya Spit, Davidova Spit	-	-	-	-	1	-	-	-	-	-	-
150	National Petroleum Reserve-Alaska	35	33	8	7	7	24	10	3	5	-	-
153	TCH Insect Relief/Calving	20	14	4	2	6	11	2	2	1	-	-
154	SUA: Utqiaġvik–Nuiqsut	20	14	4	2	6	11	2	2	1	-	-
155	Smith Bay Spotted Seal Haulout	10	5	1	1	2	6	2	1	1	-	-
156	Teshekpuk Lake Special Area/IBA	31	29	6	5	6	22	9	2	4	-	-
157	Colville River Delta IBA	2	8	3	2	-	3	2	-	1	-	-
158	Colville River Delta	-	1	-	-	-	-	1	-	-	-	-
159	Harrison Bay Spotted Seal Haulout	-	3	1	1	-	1	1	-	-	-	-
160	CAH Insect Relief/ Calving	-	8	31	10	-	1	5	-	-	-	-
161	SUA: Kaktovik–Nuiqsut	-	8	31	10	-	1	5	-	-	-	-
162	96–115 Summer	-	9	31	25	-	2	12	-	1	-	-
163	Beaufort Muskox Habitat	-	1	1	1	-	-	1	-	-	-	-
164	99–115 Fall	-	6	39	36	-	2	25	-	6	-	-
165	102–110- Winter	-	1	1	19	-	-	12	-	3	-	-
166	Arctic National Wildlife Refuge	-	2	1	43	-	1	25	-	4	-	-
167	Northeast Arctic Coastal Plain IBA	-	2	1	36	-	1	19	-	3	-	-
168	PCH Insect Relief/SUA Kaktovik	-	1	1	16	-	-	6	-	-	-	-
170	Yukon Musk Ox Wintering	-	-	-	1	-	-	1	-	-	-	-
171	Ivvavik National Park (Canada)	-	-	-	3	-	-	4	-	1	-	-
174	Yukon Moose	-	-	-	-	-	-	1	-	-	-	-
180	Russia Chukchi Coast M. Mammals	2	-	-	-	3	1	-	2	-	-	-
181	Russia Chukchi Coast	2	-	-	-	4	1	-	2	-	-	-
182	United States Chukchi Coast	1	-	-	-	1	-	-	-	-	-	-
183	United States Beaufort Coast	49	63	87	72	14	39	51	5	15	-	-
184	Canada Beaufort Coast	-	-	-	4	-	-	5	-	1	-	-

Table A17 120 Days (Summer BS)

ID	Boundary Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
3	Chukchi Sea	-	-	-	-	1	-	-	-	-	-	-
6	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
7	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
13	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
14	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
15	Chukchi Sea	-	-	-	-	1	-	-	-	-	1	-
16	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
17	Chukchi Sea	-	-	-	-	1	-	-	-	-	2	-
18	Chukchi Sea	-	-	-	-	-	-	-	-	-	3	-
19	Chukchi Sea	-	-	-	-	-	-	-	-	-	4	-
20	Chukchi Sea	-	-	-	-	1	-	-	-	-	5	-
21	Chukchi Sea	-	-	-	-	-	-	-	-	-	6	1

ID	Boundary Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
22	Chukchi Sea	-	-	-	-	-	-	-	-	-	6	-
23	Beaufort Sea	-	-	-	-	-	-	-	-	-	5	-
24	Beaufort Sea	-	-	-	-	-	-	-	-	-	5	-
25	Beaufort Sea	-	-	-	-	-	-	-	-	-	4	-
26	Beaufort Sea	-	-	-	-	-	-	-	-	-	2	-
27	Beaufort Sea	-	-	-	-	-	-	-	-	-	1	-

Table A18 through Table A21 represent winter conditional probabilities (expressed as percent chance) that a very large oil spill starting at a particular location will contact a resource type within:

Table A18 360 Days (Winter ERA)

