Request for Incidental Harassment Authorization for the Non-Lethal Taking of Whales and Seals in Conjunction with a Proposed Marine 2D Seismic Program Chukchi Sea, Alaska, 2013

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ABBREVIATIONS and ACRONYMS

°	degree(s)
µPa	micro Pascal
µPa@1m	micro Pascal at 1 meter
2D	two-dimensional
3D	three-dimensional
AASM	airgun array source model
AEWC	Alaska Eskimo Whaling Commission
AHD	Acoustic Harassment Device
ASAMM	Aerial Surveys of Arctic Marine Mammals
BCB	Bering-Chukchi-Beaufort
BLM	Bureau of Land Management
BO	Biological Opinion
BOEM	Bureau of Ocean Energy Management
BOWFEST	Bowhead Whale Feeding Ecology Study
BP	British Petroleum
BWASP	Bowhead Whale Aerial Survey Project
CFR	Code of Federal Regulations
cm	centimeter(s)
Com	Communication
COMIDA	Chukchi Offshore Monitoring in Drilling Area
ConocoPhillips	ConocoPhillips Company
CSESP	Chukchi Sea Environmental Study Program
CSPA	Chukchi Sea Planning Area
dB	decibel(s)
DL	delisted
DPS	Distinct Population Segment
EAR	Ecological Acoustic Recorder
EEZ	Exclusive Economic Zone
EN	endangered
ESA	Endangered Species Act
FR	Federal Register
ft	feet/foot
GPS	Global Positioning System
Hz	hertz
IHA	Incidental Harassment Authorization
in^3	cubic inch(es)
IWC	International Whaling Commission
JASCO	JASCO Applied Sciences
K	carrying capacity

kg	kilogram(s)
kHz	kilohertz
km	kilometer(s)
km^2	square kilometers
kW	kilowatt(s)
LOA	Letter of Authorization
m	meter(s)
mi	statute mile(s)
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MONM	Marine Operations Noise Model
ms	Millisecond(s)
M/V	Motor Vessel
N	North
NL	not listed
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NSB	North Slope Borough
NSF	National Science Foundation
NVD	night vision devices
OBC	ocean bottom cable
OCS	outer continental shelf
OLF	Oljeindustriens Landsforening (Norwegian Oil Industry Association)
OSP	Optimum Sustainable Population
POC	Plan of Cooperation
PRF	pulse repetition frequency
psi	pounds per square inch
PSO	Protected Species Observer
PTS	Permanent Threshold Shift
re	relative to
RL	received level
rms	root mean square
R/V	Research Vessel
scfm	standard cubic feet per minute
sec	second(s)
Shell	Shell Exploration and Production Company
SSV	sound source verification
TTS	Temporary Threshold Shift
UAGI	University of Alaska Geophysical Institute
U.S.	United States

USDOI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
W	West
WGS	World Geodetic System
ZOI	zone of influence

Request for Incidental Harassment Authorization for the Non-Lethal Taking of Whales and Seals in Conjunction with a Proposed Marine 2D Seismic Program Chukchi Sea, Alaska, 2013

This document serves as an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS) to allow non-lethal "take" by harassment of small numbers of whales and seals incidental to two-dimensional (2D) seismic exploration activities proposed by TGS during the 2013 open-water period in U.S. Federal waters and international waters of the Chukchi Sea. Seismic operations are proposed to occur for approximately 68 days (35 days in U.S. Federal waters and up to 33 days in international waters) sometime between 15 July and 31 October 2013 (depending on ice and weather conditions). The items required to be addressed in a request for an IHA pursuant to Chapter 50 of the Code of Federal Regulations (CFR) § 216.104, "Submission of Requests" are correspondingly addressed below as separate sections. These sections include a description of the proposed activities; marine mammal species occurring in the project area; potential impacts to these species, their habitats, and subsistence hunting; proposed measures to mitigate and monitor potential effects; and a proposed Plan of Cooperation (POC). Additional figures are provided in Appendix A with additional tables provided in Appendix B. Appendix C is the full report written by JASCO Applied Sciences (JASCO) summarizing results of sound modeling of TGS's proposed 2013 seismic source array in the Chukchi Sea project area as conducted in 2013. The latter report also provides estimates of the distances to the 160, 180 and 190 decibels relative to 1 micro Pascal (dB re 1 µPa) root mean square (rms) isopleths regulated by NMFS for mitigation and monitoring of the potential effects of pulsed seismic operations on marine mammals.

TGS's seismic acquisition timing and locations are proposed so as to minimize potential impacts to marine mammal migrations and peak abundance periods, and subsistence hunts. For example, the closest survey point to an Alaskan community is 88 kilometers (km) (55 miles [mi]) west of Point Lay, and most lines are well over 200 km (125 mi) away to the northwest including in international waters. During proposed summer seismic operations, bowhead and beluga whales are predominantly east of the project area in the Beaufort Sea. During the fall bowhead and beluga migration periods, seismic operations are scheduled to occur above 72°N and thus north and outside of the main known migration corridor. Project operations require open water, thus ice habitat (associated with many species) will be avoided. Reported densities of marine mammals in the project area are relatively low during the majority of the survey, particularly in more northern waters. Proposed mitigation is further described in Section 11.0 *Mitigation Measures*. In general, based on available studies, any takes potentially resulting from the proposed operations are expected to be temporary (e.g., short-term behavioral changes or

displacement of individuals within ensonified zones associated with seismic operations) and not of biological significance to marine mammal populations.

1.0 OPERATIONS TO BE CONDUCTED

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

TGS proposes to conduct approximately 9,600 km of 2D marine seismic surveys along pre-determined lines in U.S. Federal waters and international waters of the Chukchi Sea (Figure 1) during the 2013 open water season (operations cannot be conducted in unbroken ice and pack ice will be avoided). The purpose of the proposed seismic program is to gather geophysical data using a 3,280 cubic inch (in^3) seismic source array and an 8,100-meter (m) long hydrophone solid streamer towed by the seismic vessel. Results of the 2D seismic program will be used to identify and map potential hydrocarbon-bearing formations and the geologic structures that surround them.

TGS plans to enter U.S. Federal waters sometime between 15 July and 5 August 2013. Approximately 35 days of seismic operations are expected to occur over a period of about 45-60 days in U.S. Federal waters. In addition, up to 33 days of seismic operations may occur in international waters (depending on ice and weather conditions). Seismic operations are proposed to occur along pre-determined track lines at speeds of about four to five knots as shown in Figure 1. Seismic operations will be conducted up to 24 hours per day as possible except as potentially needed for shut-down mitigation for marine mammals. The full 3,280 in^3 sound source will only be run during seismic acquisition operations on and near the end and start of survey lines; during turns and transits between seismic lines, a single "mitigation" airgun (60 in^3 or smaller) is proposed to be operated as a mitigation measure, as described for other NMFS-approved seismic operations in the Arctic and elsewhere (www.nmfs.opr).

Seismic operations must be conducted in ice-free open waters in order to safely tow the 8,100-m long hydrophone solid streamer. Furthermore, the two proposed vessels do not have ice-breaking capabilities. Thus, TGS' seismic operations are contingent on the availability and locations of ice-free waters within the project area. To avoid pack ice conditions, TGS will employ the scout vessel, satellite imagery, and consultations with ice expertise to plan the survey. The survey will progress with ice-free areas acquired first.

1.1 Vessels

Two vessels will be used during the survey: (1) a seismic operations vessel that will tow the seismic source array and a single 8,100-m long hydrophone solid streamer, and (2) a smaller vessel that will be used to search for marine mammals and scout for ice and other navigation hazards ahead of the seismic vessel. In the event of an emergency, the scout vessel may be used to support the seismic vessel. In this extraordinary circumstance, all seismic activity will cease since the scout vessel will no longer be

devoted to monitoring the exclusion zones. Currently, no particular vessels are under contract with TGS for the project. When contracts for each of these two vessels are secured, TGS will provide National Marine Fisheries Service (NMFS) the full vessel specifications.

1.2 Seismic Equipment

The seismic vessel will tow a compressed-air seismic source array of 28 Bolt 1900 LLXT airguns with a total discharge volume of 3,280 in^3. The airguns range in volume from 40 in^3 to 300 in^3 and are arranged in a geometric lay-out of three sub-arrays (Figure A-1 [Appendix A]) that will be towed approximately 200 m behind the vessel at a depth of 6 m. The seismic vessel will also tow an 8,100-m long hydrophone solid streamer at a depth of 10 m. The seismic source would discharge every 25 m (82 feet [ft]) or approximately every 10 seconds. Additional details regarding seismic acquisition parameters are provided in Table B-1 (Appendix B). The seismic vessel has limited maneuverability while towing the hydrophone solid streamer and seismic source. To ascertain whether the seismic source array is operating correctly, the full volume will be enabled for 1 km from the start of every line (i.e., a run in). To ensure full fold data acquisition the vessel will require a 4 km run out at the conclusion of each line. We anticipate that gravity and magnetic data will also be passively acquired during the survey by measuring gravity and magnetic variations while traversing the lines (no acoustics are involved with these methods).

1.3 Echosounders

Both vessels will use industry-standard echosounder/fathometer instruments to continuously monitor water depth for navigation purposes while underway. These instruments are the same as those used aboard all large vessels to obtain information on water depths and potential navigation hazards for vessel crews during routine navigation operations. Navigation echosounders direct a single, high-frequency acoustic signal that is focused in a narrow beam directly downward to the sea floor. The reflected sound energy is detected by the echosounder instrument which then calculates and displays water depth to the user. Typical source levels of these types of navigational echosounders are generally 180–200 dB re 1 µPa at 1 meter (1 µPa@1m) (rms) (Richardson et al. 1995).

One navigational echosounder will be used by the seismic vessel and another one will be used by the scout vessel. The echosounder used by the seismic vessel will consist of a downward-facing single-beam (Kongsberg EA600) that operates at frequencies of 18 to 200 kilohertz (kHz) (output power 1–2 kilowatt [kW]). Associated pulse durations are 0.064 and 4.096 milliseconds (ms) long and repetition frequency of the pulse (i.e., the ping rate) is related to water depth. In shallow water, the highest pulse repetition frequency (PRF) is about 20 pings per second. The scout vessel will use a Furuno 292 echosounder that operates at a frequency of 28 and 88 kHz. The highest ping rate in shallow water is 12 pings per second.

1.4 Sound Propagation Modeling

The acoustic source level of the proposed 3,280 in^3 seismic source array was predicted using JASCO's airgun array source model (AASM) based on data collected from three sites chosen in the project area by JASCO (Appendix C). Water depths at the three sites were 17, 40, and 100 m. JASCO applied its Marine Operations Noise Model (MONM) to estimate acoustic propagation of the proposed seismic source array and the associated distances to the 190, 180 and 160 dB re 1 µPa (rms) isopleths relative to standard NMFS mitigation and monitoring requirements for marine mammals. The resulting isopleths modeled for the 180 and 190 dB re 1 µPa (rms) exclusion zone distances for cetaceans and pinnipeds, respectively, differed with the three water depths. An additional 10 percent distance buffer was added by JASCO to these originally modeled distances to provide larger, more conservative exclusion zone radii distances that will be adhered to during the project (Table 1).

The estimated distances to the 190, 180 and 160 dB re 1µPa (rms) isopleths for the single 60 in^3 airgun (the largest single airgun that would be used as a "mitigation" gun) were measured by JASCO during monitoring sound source verification (SSV) study conducted for Statoil USA in 2010 in the Chukchi Sea during the open water season of 2010 (Blees et al. 2010). Results indicated that the distance to the 190 dB isopleth was 13 m, the 180 dB isopleth distance was 68 m, and the 160 dB isopleth was 1,500 m (all dB re 1 µPa [rms]).

2.0 DATES, DURATION, AND REGION OF ACTIVITY

The date(s) and duration of such activity and the specific geographical region where it will occur.

2.1 Dates and Duration of Activity

This IHA is requested for the period from 15 July through 31 October 2013 in U.S. Federal waters and international waters of the Chukchi Sea. Seismic operations are anticipated to occur for about 35 days over a period of 45-60 days in U.S. Federal waters and up to about 33 days in international waters. Operations in US Federal waters are expected to be complete no later than 5 October 2013. However, poor weather, ice conditions, equipment repair, etc., will likely delay or curtail operations. Thus, this extended period allows flexibility in proposed operational dates, contingent on such conditions. Specific proposed dates and durations of project activities are listed below in proposed chronological order, but are contingent on weather and ice, etc.

1. The two TGS project vessels plan to depart Dutch Harbor in the Bering Sea sometime between 10-21 July and arrive at the Chukchi Sea project area around five days later (depending on ice and weather conditions), and after the spring whale hunt is complete (see Section 11).

Table 1 – Distances to various isopleths at three water depths in the Chukchi Sea project area based on results of JASCO Applied Sciences sound modeling of the 3,280 in^3 array. These values include a 10 percent precautionary factor above the modeled results. The 190 dB isopleth corresponds to the exclusion zone for pinnipeds, the 180 dB isopleth corresponds to the exclusion zone for cetaceans, and the 160 dB isopleth corresponds to the received levels above which Level B behavioral changes may occur (NMFS 2005).

RMS (dB re 1 µPa)	**Distance (m)**		
	Depth (m): 17-40	**Depth (m): 40-100**	**Depth (m): >100**
190	930	920	430
180	2,200	2,500	2,400
160	8,500	9,900	15,000

2. Upon arriving at the project area, SSV measurements will be collected to validate modeled radii for marine mammal monitoring, potentially as early as 15 July (see Section 11 *Mitigation Measures*).
3. Seismic line operations are proposed to begin sometime between 15 July and 5 August, depending on duration of SSV measurements and weather and ice conditions. The survey will progress with ice-free areas acquired first.
4. TGS plans on surveying U.S. Federal waters first. The latter would involve approximately 35 days of seismic operations over a period of about 45-60 days. Up to approximately 6,088 km of seismic operations with the full sound source are planned to be conducted during this period in U.S. waters as follows: 5,973 km of pre-plot lines plus approximately 115 km for 1-km run-in and 5-km run-out between seismic lines. In addition, approximately 1,556 km with the single 60 in^3 (or smaller) mitigation airgun are planned to be conducted during turns and transits between lines.
5. When the U.S. Federal waters seismic surveys are complete, TGS plans to conduct up to about 33 days of seismic operations in international waters (weather and ice contingent). This would involve up to approximately 3,691 km of seismic operations with the full seismic source as follows: 3,631 km of pre-plot lines plus about 60 km of 1-km run-in and 5-km run-out between pre-plot lines. In addition, approximately 812 km with the single 60 in^3 (or smaller) mitigation airgun are planned to be conducted during turns and transits between seismic lines. Seismic operations are planned to end by 31 October in international waters.

6. It is possible, though not anticipated or planned, that seismic operations would start in international waters if U.S. Federal waters are not "ice-free". Subsequent seismic lines would be selected based on proximity to ice-free areas.
7. Upon completion of data acquisition, all vessels will demobilize to Dutch Harbor with an estimated return transit of five days.
8. Given the uncertainty in ice and water conditions, this IHA requests authorization for seismic operations in U.S. Federal waters and international waters for the period from 15 July through 31 October, 2013, to allow for any contingencies and weather delays.

2.2 Region of Activity

The seismic operations are proposed to occur in U.S. and international waters of the Chukchi Sea between about 70-77°N and 154-165° west (W) (Figure 1). Seismic activities are proposed to start first in U.S. Federal waters on or after 15 July (depending on ice and weather conditions) and proceed north and west into international waters through October 31 (depending on ice and weather conditions)(see Section 2.1 above). Of the total proposed program, 62 percent is in U.S. Federal waters, and 38 percent in international waters. U.S. Federal waters project waters are located in Lease Sale Area 193 of the U.S. Department of the Interior (USDOI), Minerals Management Service (MMS) now called the U.S. Bureau of Ocean Energy Management (BOEM).

Seismic operations would occur outside U.S. territorial waters. The closest survey point to the nearest community is 88 km (55 mi) west of Point Lay, Alaska (see Figure 1 for table of distances to other Alaskan communities). Most of the total approximately 9,600 km of proposed seismic lines occur in water 40-100 m deep (82 percent or 7,890 km), followed by waters >100 m deep (14 percent or 1,320 km) and waters <40 m deep (4 percent or 390 km).

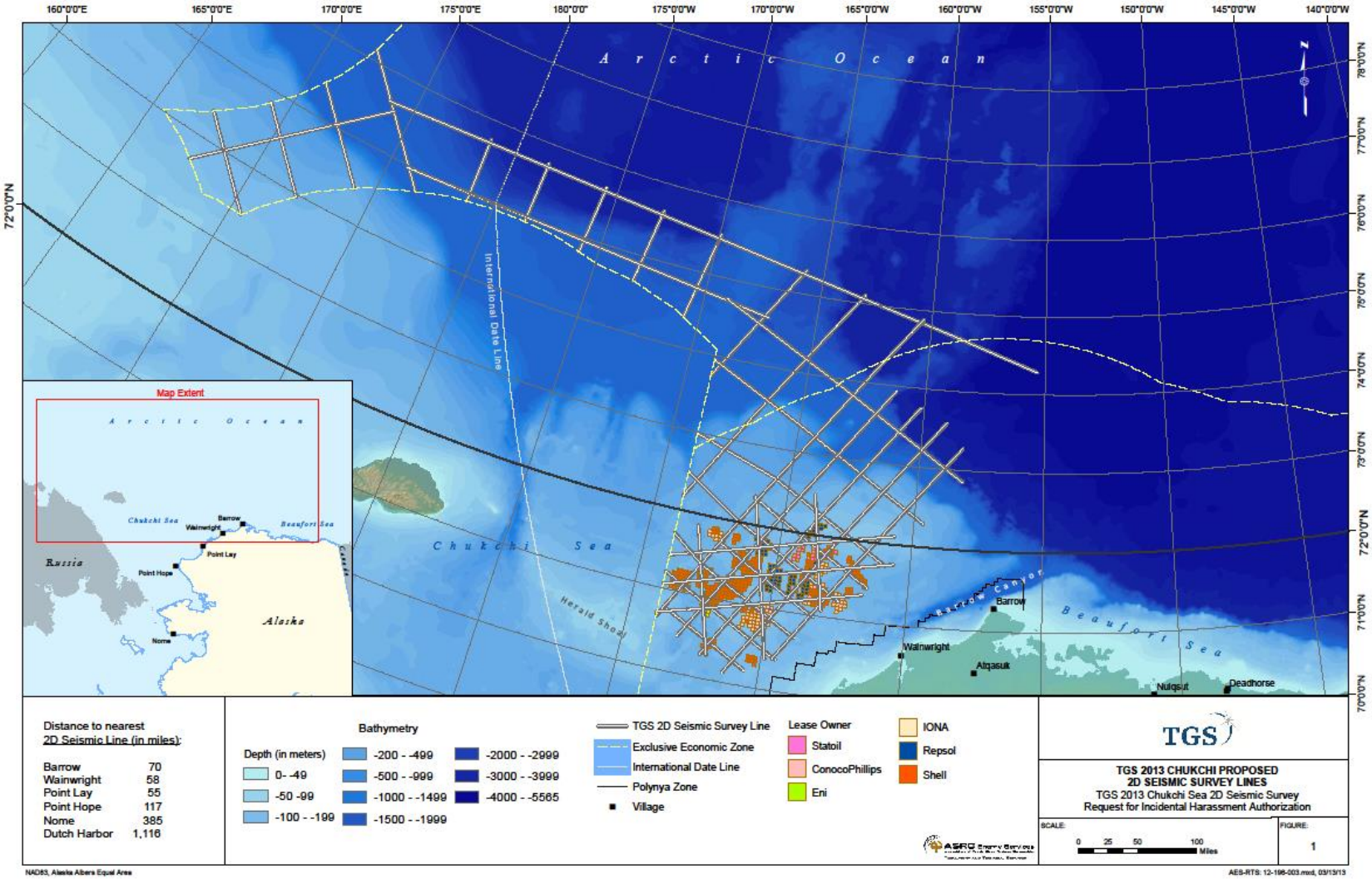

Figure 1 - Proposed seismic survey lines for TGS 2D seismic survey project during the 2013 open water season in the Chukchi Sea.

3.0 SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

The species and numbers of marine mammals likely to be found within the activity area.

3.1 Introduction

Twelve species of marine mammal that fall under NMFS jurisdiction have been documented commonly (*n* = 6 species) or uncommonly (*n* = 6) within the Chukchi Sea based on an up-to-date literature review, and thus are likely to or may occur within the proposed activity area. In addition to these 12 species, the narwhal (*Monodon monoceros*) has been documented in the Chukchi Sea but is considered extralimital. This species has not been reported within the project area boundary indicated in Figure 1. The narwhal is typically limited to Arctic waters of the Atlantic and off Russia (Heide-Jørgensen 2009). Given the rarity of this species in the Chukchi Sea, and its highly unlikely occurrence in the project area, the narwhal is not further addressed in this IHA (e.g., see LGL 2012).

The six most common species are the (1) bowhead whale (*Balaena mysticetus*), (2) gray whale (*Eschrichtius robustus*), (3) beluga whale (*Delphinapterus leucas*), (4) bearded seal (*Erignathus barbatus*), (5) ringed seal (*Phoca hispida*) and (6) spotted seal (*Phoca largha*). All six of these species have been documented within the project area based on a literature review. Three are protected under the U.S. Endangered Species Act (ESA) (1973): the bowhead whale is endangered and the ringed seal and bearded seals have recently been listed as "threatened" under the ESA (75 Federal Register [FR] 77476, 75 FR 77496).

Six additional species have occasionally been documented in the Chukchi Sea: (1) the humpback whale (*Megaptera novaeangliae*), (2) fin whale (*Balaenoptera physalus*), (3) minke whale (*B. acutorostrata*), (4) harbor porpoise (*Phocoena phocoena*), (5) killer whale (*Orcinus orca*), and (6) ribbon seal (*Histriophoca fasciata*). Only the endangered humpback and fin whale are protected by the ESA. Humpback whales are not known to regularly occur in the Chukchi Sea; however, several humpback sightings were recorded during vessel-based surveys in the Chukchi Sea in 2007 (Reiser et al. 2009, LGL 2012). Fin whale sightings and acoustic detections have only recently been documented in the Chukchi Sea (Brueggeman et al. 2009, Ireland et al. 2009, Stafford et al. 2010).

Two additional marine mammal species occur regularly in the Chukchi Sea: the Pacific walrus (*Odobenus rosmarus divergens*) and the polar bear (*Ursus maritimus*). The Pacific walrus is not classified as depleted nor is it a listed species under the ESA. Polar bears in the Chukchi/Bering seas stock are currently classified as depleted under the MMPA and listed as threatened under the ESA. However, they are not addressed in this IHA because the USFWS manages these species. Thus, a separate application for a Letter of Authorization (LOA) for incidental take of walrus and polar bears is being submitted to USFWS for this proposed seismic program. Consequently, these two species are not further addressed in this IHA.

3.2 Numbers

To avoid redundancy, the estimated numbers of individuals of the six species that are known to or may be present in the project area are further discussed in Section 4 below.

4.0 STATUS, DISTRIBUTION, AND SEASONAL DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities.

4.1 Introduction

As indicated in Section 3.0, the following 12 marine mammal species may occur in the region of the proposed seismic activity during the proposed project period from late July-October: bowhead, gray, beluga, minke, humpback, fin and killer whales; harbor porpoise; and ringed, bearded, spotted, and ribbon seals. Three of these species are listed as endangered under the ESA (bowhead, humpback and fin whale) and two are proposed for listing under the ESA (the ringed and bearded seals). All 12 species are protected by the U.S. Marine Mammal Protection Act (MMPA) (1972). These species are discussed in the following subsections and are the species for which general regulations governing potential incidental takes of small numbers of marine mammals are requested. The status, general distribution, and seasonal occurrence of these species are summarized in Table 2 and are discussed separately below.

Relatively few systematic surveys for marine mammals have occurred in the TGS project area, particularly in the more northern international waters above approximately 72°N. Some recent studies from 2007-2012 that have overlapped or have been close to the proposed project area include:

- The University of Alaska Geophysical Institute (UAGI), with research funding from the National Science Foundation (NSF), conducted a marine seismic survey in the Arctic Ocean during September and October 2011. The survey occurred in international waters and in the U.S. Exclusive Economic Zone (EEZ) encompassing the area 72.5°N to77°N, and 160°W to175°W (Cameron et al. 2012). This survey consisted of approximately 5,300 km of seismic survey lines and 407 hours of visual monitoring effort conducted over 32 days (Cameron et al. 2012). Eight species of marine mammals (three species of cetaceans and five species of pinnipeds) were identified in addition to several unidentified cetaceans and multiple unidentified pinnipeds (Cameron et al. 2012).

- In 2010, Statoil USA Exploration and Production, Inc. (Statoil), collected marine seismic data during 2D and 3D seismic exploration activities, conducted by Furgo Geoteam, Inc., in the

Chukchi Sea during the open-water period from August to October (Blees et al. 2010). The geographic region where the survey occurred was in or near Statoil lease holdings in the Chukchi Sea Planning Area designated by Oil and Gas Lease Sale 193. Seismic acquisition occurred in the Chukchi Sea approximately 240 km (150 mi) west of Barrow and about 160 km (100 mi) northwest of Wainwright in Outer Continental Shelf (OCS) waters (Blees et al. 2010). The Chukchi sea survey area was located north of Point Hope at 68.34°N. Average waters depths were 30–50 m (33-55 yards) and occurred outside the polynya zone (Blees et al. 2010). A total of 10,717 km (6,659 mi) of trackline and about 10,477 of visual observation effort occurred during 43 days from 20 August to 1 October 2010. Seven marine mammal species (3 cetacean and 4 pinniped) were identified. A total of 310 sightings of 534 marine mammals were seen (Blees et al. 2010).

- In 2011, Statoil conducted a shallow hazard and site clearance survey and a geotechnical soil investigation in the Chukchi Sea during the 2011 open-water period from August to October (Hartin et al. 2011). The geographic region where the shallow hazards site survey occurred was in or near Statoil lease holdings in the Chukchi Sea Planning Area designated by Oil and Gas Lease Sale 193 and the same location as the Statoil 2010 seismic survey. These leases are located about 240 km (150 mi) west of Barrow and about 160 km (100 mi) northwest of Wainwright in OCS waters (Hartin et al. 2011). The Chukchi sea survey area was located north of Point Hope at 68.34°N. Average waters depths were 30–50 m (33-55 yards) and occurred outside the polynya zone (Hartin et al. 2011). The survey consisted of approximately 9,301 km of survey lines and about 8,724 km of visual observation effort during 45 days from 6 August to 23 September 2011. Four species of marine mammals (one cetacean, and three pinniped species) were identified in addition to unidentified mysticete whales and unidentified pinnipeds and seals. A total of 183 sightings of 246 marine mammals were seen (Hartin et al. 2011).

- A marine mammal monitoring study occurred from July through October in 2008-2010 as part of the multi-disciplinary Chukchi Sea Environmental Study Program (CSESP). ConocoPhillips Company (ConocoPhillips) initiated this program in 2008, with cofounding and participation by Shell Exploration and Production Company (Shell). Statoil joined ConocoPhillips and Shell in 2010 and the Oljeindustriens Landsforening (Norwegian Oil Industry Association) (OLF) took over operatorship from ConocoPhillips (Aerts et al. 2011). Biologists recorded all marine mammals seen along transect lines that covered three study areas (Klondike, Burger, and Statoil) as well as transits between Wainwright (Aerts et al. 2011). The Klondike study area is located approximately 220 km (136 mi) northwest of Wainwright. The Burger study area is located approximately 100 km (62 mi) northwest of Wainwright, and the Statoil study area is located approximately 140 km (86 mi) northwest of Barrow (Aerts et al. 2011). The study areas are located at 70-72°N and 160-169°W. In 2010, a total of 405 sightings of 515 individuals of four cetacean and four pinniped species were recorded along 8,027 km of survey line during 519 hours of observation effort (Aerts et al. 2011).

- The Chukchi Offshore Monitoring in Drilling Area (COMIDA) aerial survey component was initiated in 2008, via an Interagency Agreement between the MMS (now BOEM) and the NMFS National Marine Mammal Laboratory (NMML) (Clarke et al. 2011). The goal of the COMIDA surveys was to investigate the distribution and relative abundance of marine mammals in the Chukchi Sea Planning Area (CSPA) during the open water (ice-free) months of June-October, when various species undertake seasonal migrations through the area (Clarke et al. 2011). The COMIDA study area encompassed the northeastern Chukchi Sea from the shore seaward (68°N to 72°N and 157°W to 169°W) and overlaid Lease Sale 193 (offered in February 2008) (Clarke et al. 2011). In 2011, an Interagency Agreement between the BOEM and NMML was established to authorize NMML to continue the Bowhead Whale Aerial Survey Project (BWASP) and COMIDA studies under the auspices of a single study, Aerial Surveys of Arctic Marine Mammals (ASAMM) (Clarke et al. 2011). The goal of the ASAMM study has been to document the distribution and abundance of marine mammals in areas of potential seismic surveying, drilling, construction, and production activities in the Alaskan Beaufort and northeastern Chukchi seas. The ASAMM field season commenced 16 June 2011 and ended 26 October 2011 (Clarke et al. 2011). There were 97 survey flights, of which 9 were in June, 16 in July, 21 in August, 35 in September, and 16 in October. A total of 40,006 km of effort on transect was flown during 189 hours (Clarke et al. 2011). In 2011, a total of 2,630 sightings and 115,659 individuals of four cetacean and two pinniped species were recorded (Clarke et al. 2011).

- The Bowhead Whale Feeding Ecology Study (BOWFEST) was initiated in May 2007 through an Interagency Agreement, as well as through employees at NMML, and has been conducted each year since (Shelden and Mocklin 2012). Scientists from the NMML conducted aerial surveys from 25 August-17 September 2011 in the BOWFEST study area (continental shelf waters between 157°W and 152° W and from the coastline to 72°N, with most of the effort concentrated between 157°W and 154° W and between the coastline and 71°44'N). In 2011, a total of 289 sightings of 836 individuals of three cetacean and one pinniped species were recorded during 43.9 flight hours (Shelden and Mocklin 2012). The data analysis for the 2011 survey period is still ongoing. In September 2010, three year-long Autonomous Underwater Recorder for Acoustic Listening recorders were deployed; between 19 August and 23 September, six Ecological Acoustic Recorders (EAR) were deployed (Shelden and Mocklin 2012). The EARs were deployed in shallow waters; one was deployed on a short-term mooring frame and five were deployed as movable arrays. No bowheads were heard on the fixed mooring, which only recorded for 8 of the 29 days it was deployed (Shelden and Mocklin 2012). The movable arrays recorded bowheads from 29 August until 8 September. Only one of these moorings (the EAR closest to Barrow) detected enough calls to define the peak presence, which occurred from 30 August to 8 September. One of the movable arrays recorded no bowheads.

- During the 2012 exploration drilling season (July – October), Shell Gulf of Mexico Inc. drilled up to three exploration wells at three drill sites in the Chukchi Sea (on OCS leases acquired from the BOEM) (Shell 2011). The project area is located over 103 km (64 mi) from the Alaskan Chukchi

Sea coast. Results are not publicly available yet in a 90-day report on the NMFS Office of Protected Resources website.

- Smultea et al. (2012) did a comprehensive review of systematic bowhead whale surveys conducted in the U.S. Beaufort and Chukchi seas from 1975 to 2009. This review indicated that about 200 such surveys occurred in these waters; 67 percent of those surveys were associated with monitoring and mitigation relative to offshore oil and gas exploration and development.

Table 2 – List of the 12 marine mammal species that are known to or may occur in the project area and their status, abundance, distribution, habitats, and seasonal occurrence in the Chukchi Sea. ESA-listed species are presented first followed in descending order of species relative abundance in the Chukchi Sea.

Species (*Stock*)	**U.S. Federal Status [1]**	**Estimated Stock Abundance [2]**	**Relative Abundance in Chukchi Sea**	**Preferred Habitat in Chukchi Sea**	**Seasonal Occurrence in Chukchi Sea**	**Occurrence in Project Area Boundaries**
Cetaceans						
Bowhead Whale (*Western Arctic stock*)	EN	11,836	Common seasonally	Pack ice and coastal	Primarily spring and fall migrations	July - October
Humpback Whale (*Western North Pacific stock*)	EN.	20,800	Seasonally uncommon	Widely distributed, coastal and offshore ice-free waters, shelf	Summer and fall in ice-free waters	July - September
Fin Whale (*Northeast Pacific stock*)	EN	Currently, no reliable abundance estimate is available for this stock. In 2006, it was estimated that 1,652 individuals were in the area.	Rare	Slope, mostly pelagic ice-free waters	Extra-limital	July - September
Gray Whale (*Eastern North Pacific stock*)	DL	19,126	Common seasonally	Coastal, lagoons in ice-free waters	Summer and fall feeding	July - October
Beluga Whale (*Eastern Chukchi Sea/Beaufort Sea*)	NL	3,710 / 39,258	Common seasonally	Offshore, coastal, ice edges, pack ice	Spring and fall migrations	October
Killer Whale (*Eastern North Pacific Alaska resident stock*)	NL	2,084	Rare	Widely distributed including among pack ice	Spring, summer and fall	July - October

Species (*Stock*)	U.S. Federal Status [1]	Estimated Stock Abundance [2]	Relative Abundance in Chukchi Sea	Preferred Habitat in Chukchi Sea	Seasonal Occurrence in Chukchi Sea	Occurrence in Project Area Boundaries
Harbor Porpoise (*Bering Sea Stock*)	NL	48,215	Seasonally uncommon	Coastal, inland ice-free , and, occasionally shallow offshore waters	Summer and fall in ice-free waters	July - October
Minke Whale (*Eastern North Pacific stock*)	NL	810	Seasonally uncommon	Widely distributed, coastal, shelf, and offshore in ice-free or light ice waters	Extralimital	July - October
Pinnipeds						
Ringed Seal (*Alaska*)	T	Up to 3.6 million. Currently, no reliable abundance estimate is available for the Beaufort Sea; however, combined with surveys from the Chukchi Sea, approximately 250,000 are estimated.	Common year-round in areas of ice	Landfast ice, pack ice, and open water	Regular	July - October
Bearded Seal (*Alaska*)	T	Currently, no reliable abundance estimate is available for this stock. Early estimates the Bering-Chukchi Seas was 155,000.	Common year-round	Shelf waters, pack ice, open water	Regular	May - October

Species (*Stock*)	U.S. Federal Status [1]	Estimated Stock Abundance [2]	Relative Abundance in Chukchi Sea	Preferred Habitat in Chukchi Sea	Seasonal Occurrence in Chukchi Sea	Occurrence in Project Area Boundaries
Spotted Seal (*Alaska*)	NL	Several thousand and several tens of thousands. An estimate with correction using 1992 data = 59,214 seals, but is preliminary at best.	Common year-round	Shelf waters, pack ice, coastal haul-outs, and open water	Rare	July - October
Ribbon Seal (*Alaska*)	NL	Currently, no reliable abundance estimate is available for this stock. Early estimates of the Bering sea were 49,000.	Rare	Offshore, pack ice, and open water	Rare	July - October

[1] ESA = Endangered Species Act. Stocks listed as depleted under the MMPA (Marine Mammal Protection Act) are described as any stock that falls below its optimum sustainable population must be classified as "depleted," 16 U.S.C. § 1362(1)(A). The numeric threshold for optimum sustainable population (OSP) has been interpreted by NMFS and USFWS as being above 0.6 K (i.e., greater than 60 percent of carrying capacity [K]). In other words, a stock that dropped in numbers to below 60 percent of K would qualify as "depleted" under the MMPA. The term "strategic stock" is defined as a marine mammal stock: (A) for which the level of direct human-caused mortality exceeds the Potential Biological Removal level; (B) which, based on the best available scientific information, is declining and is likely to be listed as a Threatened species under the Endangered Species Act of 1973 within the foreseeable future; or (C) which is listed as a Threatened species or Endangered species under the Endangered Species Act of 1973, or is designated as depleted under [the MMPA]. DL = Delisted, EN = Endangered, NL = Not listed, T = Threatened under ESA, Not listed as depleted under MMPA, and not classified as a strategic stock.

[2] See text under individual species for population estimate sources.

4.2 Bowhead Whale

Of the four recognized stocks of bowhead whales world-wide, the largest is the Western Arctic stock (also known as the Bering-Chukchi-Beaufort [BCB] Sea stock) (International Whaling Commission [IWC] 2010, Allen and Angliss 2012). This stock inhabits the Bering, Chukchi, and Beaufort seas (Figure A-2 [Appendix A]) (Rugh et al. 2003, Allen and Angliss 2012), and is the focus of this IHA request. The stock is currently listed as federally Endangered under the ESA (35 FR 18319) and is classified as a strategic stock by NMFS (LGL 2012). No critical habitat is designated for this species.

The Western Arctic stock winters in the Bering Sea. From March through June, the stock migrates north and east across the Chukchi Sea following open ice leads to summer and feed in the Canadian Beaufort Sea (Braham et al. 1980, Braham et al. 1984, Moore and Reeves 1993, Rugh et al. 2003, Quakenbush et al. 2010a,b, Allen and Angliss 2012). In the fall, these bowhead whales migrate back west past Barrow and through the northern Chukchi sea, some into Russian waters, before turning southeast towards the Bering sea (Moore et al. 1995, Mate et al. 2000, Quakenbush et al. 2010a). A small number of satellite-tagged bowheads reached approximately 75°N during the westward fall migration (Quakenbush et al. 2010a).

Based on aerial and vessel survey data and satellite-tagging studies, a small number of individuals from this stock have been documented in or near waters of the project area in August – October during the species' westward migration (Brueggeman et al. 2009, 2010, Quakenbush and Huntington 2010, Quakenbush et al. 2010a,b, Aerts et al. 2011, Clark et al. 2011, Clarke et al. 2012). Bowhead whales potentially occurring in the project area would be expected to prefer waters less than 200 m deep based on results of other studies (summarized in LGL 2012). No confirmed bowheads were seen or heard during extensive summer-fall vessel-based marine mammal monitoring programs associated with the 2011 UAGI seismic project in an area overlapping the proposed TGS operations as reported in the associated 90-day reports to NMFS (Cameron et al. 2012). However, bowheads were seen or heard from 18 September to 12 October 2011 during the Statoil marine mammal monitoring program out to approximately 200 km northwest of Wainright (Hartin et al. 2010).

The Western Arctic stock of bowhead whales has been steadily increasing in numbers as documented over the last four decades. George et al. (2004) reported that the stock has increased at a rate of 3.4 percent from 1978-2001. During this period, abundance doubled from approximately 5,000 to 10,000 whales (LGL 2012). The count of 121 calves during the 2001 census was the highest yet recorded. This peak was likely caused by a combination of variable recruitment and the large population size (George et al. 2004, LGL 2012). The calf count provides corroborating evidence for a healthy and increasing population (LGL 2012). The Western Arctic stock was recently estimated at 11,836 whales and has been growing at an annual rate of about 3.2 percent (Schweder et al. 2009, LGL 2012).

The bowhead whale is an important subsistence species for Alaska Native communities. Eskimos have been taking bowhead whales for at least 2,000 years (Stoker and Krupnik 1993, NMFS 2008).

Subsistence takes have been regulated by a quota system under the authority of the IWC since 1977 (NMFS 2008). There are two Alaska villages currently participating in subsistence hunts that are located in or near the project area: Wainwright and Barrow. These villages are along the coast of the Chukchi Sea (NMFS 2008).

4.3 Gray Whale

The Eastern North Pacific stock or California gray whale population, like all large whale populations, was once hunted to near extinction. However, it has since recovered significantly from commercial whaling. The stock was removed from the U.S. Endangered Species List in 1994 and is not considered by NMFS to be a strategic stock (Allen and Angliss 2012). The population is currently estimated at 19,126 whales (LGL 2012, Allen and Angliss 2012).

The eastern North Pacific gray whale ranges from the Bering, Chukchi, and Beaufort seas (in summer) to the Gulf of California (in winter) (Rice and Wolman 1971, Nerini 1984, Rice 1998, Moore et al. 2003). However, gray whales also forage in waters off of Southeast Alaska, British Columbia, Washington, Oregon, and California (Rice and Wolman 1971, Berzin 1984, Nerini 1984, Darling 1984, Clarke et al. 1989, Quan 2000, Calambokidis et al. 2002, Moore et al. 2007, Allen and Angliss 2012). Most of the eastern North Pacific population makes a round-trip annual migration of over 8,000 km from Alaskan feeding waters to breeding and calving waters in Baja California, Mexico (Rice and Wolman 1971, Rice et al. 1981, Allen and Angliss 2012). From late May to early October, the majority of the population feeds in the northern and western Bering and Chukchi seas.

Typically, gray whales inhabit shallow water, remaining closer to shore than any other large cetacean throughout the year. Gray whales are considered common summer residents in the nearshore waters of the eastern Chukchi Sea. They are occasionally seen east of Point Barrow in late-spring and summer, as far east as Smith Bay (Green et al. 2007). Sightings of small groups or individuals have been reported in the project area during August – October (Brueggeman et al. 2009, 2010, Clarke et al. 2011). At least 8 gray whales were seen between 6 Aug and 27 September 2011 during marine mammal monitoring associated with the Statoil project in an area overlapping the TGS Alaskan (U.S. Federal waters) project area (LGL 2011). No gray whales were reported during vessel-based monitoring for the UAGI seismic project during 8 September to 9 October 2011 in an area overlapping the Alaskan TGS project area (Cameron et al. 2012).

Based on available data, gray whale numbers in the Chukchi Sea are expected to be much higher during summer than fall, with most individuals concentrated in nearshore areas well east of the TGS project area. Furthermore, gray whales rarely range north of 72°N in the Chukchi Sea (Figure A-3 [Appendix A]). Thus, relatively low numbers of gray whales are expected to be encountered in the project area, with few if any expected to occur near proposed fall operations north of 72°N.

4.4 Beluga Whale

Of the five beluga stocks occurring in Alaska (O'Corry-Crowe et al. 1997, Allen and Angliss 2012) only the Eastern Chukchi Sea stock and possibly the Beaufort Sea stock may be encountered in the project area (Figure A-4 [Appendix A]). Any occurrences of the beluga whale in the project area are most likely individuals from the Eastern Chukchi Sea stock. The latter stock is not considered by NMFS to be a strategic stock, and the current population trend of the Beaufort Sea stock is not in decline (Allen and Angliss 2012). Small numbers of beluga whales may occur in the project area in October (Clarke et al. 2011). However, none were seen or heard during extensive summer-fall marine mammal monitoring programs associated with the 2011 UAGI and 2010 Statoil seismic projects in areas overlapping the proposed TGS operations in U.S. Federal waters as reported in the associated 90-day reports to NMFS (Hartin et al. 2011, Cameron et al. 2012).

Both stocks overlap in the Beaufort Sea, and both winter in the Bering Sea (Suydam et al. 2001, Allen and Angliss 2012). Much of the Eastern Chukchi stock breeds in Kasegaluk Lagoon in June and July. The current abundance estimate of 3,710 is considered the "most reliable" for the eastern Chukchi Sea beluga whale stock based on 1989–1991 aerial surveys (Frost et al. 1993, Allen and Angliss 2012). Additional surveys were conducted in 1998 (DeMaster et al. 1998) and again in July 2002 (Lowry and Frost 2002), but both were partial surveys and therefore, a more complete abundance estimate for this stock is not available (Allen and Angliss 2012). The Beaufort Sea stock moves out of the Chukchi Sea into the Beaufort Sea during spring (April to May) (Braham et al. 1984, Richardson et al. 1995). They return in fall for their annual migration back to Bering Sea wintering areas. Migration generally occurs in deeper water along the ice front (Hazard 1988, Clarke et al. 1993, Richardson et al. 1995, Miller et al. 1998).

Aerial surveys conducted in 2006 and 2007 in the Chukchi Sea reported peak sightings of belugas within about 37 km from shore in July (Thomas et al. 2009). Monthly sighting rates were lowest in September. Based on combined data, sightings rates of belugas and numbers of individuals were highest within 26-35 km from shore in the Chukchi Sea. However the largest groups were seen within 5 km of shore. In summary, results reported by Thomas et al. (2009) indicate that the highest numbers of belugas in this region occur close to the Alaskan coast in the Chukchi Sea during summer.

Beluga whales are also known to congregate in Kasegaluk Lagoon along the Chukchi Alaskan coast during summer. However, a small number of individuals have been shown to range from this lagoon into the Arctic Ocean north of the Beaufort Sea based on satellite-tagging studies (Suydam et al. 2005). Of 23 beluga whales satellite-tagged in late June and early July of 1998-2002, 5 individuals moved into pack ice of the Arctic Ocean to 79-80°N (Suydam et al. 2005). These whales as well as other tagged individuals traveled to areas up to 1,102 km from shore between Barrow and the Mackenzie River Delta in areas characterized by up to 90 percent ice coverage.

Small numbers of belugas could be encountered in the project area during proposed seismic operations. However, the number of belugas in the project area is expected to be relatively low, as most individuals occur much closer to shore and/or are closely associated with sea ice habitat. While some belugas may concentrate at inshore breeding lagoons during summer, the majority of the migration will have passed this area by July on their way to the Beaufort Sea. However, a small number could also be encountered in waters north of 72°N in summer or fall based on satellite-tagging studies. If proposed seismic surveys extend into the fall, southward migrating belugas might also be encountered. However, proposed TGS operations would occur at least 88 km from the Alaskan coast, with most operations much farther offshore where beluga density is expected to be relatively low. In addition, the seismic program will avoid ice conditions preferred by this species.

4.5 Fin Whale

Based on limited information, the IWC considers fin whales in the North Pacific to all belong to the same stock (Mizroch et al. 1984). However, there is additional evidence that supports establishment of subpopulations in the North Pacific (Allen and Angliss 2012). For management purposes, three stocks of fin whales are currently recognized in U.S. waters: Alaska (Northeast Pacific), California/Washington/Oregon, and Hawaii. Fin whales that in the Bering Sea belong to the Northeast Pacific stock. Fin whales occur seasonally off the coast of North America and in the Bering Sea during summer (Allen and Angliss 2012). The fin whale is listed as endangered under the ESA, and therefore designated as depleted under the MMPA. As a result, the Northeast Pacific stock is classified as a strategic stock.

The population for the entire North Pacific region was estimated at 1,652 in 2006 (Zerbini et al. 2006). However, reliable estimates of current and historical abundance for the entire Northeast Pacific fin whale stock are currently not available (Allen and Angliss 2012). Recent studies provide some information on the distribution and occurrence of fin whales. However, they do not provide estimates of population size. Fin whale abundance estimates were nearly five times higher in the central-eastern Bering Sea than the southeastern Bering Sea (Moore et al. 2002). Most sightings in the central-eastern Bering Sea occurred in a zone of particularly high productivity along the shelf break (Moore et al. 2000, Allen and Angliss 2012).

Fin whale calls were detected in the southeast Bering Sea using an instrument moored there from April 2006 through April 2007. Results showed fin whale call detections peaked from September through November 2006 and also in February and March 2007 (Stafford et al. 2010, Allen and Angliss 2012). Fin whales could be encountered in very low numbers in the project area, and are unlikely to occur above 72°N where TGS expects to be operating during September-October.

4.6 Humpback Whale

The stock origin of the few individual humpbacks whales recorded in the Chukchi Sea is not known. These individuals may belong to the Central North Pacific stock (Funk et al. 2010, Allen and Angliss 2012), or the Western North Pacific stock (Hashagen et al. 2009). The humpback whale is listed as endangered under the ESA and is designated as "depleted" under the MMPA. Humpback whales are not taken for subsistence purposes by Alaska Natives from villages near the Chukchi or Beaufort Seas. The most recent population estimate for the Central North Pacific stock was 6,000-14,000 (Allen and Angliss 2012).

Currently, the "approximate distribution" of the Western North Pacific Stock of humpback whales extends into the southwestern Chukchi Sea during the summer feeding period (Allen and Angliss 2012). They have been known to feed periodically in the southern Chukchi Sea (Zenkovich 1954, Nemoto 1957, Tomlin 1967, Johnson and Wolman 1984, Mel'nikov 2000, Allen and Angliss 2012). However, the species is considered extralimital in the northern Chukchi Sea, including the project area vicinity. Only one humpback whale was observed during aerial surveys conducted from 2008-2010 (Clarke et al. 2011) in the northern Chukchi Sea. The single observation was recorded in July 2009 and was within the proposed TGS project area.