ID	Environmental Resource Area Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
0	Land	62	70	89	83	36	51	69	20	37	5	10
2	Point Barrow, Plover Isls.	9	2	-	-	5	3	-	3	1	-	1
3	SUA: Enurmino-Neshkan/Russia	1	-	-	-	1	-	-	-	-	-	-
5	Beaufort Sea Shelf Edge IBA	5	5	1	2	9	11	4	6	5	-	2
6	Hanna Shoal	7	1	-	-	9	2	-	5	1	1	1
7	Krill Trap	8	2	-	-	6	3	1	2	1	-	-
8	Maguire & Flaxman Isls.	-	3	3	5	-	1	3	-	1	-	-
9	Stockton & McClure Isls.	-	3	5	2	-	1	2	-	1	-	-
11	Wrangel Isl. 12 nmi & Offshore	2	-	-	-	7	1	-	4	-	5	1
12	SUA: Nuiqsut-Colville River Delta	4	14	2	2	1	7	3	1	2	-	-
15	Cape Lisburne Seabird Area	-	-	-	-	1	-	-	-	-	-	-
16	Barrow Canyon	4	1	-	-	5	1	-	2	-	-	-
17	Angun & Beaufort Lagoons	-	-	-	3	-	-	2	-	1	-	-
18	Murre Rearing & Molting Area	2	-	-	-	3	-	-	2	-	1	-
19	Chukchi Sea Spring Lead System	7	1	-	-	8	2	-	3	1	-	-
23	Polar Bear Offshore	4	1	-	-	10	1	-	5	1	1	-
30	Beaufort Spring Lead 1	20	4	1	1	23	6	1	8	3	-	1
31	Beaufort Spring Lead 2	11	5	1	1	28	9	2	12	5	-	3
32	Beaufort Spring Lead 3	5	4	1	1	12	10	3	13	6	-	4
33	Beaufort Spring Lead 4	3	3	-	1	4	8	3	12	8	-	5
34	Beaufort Spring Lead 5	1	3	-	-	1	6	2	7	11	-	5
35	Beaufort Spring Lead 6	-	2	1	1	-	4	3	3	15	-	5
36	Beaufort Spring Lead 7	-	2	1	1	-	2	3	2	16	-	6
37	Beaufort Spring Lead 8	-	1	-	1	-	2	2	1	16	-	7
40	SUA: Icy Cape-Wainwright	2	-	-	-	4	1	-	1	-	-	-
41	SUA: Utqiaġvik-Chukchi	15	3	1	-	13	4	-	4	1	-	-
42	SUA: Utqiaġvik-East Arch	32	7	2	2	22	13	2	10	5	-	2
43	SUA: Nuiqsut-Cross Isl.	-	1	-	1	-	1	1	-	1	-	-
44	SUA: Kaktovik	-	3	2	18	-	3	15	1	6	-	1
45	Beaufort Spring Lead 9	1	1	-	1	1	1	2	1	13	-	11
46	Wrangel Isl. 12 nmi Buffer 2	1	-	-	-	3	-	-	2	-	2	-
47	Hanna Shoal Walrus Use Area	8	2	-	-	15	4	-	11	1	3	2
48	Chukchi Lead System 4	17	4	-	1	17	6	1	5	1	-	-
49	Chukchi Spring Lead 1	1	-	-	-	1	-	-	-	-	-	-
50	Pt. Lay Walrus	-	-	-	-	1	-	-	-	-	-	-
52	Russian Coast Walrus Offshore	2	-	-	-	3	-	-	2	-	1	-
53	Chukchi Spring Lead 2	1	-	-	-	2	-	-	1	-	-	-
54	Chukchi Spring Lead 3	8	2	-	-	12	3	-	5	1	-	-
55	Point Barrow, Plover Isls.	31	7	1	1	15	11	2	6	3	-	1
56	Hanna Shoal Area	1	-	-	-	1	-	-	1	-	-	-
57	Skull Cliffs	1	-	-	-	1	-	-	-	-	-	-
58	Russian Coast Walrus Nearshore	1	-	-	-	1	-	-	1	-	-	-
60	SUA: King Pt.-Shallow Bay	-	-	-	-	-	-	1	-	1	-	-
61	Pont Lay–Utqiaġvik BH GW SFF	3	1	-	-	2	2	-	1	-	-	-