The area proposed for TGS's 2D seismic program is not within normal humpback whale feeding or migration areas. Thus, they are considered highly unlikely to be encountered during the program.

4.7 Killer Whale

Of the eight killer whale stocks recognized in the Pacific, the trans-boundary Alaska Resident stock inhabiting southeastern Alaska to the Chukchi Sea (Allen and Angliss 2012) is the only stock that could possibly be encountered during the TGS 2D seismic program. Based on aerial and vessel survey data, a small number of individuals have been reported in the project area in August – October (Brueggeman et al. 2009). Based on NMML surveys, the Alaska Resident stock consists of a minimum estimate of 2,084 killer whales (Allen and Angliss 2012).

Killer whales inhabit all Alaskan waters (Braham and Dahlheim 1982), although they are considered rare in the Chukchi Sea. This species occurs throughout the world's oceans and seas, from the equator's more tropical waters to the cooler waters in the high latitudes (Leatherwood and Dahlheim 1978). They are most common in cooler coastal waters of both hemispheres, but appear in greatest numbers within 800 km from continental coasts (Mitchell 1975, Leatherwood and Dahlheim 1978, Forney and Wade 2006). Sightings near Point Barrow have coincided with the bearded seal migration, which may attract killer whales to this quite northern location. Sightings of small groups or individuals have been reported in Alaskan waters of the project area in August to October (Brueggeman et al. 2009).

4.8 Harbor Porpoise

Harbor porpoises are unlikely to occur in significant numbers within the seismic acquisition area as the seismic transects will occur well offshore in water depths averaging approximately 40-100 m or more. Harbor porpoise are not listed as "depleted" under the MMPA or listed under the ESA. The Bering Sea stock of harbor porpoise is not classified as a strategic stock. Population trends and status of this stock relative to OSP are currently unknown.

The harbor porpoise is a small coastal cetacean generally inhabiting shallow, coastal waters (Gaskin 1984, Dahlheim et al. 2000, 2009). The Bering Sea stock, which ranges to Point Barrow (Suydam and George 1992), occurs most frequently in waters less than 100 m deep (Waite and Hobbs 2010, Allen and Angliss 2012). During summer, however, a small number of harbor porpoises from the Bering Sea stock do regularly move north into the Chukchi Sea (Allen and Angliss 2012). The harbor porpoise is considered highly unlikely to occur in the TGS project area given its rarity in the Chukchi Sea, particularly the offshore relatively deep waters characterizing the project area.

The most recent abundance estimate for the Bering Sea stock, based on aerial surveys conducted by NMML in Bristol Bay, is about 48,000 animals (Allen and Angliss 2012). These estimates are considered conservative, but are higher than an earlier estimate of about 11,000 by Dahlheim et al. (2000).

4.9 Ringed Seal

The ringed seal is the most abundant marine mammal in the Beaufort, Chukchi, and Bering Seas (Frost et al. 1988, Funk et al. 2010, Kelly et al. 2010). In the North Pacific, ringed seals inhabit the southern Bering Sea and range as far south as the Seas of Okhotsk and Japan (Figure A-5 [Appendix A]) (Harwood and Stirling 1992, Allen and Angliss 2012). Throughout their range, ringed seals have an affinity for ice-covered waters and are well adapted to occupying seasonal and permanent ice (Kelly 1998, Allen and Angliss 2012). They are year-round residents throughout the Beaufort, Chukchi, and Bering Seas, to as far south as Bristol Bay in years of extensive ice coverage. They tend to prefer large ice floes (i.e., over 48 m [157 ft] in diameter) and often inhabit interior pack ice where sea ice coverage is over 90 percent (Simpkins et al. 2003, Kelly et al. 2010). Ringed seals remain in contact with ice most of the year and pup on the ice in late winter to early spring (Allen and Angliss 2012).

During late April through June, ringed seals are distributed throughout their range from the southern ice edge northward (Braham et al. 1984). Bengston et al. (2005) conducted ringed seal surveys in the Chukchi Sea in 1999 and 2000 and found higher densities at nearshore locations. The Chukchi population is estimated to number about 250,000 seals (Frost et al. 2002, Allen and Angliss 2012). However, there is currently no reliable information on population abundance or trends of ringed seals for the Alaska stock (Allen and Angliss 2012).

Large concentrations of ringed seals are not expected to be encountered near the proposed seismic survey areas in the northern Chukchi Sea during the summer and fall time period. These seals are generally found in association with the ice front that would be avoided during this project. Based on aerial and vessel survey data, a small number of individuals from this stock may occur in or near waters of the project area during August – October (Brueggeman et al. 2009, 2010, Hartin et al. 2011, Cameron et al. 2012). The Alaska stock of ringed seals is not classified as a strategic stock by NMFS and critical habitat has not been designated for ringed seals. NMFS conducted a status review for the ringed seal (Kelly et al. 2010), and has recently listed the Arctic subspecies of ringed seals as threatened under the ESA due to threats from global warming (75 FR 77476).

4.10 Spotted Seal

Spotted seals inhabiting the Chukchi Sea belong to the Alaska stock (Allen and Angliss 2012). Spotted seals are a coastal pinniped that summers in nearshore areas in the Chukchi and winters along the ice edge in the Bering Sea (Figure A-6 [Appendix A]) (Quakenbush 1988, Lowry et al. 1998, Simpkins et al. 2003). During summer months, ringed seals haul out on sand spits in bays and lagoons in the Bering and Chukchi Seas, with some animals ranging to the Colville River Delta (Rugh et al. 1997, Lowry et al. 1998).

A reliable abundance estimate for the spotted seal is not currently available (Boveng et al. 2009, Allen and Angliss 2012). However, Allen and Angliss (2012) estimated the Alaskan population at about 141,000 animals based on limited surveys conducted by the Alaska Department of Fish and Game.

The activities associated with the proposed 2D seismic program in the Chukchi Sea are expected to encounter few, if any, spotted seals, mainly because most seals would be confined to nearshore waters. Sightings of small groups or individuals have been reported in Alaskan waters of the project area during August through October (Brueggeman et al. 2009, 2010). The Alaska stock of spotted seals is not classified as a strategic stock by NMFS.

4.11 Bearded Seal

The bearded seal is the second-most common seal species in the Chukchi Sea after the ringed seal (Laidre et al. 2008). Bearded seals inhabiting the Chukchi Sea, and possibly the project area, belong to the Alaska Stock (Figure A-7 [Appendix A]) (Allen and Angliss 2012). The distribution of bearded seals is dictated by the presence of ice and they prefer water depths of less than 200 m (656 ft) (Burns 1981). Bearded seals feed mainly on the seafloor, thus are rarely found in water depths they cannot effectively access (Allen and Angliss 2012). Like all Alaskan ice seals, bearded seals winter along the ice front in the Bering Sea, then move north in the spring with the receding ice edge (Burns 1981, Burns and Harbo 1972, Moulton and Lawson 2002, Allen and Angliss 2012). During summer, bearded seals occur in both the Chukchi and Beaufort Seas in areas of high ice coverage along the pack ice edge (Burns et al. 1981, Bengston et al. 2000, Simpkins et al. 2003).

A reliable abundance estimate for the Alaska stock of bearded seals is not available (Allen and Angliss 2012). The most recent surveys occurred in May to June of 1999 and 2000 between Shismaref and Barrow with average densities of between 0.07 and 0.14 seals per squared kilometers (km^2) (100 hectares per km^2), respectively (Bengston et al. 2005). There is no correction factor available for these data. Early estimates of the Bering-Chukchi Sea population ranged from 250,000 to 300,000 (Burns 1981).

Small numbers of bearded seals may occur in Alaska waters of the TGS project area during the open-water season. However, their occurrence is unlikely since the proposed operations will specifically avoid ice-front areas where bearded seals concentrate. Based on aerial and vessel survey data, individuals from this stock may occur in or near waters of the project area in August through October (Brueggeman et al. 2009, 2010, Clarke et al. 2011, Aerts et al. 2011). The Alaska stock of bearded seals is not classified by NMFS as a strategic stock nor has critical habitat been designated for bearded seals. The Alaska stock of bearded seals, part of the Beringia Distinct Population Segment (DPS), has recently been listed by NMFS as threatened under the ESA (75 FR 77496).

4.12 Ribbon Seal

Ribbon seals occurring in the Chukchi Sea, and possibly the project area, belong to the Alaska Stock (Allen and Angliss 2012). Ribbon seals inhabit the North Pacific Ocean and adjacent parts of the Arctic Ocean (Figure A-8 [Appendix A]). In Alaskan waters, ribbon seals inhabit the open sea on pack ice, and only rarely shorefast ice (Kelly 1988, Allen and Angliss 2012). As the ice recedes in May to mid-July these seals move farther to the north in the Bering Sea, where they haul out on the receding ice edge and remnant ice (Burns 1970, Burns 1981, Burns et al. 1981). There is little known about the range of ribbon seals during the rest of the year. Recent sightings and a review of the literature suggest that many ribbon seals migrate into the Chukchi Sea for the summer (Kelly 1988, Allen and Angliss 2012). Satellite tag data from 2005 and 2007 suggest ribbon seals disperse widely (Allen and Angliss 2012).

A reliable abundance estimate for the Alaska stock of ribbon seals is currently not available (Allen and Angliss 2012). Ribbon seals have been reported in very small numbers within the Chukchi Sea by observers on industry vessels (Patterson et al. 2007, Haley et al. 2010, LGL 2012). Based on vessel survey data, a small number of individuals from this stock may occur in or near waters of the project area during August through October (Brueggeman et al. 2010). Ribbon seals are not listed as depleted under the MMPA or listed as threatened or endangered under the Endangered Species Act.

4.13 Minke Whale

Minke whales are baleen whales found in coastal and offshore waters, including along ice floes and pack ice. Its normal range in Alaska is limited to the Gulf of Alaska north to the Bering and Chukchi Seas, where it is considered relatively common (Mizroch 1991, Allen and Angliss 2012). Minke whales are

known to penetrate loose ice during the summer, and some individuals venture north of the Bering Strait (Leatherwood et al. 1982, Allen and Angliss 2012).

The population of minke whales in Alaska is unknown and there is insufficient data to determine population trends for this stock (Allen and Angliss 2012). Minke whales are not expected to be encountered in high numbers, as the expected density of this species is 0.6 individuals per km^2 (Ireland et al. 2008). Based on aerial and vessel survey data, a small number of individuals from this stock may occur in or near waters of the project area during August through October (Brueggeman et al. 2009, 2010, Hartin et al. 2011).

5.0 TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

The type of incidental taking authorization that is being requested (i.e., takes by harassment only; takes by harassment, injury, and/or death) and the method of incidental taking.

TGS requests an IHA pursuant to Section 101(a)(5)(D) of the MMPA for incidental non-lethal take by harassment of small numbers of whales and seals during its planned seismic surveys in U.S. Federal waters and international waters of the Chukchi Sea during the 2013 open-water season. The type of incidental take most likely to occur is that associated with Level B harassment (i.e., disturbance at ≥160 dB re 1 µPa [rms] for cetaceans and ≥170 dB µPa [rms] for pinnipeds) as the result of pulsed (impulse) noise produced by the seismic profiling survey equipment.

No serious injury or lethal takes are expected as a result of the proposed activity with proposed mitigation and monitoring. Minimum sound levels considered potentially injurious to marine mammals by NMFS (180 and 190 dB µPa [rms]) at frequencies detectable by marine mammals should be fully mitigated by establishing “shutdown” and “power down” radii. In addition, some individuals are expected to move away from seismic sounds (see Section 11.0). Based on available data, disturbance reactions and thus the overall number of “incidental” takes that might occur are expected to vary by the species of cetacean or pinniped, the animal’s behavior at the time of the sound reception, and distance and received level of the sound (see Section 7.0).

With implementation of the monitoring and mitigation procedures described in this IHA request, any potential disturbances to marine mammals are expected to be temporary and minor, with no long-term impacts to individuals or populations based on available studies.

6.0 NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in Section 5, and the number of times such takings by each type of taking are likely to occur.

This section describes the numbers of marine mammals that may be "taken by harassment" through behavioral disturbance or displacement via exposure to pulsed seismic sounds ≥160 dB re1µPa (rms). The basis for estimating potential "take" is first presented based on available density data on marine mammals occurring in and near the project area. This is followed by a description of how take "exposures" were calculated (note however, that not all animals exposed to seismic sounds would be "taken" as defined under the MMPA [66 FR 9291] [NMFS 2005]). The section concludes with the estimated numbers of individuals by species that may be exposed to TGS seismic sounds ≥160 dB re1µPa (rms). Notably, few systematic surveys have occurred in offshore waters of the project area beyond 100 km from shore, especially north of 72°N and in international waters where much of the proposed operations will occur (see Section 4).

The general approach and basis for estimating the number of marine mammals that might be "taken by harassment" through exposure to TGS seismic sounds ≥160 dB re1µPa (rms) during the proposed survey in the Chukchi Sea are summarized in Section 6.1. The approach is similar to that applied for the recent (1) UAGI IHA in the northern Chukchi Sea (LGL 2011), (2) ION IHA in the Beaufort Sea (LGL 2012), and (3) Shell Chukchi Sea 2012 IHA in a small drilling area in the northeast Chukchi Sea (Shell 2011), as well as the associated NMFS Biological Opinions (BO) (NMFS 2012a,b). Thus, the general method was to multiply densities for each species by the area estimated to be ensonified to the ≥160 dB re1µPa (rms) by TGS' seismic sounds.

The anticipated radii of influence of the echosounders are less than those for the seismic source array (75 FR 60173). It is assumed that during simultaneous operations of the seismic source and echosounders, any marine mammals close enough to be affected by the echosounder would already be affected by the seismic source. However, even if the echosounder is operating while the seismic source is off, marine mammals are expected to exhibit no more than short-term behavioral responses to the echosounders given their operating characteristics. Such reactions are not considered to constitute "taking" (66 FR 9291). Therefore, no additional allowance is included for animals that might be affected by sound sources other than the seismic source.

6.1 Basis for Estimating Numbers of Marine Mammals that Might be "Taken by Harassment"

The first step in estimating the number of marine mammals that might be "taken by harassment" was to conduct a review of available data on density estimates for the marine mammal species occurring in the

project vicinity and adjacent areas of the Chukchi Sea. While several densities are available for U.S. Federal waters in the Chukchi Sea, no reliable estimates are known for U.S. Federal waters north of 72°N. Furthermore, no systematic surveys are known from the western half of the proposed project area in international waters (Figure 1).

Densities used to estimate exposures were based on two recent IHA applications and three 90-day reports to NMFS summarizing results of field monitoring surveys. These project areas overlapped the proposed TGS project area to at least some extent as well as TGS' proposed July-October seismic operations period. A map showing the boundaries of these survey areas relative to TGS' proposed seismic line locations is provided in Figure 2. The surveys consisted of the (1) two Statoil 90-day reports (to NMFS) from the northern Chukchi Sea (Blees et al. 2010, Hartin et al. 2011), (2) UAGI's IHA (LGL 2011) and 90-day report (Cameron et al. 2012), and (3) Shell 2012 IHA (Shell 2011). These data are considered the "best available" density estimates and occurrence data currently available for the project area (see Section 4.1 *Introduction* for a summary and further description of these surveys relative to the proposed TGS project area).

Table 3 shows reported recent density estimates for four different project areas overlapping the TGS project area based on the observed or derived densities reported in other studies as depicted in Figure 2 (Blees et al. 2010, Hartin et al. 2011, LGL 2011, Shell 2011, Cameron et al. 2012). Note that only the Cameron et al. (2012) survey occurred north of 72°N in U.S. Federal waters and international waters partially overlapping the TGS project area (see Section 4.1 *Introduction*). Sightings providing data on observed densities were available for the following six species: the bowhead, gray and beluga whale, and the bearded, ringed and spotted seal. The remaining other six species occur so rarely in the project area vicinity that reliable densities are not available for them and/or no sightings were made during the reported surveys: the humpback, minke, fin, and killer whales, the harbor porpoise, and the ribbon seal (Blees et al. 2010, Hartin et al. 2011, Cameron et al. 2012). Thus, minimal arbitrary densities were assigned to them based on those reported for other IHAs overlapping the proposed TGS project area, to address the rare chance of an encounter (Blees et al. 2010, Hartin et al. 2011, LGL 2011, Shell 2011, Cameron et al. 2012).

<u>Adjustment Factors Applied to Provide Lower and Upper Estimates of Density</u>

A number of habitat parameters have been shown to influence the distribution of marine mammal species occurring in the TGS project area. These parameters were applied to adjust the density of species accordingly, as done in previous IHA applications (e.g., Blees et al. 2010, Hartin et al. 2011, LGL 2011, Shell 2011, Cameron et al. 2012). These included (1) open water (i.e., ice-free) vs. ice-edge margin (higher densities of pinnipeds and beluga whales occur near and/or within the ice margin), (2) summer (July-August) vs. fall (September-October), (3) water depth (>200 vs. <200 m deep), and (4) likelihood of occurrence above or below 72°N. Open-water densities were used if available because TGS operations must completely avoid ice to be able to safely and effectively conduct operations.

Densities (shown in Table 3) used to estimate and calculate the number of exposures to TGS' pulsed seismic sounds ≥160 dB re1µPa (rms) were obtained by (1) averaging the densities from the four previous studies by summer (July-August), fall (September-October), and summer-fall, and then (2) multiplying the resulting averaged densities by adjustment factors for water depth (shallower or deeper than 200 m) and expected occurrence in waters north or south of 72°N. Notably, TGS plans to operate above 72°N for about half (32 days) of the total 45-60-day period in US Federal waters (35 days of which would involve seismic operations), and for all operations in international waters, up to 33 days. These northern waters above 72°N would be accessed sometime between about mid-September and 15 October (when waters are ice-free).

Because few data were available for most of the survey area, particularly north of 72°N and west of Barrow, it is not known how closely the applied average densities reflect the actual densities that will be encountered during the proposed TGS seismic survey. Thus, lower and upper adjustment factors (Table 4) were multiplied by the averaged densities to provide a range of density estimates. The latter adjustment was incorporated into a formula to estimate exposures to seismic sounds (see Section 6.2). The "lower adjustment factor" does not apply adjustment factors to densities north of 72°N for the bowhead and beluga whale and the ringed and bearded seal. In contrast, the "upper adjustment factor" applies factors to account for the expected lower density of marine mammal species north of 72°N. Adjustment factors differed by species and were based on (1) the reported distribution and occurrence of each species in these waters, and (2) factors applied by ION (LGL 2012) for their 2012 IHA application for the fall period of Oct-Dec 2012 that overlapped the fall period (mid-to-late September-October) and north-easternmost region that TGS expects to operate in international waters during fall.

Upper-adjusted Density Estimates. We applied the best available data and previously used ION factors to account for expected lower densities above 72°N where waters are predominantly >1,000 m deep (see Figure 1 map under Response to Question 1 above). The upper-adjusted (i.e., lower) density estimate was calculated by multiplying reported fall densities for more southern Chukchi waters as follows: (1) by a factor of 0.0 for fin, humpback, minke and killer whales, and harbor porpoise and ribbon and spotted seals as they are not expected in waters above 72°N and thus were assumed not to occur there; (2) by an adjustment factor of 0.01 for gray whales (since the northernmost boundary of their distribution is near 72°N and they are thus considered highly unlikely to occur above 72°N--see third bullet below); (3) by a factor of 0.1 for bowhead whales as the area is outside the main migration corridor, and (4) by a factor of 0.1 for beluga whales and bearded and ringed seals as they are closely associated with ice, and thus considered less likely to occur in ice-free waters needed to conduct the TGS seismic operations.

A similar 0.1 adjustment factor was applied in the ION IHA [LGL 2012] for species where the seismic survey area was on the edge of that species' range at the given time of year. ION's adjustment factor of 0.1 was used for TGS density estimates because TGS proposes to be well north and west of ION's westernmost 2012 survey lines no earlier than 15-30 September through 31 October 2013. In comparison, ION proposed their program for 1 October through mid-December, and their actual

program occurred in the Chukchi and Beaufort Seas from 20 October - 9 November, 2012. These periods overlap the majority of the period that TGS is expected to be operating at or near the westernmost seismic lines (no earlier than 15-30 September through October) between 73°-76°N and 160°W to 160°E. Thus, ION's "late season" period coincides with TGS' proposed late fall season both in time and space relative to waters above 72°N. Consequently, we believe that the factors we applied to the density of gray, bowhead and beluga whales, and bearded and ringed seals in the Nov 2012 IHA are realistic and are comparable and applicable to the 0.10 factor that ION used.

Lower-adjusted Density Estimates. The upper density estimates consisted of the averaged fall densities for more southern Chukchi waters by only (1) a smaller adjustment factor of 0.20 for gray whales (Table 4), and (2) by the same factor of 0.0 for fin, humpback, minke and killer whales, and harbor porpoise and ribbon and spotted seals as described above.

Additional Rationale for Adjusting Densities North of 72°N

- No whale sightings have been reported in waters north of 72°N during the few recent vessel-based surveys conducted there that overlapped the southern or eastern part of the proposed TGS project area and season (Blees et al. 2010, Hartin et al. 2011, Cameron et al. 2012).
- The main fall migration corridor for bowheads reportedly occurs south of 72°N (Quakenbush et al. 2010a). However, satellite-tagging studies indicate that at least some individual bowheads migrate generally west/southwest across the project area in waters above 72°N and west of Barrow during the fall migration from September-November (Quakenbush 2007, LGL 2011, Quakenbush et al. 2012) (see Section 4) (Figure A-2 [Appendix A]).
- The reported gray whale distribution in the Chukchi Sea normally does not extend much north of 72°N during summer/fall (Figure A-3 [Appendix A]) (Jefferson et al. 2008). This northernmost peripheral boundary area is thus expected to have very low gray whale densities. Furthermore, most gray whales will have migrated south of the project area by fall (Rice and Wolman 1971, Allen and Angliss 2012).

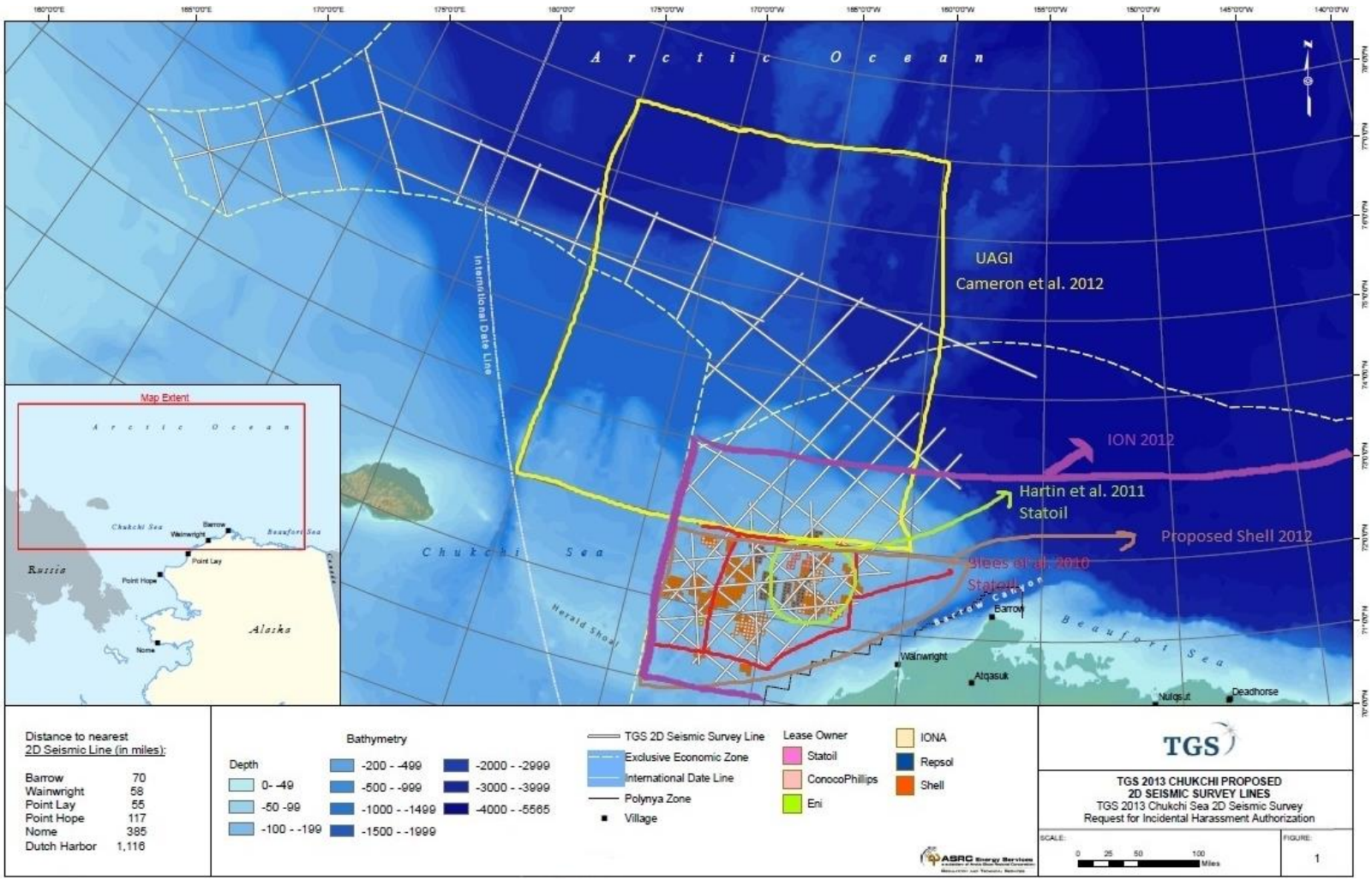

Figure 2 – Approximate boundaries of previous recent monitoring surveys for marine mammals in and near the proposed TGS 2013 survey area. Densities reported from these surveys were used to estimate densities used to calculate the estimated number of exposures of marine mammals to TGS' proposed 2013 seismic sounds. TGS' proposed seismic lines are also depicted.