ID	Environmental Resource Area Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
62	Herald Shoal Polynya 2	1	-	-	-	3	-	-	2	-	1	-
64	Peard Bay/Franklin Spit Area	1	-	-	-	1	-	-	-	-	-	-
65	Smith Bay	3	1	-	-	1	2	-	1	1	-	-
66	Herald Island	1	-	-	-	2	-	-	1	-	1	-
67	Herschel Island (Canada)	-	-	-	1	-	-	1	-	1	-	-
68	Harrison Bay	3	6	1	1	-	4	2	-	2	-	-
69	Harrison Bay/Colville Delta	2	6	1	1	-	3	1	-	1	-	-
70	North Central Chukchi	-	-	-	-	1	-	-	-	-	-	-
71	Simpson Lag., Thetis & Jones Isls.	-	4	1	1	-	2	1	-	1	-	-
72	Gwyder Bay, Cottle & Return Isls.	-	4	2	2	-	2	2	-	1	-	-
73	Prudhoe Bay	-	1	1	-	-	-	-	-	-	-	-
74	Hershel Isl.	-	-	-	3	-	-	4	-	3	-	1
75	Boulder Patch Area	-	9	49	6	-	3	5	-	2	-	-
76	Kendall Isl. Bird Sanctuary (Canada)	-	-	-	1	-	-	3	-	2	-	1
77	Sagavanirktok Delta/Foggy Isl. Bay	-	2	9	2	-	1	2	-	1	-	-
78	Mikkelsen Bay	-	1	16	1	-	1	1	-	-	-	-
79	Demarcation Bay Offshore	-	-	-	5	-	-	4	-	2	-	-
80	Chukchi Sea Nearshore IBA	11	3	-	1	10	4	1	4	2	-	1
81	Simpson Cove	-	-	-	1	-	-	1	-	-	-	-
82	North Chukotka Nearshore 2	2	1	-	-	4	1	-	2	-	2	-
83	North Chukotka Nearshore 3	1	-	-	-	2	-	-	1	-	-	-
84	Canning River Delta	-	2	1	3	-	1	1	-	1	-	-
85	Sagavanirktok River Delta	-	7	38	5	-	3	4	-	2	-	-
86	Harrison Bay	10	18	4	3	1	10	4	1	3	-	-
87	Colville River Delta	2	12	2	2	1	5	3	1	2	-	-
88	Simpson Lagoon	1	13	5	3	1	6	4	1	2	-	-
89	Mackenzie River Delta	-	-	-	2	-	1	5	-	3	-	2
91	Bowhead Whale Summer (Ca)	-	-	-	1	-	-	2	-	3	-	3
92	Thetis, Jones, Cottle & Return Isl.	1	17	9	5	1	8	6	1	3	-	-
93	Cross & No Name Isls.	-	5	4	2	-	2	2	-	1	-	-
94	Maguire, Flaxman & Barrier Isl.	-	7	6	13	-	3	7	-	3	-	-
95	Arey & Barter Isls., Bernard Spit	-	1	1	8	-	1	5	-	2	-	-
96	Midway, Cross & Bartlett Isls.	-	2	1	1	-	1	1	-	1	-	-
98	Anderson Point Barrier Isls.	-	-	-	1	-	-	1	-	-	-	-
99	Arey & Barter Isls., Bernard Spit	-	1	-	2	-	1	2	-	1	-	-
100	Jago & Tapkaurak Spits	-	-	-	2	-	-	2	-	1	-	-
102	Opilio Crab EFH	1	-	-	-	1	-	-	-	-	-	-
103	Saffron Cod EFH	14	3	1	-	14	4	-	5	1	-	-
104	Ledyard Bay-Icy Cape IBA	-	-	-	-	1	-	-	-	-	-	-
105	Fish Creek	5	14	2	2	1	5	3	1	2	-	-
106	Shaviovik River	-	12	73	8	-	4	6	-	3	-	-
107	Point Hope Offshore	1	-	-	-	1	-	-	1	-	-	-
109	AK BFT Shelf Edge	-	-	-	2	-	1	4	-	2	-	1
110	AK BFT Outer Shelf & Slope 1	-	1	-	2	-	1	4	-	4	-	2
111	AK BFT Outer Shelf & Slope 2	-	1	-	2	-	1	4	1	4	-	1
112	AK BFT Outer Shelf & Slope 3	-	1	1	2	-	2	4	1	3	-	1
113	AK BFT Outer Shelf & Slope 4	-	2	1	2	-	2	3	1	3	-	1
114	AK BFT Outer Shelf & Slope 5	-	2	1	1	-	3	2	1	3	-	1
115	AK BFT Outer Shelf & Slope 6	1	2	1	1	1	4	2	1	3	-	1
116	AK BFT Outer Shelf & Slope 7	2	3	1	1	2	5	2	3	4	-	2
117	AK BFT Outer Shelf & Slope 8	2	2	-	-	3	4	1	3	3	-	1
118	AK BFT Outer Shelf & Slope 9	2	1	-	-	4	3	1	3	2	-	1
119	AK BFT Outer Shelf & Slope 10	4	2	-	-	7	3	1	3	2	-	1
121	Cape Lisburne–Pt. Hope	-	-	-	-	1	-	-	1	-	-	-
122	Bowhead Fall (Canada)	-	-	-	1	-	-	3	-	1	-	-