Table 3 – Reported and averaged densities (#/km^2) of marine mammals based on surveys conducted in areas overlapping the TGS project area in U.S. Federal waters and international waters of the Chukchi Sea. Densities shown in italics are the average densities calculated separately for summer and fall then summer-fall, that were then used to calculate the estimated number of marine mammals exposed to TGS seismic operations proposed to occur July-October 2013. Species in italics are listed as endangered under the U.S. Endangered Species Act (1973).

	Summer			**Fall**						**Summer-Fall**
	Jul-Aug	**Aug**	**Jul-Aug**	**Sep-Oct** [1/]	**Sep-Oct**	**Sep**	**Sep-Oct (depth <200 m)**	**Sep-Oct (depth >200 m)**	**Sep-Oct**	**Jul-Oct**
Species	**Shell IHA (Shell 2012)**	**Statoil 2011 90-day Rept (Hartin et al. 2011)**	***Summer Average*** [2/]	**Statoil 2010 90-day Rept (Blees et al. 2010)**	**Shell IHA (Shell 2012)**	**Statoil 2011 90-day Rept (Hartin et al. 2011)**	**UAGI IHA (LGL 2011)**	**UAGI IHA (LGL 2011)**	***Fall Average*** [2/]	***Summer- Fall Average*** [2/]
Gray whale	0.0258	0.0200	*0.0229*	0.0004	0.0080	0.00	0.0015	0.0000	*0.0022*	*0.0125*
Bowhead whale	0.0013	0.0000	*0.0007*	0.0006	0.0219	0.00	0.0019	0.0000	*0.0051*	*0.0029*
Humpback whale	0.0001	0.0000	*0.0001*	0.0000	0.0001	0.00	0.0000	0.0000	*0.0000*	*0.0000*
Fin whale	0.0001	0.0000	*0.0001*	0.0000	0.0001	0.00	0.0000	0.0000	*0.0000*	*0.0000*
Minke whale	0.0001	0.0000	*0.0001*	0.0003	0.0001	0.00	0.0000	0.0000	*0.0000*	*0.0000*
Killer whale	0.0001	0.0000	*0.0001*	0.0000	0.0001	0.00	0.0000	0.0000	*0.0000*	*0.0000*
Beluga whale	0.0010	0.0000	*0.0005*	0.0000	0.0015	0.00	0.0017	0.0068	*0.0020*	*0.0012*

Species	Summer			Fall						Summer-Fall
	Jul-Aug	Aug	Jul-Aug	Sep-Oct [1/]	Sep-Oct	Sep	Sep-Oct (depth <200 m)	Sep-Oct (depth >200 m)	Sep-Oct	Jul-Oct
	Shell IHA (Shell 2012)	Statoil 2011 90-day Rept (Hartin et al. 2011)	*Summer Average* [2/]	Statoil 2010 90-day Rept (Blees et al. 2010)	Shell IHA (Shell 2012)	Statoil 2011 90-day Rept (Hartin et al. 2011)	UAGI IHA (LGL 2011)	UAGI IHA (LGL 2011)	*Fall Average* [2/]	*Summer- Fall Average* [2/]
Harbor porpoise	0.0011	0.0000	*0.0006*	0.0000	0.0007	0.00	0.0000	0.0000	*0.0001*	*0.0003*
Bearded seal	0.0107	0.0460	*0.0284*	0.0792	0.0107	0.01	0.0142	0.0000	*0.0236*	*0.0260*
Ribbon seal	0.0005	0.0000	*0.0003*	0.0000	0.0005	0.00	0.0003	0.0003	*0.0002*	*0.0002*
Ringed seal	0.3668	0.0420	*0.2044*	0.0078	0.2458	0.01	0.0489	0.0489	*0.0713*	*0.1378*
Spotted seal	0.0073	0.0000	*0.0037*	0.0033	0.0049	0.00	0.0010	0.0010	*0.0020*	*0.0028*

[1/] The Statoil 2010 project (Blees et al. 2010) occurred from 11 August-4 October 2010 near the same location as the Shell (2012) project area in the U.S. Chukchi Sea; since most of the Statoil 2010 project (Blees et al. 2010) period was during fall, it was categorized as such for the purposes of the IHA. Densities during "non-seismic" periods of confirmed species sightings were used here for the Statoil 2010 project (Blees et al. 2010). [2/] See Section 6 of the IHA application for details on how average and adjusted densities were calculated for the 2013 TGS IHA.

[2/] Summer-fall average density was used to estimate number of exposures to TGS seismic sounds >160 dB re 1 µPa (rms) in U.S. Federal water from approximately July through early September (depending on weather and ice conditions affecting delays and/or interruptions of project activities).

[3/] Fall average density was used to estimate number of exposures to TGS seismic sounds >160 dB re 1 µPa (rms) in international waters from approximately mid-to-late September through October (depending on weather and ice conditions affecting delays and/or interruptions of project activities).

Table 4 – Low and high adjustment factors applied to adjust for densities of marine mammals in waters north (N) and south of 72°N and in waters deeper than 200 m in the proposed TGS 2013 project area in U.S. Federal waters and international waters of the Chukchi Sea.

	Adjustment Factors for >72 Degrees N		Adjustment Factor >200 m Water Depth
Species	**Low Adjustment***	**High Adjustment***	
Gray Whale	0.2	0.01	0
Bowhead Whale	1	0.1	0
Humpback Whale	0	0	0
Fin Whale	0	0	0
Minke Whale	0	0	0
Killer Whale	0	0	0
Beluga Whale **	1	0.1	1
Harbor Porpoise	0	0	0
Bearded Seal	1	0.1	0
Ribbon Seal	0	0	1
Ringed Seal	1	0.1	1
Spotted Seal	0	0	1

* A higher adjustment value results in a higher density, as the adjustment factor is multiplied by the average densities shown in Table 3 within the formula used to calculate estimated number of exposures to TGS seismic sounds >160 dB re 1 MPa (rms) (see Section 6.2).

Table 5 – Range of estimated possible number of marine mammals that might be exposed to received pulsed seismic sound levels ≥160 dB re 1 µPa (rms) during TGS's proposed seismic survey in U.S. Federal waters and international waters of the Chukchi Sea July-October 2013. The proposed sound source consists of a 28-airgun array (total discharge volume 3,280 in^3). Received levels of seismic source sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed as endangered under the U.S. Endangered Species Act (1973). The number of "harassment takes" for which authorization is sought are indicated in the far right column (in boldface type).

Species	U.S. Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms) [2/]	Intl Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms) [2/]	Total U.S. & Intl Waters Estim. # Indiv. Exposed to ≥160 dB µPa (rms)[2/]	Estimated Population [3/]	Percent of Population of Estimated Exposures	Requested "Take" Authorization
Gray whale	1205-1285	53-78	1258-1363	19,126	**6.6-7.1**	**1363**
Bowhead whale	284-370	151-424	435-794	11,836	**3.7-6.7**	**794**
Humpback whale	4	1	5	20,800	**0.0**	**5** [4/]
Fin whale	4	1	5	1,652	**0.2**	**5** [4/]
Minke whale	4	1	5	810	**0.5**	**4** [4/]
Killer whale	4	1	5	2,084	**0.2**	**5** [4/]
Beluga whale	138-175	130-237	268-412	42,968	**0.6-1.0**	**412**
Harbor porpoise	33	3	36	48,215	**0.1**	**36**

[1/] See Section 6 of the IHA application for details on how densities were derived and number of exposures was calculated for the 2013 TGS IHA. No reliable densities are available for international waters for any of the species; thus, densities from more southern Alaskan Chukchi waters were used but are considered inflated for international waters (particularly the Shell [2012] IHA estimated densities) and were thus adjusted as described in Section 6 of the IHA application.

[2/] Includes seismic operations with 1 mitigation airgun during turns and transits between seismic lines.

[3/] See Table 2 for sources of population estimates.

[4/] The nominal number of requested takes of humpback, fin, minke and killer whales was increased by two individuals each in the case of rare sightings during project operations.

Table 5 – Range of estimated possible number of marine mammals that might be exposed to received pulsed seismic sound levels ≥160 dB re 1 µPa (rms) during TGS's proposed seismic survey in US Federal waters and international waters of the Chukchi Sea July-October 2013. The proposed sound source consists of a 28-airgun array (total discharge volume 3,280 in^3). Received levels of seismic source sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed as endangered under the U.S. Endangered Species Act (1973). The number of "harassment takes" for which authorization is sought are indicated in the far right column (in boldface type).

Species	**U.S. Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Intl Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Total U.S. & Intl Waters Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Estimated Population** [3/]	**Percent of Population of Estimated Exposures**	**Requested "Take" Authorization**
Gray whale	1,205-1,285	53-78	1,258-1,363	19,126	**6.6-7.1**	**1,363**
Bowhead whale	284-370	151-424	435-794	11,836	**3.7-6.7**	**794**
Humpback whale	4	1	5	20,800	**0.0**	**5** [4/]
Fin whale	4	1	5	1,652	**0.2**	**5** [4/]
Minke whale	4	1	5	810	**0.5**	**4** [4/]
Killer whale	4	1	5	2,084	**0.2**	**5** [4/]
Beluga whale	138-175	130-237	268-412	42,968	**0.6-1.0**	**412**

Species	U.S. Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms) [2/]	Intl Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms) [2/]	Total U.S. & Intl Waters Estim. # Indiv. Exposed to ≥160 dB µPa (rms)[2/]	Estimated Population [3/]	Percent of Population of Estimated Exposures	Requested "Take" Authorization
Harbor porpoise	33	3	36	48,215	**0.1**	**36**
Bearded seal	2,575-3,355	703-1,971	3,278-5,326	155,000	**2.1-3.4**	**6,000** [5/]
Ribbon seal	25	12	37	49,000	**0.1**	**100** [5/]
Ringed seal	15,320-19,461	4,678-8506	19,998-27,967	250,000	**8.0-11.2**	**30,000** [5/]
Spotted seal	307	122	428	59,214	**0.7**	**500** [5/]

[1/] See Section 6 of the IHA application for details on how densities were derived and number of exposures was calculated for the 2013 TGS IHA. No reliable densities are available for international waters for any of the species; thus, densities from more southern Alaskan Chukchi waters were used but are considered inflated for international waters (particularly the Shell [2012] IHA estimated densities) and were thus adjusted as described in Section 6 of the IHA application.
[2/] Includes seismic operations with 1 mitigation airgun during turns and transits between seismic lines.
[3/] See Table 1 for sources of population estimates.
[4/] The nominal number of requested takes of humpback, fin, minke and killer whales was increased by two individuals each in the case of rare sightings during project operations.
[5/]The number of requested take authorizations for these pinniped species was increased and rounded up to be conservative since the population numbers are estimated to be relatively large compared to other marine mammal species in the region (see Table 1 for population estimates).

Table 5 – Range of estimated possible number of marine mammals that might be exposed to received pulsed seismic sound levels ≥160 dB re 1 µPa (rms) during TGS's proposed seismic survey in US Federal waters and international waters of the Chukchi Sea July-October 2013. The proposed sound source consists of a 28-airgun array (total discharge volume 3,280 in^3). Received levels of seismic source sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Species in italics are listed as endangered under the U.S. Endangered Species Act (1973). The number of "harassment takes" for which authorization is sought are indicated in the far right column (in boldface type).

Species	**U.S. Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Intl Waters - Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Total U.S. & Intl Waters Estim. # Indiv. Exposed to ≥160 dB µPa (rms)** [2/]	**Estimated Population** [3/]	**Percent of Population of Estimated Exposures**	**Requested "Take" Authorization**
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[2/] Includes seismic operations with 1 mitigation airgun during turns and transits between seismic lines.
[3/] See Table 1 for sources of population estimates.
[4/] The nominal number of requested takes of humpback, fin, minke and killer whales was increased by two individuals each in the case of rare sightings during project operations.
[5/]The number of requested take authorizations for these pinniped species was increased and rounded up to be conservative since the population numbers are estimated to be relatively large compared to other marine mammal species in the region (see Table 1 for population estimates).

6.2 Exposure Calculation Methods

The approach used to calculate the estimated number of individuals of each marine mammal species potentially exposed to received levels of pulsed seismic source sounds ≥160 dB re 1 µPa (rms) during the proposed seismic project is described below. The latter 160 dB criterion is used by NMFS to determine Level B "take" associated with behavioral impacts resulting from exposure to pulsed sounds for all marine mammals (NMFS 2005). NMFS assumes that marine mammals exposed to seismic source sounds this strong might change their behavior sufficiently to be considered "taken by harassment". However, not all exposures to this sound level or higher would meet necessarily meet the definition of "take" in the MMPA.

1. The area of water (in km^2) ensonified to ≥160 dB re 1 µPa (rms) around the operating seismic source array on seismic lines as well as turns and transits between seismic lines was calculated for U.S. Federal and international waters for waters shallower and deeper than 200 m, and for waters north and south of 72°N (Table 6). It was assumed for purposes of this estimation that the full seismic source array would be used during all seismic lines and during the 1-km run-in and 5-km run-out between seismic lines (see Section 2.1 *Dates and Duration of Activities).* In addition, it was assumed that a single 60 in^3 (or smaller) airgun would be used during turns and transits between seismic lines (see Section 11 *Mitigation Measures*). Ensonified waters were calculated as follows.
2. A buffer was applied on both sides of the planned survey tracklines equivalent to the distances modeled for the proposed 3,280 in^3 seismic source array by JASCO in 2010 at three locations in the project area (Zykov et al. 2013). The buffer width corresponding to this 160 dB re 1 µPa (rms) isopleth varied with three water depth categories as shown in Figure 3 and Table 1 (Appendix B). Thus, survey tracklines located over waters 17-40 m deep were buffered by 8.5 km, those over waters 41-100 m deep were buffered by 9.9 km, and those over water depths of >100 m were buffered by 15 km.
3. A smaller buffer was applied to both sides of turns lines between seismic lines equivalent to the measured distance to the 160 dB re 1 µPa (rms) isopleth of a single 60 in^3 array as measured by JASCO (see Appendix C and Figure 3). The associated area in km^2 was calculated using Mysticetus ™ software. Mysticetus ™ identified water depths at 100-m intervals along the survey trackline using bathymetric data. At each 100-m interval, Mysticetus™ applied one of the three aforementioned 160 dB re 1 µPa (rms) radius isopleths corresponding to that water depth. Overlapping areas were treated separately. The resulting World Geodetic System (WGS) 84 polygons were re-projected into North Pole Stereographic coordinates and the total area was calculated.
4. Averaged densities of marine mammals (Table 3) were adjusted as applicable (Table 4) then multiplied by the area predicted to be ensonified to ≥160 dB re 1 µPa (rms). The procedure is outlined below.

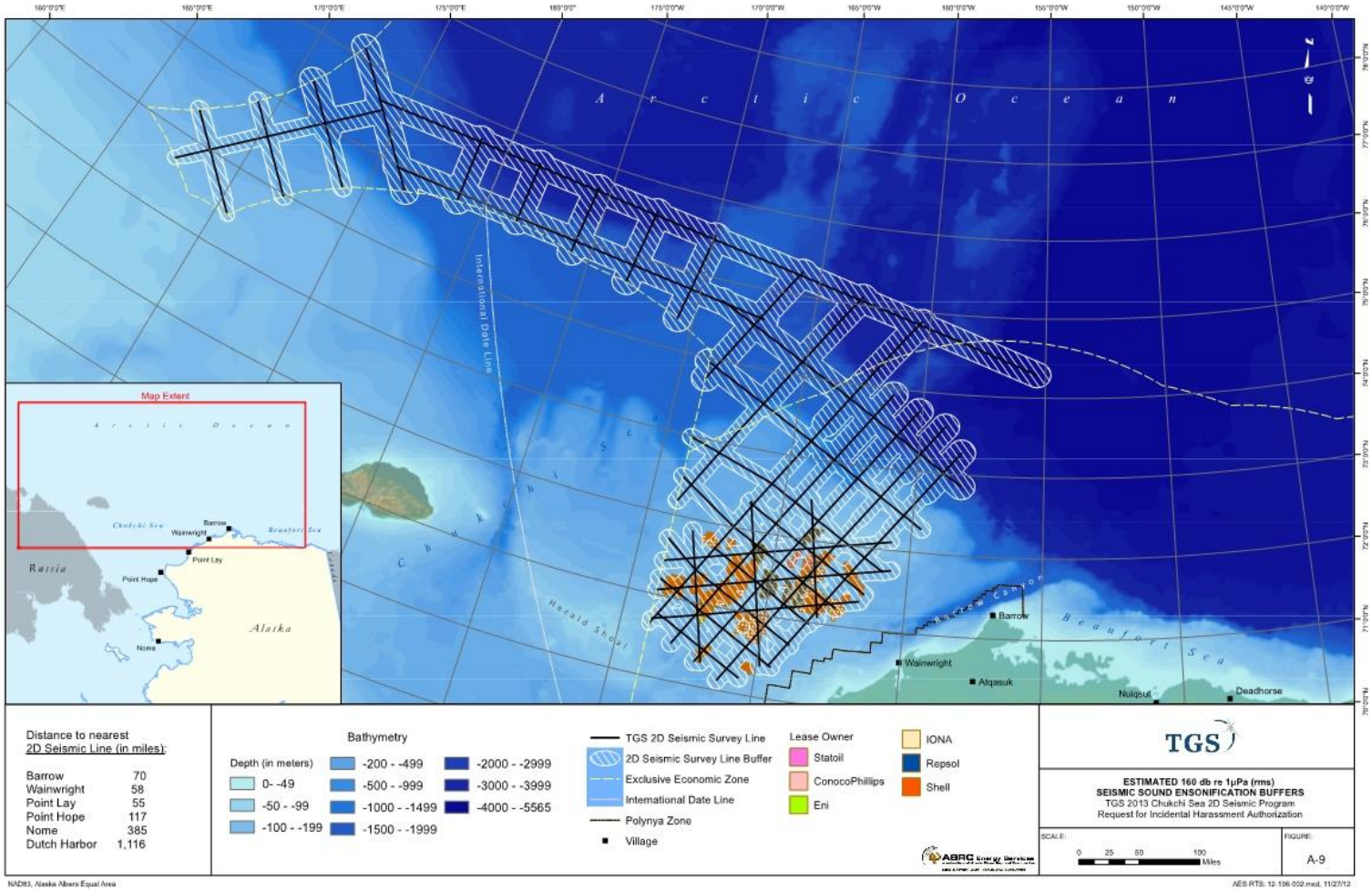

Figure 3 – Map of areas estimated to be exposed (i.e., ensonified) to seismic sound at received levels ≥160 dB re 1 µPa (rms) by three water depth categories (17-40, 41-100, and >100 m deep) during the TGS Chukchi Sea two-dimensional seismic survey proposed for July-October 2013.

a. Because TGS expects to conduct seismic lines in U.S. Federal waters sometime between mid-July and mid-September in late summer and early fall, the proportion of U.S. Federal waters ensonified to ≥ 160 dB re 1 µPa (rms) was multiplied by the average of summer and fall densities reported from other studies (Table 3).
b. Because TGS expects to conduct seismic lines in international waters starting in fall from mid-to-late September through October, the proportion of international waters ensonified to ≥ 160 dB re 1 µPa (rms) was multiplied by the average of fall densities reported from other studies (based nearly exclusively on surveys south of 72°N since it is considered the best and only systematic data available for the region) (Tables 3 and 6).
c. The proportions of ensonified waters north and south of 72°N were also calculated for US Federal and international waters (Table 6). Species-specific average summer-fall and fall densities associated with these depth categories (as reported in Table 3) were multiplied by the corresponding proportion and season.
d. In addition, the proportions of ensonified waters where water depth along the seismic line was <200 m deep or >200 m deep were calculated. Species-specific average summer-fall and fall densities associated with these depth categories (as reported in Table 3) were multiplied by the corresponding proportion and season.
e. Reported fall density estimates for gray, bowhead and beluga whales, and bearded and ringed seals were adjusted for ice-free waters N of 72°N by multiplying reported fall densities for more southern Chukchi waters by low and high adjustment factors described in Section 6.1 above to provide a range of potential exposures.
f. The formula for estimating the number of exposures to TGS seismic sounds > 160 dB re 1 µPa (rms) is identified below. Estimated number of exposures was calculated separately for U.S. Federal (average summer-fall density) and international waters (average fall density) as follows:
    i. Estimated Species Exposures = Species Density (by Season) * Total area ensonified to ≥160 dB re 1µPa (rms) * ((>72°N correction factor * % of area> 72°N) + (>200 m depth correction factor * % of area >200 m deep) + (1 - % of area >72°N + (1 - % of area > 200 m deep)) / 2
    ii. The estimated species takes for U.S. Federal waters and international waters were then summed to obtain the total estimated takes (Table 5).

Table 6 – Estimated area (km^2) ensonified to >160 dB re 1 µPa (rms) by seismic sounds along TGS' 2013 proposed seismic lines and turns in U.S. Federal and international waters of the Chukchi Sea. Ensonified areas assumed that the full 3,280 in^3 array operated continuously on survey lines and that the single mitigation airgun (60 in^3) operated continuously on turns (and transits) between survey lines. The distance to this 160 dB isopleth on survey lines for the full 3,280 in^3 array differed based on three water depths as modeled by JASCO (see Table 1 and Appendix C). The distance to the 160 dB isopleth on turns (and transits) was 1.5 km as modeled by JASCO (Appendix C). Areas (in km^2) were calculated using the software Mysticetus by drawing polygons around the survey lines the width of which corresponded with the distances to the three 160-dB isopleths depending on the water depth under the array. Water depths were determined using world-wide 1-arc minute bathymetry data (ETOPO1). These areas were multiplied by the lower-end and upper-end estimated densities of marine mammals as described in Appendix D.

	Above 72°N		***Below 72°N***		***Water Depth < 200 m***		***Water depth > 200 m***		***All Lines***	***All Turns***	***All Lines and Turns***	***Turn to Line Ratio***	***Above 72°N %***	***> 200 m deep %***
	Total Lines Area (km^2)	***Turns Area (km^2)***	***Total Lines Area (km^2)***	***Turns Area (km^2)***	***Total Lines Area (km^2)***	***Turns Area (km^2)***	***Total Lines Area (km^2)***	***Turns Area (km^2)***	***Total Lines Area (km^2)***	***Total Turns Area (km^2)***	***Total Ensonified Area (km^2)***			
US	65477	1294	72974	1442	114858	2270	23594	466	138452	2736	141188	0.01	47%	17%
International	115135	4200	0	0	45954	1676	69181	2524	115135	4200	119335	0.04	100%	60%
Total	180612	5494	72974	1442	160812	3946	92775	2990	253586	6936	260522	0.03	71%	37%

6.3 Estimated Number of Exposures

Estimates of the range of numbers of marine mammals that might be "taken by harassment" through exposure to received levels of pulsed seismic sounds ≥160 dB re 1 µPa (rms) and requested "take" authorizations are shown in Table 5. These numbers are considered precautionary, and likely are overestimates. The actual number of potential such exposures is likely to be lower than estimated for the following reasons:

- The estimates assume that the full seismic source array will operate continuously along all seismic lines. However, this is unlikely to occur. Adverse weather and ice conditions and potential equipment delays will likely curtail operations, as is typical during offshore surveys in the Chukchi Sea in summer and fall. Based on past TGS Arctic experience, approximately one-third of all survey days will be inoperable for the seismic array. It is likely, for example, that the encroaching ice pack will curtail seismic operations in September or October as occurs in most years in the region.
- The proportion of time that the seismic array will actually be operating (i.e., "on") is very small compared to the proportion of time that TGS will be in the project area. This is because each pulse with the full seismic array lasts only about 3 milliseconds, and is repeated at an interval of approximately 10 sec. Furthermore, each 3-millisecond pulse by the single mitigation airgun is proposed to be spaced apart by 60 sec.
- The distances to the 160 dB re 1 µPa (rms) isopleths applied during the project are 10 percent larger than actually estimated by JASCO modeling (Appendix C). Thus, marine mammals within the far edge of this isopleth are actually expected to be exposed to sounds < 160 dB re 1 µPa (rms).
- JASCO's modeling of TGS' proposed 3,280 in^3 seismic array is wider to the sides than in front of the array (Appendix C). Thus, although the estimated number of exposure assumes that the entire 160 dB isopleth radius is ensonified to this sound level, the actual area ensonified to this isopleth varies by distance. This is related to differences in azimuthal directivity patterns that vary by sound frequency and 1/3-octave bands. Thus, some of this isopleth is ensonified to <160 dB re 1 µPa (rms).
- Any marine mammal sightings within or near the designated exclusion zone will result in the shut down or power down of seismic operations as a mitigation measure (see Section 11).
- Furthermore, as summarized in Section 5 above, pinnipeds seem to be less responsive to seismic source sounds than are some mysticetes. Thus, pinnipeds may not exhibit behavioral changes when exposed to the 160 dB re 1 µPa (rms) criterion currently applied by NMFS, on which the take estimates are based.
- In addition, responses of bowheads and other cetaceans have been found to vary by behavior state, time of season, received sound level, etc. (see Section 7). Thus, not all cetaceans are expected to exhibit behavioral changes when exposed to the 160 dB re 1 µPa (rms) criterion currently applied by NMFS, on which the take estimates are based. In addition, some individuals

may react at received sound levels <160 dB re 1 µPa (rms) based on various studies, but would not be considered "take" under the current NMFS criteria for impulse sounds such as seismic.

- Results of mitigation and monitoring efforts for marine mammals during TGS's proposed 2013 2-D seismic survey are expected to provide additional data on the occurrence of marine mammals species from a sparsely surveyed area that can be used to better estimate densities post-project, particularly north of 72°N. It is recognized that observations from the seismic vessel during seismic are likely to be downward biased due to potential displacement and changes in behavior of marine mammals exposed to seismic sounds. However, observations from the scout vessel when away from the seismic source, and from periods without seismic emissions, should provide less-biased data typical of vessel-based marine mammal surveys.

7.0 ANTICIPATED IMPACT ON SPECIES OR STOCKS

The anticipated impact of the activity upon the species or stock.

7.1 Introduction

The proposed project activities potentially affecting marine mammals include seismic source operations and echosounders. These activities are expected to result in a temporary displacement of whales and seals within the ensonified zones, but are not expected to result in significant behavior disruption. Impacts on Chukchi Sea whale and seal populations are likely to be short-term, and transitory and temporary displacement should occur only when seismic sounds emit received noise levels greater than 160 dB re 1 µPa (rms). Although impacts such as brief behavioral and acoustical alterations may occur, due to a lack of scientific data, it is impossible to determine the level of physical damage on marine mammal hearing mechanisms. To prevent risk of auditory damage, the Protected Species Observer (PSO) program and procedures to ramp-up from a 60 in^3 (or smaller) airgun prior to seismic data collection, should alleviate significant impact. Further, these activities are not expected to result in a significant impact on species or stocks of marine mammals and should also not affect the availability of species or stocks for subsistence uses.

7.2 Behavioral Response

7.2.1 Baleen Whales (Mysticetes)

7.2.1.1 Bowhead Whale

Bowhead whales (Figure A-2 [Appendix A]) will likely show some behavioral changes during seismic source activity based on available studies. However, depending on distance and received sound levels from the sound source, overall displacement should be minimal. Bowhead whales belong to the low-frequency functional hearing group of baleen whales (Southall et al. 2007). Inferring from their vocalizations, bowhead whales should be most sensitive to frequencies between 20 hertz (Hz) - 5 kHz,

with maximum sensitivity between 100-500 Hz (LGL 2012). Baleen whales exposed to strong noise pulses from seismic sources often react by deviating from their normal migration route and/or interrupting their feeding and moving away (LGL 2012). Bowhead whales in the Beaufort Sea were observed remaining in a location where they were exposed to seismic, dredging, and drilling sounds. Their social and feeding behavior appeared normal as industry-related noises occurred (Richardson and Würsig 1997). When observed over multiple years, bowhead whales in the same area also did not appear to avoid seismic locations. MMS did not find a statistical difference in the change of direction for bowhead whales traveling during seismic activity when analyzing fall migration data from 1996 to 1998 (Minerals Management Service [MMS] 2005). Bowhead and gray whales have appeared unbothered when seismic pulses between 160 to 170 dB re 1 µPa (rms) were discharged from a seismic vessel within a few km of their locality, but tended to avoid the area when levels exceeded 170 dB re 1 µPa (rms) (Richardson and Würsig 1997).

It is unclear exactly what causes displacement. However, whales have tended to show shorter surface and dive times, fewer blows per surfacing, and longer blow intervals when noise levels were at or above 152 dB re 1 µPa (rms); they also have exhibited avoidance of seismic operations within a 20 km (12.4 mile) radius (Ljungblad et al.1988, Richardson 1999). Bowhead whales may also leave or show total avoidance of vessels if they are too close (Richardson and Würsig 1997). Bowhead whales showed total avoidance at distances of 1.3 km, 7.2 km, 3.5 km, and 2.9 km (0.8 mi, 4.5 mi, 2.2 mi, and 1.8 mi) when the sound level was 152 dB, 165 dB, 178 dB, and 165 dB re 1 µPa (rms), respectively (Ljungblad et al. 1988).

In 1996-1998, studies were conducted on the effects on fall migrating bowheads from seismic source operations located within the main migration corridor in the Beaufort Sea. Results indicated a tendency for the general bowhead whale migration corridor to be farther offshore on days with a seismic source operating vs. days without a seismic source operating (Richardson 1999). However, the distribution of bowheads overlapped in terms of distances from shore during both the presence and absence of seismic source operations. Data from aerial surveys suggested that bowheads appeared to avoid the area within about 20-30 km of the operating source. Within 20 km of seismic operations, sighting rates were significantly lower in the presence vs. the absence of seismic sounds. From 12-24 hours after seismic operations stopped, sighting rates were similar within 20 vs. beyond 20 km away. No obvious changes in headings, general activities, or swimming speeds were recorded in the presence vs. absence of seismic operations. Overall, results indicated that during seismic operations, most bowheads occurred 20-30 km away.

The above reported avoidance distance of 20-30 km is the largest such radius documented for any baleen whale. This includes extensive studies conducted on the behavior and occurrence of bowheads near industrial activities in the Beaufort Sea in the 1980s; however, this is a smaller avoidance radius than the 55 km (30 mi) suggested by subsistence whalers (the latter is based on their impression of seismic operational effects prior to 1996) (Richardson 1999). During the 1980s, seismic activities

involved 2D in deeper water. The more recent seismic activities involved three-dimensional (3D) ocean bottom cable (OBC) focused in shallow water.

Analyses of bowhead whale calls recorded during the same 1996-1998 study indicated the following (per Greene et al. 1999a): (1) during the fall migration, bowhead whales called in the study area (2) calling continue when exposed to seismic source pulses; and (3) detection rates of calls differed significantly at some locations when a seismic source was detectable vs. not detectable. However, no significant consistent tendency was noted for changes in call-detection rates relative to the staring or stopping of the seismic source.

As a result of the aforementioned 1996-1998 studies, a summary statement was released by the peer-review group at the 2001 Arctic Open-Water Noise Peer Review Workshop. The statement supported the study's methods and results showing bowhead avoidance of seismic sounds. The peer-review group stated: monitoring studies of 3-D seismic exploration (a seismic source array consisting of 8-16 airguns totaling 560-1,500 in^3) in the nearshore Beaufort Sea during 1996-1998 have demonstrated that nearly all bowhead whales will avoid an area within 20 km of an active seismic source, while deflection may begin at distances up to 35 km. Sound levels received by bowhead whales at 20 km ranged from 117-135 re 1 µPa (rms) and 107-126 dB re 1 µPa (rms) at 30 km. The received sound levels at 20-30 km are considerably lower levels than have previously been shown to elicit avoidance in bowhead or other baleen whales exposed to seismic pulses."

Miller et al. (2002) estimated that bowheads observed surfacing 323-614 m from the operating seismic vessel would have been exposed to sound levels of approximately 180 dB re 1 µPa (rms) before the seismic source array was immediately shutdown as mitigation (Miller et al. 2002). A total of seven shutdowns occurred when bowheads were observed less than1 km away from the seismic vessel. The authors estimated that at 1,957 m from the operating seismic source array (the average vessel-based sighting distance), bowheads would have been exposed to sound levels of approximately 170 dB re 1 µPa (rms). The estimated received sound level for the multiple sightings made from the observation aircraft 5.3-19.9 km from the seismic vessel ranged from about 150- 130 dB re 1 µPa (rms), respectively.

In contrast, a study conducted in summer 2001 (Miller et al. 2002) showed very different results for bowhead whales exposed to seismic sounds. For example, in the 2001 study, a total of 262 bowhead sightings were made from the seismic observation vessel compared to only bowhead sighting during six seasons spanning 1996-2001. The avoidance distance in 2001 was much smaller (approximately 2 km) than the up to 20-30 km reported for migrating fall bowheads. It was concluded that fall migrating bowheads appeared to be more sensitive to seismic sound disturbance than summer feeding bowheads (Davis 1987).

Proposed seismic operations are likely to result in short-term behavioral changes by some bowheads based on results of studies summarized above and other studies. There is no evidence that such short-term behavioral changes result in injurious or long-term effects on individuals or populations of

bowheads, and no such effects are expected. Weather and ice permitting, TGS plans to begin survey operations in late July-early August when bowheads are feeding primarily in Canadian waters of the Beaufort Sea. When bowheads begin migrating back to the Chukchi and Bering Seas in the fall, TGS plans to be conducting seismic operations north of 72°N in international waters, where bowheads are much less likely to be found based on available data (see Figure 1 and Figure A-1 [Appendix A]). Furthermore, on average, studies indicate that by October 15, about 97% of bowheads have migrated through the eastern U.S. Beaufort Sea (Miller et al. 2002) and are south of 72°N when the TGS operations are planned to be in international waters above this latitude.

7.2.1.2 Gray Whale

Gray whales are likely to show behavioral avoidance to seismic sounds exceeding 170 dB re 1 µPa (rms) based on available studies (Richardson et al. 1995, Richardson and Würsig 1997). These studies indicate that feeding and migrating gray whales tend to move away from seismic operations when the received seismic source level is greater than or equal to 163 dB re 1 µPa (rms) (Malme et al 1988). Behavioral changes such as increased swim speed and shorter blow periods have been observed as a result of exposure to seismic sounds at distances up to 30 km away (Würsig et al. 1999). However, when conducting shore-based counts, Johnson et al. (2007) did not mention any change in behavior and found no significance between abundance and seismic activity. In addition, gray and bowhead whales have appeared unbothered when seismic pulses between 160 to 170 dB re 1 µPa (rms) were discharged from a seismic vessel within a few km of their locality, but tended to avoid the area when levels exceeded 170 dB re 1 µPa (rms) (Richardson and Würsig 1997).

7.2.1.3 Humpback Whale

Very few humpback whales are expected to occur within the TGS project area. If any responses occur, activities can be expected to result in temporary behavioral changes. Humpback whales are well known for utilizing sound to communicate. Marine mammal observations from seismic surveys conducted near Angola indicated that there was no significant difference in the encounter rate of 207 humpback whales in relation to seismic source operations (Weir 2008). There was also no evidence for prolonged or large-scale displacement (Weir 2008). Another seismic survey near Australia revealed that humpback whales exhibited avoidance behavior of seismic vessels at distances over 4 km (2.5 mi) away (McCauley et al. 2000). These studies suggest that humpback whales can detect seismic sounds at great distances and, if they do occur in the TGS project area, can be expected to avoid the survey vessel during seismic operations.

7.2.1.4 Minke Whale

The estimated density of minke whales in the project area is expected to be low. Thus, TGS seismic activities should have only rare encounters with minke whales. If minke whales should occur in the project area, minke whales are likely to exhibit behavioral responses such as avoidance and general displacement, similar to humpback and gray whales reported above. Stone (2003) reported that during

seismic activities, minke whale sightings occurred in the ensonified region. Minke whales have also been observed to approach an active seismic source where the sound level was 170-180 dB re 1 µPa (rms) (MacLean and Haley 2004).

7.2.2 Toothed Whales (Odontocetes)

7.2.2.1 Beluga Whale

Seismic activities are expected to cause temporary displacement of beluga whales, but the impact is not expected to be significant. Belugas have been shown to have greater displacement in response to a moving source (e.g., seismic source activity on a moving vessel) and less displacement or behavioral change in response to a stationary source (Richardson et al. 1995, 73 FR 34254). Belugas have been recorded within the ensonified zones of industrial sites near platforms and stationary dredges and reportedly did not appear to be affected. When drilling sounds were played back to belugas in industry-free areas, behavioral reactions occurred only in response to high received noise levels (Richardson et al. 1997). An initial scare behavioral response has been reported for beluga whales when exposed to played back drilling sounds at estimated received levels of 153 dB re 1 µPa (rms) (Richardson et al. 1997). It was suggested that this might be a result of belugas having less sensitivity to low frequency sounds. Other reports suggest that belugas will remain far away from seismic vessels (Miller et al. 2005). A study in the Beaufort Sea observed low numbers of belugas within 10 to 20 km (6 to 12 mi) of seismic vessels (LGL 2006).

7.2.2.2 Harbor Porpoise

Few if any harbor porpoise are expected to occur in the TGS project area. Proposed seismic operations can be expected to result in temporary behavioral responses. Of the several odontocete species, harbor porpoises are considered to have acute hearing within a high frequency range (Kastelein et al. 2005). Studies have shown that harbor porpoises show strong avoidance to received levels of at least 140 dB re 1µPa (rms) and also displayed sensitivity to acoustic exposure (NMFS 2005). Captive harbor porpoises have also displayed discomfort at sound levels ranging between 97 to 111 dB re 1 µPa (rms) (Kastelein et al. 2005). Harbor porpoises avoided feeding habitat when installed acoustic harassment devices (AHD) emitted sounds of over 180 dB re 1 µPa@1 m; density also decreased up to 3.5 km (2.2 mi) around the AHD array (Johnston 2002). Harbor porpoises are expected to avoid seismic activities, and mitigation measures including seismic ramp-up procedures should prevent significant impacts.

7.2.2.3 Killer Whale

Very few killer whales are expected to occur in the project area based on available data. Thus, TGS seismic activities should have only rare encounters with killer whales. If killer whales occur in the project area, proposed seismic activities can be expected to result in short-term behavioral responses such as avoidance and general displacement. Stone (2003) reported that during seismic activities, killer whale sightings remained constant, but distance from the seismic source during seismic operations was

significantly greater. Killer whales also appeared more resilient to seismic sounds in deeper waters (Stone 2003). Killer whales have been shown to avoid AHDs over a number of years (Morton and Symonds 2002).

7.2.3 Pinnipeds

Seals are expected to show little or no avoidance reaction to seismic activities involving operation of a seismic source based on available data. Typically, seals may show an initial reaction to loud noises, but generally do not react to noises from a seismic source. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of a seismic source by pinnipeds, and only slight (if any) changes in behavior (LGL 2011). Observation rates for ringed seals, bearded seals, and spotted seals in the Beaufort Sea were similar when there was no seismic source operating (0.63 seals per hour), a single airgun source operating (0.60 seals per hour), and a full seismic source array operating (usually consisting of an array of 8 to 11 airguns) (0.63 seals per hour) (Harris et al. 2001). In the same study, the mean sighting distance during operation of a full seismic source array was 234 m (768 ft) and 144 m (472 ft) with no seismic source operating (Harris et al. 2001). In the Beaufort Sea, some ringed seals avoided an area of 100 m to (at most) a few hundred meters around seismic vessels; however, many seals remained within 100–200 m of the trackline as the operating seismic source array passed by (Moulton and Lawson 2002, Miller et al. 2005, LGL 2011). Ringed seal sightings averaged somewhat farther away from the seismic vessel when the seismic source array was operating than when it was not; however, this difference was small (Moulton and Lawson 2002, LGL 2011). Similarly, in Puget Sound, sighting distances for harbor seals and California sea lions tended to be farther when a seismic source array was operating (Calambokidis and Osmek 1998, LGL 2011). Previous telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998, LGL 2011). Only short-term and temporary displacement should occur as a result of the proposed project. Seals are not likely to be exposed to source levels of over 190 dB re 1 µPa given proposed mitigation measures.

7.3 Hearing Impairments

7.3.1 Sound Transmission

Marine mammals rely on sound transmission for foraging, orientation, and predator avoidance (Au et al. 2000, Southall et al. 2007). Marine mammals typically show different reactions to sound based on species, sex, reproductive status, and previous exposure to sound. Marine mammals have also demonstrated a higher behavioral sensitivity when traveling with their young (MMS 2006). Although various marine mammals hear and vocalize at different frequencies, current criteria set forth by NMFS for Level A and B harassment to cetaceans is 180 dB 1 µPa (rms)and 160 dB 1 µPa (rms), respectively; and 170 dB for Level B harassment to pinnipeds (Southall et al. 2007).

Currently, it is presumed that species will remain unaffected by sounds outside their range of hearing (Southall et al. 2007). Consequently, baleen whales and pinnipeds are expected to show more sensitivity to low and middle frequencies while odontocetes would show greater sensitivity to high-frequency sounds (MMS 2006, Southall et al. 2007).

7.3.2 Temporary Threshold Shift and Permanent Threshold Shift

When conducting seismic activities, a Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS) is not expected to occur in marine mammals. TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985, LGL 2012). When marine mammals located within a vulnerable range are impacted by impulsive noises, the noises can lead to TTS or PTS. When TTS occurs, the result is reversible: hearing in exposed mammals is temporarily affected. A TTS may result in mammals failing to locate predators or prey and the inability to communicate effectively with other individuals of the same species (73 FR 34254). If this threshold does not return to the original threshold levels, the damage is classified as PTS. It is unknown what level of sound will cause PTS in marine mammals, but it is reasoned to occur at a much higher level than that caused by TTS (NMFS 2005).

TTS and PTS for any given species depend on the frequency sensitivity of that species. Bowhead and gray whales use low-frequency sounds, killer whale and beluga use mid frequencies, and the harbor porpoise used high frequencies (Southall et al. 2007). Finneran et al. (2002) estimated that exposure to sound levels over 192 dB re 1 µPa will lead to a TTS in most cetaceans (NMFS 2005). There are no data identifying the level of sound intensity that causes a TTS in baleen whales. However, because most baleen whales show avoidance at certain sound intensities, TTS is unlikely to occur (MMS 2006, Southall et al. 2007).

Under prolonged exposure, pinnipeds have been shown to exhibit TTS. Kastak et al. (1999) investigated the effects of noise on two California sea lions *(Zalophus californianus)*, one northern elephant seal (*Mirounga angustirostris)* and one harbor seal (*Phoca vitulina*). They subjected each pinniped to a noise source (100 to 2,000 Hz) for 20 to 22 minutes. Each pinniped showed a threshold shift averaging 4.8 dB *(*harbor seal), 4.9 dB *(*sea lion), and 4.6 dB (northern elephant seal). The hearing threshold returned to pre-exposure values within 12 hours. AES mitigation measures such as monitoring by PSOs within the exclusion zone, ramp-up prior to seismic operations, and behavioral avoidance of loud sounds are expected to avoid exposure of marine mammals to sound exposure levels that could cause TTS and PTS.

7.3.3 Masking

Masking is the coverage or reduction of a sound (e.g., marine mammal communications) when a stronger sound (e.g., seismic source pulsed sounds) interferes with that sound (Richardson et al. 1995). Masking effects are expected to be limited and rarely interfere with whale calls. It is presumed, but not yet determined, that like humans, marine mammals in their natural environment have the ability to sort

out sounds specific to communication, foraging, and safety while overlapping noises occur (Bergman 1990, Madsen et al. 2002, Southall et al. 2007). During 13 days of seismic survey pulses, sperm whales continued normal calls, and vocalization patterns remained undisturbed by received noise levels up to 146 dB re 1µPa (Madsen et al. 2002). Bowhead whale calls are frequently detected in the presence of seismic pulses; however, call detection rate may sometimes decrease in the presence of seismic source pulses (Richardson et al. 1986, Greene et al. 1999a, Blackwell et al. 2009a, LGL 2012). Bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic operations; however, movement out of the area might also have contributed to the lower call detection rate (Blackwell et al. 2009a,b, LGL 2012). Some studies suggest several whale species might alter their vocalization levels to adjust to various levels of background noise (MMS 2006). Belugas in the St. Lawrence River in Canada adjusted to high noise levels by vocalizing louder when exposed to high-level sound sources (Scheifele 2005). Some of the smaller odontocetes communicate at frequencies higher than those produced by a seismic source, so their calls should naturally avoid masking.

Low-frequency sounds emitted by a seismic source overlap with mysticete communication frequency, although not with frequencies used by odontocetes and pinnipeds. Some baleen and toothed whales are known to continue calling in the presence of seismic pulses; these calls usually can be heard between the seismic pulses (e.g., Richardson et al. 1986, McDonald et al. 1995, Greene et al. 1999a,b, Nieukirk et al. 2004, Smultea et al. 2004, Holst et al. 2005a,b, 2006, Dunn and Hernandez 2009). However, mitigation measures are expected to prevent close contact between marine mammals and the seismic source. Precautionary measures should prevent mysticete masking and consequently not disrupt communication.

7.4 Tolerance

Numerous studies have shown that pulsed sounds from a seismic source are often readily detectable in the water at distances of many kilometers (LGL 2012), and that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. Some sounds emitted by a seismic source may be detected by marine mammals at great distances and may not necessarily result in a behavioral response. Generally, pinnipeds seem to be more tolerant of exposure to seismic source pulses than are cetaceans, with relative responsiveness of baleen and toothed whales being variable (LGL 2012).

7.5 Stranding and Mortality

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by seismic source arrays are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to physical damage and mortality (Balcomb and Claridge 2001, NOAA and USN 2001,

Jepson et al. 2003, Fernández et al. 2005, LGL 2012), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound. Additionally, the sound produced during the project from the proposed activities will be at much lower levels than those reported during stranding events.

8.0 ANTICIPATED IMPACTS ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

8.1 Introduction

Subsistence hunting and fishing is historically, and continues to be, an essential aspect of Native life, especially in rural coastal villages. The Iñupiat participate in subsistence hunting and fishing activities in and around the Chukchi Sea. The animals taken for subsistence provide a significant portion of the food that will last the community through the year. Along with the nourishment necessary for survival, the subsistence activities strengthen bonds within the culture, provide a means for educating the young, provide supplies for artistic expression, and allow for important celebratory events.