Table A19 360 Days (Winter LS)

ID	Land Segment Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
6	Ostrov Mushtakova	-	-	-	-	-	-	-	-	-	1	-
7	Kosa Bruch	-	-	-	-	1	-	-	1	-	1	-
8	E. Wrangel Island, Skeletov	-	-	-	-	1	-	-	1	-	1	-
10	Bukhta Davidova	-	-	-	-	1	-	-	-	-	-	-
12	Bukhta Predatel'skaya	-	-	-	-	1	-	-	-	-	-	-
22	Rypkarpyy, Mys Shmidta	-	-	-	-	1	-	-	-	-	-	-
26	Ekugvaam, Kepin, Pil'khin	-	-	-	-	1	-	-	-	-	-	-
84	Will Rogers & Wiley Post Mem.	1	-	-	-	-	-	-	-	-	-	-
85	Barrow, Browerville, Elson Lag.	13	2	-	-	8	3	-	3	1	-	-
86	Dease Inlet, Plover Islands	5	1	-	-	3	2	-	1	-	-	-
87	Igalik & Kulgurak Island	6	1	-	-	3	2	-	1	1	-	-
88	Cape Simpson, Piasuk River	11	4	1	-	3	6	1	2	1	-	-
89	Ikpikpuk River Point Poleakoon	2	1	-	-	1	1	-	-	-	-	-
90	Drew & McLeod Point, Kolovik	3	1	-	-	1	1	-	-	-	-	-
91	Lonely, Pitt Pt., Pogik Bay, Smith R	4	2	-	-	1	3	1	1	1	-	-
92	Cape Halkett, Garry Creek	7	13	3	2	1	9	3	1	2	-	-
93	Atigaru Pt, Eskimo Isl., Kogru R.	2	5	1	1	-	2	1	-	1	-	-
94	Fish Creek, Tingmeachsiovik River	1	2	-	-	-	1	-	-	-	-	-
95	Colville River	1	3	-	-	-	1	1	-	-	-	-
96	Oliktok Point	1	3	-	-	-	2	1	-	-	-	-
97	Milne Point, Simpson Lagoon	-	6	3	2	-	3	2	-	1	-	-
98	Kuparuk River	-	6	4	3	-	2	3	-	1	-	-
99	Point Brower, Prudhoe Bay	-	5	19	3	-	2	3	-	1	-	-
100	Foggy Island Bay, Kadleroshilik River	-	3	29	3	-	1	2	-	1	-	-
101	Bullen, Gordon & Reliance Points	-	3	21	2	-	1	1	-	1	-	-
102	Pt. Hopson & Sweeney, Staines River	-	3	3	3	-	1	2	-	1	-	-
103	Brownlow Point, Canning River	-	2	1	7	-	1	3	-	1	-	-
104	Collinson Point, Konganevik Point	-	1	1	4	-	1	2	-	1	-	-
105	Anderson Point, Sadlerochit River	-	1	-	4	-	1	2	-	1	-	-
106	Arey Island, Barter Island,	-	1	1	6	-	1	3	-	1	-	-
107	Kaktovik	-	-	-	6	-	1	5	-	2	-	-
108	Griffin Point, Oruktalik Lagoon	-	-	-	6	-	-	5	-	2	-	-
109	Angun Point, Beaufort Lagoon	-	-	-	7	-	-	4	-	1	-	-
110	Icy Reef, Kongakut R., Siku Lag.	-	-	-	6	-	-	4	-	1	-	-
111	Demarcation Bay & Point	-	-	-	5	-	-	3	-	1	-	-
112	Clarence Lagoon, Backhouse River	-	-	-	3	-	-	3	-	1	-	-
113	Komakuk Beach, Fish Creek	-	-	-	2	-	-	3	-	1	-	-
114	Nunaluk Spit	-	-	-	1	-	-	1	-	1	-	-
115	Herschel Island	-	-	-	2	-	-	2	-	1	-	-
123	Outer Shallow Bay, Olivier Islands	-	-	-	-	-	-	1	-	-	-	-
124	Middle Channel, Gary Island	-	-	-	1	-	-	1	-	1	-	-
125	Kendall Island	-	-	-	-	-	-	1	-	-	-	-
126	North Point, Pullen Island	-	-	-	1	-	-	1	-	1	-	-

Table A20 360 Days (Winter GLS)

ID	Grouped Land Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
133	Somnitel'naya Spit, Davidova Spit	-	-	-	-	1	-	-	-	-	-	-
150	National Petroleum Reserve-Alaska	41	27	6	5	14	26	7	7	7	-	2
153	TCH Insect Relief/Calving	19	13	2	2	9	13	3	4	4	-	1
154	SUA: Utqiaġvik–Nuiqsut	5	4	1	1	2	4	1	1	1	-	1
155	Smith Bay Spotted Seal Haulout	5	1	-	-	2	3	-	1	1	-	-
156	Teshekpuk Lake Special Area/IBA	15	10	2	2	6	11	3	3	3	-	1
157	Colville River Delta IBA	2	5	1	1	-	2	1	-	1	-	-
158	Colville River Delta	1	3	-	-	-	1	1	-	-	-	-

ID	Grouped Land Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
159	Harrison Bay Spotted Seal Haulout	-	1	-	-	-	1	-	-	-	-	-
160	CAH Insect Relief/ Calving	1	11	25	8	-	5	7	-	4	-	-
161	SUA: Kaktovik–Nuiqsut	-	3	4	2	-	2	3	-	1	-	-
162	96–115 Summer	1	11	20	22	-	7	21	1	11	-	2
163	Beaufort Muskox Habitat	-	8	5	3	-	3	3	-	1	-	-
164	99–115 Fall	-	2	8	9	-	2	7	-	3	-	1
165	102–110- Winter	-	5	4	36	-	3	21	1	7	-	1
166	Arctic National Wildlife Refuge	-	5	3	46	-	4	28	1	10	-	2
167	Northeast Arctic Coastal Plain IBA	-	3	1	17	-	2	12	-	5	-	1
168	PCH Insect Relief/SUA Kaktovik	-	1	-	4	-	1	4	-	2	-	-
169	PCH Calving	-	1	1	11	-	1	10	-	5	-	1
170	Yukon Musk Ox Wintering	-	-	-	8	-	-	8	-	3	-	1
171	Ivvavik National Park (Canada)	-	-	-	8	-	-	8	-	4	-	1
172	112–132 Spring	-	-	-	5	-	1	8	-	6	-	2
173	112–121 Winter	-	-	-	3	-	-	4	-	2	-	1
174	Yukon Moose	-	-	-	-	-	-	1	-	1	-	-
175	Tarium Nirutait MPA	-	-	-	1	-	-	2	-	2	-	1
176	122–132 Spring	-	-	-	1	-	-	2	-	2	-	1
177	122–132 Winter	-	-	-	2	-	-	3	-	1	-	-
178	Kendall Island Bird Sanctuary (Ca)	-	-	-	-	-	-	1	-	1	-	1
179	TYH CBH Insect Relief	-	-	-	-	-	-	-	-	1	-	-
180	Russia Chukchi Coast M. Mammals	2	-	-	-	4	-	-	3	-	2	-
181	Russia Chukchi Coast	5	1	-	-	11	1	-	6	1	5	1
182	United States Chukchi Coast	2	-	-	-	2	-	-	1	-	-	-
183	United States Beaufort Coast	56	68	88	72	23	48	54	12	26	-	5
184	Canada Beaufort Coast	-	1	1	11	-	1	16	-	11	-	4

Table A21 360 Days (Winter BS)

ID	Boundary Segments Name	LA										
		1	2	3	4	5	6	7	8	9	10	11
4	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
5	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
16	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
17	Chukchi Sea	-	-	-	-	1	-	-	-	-	1	-
18	Chukchi Sea	-	-	-	-	-	-	-	-	-	1	-
19	Chukchi Sea	-	-	-	-	-	-	-	-	-	2	-
20	Chukchi Sea	-	-	-	-	-	-	-	-	-	2	-
21	Chukchi Sea	-	-	-	-	-	-	-	-	-	3	-
22	Chukchi Sea	-	-	-	-	-	-	-	-	-	3	-
23	Beaufort Sea	-	-	-	-	-	-	-	-	-	3	-
24	Beaufort Sea	-	-	-	-	-	-	-	-	-	4	-
25	Beaufort Sea	-	-	-	-	-	-	-	-	-	3	-
26	Beaufort Sea	-	-	-	-	-	-	-	-	-	2	-
27	Beaufort Sea	-	-	-	-	-	-	-	-	-	1	-
37	Beaufort Sea	-	-	-	-	-	-	-	-	-	-	1
38	Beaufort Sea	-	-	-	-	-	-	-	-	-	-	1
39	Beaufort Sea	-	-	-	-	-	-	-	-	1	-	1
40	Beaufort Sea	-	-	-	-	-	-	-	-	1	-	1

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Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.