The potential impact of seismic and vessel noise and vessel presence associated with seismic surveys on subsistence could be substantial. If whales are permanently deflected away from their migration path, there could be significant repercussions to the subsistence use villages. Mitigation efforts will be put into action to minimize or avoid completely any adverse effects on all marine mammals as follows (see Section 11). Firstly, the survey timing was designed as a mitigation effort to minimize impacts to migrating whales, which are hunted during their migration (See Section 11). Appendix D summarizes estimated locations and harvest seasons by species for communities where such data are publically available including Barrow, Wainwright, Point Lay, and Point Hope. TGS plans to begin their seismic acquisition between 15 July and 5 Aug, after the spring whale hunt is completed and migrating bowhead whales have moved east of Barrow. TGS will maintain communications with subsistence communities via the communication centers (Com and Call Centers) and outlined in the Conflict Avoidance Agreement (CAA) signed by TGS. Communication between the project vessels and land-based Com and Call Centers will provide additional insight to the status and location of current susbsistence activities to further that TGS minimizes adverse impacts to the availability of marine mammals for subsistence use.

8.2 Subsistence Hunting

Alaska Natives, including the Iñupiat, legally hunt several species of marine mammals. Communities that participate in subsistence activities potentially affected by seismic surveys within the proposed project area are Point Hope, Point Lay, Wainwright, and Barrow. Marine animals used for subsistence in the proposed area include: bowhead and beluga whales, ringed, spotted, and bearded seals, Pacific walrus, and polar bears. In each village, there are key subsistence species. Hunts for these animals

occur during different seasons throughout the year. Depending upon the village's success of the hunt for a certain species, another species may become a priority in order to provide enough nourishment to sustain the village. Appendix tables B-2 through B-5 provide summaries of marine mammal subsistence species, estimated location and harvest season at various villages.

Point Hope resident's subsistence hunt for bowhead and beluga whales, polar bears, and walrus. Bowhead and beluga whales are hunted in the spring and early summer along the ice edge. Beluga whales may also be hunted later in the summer along the shore. Seals are available from October through June, but are harvested primarily during the winter months, from November through March, due to the availability of other resources during other periods of the year (MMS 2007).

With Point Lay (Figure A-10 [Appendix A]) situated near Kasegaluk Lagoon, the community's main subsistence focus is on beluga whales that seasonally occur there. Seals are available year-round, and polar bears and walruses are normally hunted in the winter. Hunters typically travel to Barrow, Wainwright, or Point Hope to participate in bowhead whale harvest, but there is interest in reestablishing a local Point Lay harvest.

Wainwright (Figure A-11 [Appendix A]) residents subsist on both beluga and bowhead whales in the spring and early summer. During these two seasons the chances of landing a whale are higher than during other seasons. Seals are hunted by this community year-round and polar bears are hunted in the winter.

Barrow residents' main subsistence focus is concentrated on biannual bowhead whale hunts. They hunt these whales during the spring and fall. Other animals, such as seals, walruses, and polar bears are hunted outside of the whaling season, but they are not the primary source of the subsistence harvest (URS Corporation 2005).

8.2.1 Bowhead Whales

Bowhead whales that could potentially be affected by seismic activity in the Chukchi Sea come from the Western Arctic stock. The majority of these whales migrate annually during the spring from wintering grounds in the Bering Sea, through the Chukchi Sea, to summer grounds in the Beaufort Sea. During the fall migration, the whales travel back through the Chukchi Sea to the wintering grounds in the Bering Sea. While on their spring migration route, bowhead whales travel through leads in the ice between the shorefast ice and pack ice.

Ten primary coastal Alaskan villages deploy whaling crews during whale migrations. The primary bowhead hunting villages affected in the project area are Barrow, Wainwright, and Point Hope. These communities are part of the Alaska Eskimo Whaling Commission (AEWC). The AEWC was formed as a response to the IWC past prohibition of hunting bowhead whales for subsistence purposes. IWC sets a quota for the whale hunt, and AEWC allocates the quota between villages. Each of these villages is represented by a whaling captains association. Bowhead whales migrate within the hunting range of

whaling crews, in the spring (north migration) and the fall (south migration). In the spring, the whales must travel through leads in the ice that tend to occur close to shore, whereas in the fall, the water is much more open, allowing the whales to travel further from the coast. Whaling crews in Barrow hunt in both the spring and the fall (Funk and Galginaitis 2005).

The primary bowhead whale hunt in Barrow occurs during spring, while the fall hunt is used to meet the quota and seek strikes that can be transferred from other communities. In the spring, the whales are hunted along leads that occur when the pack ice starts deteriorating. This tends to occur between the first week of April through May in Barrow and the first week of June in Wainwright, well before the proposed shallow hazards and site clearance surveys will be conducted. The surveys will start after all the ice melts, usually near mid-July. In the fall, whaling activities occur to the east of Point Barrow, and therefore, will not likely be part of the area affected by the project (USDOI, Bureau of Land Management [BLM] 2005). The Point Hope bowhead whale hunt occurs from March to June. Whaling camps are established on the ice edge south and southeast of Point Hope, 10 to 11 km (6 to 7 mi) offshore (MMS 2007). Due to ice conditions, the Point Hope hunt will likely be completed prior to commencement of the surveys.

8.2.2 Beluga Whales

Beluga whales (Figure A-4 [Appendix A]) summer in waters of the Chukchi and Beaufort Seas and winter in the Bering Sea. Living in areas mostly covered in ice, they are associated with leads and polynyas (Hazard 1988, Allen and Angliss 2012). Beluga whales can be hunted from the first week in April to possibly July or August. It is common for the Iñupiat, other than residents of Point Lay, to refrain from hunting beluga during the spring or fall bowhead whale hunt to prevent scaring the larger whales away from hunting locations. Belugas do not account for a majority of the total subsistence harvest in Barrow or Wainwright (BLM 2005). Between 2005 and 2009, the annual beluga subsistence take was 94 whales (Allen and Angliss 2012).

In a study of sperm whales (a toothed whale, like the beluga) near seismic activity emitting similar sounds that will be emitted from this proposed project, Madsen et al. (2002) found that during the seismic sounding, the distribution of the whales did not change. TGS does not plan to survey within 88 km (55 mi) of the coast, near Kasegaluk Lagoon, or near major polynyas. This can assure that any possible effect on the distribution or behavior of belugas will be avoided. PSOs will conduct wildlife surveys from the vessels to ensure that marine mammals are sighted and avoided.

8.2.3 Ringed Seals

Ringed seals (Figure A-5 [Appendix A]) are distributed throughout the Arctic Ocean where they inhabit both seasonal and permanent ice. In 2000, the annual estimated subsistence take from Alaska of ringed seals was 9,567 (Allen and Angliss 2012). Ice conditions could account for great differences between years in the number of seals available to a particular community for harvest (Coffing et al. 1999, Allen

and Angliss 2012). An abundance and distribution study conducted in the Beaufort Sea before, during, and after anthropogenic sound-producing construction found that there were only slight changes near construction activities around British Petroleum's (BP) Northstar oil development that were most likely caused by environmental factors (Moulton et al. 2005).

Harris et al. (2001) performed a study using 3D seismic source arrays, and found that the number of seal sightings varied only slightly in periods of no sonar firing, single sonar, and multiple-array of sonar firing. Seals tended to stay slightly further away from the vessel at times when full array sonar was fired, but they rarely moved beyond 250 m (820 ft) of the vessel even at that point. Sonar activity was interrupted when seals came within a certain radius (150 to 250 m [492 to 820 ft]) of the vessel in accordance to regulations set by NMFS.

Ringed seals are available to subsistence users year-round, but they are primarily hunted in the winter because of the rich availability of other mammals in the summer. Therefore, the bulk of the ringed seal hunting will occur outside of the time scope of the surveys. To further mitigate the chance of the seismic vessel interfering with the occasional summer subsistence hunting of seals, the vessel will stay offshore and away from the coastal seal hunting ground. Therefore, TGS does not anticipate any adverse impacts on ringed seals as a result of the proposed survey.

8.2.4 Spotted Seals

Spotted seals (Figure A-6 [Appendix A]) in Alaska are distributed along the continental shelf of the Beaufort, Chukchi, and Bering Seas. These seals migrate south from the Chukchi Sea, through the Bering Strait, into the Bering Sea beginning in October. They spend the winter in the Bering Sea traveling east and west along the ice edge (Allen and Angliss 2012). Because of the numbers and opportunities for subsistence harvesting of whales and bearded seals, spotted and ringed seals are primarily hunted during winter months in the Chukchi Sea. Since this time frame is outside of the scope of the proposed surveys, the subsistence activities involving these seals is unlikely (BLM 2005), and as mentioned above, the seismic vessel will stay several miles offshore and will not affect seals near coastal hunting grounds.

8.2.5 Bearded Seals

Bearded seals (Figure A-7 [Appendix A]) tend to inhabit relatively shallow water (less than 200 m) [656 ft]) that does not have much ice. In Alaska they are distributed along the continental shelf of the Bering, Chukchi, and Beaufort Seas. Most bearded seals migrate in the spring from the Bering Sea, through the Bering Strait, and into the Chukchi Sea, and spend the summer season along the ice edge. Some bearded seals do not migrate and spend all year in the waters of the Bering and Chukchi Seas. According to a subsistence harvest database, the 2000 annual harvest of bearded seals in Alaska was 6,788 (Allen and Angliss 2012). Bearded seals are an important source of meat and hide for Chukchi Sea villages. Because of their greater size compared to other seals, they tend to be targeted by subsistence users. This provides a lot of meat to the communities as well as skins for constructing boats (BLM 2005).

To avoid affecting subsistence users that hunt bearded seals during the time of the seismic surveys, the vessel will stay offshore away from coastal hunting grounds.

9.0 ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed 2D seismic program will not result in any permanent impact on habitats used by marine mammals or to their prey sources. Seismic activities in U.S. Chukchi Sea waters will occur during the time of year when bowhead whales are feeding east of Point Barrow predominantly in the Canadian Beaufort Sea. Thus, during the July through October survey period, bowheads would be expected to occur in very low numbers within the survey area. In particular, relatively few bowheads would be likely to occur above 72°N in international project area waters. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow. Any effects would be temporary and of short duration at any one place. The primary potential impacts to marine mammals are associated with elevated sound levels from the proposed seismic source array as discussed in detail earlier in Sections 6 and 7.

A broad discussion on the various types of potential effects of exposure to seismic on fish and invertebrates can be found in LGL (2005), and includes a summary of direct mortality (pathological/physiological) and indirect (behavioral) effects.

Mortality to fish, fish eggs, and larvae from seismic energy sources would be expected within a few meters (0.5 to 3 m [1.6 to 10 ft]) from the seismic source. Direct mortality has been observed in cod and plaice within 48 hours that were subjected to seismic pulses 2 m (7 ft) from the source (Matishov 1992); however, other studies did not report any fish kills from seismic source exposure (La Bella et al. 1996, IMG-Golder Corp 2002, Hassel et al. 2003). To date, fish mortalities associated with normal seismic operations are thought to be slight. Saetre and Ona (1996) modeled a worst-case mathematical approach on the effects of seismic energy on fish eggs and larvae, and concluded that mortality rates caused by exposure to seismic are so low compared to natural mortality that issues relating to stock recruitment should be regarded as insignificant.

Limited studies on the physiological effects on marine fish and invertebrates to acoustic stress have been conducted. No significant increases in physiological stress from seismic energy were detected for various fish, squid, and cuttlefish (McCauley et al. 2000) or in male snow crabs (Christian et al. 2003). Behavioral changes in fish associated with seismic exposures are expected to be minor at best. Because only a small portion of the available foraging habitat would be subjected to seismic pulses at a given time, fish would be expected to return to the area of disturbance anywhere from 15 to 30 minutes (McCauley et al. 2000) to several days (Engås et al. 1996).

Available data indicates that mortality and behavioral changes do occur within very close range to the seismic source; however, the proposed seismic activities in the Chukchi Sea are predicted to have a negligible effect to the prey resource of the various life stages of fish and invertebrates available to marine mammals.

10.0 ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

The anticipated impact of the loss or modification of the habitat on the marine mammal populations.

The effects of the planned seismic activity on marine mammal habitats and food resources are expected to be negligible, as described in Section 9. It is estimated that only a small portion of the animals utilizing the areas of the proposed activities would be temporarily displaced.

During the seismic program (July through October), most marine mammals would be dispersed throughout the area, with higher densities expected close to shore, near the pack ice edge, south of 72°N, and in waters <200 m deep. The peak of the fall bowhead whale migration through the Chukchi Sea typically occurs in October, when TGS anticipated being in international waters above 72°N. Few if any bowheads are expected to occur in these waters at that time. Efforts to reduce potential impacts during this time will be addressed at the actual start of the migration and with the whaling communities. The timing of survey activities in the Chukchi Sea will be when the whales are widely distributed and would be expected to occur in very low numbers within the seismic activity area. Starting in late August, bowheads may travel in proximity to the survey areas and hear sounds from vessel traffic and seismic activities; some whales may be temporarily displaced as a result. The numbers of cetaceans and pinnipeds subject to displacement are small in relation to abundance estimates for the mammals addressed under this request for IHA.

In addition, feeding does not appear to be an important activity of bowheads migrating through the Chukchi Sea in most years. However, sightings of bowhead whales do occur in the summer near Barrow (Moore and DeMaster 2000), and there are suggestions that certain areas near Barrow are important feeding grounds. In addition, a few bowheads can be found in the Chukchi and Bering Seas during the summer. Rugh et al. (2003) suggested that this may be an expansion of the Western Arctic stock although more research is needed. In the absence of important feeding areas, the potential diversion of a small number of bowheads away from survey activities is not expected to have any significant or long-term consequences for individual bowheads or their population. Bowheads, gray, beluga, minke, and killer whales, and harbor porpoise are not expected to be excluded from any habitat.

The proposed activities are not expected to have any habitat-related effects that would produce long-term effects to marine mammals or their habitat due to the limited extent of the acquisition areas and timing of the activities.

11.0 MITIGATION MEASURES

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

The planned 2D seismic survey has been designed to minimize impact to marine mammal species and subsistence hunts as identified in Table 7. However, the survey plan is dependent on weather and sea-ice conditions and therefore may require modification. Mitigation methods summarized below will be employed to ensure minimal impact to marine mammals and subsistence activities. Additionally, TGS does not anticipate interaction with other operators. However, TGS will maintain a minimum spacing of 24 km (15 mi) between all active seismic vessels. TGS will make every effort to acquire the lines that are located nearest to any projected drilling locations prior to the arrival of a drilling vessel. If a drilling vessel is occupying a location prior to the acquisition of the seismic line, TGS will maintain an agreed upon (with the operator of the drilling vessel) safety radius from the drilling vessel.

Table 7 – Marine mammal and subsistence mitigation measures resulting from the TGS 2D seismic survey design.

Proposed Plan	Timeframe (2013)	Resulting Mitigation
Begin seismic operations	Late-July or early-August (depending on ice conditions and weather)	After spring whale hunt complete
Remain in ice-free waters	Throughout survey	Avoid most encounters with ice-associated ice-seals, walruses and polar bears
Survey south of 72 °N first	July-August	Avoid bowhead/belugas and subsistence activities
Extend northward into international waters as ice recedes (>200 nm N/NW from shore)	September -October	Avoid fall migrating bowhead whales and subsistence hunts

Vessel operators associated with TGS's proposed 2013 seismic program anticipate monitoring communication centers (Com- and Call-Centers) proposed to be operated in Barrow, Point Hope, and Point Lay. This will further enable vessel operators to be aware of marine mammals and subsistence

activity in the area. PSOs will be placed onboard the seismic and scout vessels to implement mitigation measures minimizing exposure to the seismic sound source. Vessel-based mitigation measures include ramp-up procedures while initiating seismic operations and power-down and a shut-down procedure if a marine mammal is detected approaching or within designated distances from the sound source. These distances have been determined by acoustic propagation modeling, provided by JASCO Applied Sciences. The full report is provided in Appendix C, but the results are summarized in Table 1. A single 60 in^3 (or smaller) airgun in the seismic source array will be used as a mitigation seismic source to continuously produce a small amount of sound into the environment to alert marine mammals of the presence of a sound source in the environment. Associated distances to the 160, 180 and 190 dB re 1 µPa (rms) for the single 60 in^3 airgun were provided in Section 1.4 *Sound Propagation Modeling*. Furthermore, TGS has designed their program to mitigate impacts to marine mammals by incorporating the following operational procedures:

- No multi-beam sonar or sub-bottom profilers will be used, only standard vessel fathometers for safety and navigation
- Only one small source element (mitigation source) will be operating during line changes, which take between 5-12 hours each
- The number of seismic pulses of the mitigation source will be reduced during line changes to reduce the acoustic footprint and overall input of noise into the water.

11.1 Vessel-Based Marine Mammal Monitoring

To reduce incidental takes of marine mammals during proposed surveys, vessel-based PSOs will monitor for marine mammals during all daytime seismic source operations and any nighttime start-up of the seismic source (unless nighttime or weather conditions make observations impossible). These observations provide real-time data necessary to implement some of the key mitigation measures. When marine mammals are detected approaching or within designated exclusion zone (see Section 11.2 below) where there is a possibility of significant effects on hearing or other physical effects, the seismic source will be powered down or shut down immediately. PSOs will communicate mitigation measures to the seismic source operators and vessel captain/crew.

Vessel-based PSOs will monitor during all daylight seismic operations and when there has been no mitigation source element in operation for a minimum of 30-minutes prior to initiation of the seismic source (i.e. Ramp-up) after an extended shutdown period. PSOs will conduct opportunistic observations during all daylight periods when no seismic activities are taking place. TGS plans to conduct seismic operations 24-hours per day, including during nighttime. PSOs are not required to observe during extended periods of darkness, however night-vision devices will be available to aid in any nighttime observations. Nighttime seismic operations may only commence if the single mitigation was initiated before dark and continuously operated since PSO monitoring ended. The vessel captain/crew is to notify PSOs of any marine mammal observations during nighttime seismic operations and adhere to the

required mitigation measures as per the NMFS IHA and USFWS LOA. After a complete shutdown at night, seismic activity will be suspended until the entire exclusion zone is visible the following day.

TGS's approach to monitoring is to station a sufficient number of PSOs aboard both the seismic vessel and scout vessel to document the occurrence of marine mammals within the survey area, to help implement mitigation requirements, and to record the reactions of marine mammals to the survey. At least one PSO will be an Inupiaq trained in collecting marine mammal data. PSOs will observe no more than four consecutive hours for a maximum of 12 hours per day. Each PSO will, while on duty, scan the area of operation for marine mammals using reticle binoculars (e.g., 7x50 Fujinon) and big-eye binoculars (25x150), recording the species, location, distance from survey vessel, and behavior (and associated weather data) of all that are seen. The proposed monitoring plan is described in greater detail in Section 13.

11.2 Establishment and Monitoring of Exclusion Zones

Current NMFS guidelines (NMFS 2000) define "exclusion radii", hereafter referred to as exclusion zones, for marine mammals around industrial sound to be 180 dB re 1 µPa (rms) for cetaceans and 190 dB re 1 µPa (rms) for pinnipeds. Such guidelines are place to minimize disturbance or behavioral effects to marine mammals based on the assumption that sound energy at lower received levels will not impair their abilities to hear, but higher received levels may have such effects.

Upon arrival to the project area, sound source levels for the equipment will be measured and verified against the modeled sounds. The SSV will establish in the field more exact distances to the 190 dB, 180 dB rms, and 160 dB isopleths. PSOs will monitor for marine mammals using the modeled exclusion radii (Table 1) during the SSV.

Protected species observers aboard the seismic and scout vessels will perform a substantial role in monitoring for marine mammals and the implementation of mitigation measure. PSOs aboard the seismic vessel will monitor for marine mammals prior to initiation of the seismic source to ensure none are detected within the specified exclusion zones for a 30-minute period. The scout-vessel will be utilized to detect aggregations of baleen whales (12 or more) within the ≥160 dB zone.

11.3 Marine Mammal Mitigation during Operations

TGS will adhere to the following mitigation measures during seismic operations, when mobilizing to the project area, when demobilizing from the project area, and in the performance of any other operations in support of the 2D seismic program:

- *Speed or course alterations, provided that doing so will not compromise safety of the operations.*

- *The seismic and scout vessel will be staffed with PSOs who will alert the crew to the presence of marine mammals so that vessel crews can initiate appropriate mitigation measures, including power-down, shut-down, and ramp-up procedures.*
- *Initiation of the seismic source will occur only after the 180 dB zone is visible for 30-minutes during day or night.*

During periods of poor visibility or nighttime, TGS will adhere to the following:

- *During limited visibility due to fog and/or darkness, the entire 180 dB exclusion zone may not be visible. If the entire zone is not visible for a minimum of 30-minutes, initiations of the seismic source will not occur.*
- *During nighttime, initiation of the seismic source will only occur if the entire 180 dB exclusion zone is visible for 30-minutes using night-vision devices (NVDs) and/or vessel lights.*
- *If a single airgun seismic source or a seismic source array have been operational before visibility decreased or nightfall, the seismic source operations may continue even though the entire exclusion zone may not be visible.*

11.3.1 Speed or Course Alteration

In the event that a marine mammal is outside of the exclusion or disturbance zones and is likely to enter the exclusion radius based on its movements, the vessel will speed up or change its course to avoid disturbance to the marine mammal. This procedure will be conducted with safety and practicality in mind, and further course alterations or the seismic source power downs will occur if necessary.

11.3.2 Power-down Procedures

Power-down procedures include reducing the seismic source array volume (by reducing the number of active airguns) thereby reducing the 180 dB and 190 dB exclusion zones to an extent that the marine mammal(s) are no longer within the applicable zone. Power-downs may also occur when the seismic vessel is transitioning between survey lines. In this case, the seismic source array will be reduced to a single 60 in^3 (or smaller) mitigation airgun or shut-down completely (Section 11.3.3). The single mitigation airgun seismic source is intended to alert marine mammals of the presence of a sound source in the environment and retain the option to initiate seismic source ramp-up procedures (Section 11.3.4) under conditions of poor visibility or darkness.

If a marine mammal is detected outside, but approaching the appropriate exclusion zone, a power-down will be immediately requested by the PSO to power-down to the 60 in^3 (or smaller) mitigation airgun. Similarly, if a marine mammal is detected within the appropriate exclusion zone, a power-down will be requested immediately as long as the marine mammal is not within or approaching the reduced exclusion zone of the single mitigation airgun seismic source. Measured reported distances for the 60 in^3 mitigation airgun were reported in Blees et al. (2010) as recorded by JASCO Applied Research, and

were 13 m for the 190 dB isopleth, 68 m for the 180 dB isopleth, and 1500 m for the 160 dB isopleth. If the marine mammal continues to approach the reduced exclusion zone of the single mitigation airgun seismic source, it will also be deactivated resulting in a complete shut-down of the seismic source (Section 11.3.3).

Once powered down, seismic source operations will only resume once the marine mammal has been confirmed outside the exclusion zone. A marine mammal is considered to have cleared the zone if:

- *it has been visually detected outside of the exclusion zone;*
- *it has not been observed for 15 minutes (pinnipeds or small odontocetes)*
- *it has not been observed for 30 minutes (mysticetes; large odontocetes do not occur in the survey area)*

11.3.3 Shut-down Procedures

Shut-down procedures include a complete cessation of the seismic source. These procedures will be implemented if a marine mammal is observed within the appropriate exclusion zone of the single mitigation airgun (Section 11.3.2). Once shut-down, the seismic source operations will only resume once the marine mammal has been confirmed outside the exclusion zone as described for power-downs (Section 11.3.2).

Emergency shut-downs will occur immediately if observations are made or credible reports are received that one or more marine mammals within the seismic survey area and are injured, dead, dying, or indicate acute distress due to seismic noise. In this case an emergency shutdown will be ordered and NMFS (or USFWS for Pacific walrus and polar bear) will be contacted immediately. If it can be determined that the marine mammal injury or death is likely not due to seismic or drilling activities (e.g., obvious signs of killer whale predation; signs of hunting, such as bullet wounds), TGS will collect information as specified in Section 13 of this document, notify the USFWS or NMFS, and resume seismic activities. If cause of death cannot be attributed to causes other than the seismic program, the activities will not be restarted until approval has been given by USFWS or NMFS.

11.3.4 Ramp-up Procedures

Ramp-up procedures involve a step-wise increase in number and volume of the seismic source to provide a gradual increase of sound levels into the environment. This procedure is intended to alert marine mammals of seismic activity in the area and allow them time to leave the area so as to avoid injury or hearing impairment. PSOs will be on duty during the 30-minute observation period prior to ramp-ups, during ramp-ups, and all seismic source operations.

NMFS normally requires that, once ramp-up commences, the rate of ramp up be no more than 6 dB per 5-minute period. Ramp-up will likely begin with a single 60 in^3 (or smaller) airgun seismic source. The

precise ramp-up procedure has yet to be determined, but TGS intends to follow the ramp-up guidelines with a ramp-up rate of no more than 6 dB per 5-minute period (unless otherwise required). During ramp-up, the exclusion zone of the full seismic source array will be maintained.

After a complete shut-down, ramp-up procedures will not commence until the exclusion zone of the full array is visible and no marine mammals are present. In this case of a "cold start," the exclusion zone must remain completely visible during the entire 30-minute period. If a marine mammal is observed within the appropriate exclusion zone, a cold start may not be initiated until the animal is observed outside of the exclusion zone or not observed for at least 15-minutes for pinnipeds and 30-minutes for cetaceans.

Ramp-up procedures will be adhered to when the seismic source array has been shut-down or operating with reduced volume (e.g. mitigation gun) for a specified duration of time. This specified time period (often about 5 minutes) is generally the amount of time it would take the vessel to cover the 180 dB zone and depends on the speed of the seismic vessel, water depth, and array volume. If the seismic source array has been operating with one or more airguns (i.e., survey line changes), ramp-up procedures to the full seismic source array volume may commence during nighttime or periods of poor visibility on the assumption that marine mammals will be alerted by the sounds and able to move out of the area.

12.0 PLAN OF COOPERATION

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a "plan of cooperation" or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan of cooperation must include:

- **A. A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;**
- **B. A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;**
- **C. A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and**
- **D. What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting the activity, to resolve conflicts and to notify the communities of any changes in the operation.**

TGS will prepare a POC to fulfill the requirements of the three major federal permits: the NMFS IHA, the USFWS LOA, and the BOEM Geophysical and Geological permit. The POC document will summarize the actions TGS has taken to describe important subsistence activities near the proposed survey program; methods they have taken to inform subsistence communities of the proposed survey activities; and

measures they will take to minimize adverse effects on marine mammals where proposed activities may affect the availability of a species or stock of marine mammals for arctic subsistence uses or near a traditional subsistence hunting area.

TGS began stakeholder engagement by introducing the project to the North Slope Borough Planning Commission on October 25, 2012 and they also met with the NSB Planning Director and other Barrow leadership. In December 2012, TGS is scheduled to meet with Chukchi Sea community leaders at the tribal, city, and corporate level in Barrow, Wainwright, Point Hope, Point Lay, and Kotzebue. TGS will also introduce the project to the Alaska Eskimo Whaling Commission (AEWC) at their 4th Quarter Meeting on December 12-14, 2012, in Anchorage.

Community POC meetings are scheduled to occur in Barrow, Wainwright, Point Hope and Point Lay (possibly Kotzebue) sometime between January and March 2013 depending on stakeholder schedule and availability. A draft POC document will be prepared and provided to the community leaders and NMFS, USFWS, and BOEM in advance of the meetings.

A final POC that documents all consultations with community leaders and subsistence users will be submitted to NMFS, USFWS, and BOEM completion of consultation. The final POC will include feedback from the Leadership Meetings and POC meetings. TGS will continue to document all consultation with the communities and subsistence stakeholders as the survey progresses.

13.0 MONITORING AND REPORTING PLAN

The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding.

13.1 Monitoring

TGS plans to support the marine mammal monitoring throughout the project in order to implement the proposed mitigation measures, contribute to the marine mammal knowledge of the study area, satisfy the monitoring requirements of the NMFS IHA, USFWS LOA and those agreed to as part of the Plan of Cooperation. TGS understands that the Monitoring Plan described in this section will be subject to review by NMFS and others and that modification may be required. In addition to collecting marine mammal distribution and behavioral data, the PSO program will provide insight on marine mammal activities when seismic activities are taking place or not. TGS is prepared to discuss coordination of its

monitoring program with any related work that might be done by other groups insofar as this is practical.

13.1.1 Vessel-based Visual Monitoring

- *Vessel-based PSOs will observe from both the seismic and scout vessel to monitor the presence of marine mammals during all daylight seismic operations. The primary purpose of the PSOs will be to monitor the exclusion zones and implement mitigation measures (e.g. ramp-ups, power-downs, and shut-downs of the seismic source) as described in Section 11. PSOs will be appointed by TGS and approved by NMFS and USFWS. At least one PSO on each vessel will be an Inupiaq resident knowledgeable about the marine mammals of the area. The vessel-based monitoring will provide: the foundation for real-time mitigation as required by the permitting agencies;*
- *information necessary to estimate the number of "takes" of marine mammals that must and will be reported to NMFS or USFWS;*
- *information necessary to evaluate the impact of activities authorized by the IHA and LOA on marine mammals and local subsistence activities;*
- *marine mammal distribution, movement, and behavioral data in the survey area when seismic activities are taking place or not.*

13.1.2 Protected Species Observer Protocol

TGS intends to begin operations during July when there are approximately 24-hours of daylight. To adequately monitor proposed exclusion zones during all daylight seismic operations, at least five PSOs are proposed to be based aboard the seismic vessel with at least three and up to five aboard the scout vessel pending any bunk-space restrictions. As daylight decreases during the survey, the number of PSOs aboard the seismic vessel may be reduced. At least one observer will be on duty during all daylight seismic source operations; however two observers will be on duty whenever possible. An observation schedule with five PSOs allows for two observers to be on duty at one time for 21 hours per 24 hour day. The three hours with only one PSO on duty would be during nighttime hours when observations will be increasingly limited by daylight. In addition, two observers will be on duty during all 30-minute periods prior to seismic source ramp-up and during all ramp-ups. PSOs will be on duty for no longer than four consecutive hours with a maximum of 12-hours on duty per day per PSO.

Prior to mobilization, PSOs will attend a NMFS-approved survey-specific training program and receive a detailed manual that summarizes the observer protocol and mitigation procedures as stipulated in the permits and issued IHA and LOA. Once onboard the vessels and prior to the start of the survey, the lead-PSO aboard the seismic vessel will communicate the role of the PSO-teams to the vessel crew(s) and establish a method of communication for relaying mitigation requests to the seismic source operators (see below).

Marine mammal observations will be conducted from the bridge or other suitable platform on the source and scout vessels. During daylight, PSOs will systematically scan the area around the vessel with reticle binoculars (7 x 50 Fujinon or equivalent), big-eye binoculars (Fujinon 25×150 or equivalent) and the naked eye. Night-vision devices (NVDs; ITT F500 Series Generation 3 binocular-image intensifier or equivalent) will be available to aid observations during any periods of darkness. PSOs will be provided with a laser rangefinder to assist with distance estimation; however these tools are more commonly used to train PSOs to estimate distances visually, rather than for measuring distances to animals in the field.

13.1.3 Communication Procedures

When PSOs detect marine mammals within or approaching the applicable exclusion zone, the seismic source will be powered-down or shut-down immediately. To facilitate this, a direct line of communication with the seismic source operators will be established (i.e., VHF radio) and sightings will be mapped and displayed on a PC monitor relative to exclusion zones in real-time using Mysticetus™ (see Section 13.1.7). PSOs will continue to monitor the exclusion zones after implementation of a power- or shut-down. As described in Section 11, the PSOs will communicate resumption of the array if the marine mammal(s) is observed outside and moving away from the applicable exclusion zone within five-minutes of power- or shut-down. If more than five-minutes have elapsed since the seismic source was reduced, then the exclusion zones must be free of marine mammals for at least 15-minutes for pinnipeds and 30-minutes for cetaceans. Once the PSO(s) has cleared the zones, they will communicate to the seismic source operators to initiate ramp-up procedures (Section 11.3.4).

13.1.4 Data Recording

The operator of the seismic vessel will maintain a digital log of seismic surveys, noting the date and time of all changes in seismic activity (ramp up, power down, changes in the active seismic source, shutdowns, etc.) and any corresponding changes in monitoring radii in a project-customized Mysticetus observation software spreadsheet. In addition, PSOs will utilize this standardized format to record all marine mammal observations and mitigation actions (seismic source power-downs, shut-downs, and ramp-ups). Information collected during marine mammal observations will include the following:

- *Vessel speed, position, and activity*
- *Date, time, and location of each marine mammal sighting*
- *Number of marine mammals observed, and group size, sex, and age categories*
- *Observer's name and contact information*
- *Weather, visibility, and ice conditions at the time of observation*
- *Estimated distance of marine mammals at closest approach*
- *Activity at the time of observation, including possible attractants present*

- *Animal behavior*
- *Description of the encounter*
- *Duration of encounter*
- *Mitigation action taken*

Data will preferentially be recorded directly into a handheld computer or as a back up, transferred from hard-copy data sheets into an electronic database. A system for quality control and verification of data will be facilitated by the pre-season training, supervision by the crew leader, in-season data checks, and will built into the Mysticetus software (i.e., Mysticetus will recognize and notify the operator if entered data are non-sensical). Computerized data validity checks will also be conducted, and the data will be managed in such a way that it is easily summarized during and after the field program and transferred into statistical, graphical, or other programs for further processing. Mysticetus will be used to quickly and accurately summarize and display these data.

13.1.5 Acoustic Monitoring

Prior to or at the beginning of the seismic survey, sound levels will be measured as a function of distance and direction from the proposed seismic source array (full and reduced to a single mitigation airgun). Results of the acoustic characterization and SSV will be used to refine the modeled distance estimates of the pre-season 190 dB, 180 dB, and 160 dB isopleths. The refined SSV exclusion zones will be used for the remainder of the seismic survey. Distance estimates for the 120 dB isopleth will also be modeled, however current acoustic criteria do not require mitigation be implemented for pulsed sounds beyond the 160 dB isopleths. A preliminary report of results will be submitted to NMFS shortly after data collection, as required by NMFS.

Passive acoustic monitoring was evaluated for real-time monitoring of the exclusion zones and TGS will submit details of their marine mammal monitoring and mitigation plan separately as a supplement to this IHA application.

13.1.6 Aerial Monitoring

TGS evaluated the feasibility, technology (including real-time unmanned aerial systems), and risk associated with aerial surveys and does not intend to conduct aerial surveys as part of the monitoring and mitigation plan for the Chukchi Sea seismic survey as they would be impractical and unsafe due to the location and extent of offshore waters of the survey area (Figure 1).

13.1.7 Real-Time Monitoring and Communication Between Vessels

TGS is proposing to incorporate Mysticetus™ software as an "all-in-one" PSO platform. The system will be used by PSOs to quickly enter marine mammal observations into a program and real-time map display that can be seen by both vessels on a computer screen monitor. This is achieved by placing an Automatic Identification System (AIS) transceiver and antenna on each vessel. The program also creates automatic high-resolution mapping, so animals can be tracked relative to locations of the vessels and the seismic array and associated mitigation and monitoring isopleths. PSOs will be able to see and monitor exclusion zones on the map display and instantly plot where a marine mammal occurs relative to its exclusion zone. This ability adds confidence and improves the speed and accuracy of communicating sighting locations between vessel platforms to implement real-time mitigation measures. In addition, the distance from sightings to the array and mitigation zones is instantly displayed in real time. Headings and multiple sighting locations of the same sightings can also be displayed. Both vessels can view the same data and map display, thus creating another mode of real-time communication between vessels. An example of marine mammals plotted relative to a seismic vessel and its exclusion zones is shown below in Figure 4.

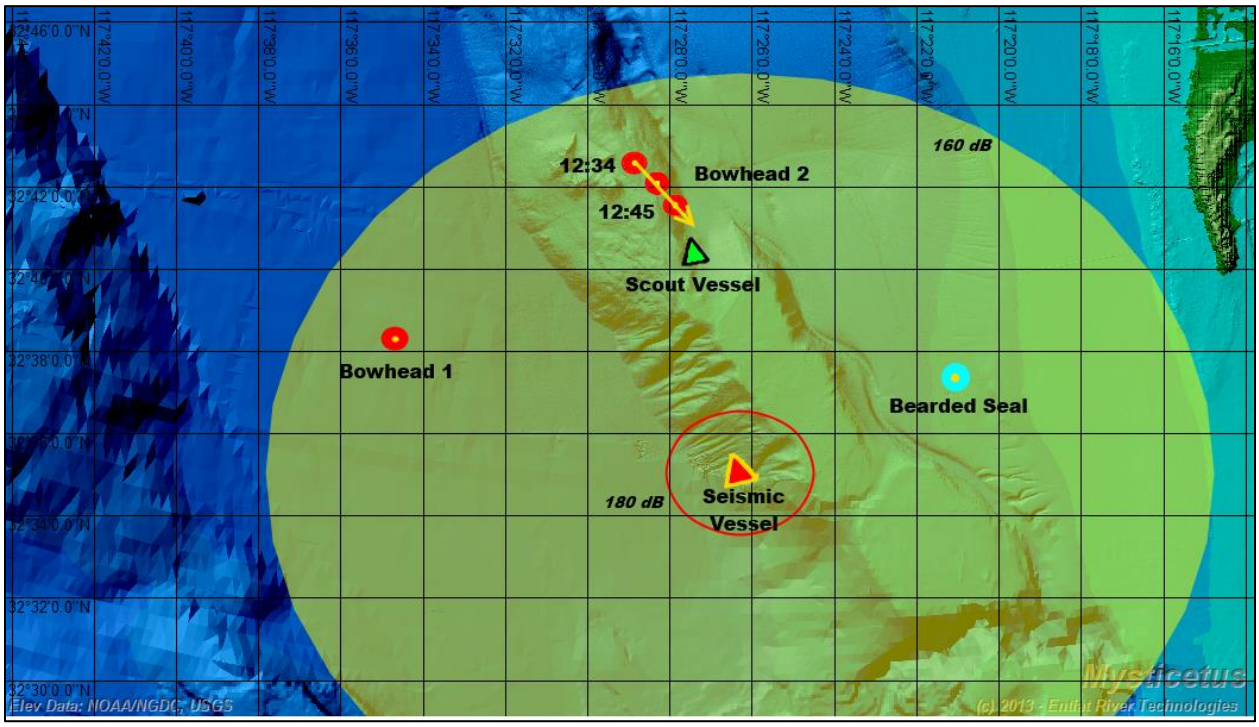

Figure 4 – Example display of AIS real-time mapping displaying the 180-dB exclusion zone (red circle), the 160-dB monitoring zone (green circle), marine mammal sightings, and relative vessel locations in Mysticetus™. Circles indicate marine mammal sightings, arrows indicate direction of repeat sightings, and triangles represent vessels. The map can be zoomed in or out instantly for more or less detail.

13.2 Reporting

During the field season, brief summary reports will be provided to NMFS, if required per the IHA, on a schedule specified in the IHA. A report summarizing the preliminary results of the SSV (Section 13.1.5.4) and refined monitoring exclusion zones for the seismic sources will be submitted shortly after the measurements are complete at the beginning of the field season.

Results of the vessel-based PSO program, including estimates of takes by harassment, will be described in a report to be submitted within 90 days of the end of the program. This report will adhere to the requirements established by the NMFS IHA and USFWS LOA and will include the following:

- *A summary of the monitoring effort*
- *Analysis of factors affecting the visibility and detectability of marine mammals by monitoring*
- *Analysis of distribution and abundance of marine mammal sightings, and description of marine mammal behavior in relation to date, location, ice conditions, and operations*
- *Estimates of takes based upon density estimate derived from monitoring and survey efforts.*
- *Reporting of acoustic monitoring results to include: sound source levels of source- and scout-vessels and seismic surveys; acoustic detections of marine mammals, and continuous sound levels at the stationary recording locations.*
- *Estimates of "take by harassment."*

14.0 COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

Suggested means of learning, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

To reduce and evaluate incidental take, TGS will encourage and coordinate collaborative research opportunities within state, federal, and NSB divisions. Active communication will ensure proper regulatory compliance, build local biological knowledge, and thus may reduce incidental take. Contacts such as USFWS and NMFS can assist with marine mammals or avian interactions and abnormal behavior. To better understand the importance of issues surrounding marine mammals and fisheries within the region, NSB Department of Wildlife Management biologists might also provide input and advice. TGS is committed to coordinating with other monitoring programs to ensure that all measures are taken to minimize any impacts from its 2D seismic program.

TGS received recommendations regarding its program and ways to reduce incidental take from the NMFS Peer Review Panel on 26 February 2013. TGS's response to their recommendations are summarized below in Table 8.

Table 8 – TGS responses to NMFS Peer Review Panel Recommendations.

Recommendation	TGS Response
Reduce sound emissions	• Reduced array size 4,100 to 3,280 in^3 • Pulses to be separated by 40-60 vs. 12 sec on turns • Turn off fathometers when safe to do so
Share sightings, tracks & seismic log data	• Upload data to public website OBIS-SEAMAP • Integrate with other 2013 studies as possible • Send agencies digital sighting/effort data
Constant PSO communications – both vessels	Real-time AIS multi-vessel map display of vessels, isopleths, and marine mammal detections using *Mysticetus*™ custom software
Add far-field monitoring component	Evaluated far-field monitoring options, including aerial methods and various passive acoustic monitoring techniques for the survey area
Re-evaluate beluga take estimates	Revised beluga, bowhead, and gray whale, and ringed and bearded seal take estimates by providing a range of potential take estimates (see Table 5)
Use 2013 NMFS aerial data for baseline take estimates	• NMFS indicated that these data will not be available before the 90-day report is due to NMFS • DISTANCE to analyze density
Scout vessel survey ahead of seismic	TGS agrees

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Appendix A
Figures

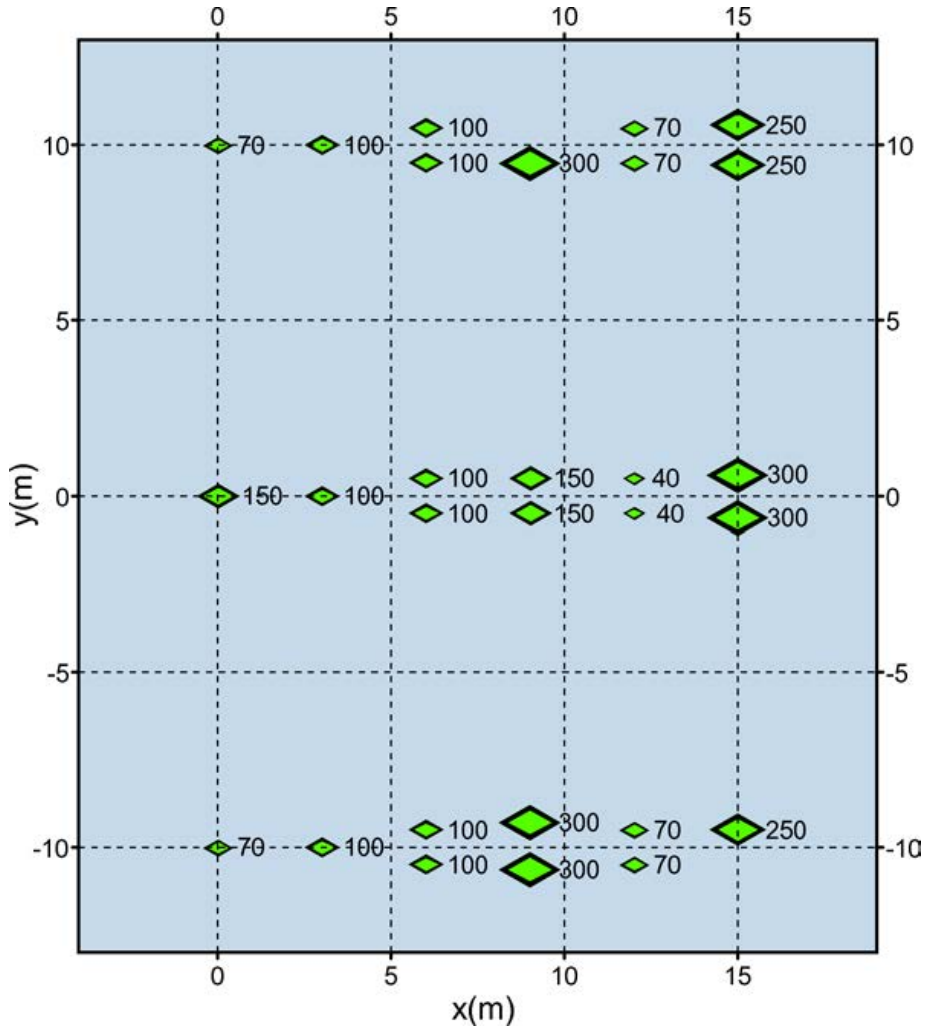

Figure A-1. Geometric arrangement of the 3,280 cubic inches (in^3) seismic source array consisting of three sub arrays of 28 airguns ranging in volume from 40 to 300 in^3.

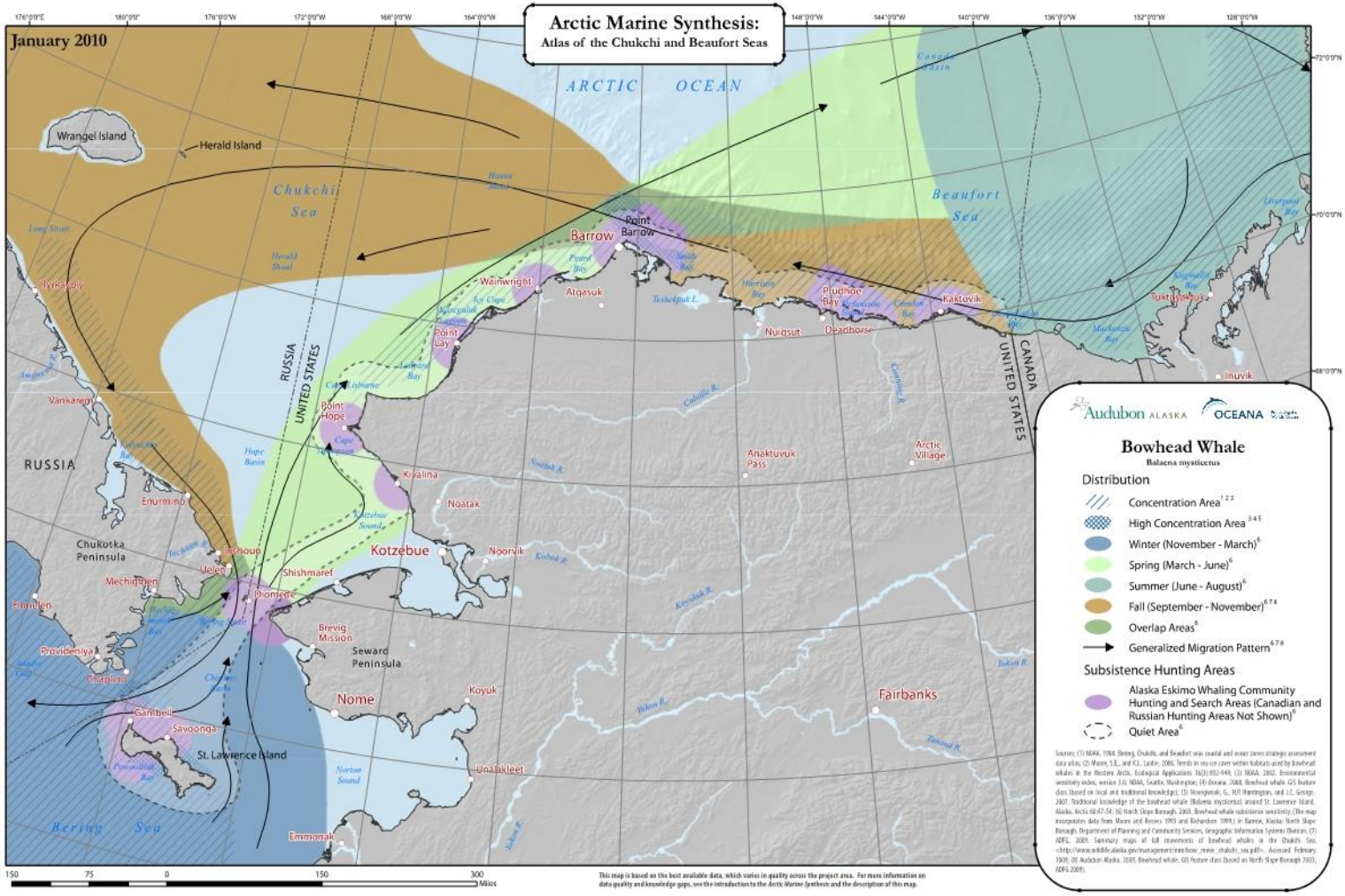

Figure A-2. Bowhead whale (*Balaena mysticetus*) distribution and subsistence communities in the U.S. Chukchi and Beaufort seas.

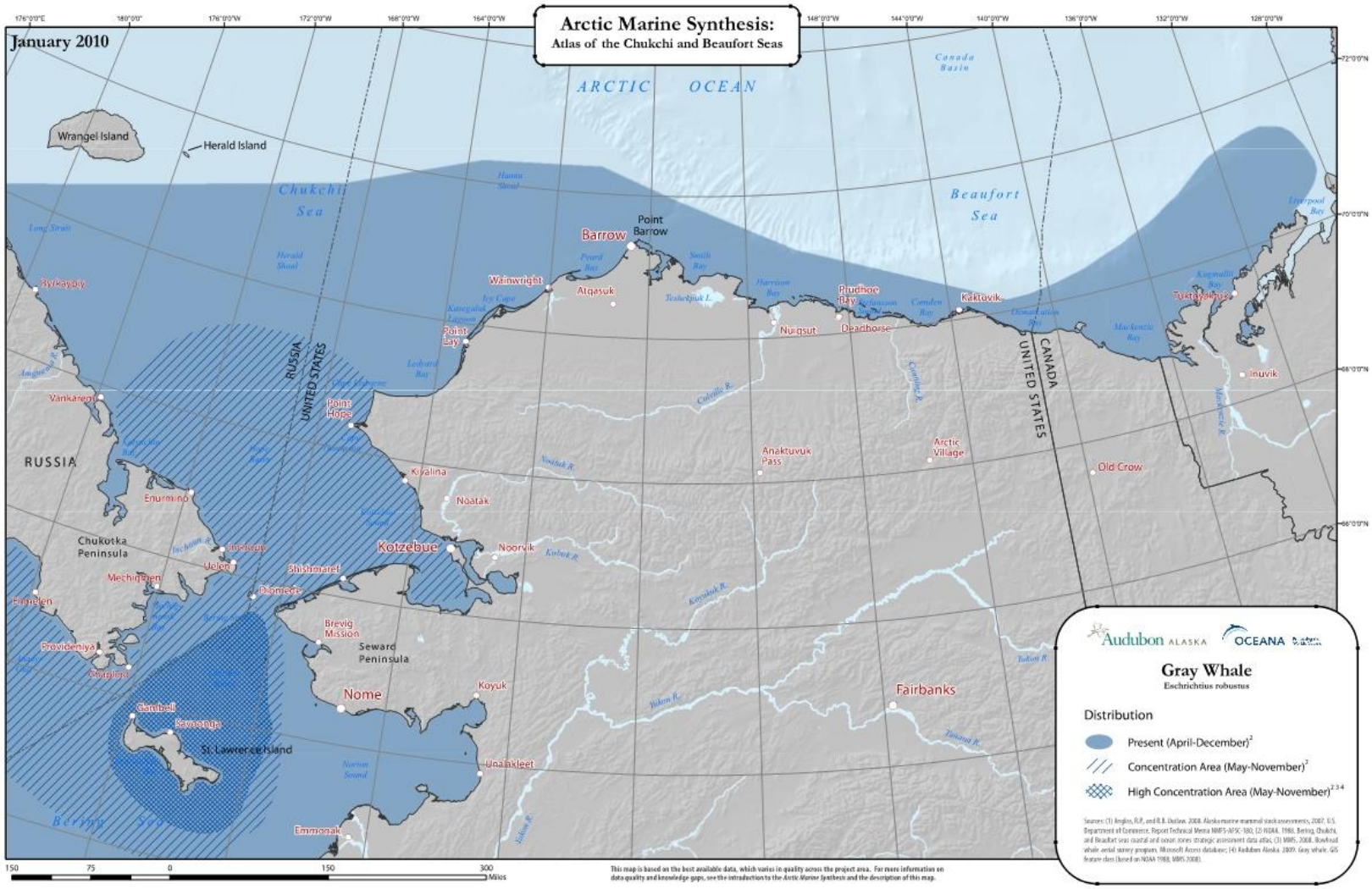

Figure A-3. Gray whale (*Eschrichtius robustus*) distribution in the U.S. Chukchi and Beaufort seas.

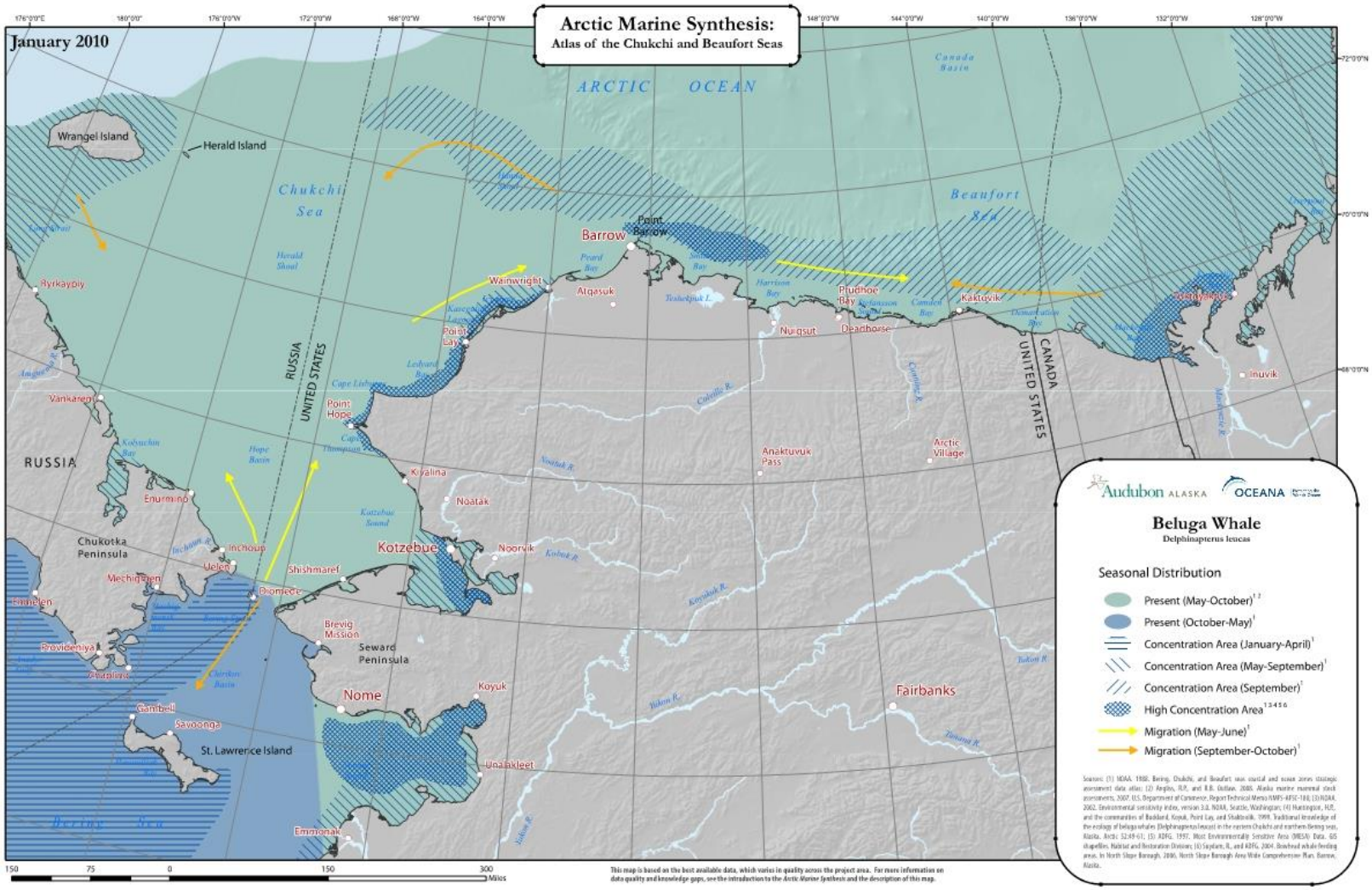

Figure A-4. Beluga whale (*Delphinapterus leucas*) distribution in the U.S. Chukchi and Beaufort seas.

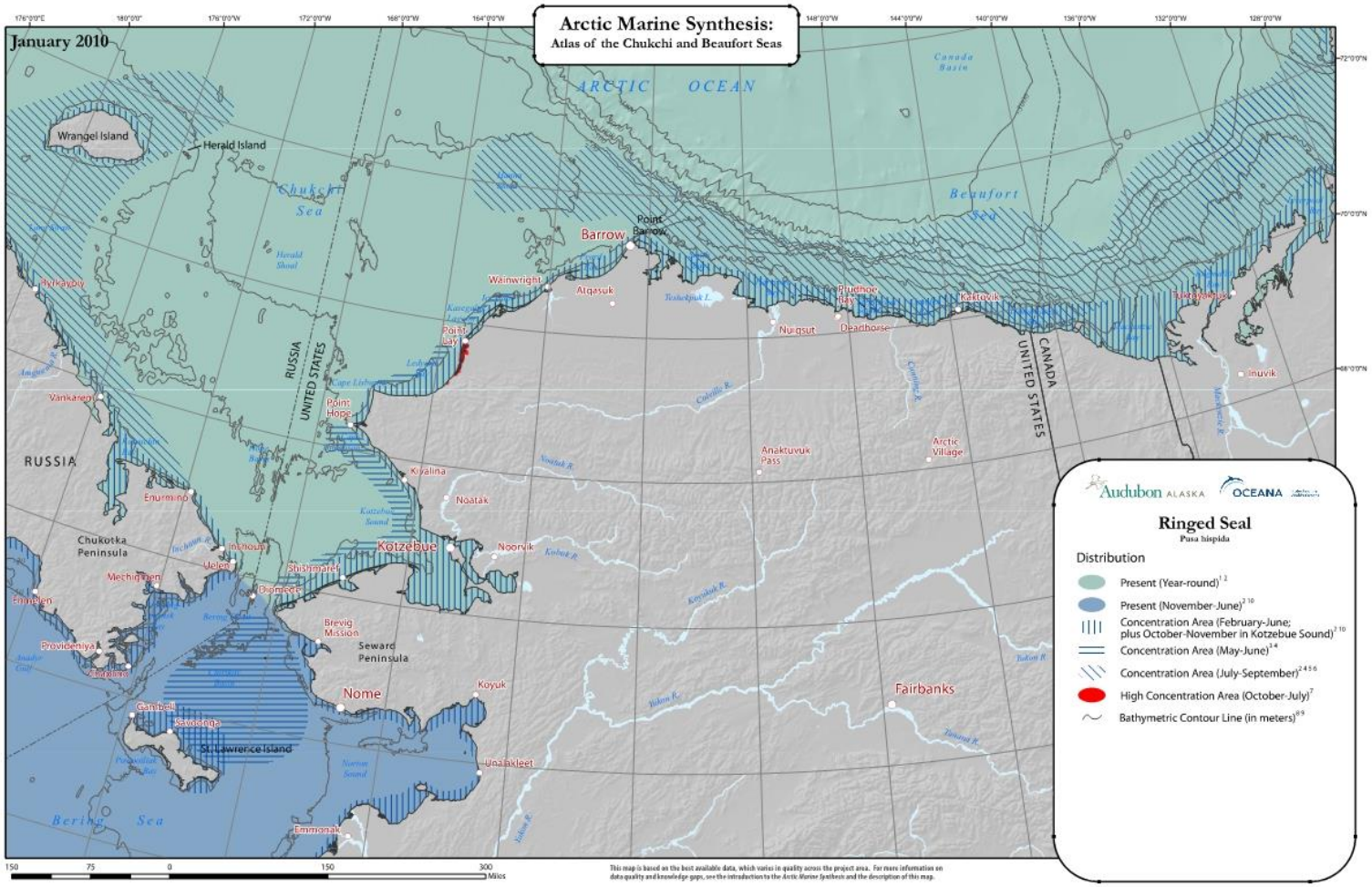

Figure A-5. Ringed Seal (*Phoca hispida*) distribution in the U.S. Chukchi and Beaufort sea

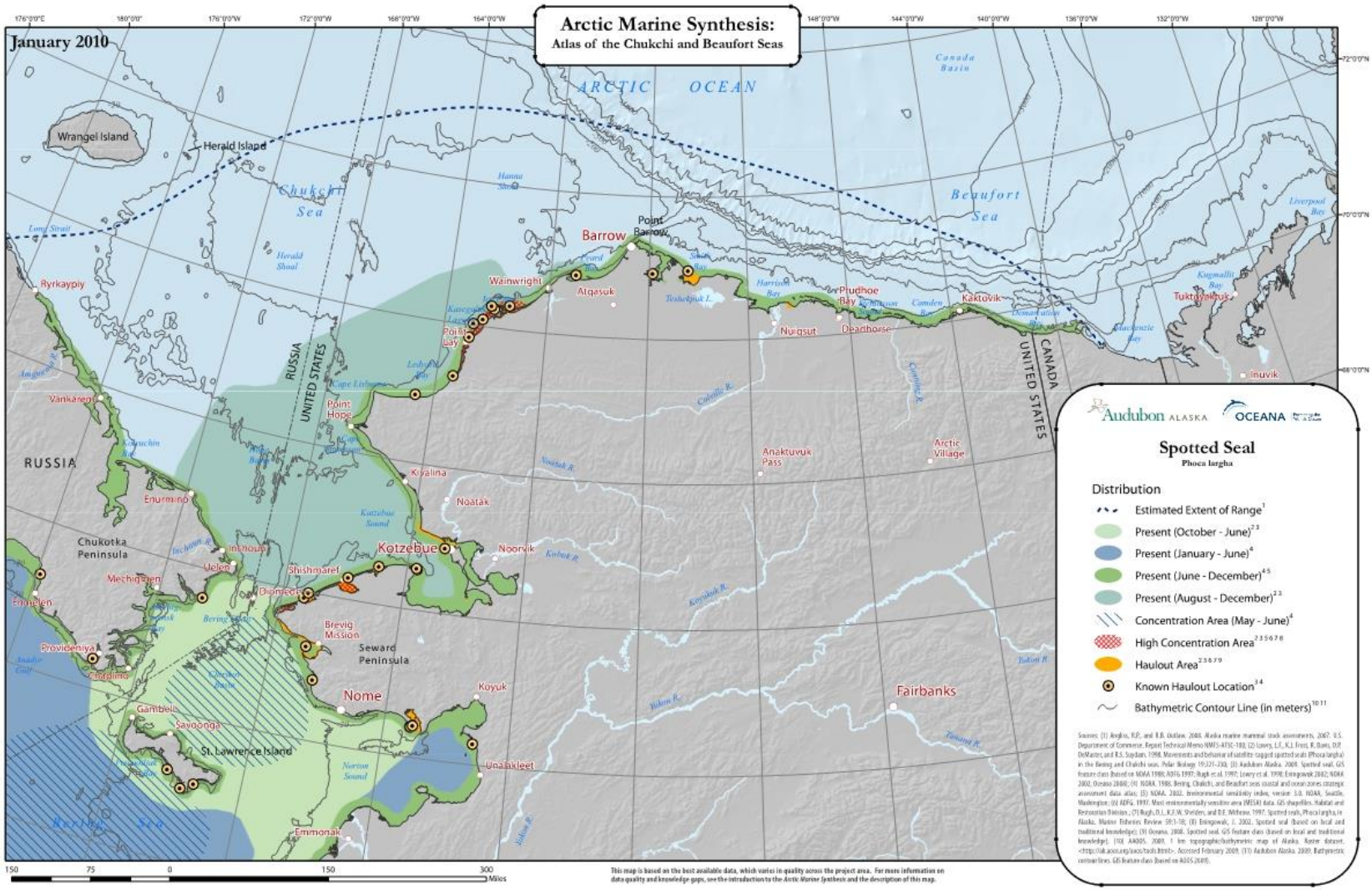

Figure A-6. Spotted seal (*Phoca largha*) distribution in the U.S. Chukchi and Beaufort seas.

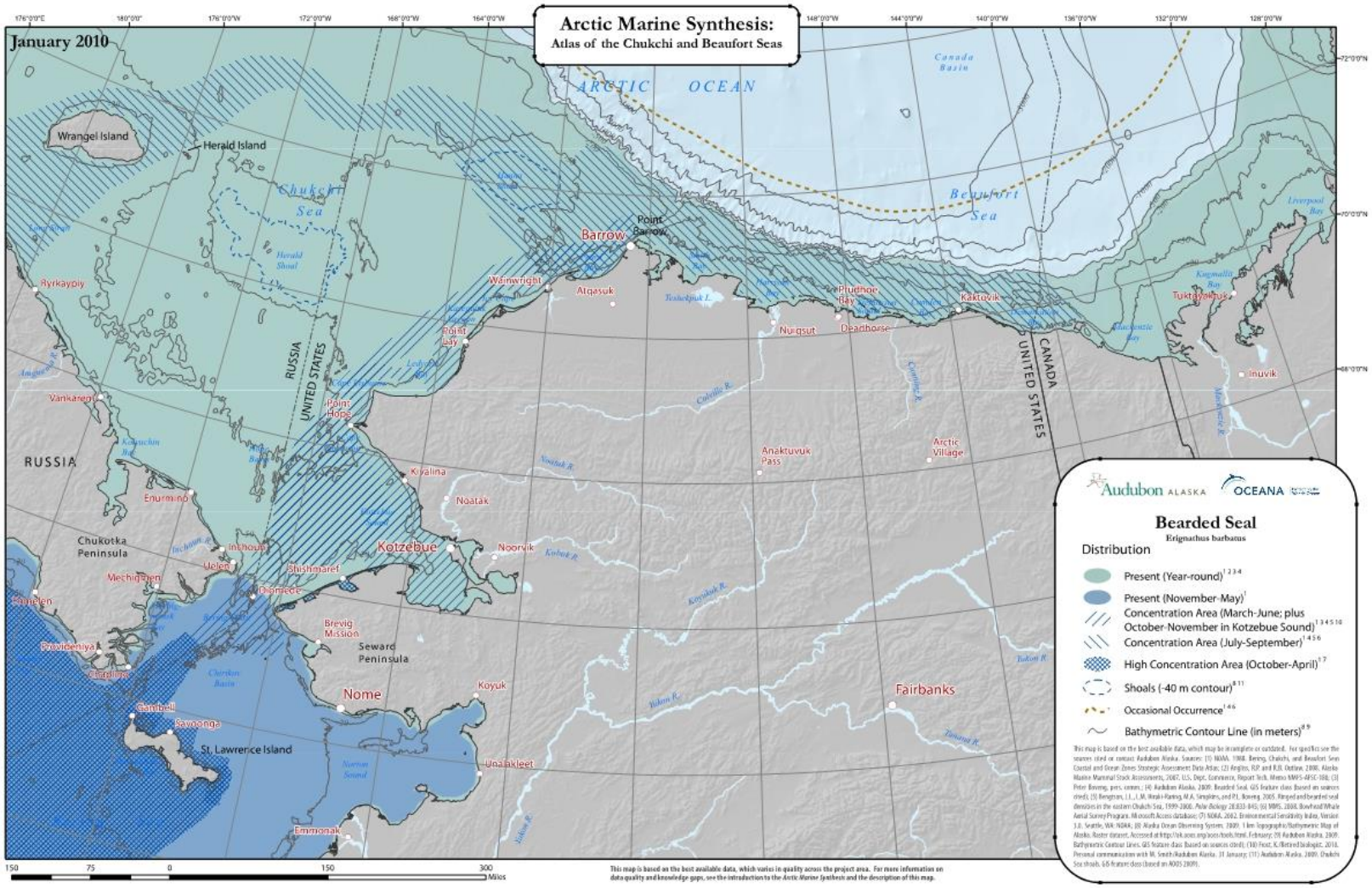

Figure A-7. Bearded seal (*Erignathus barbatus*) distribution in the U.S. Chukchi and Beaufort seas.

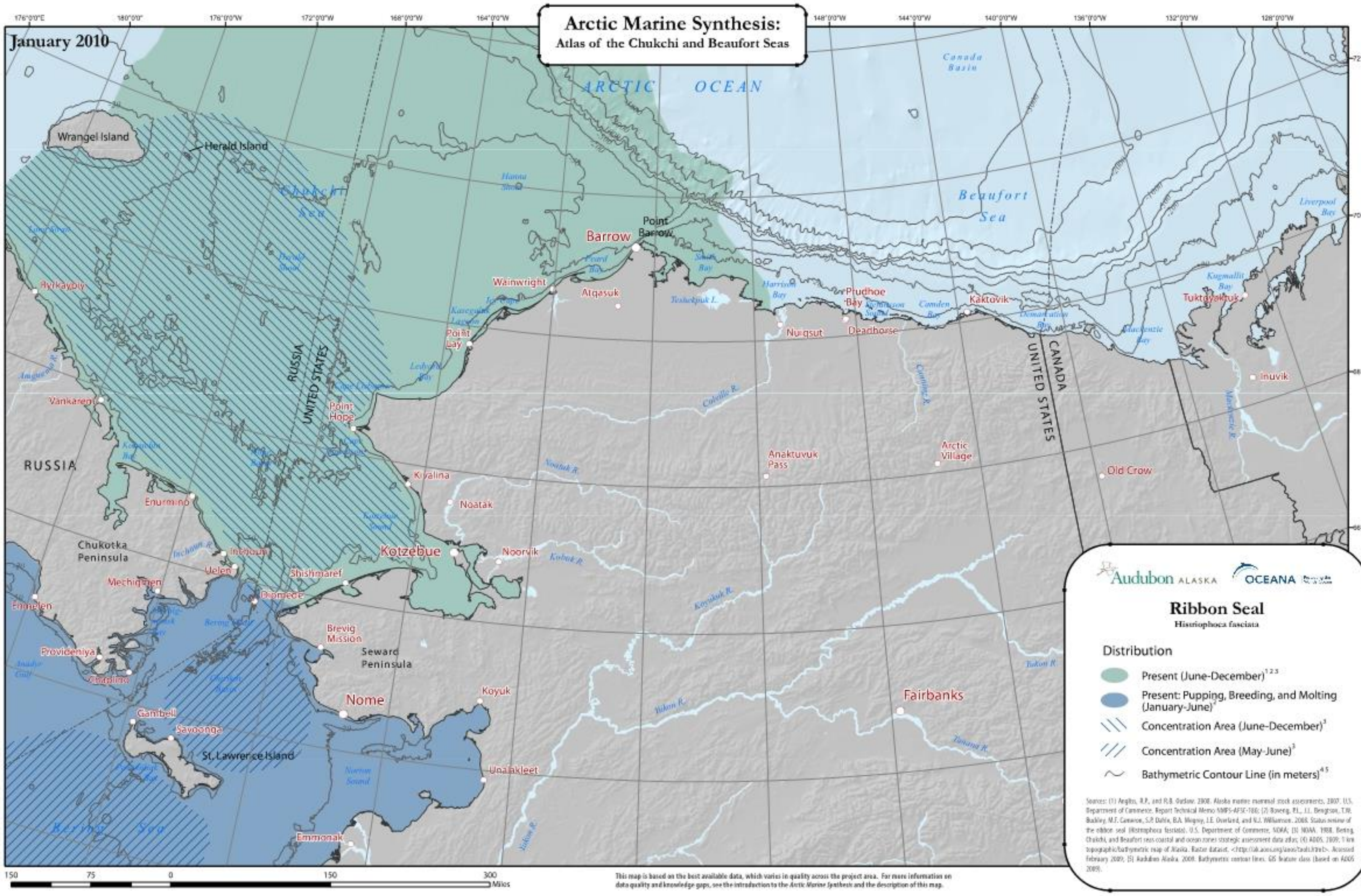

Figure A-8. Ribbon seal (*Histriophoca fasciata*) distribution in the U.S. Chukchi and Beaufort seas.

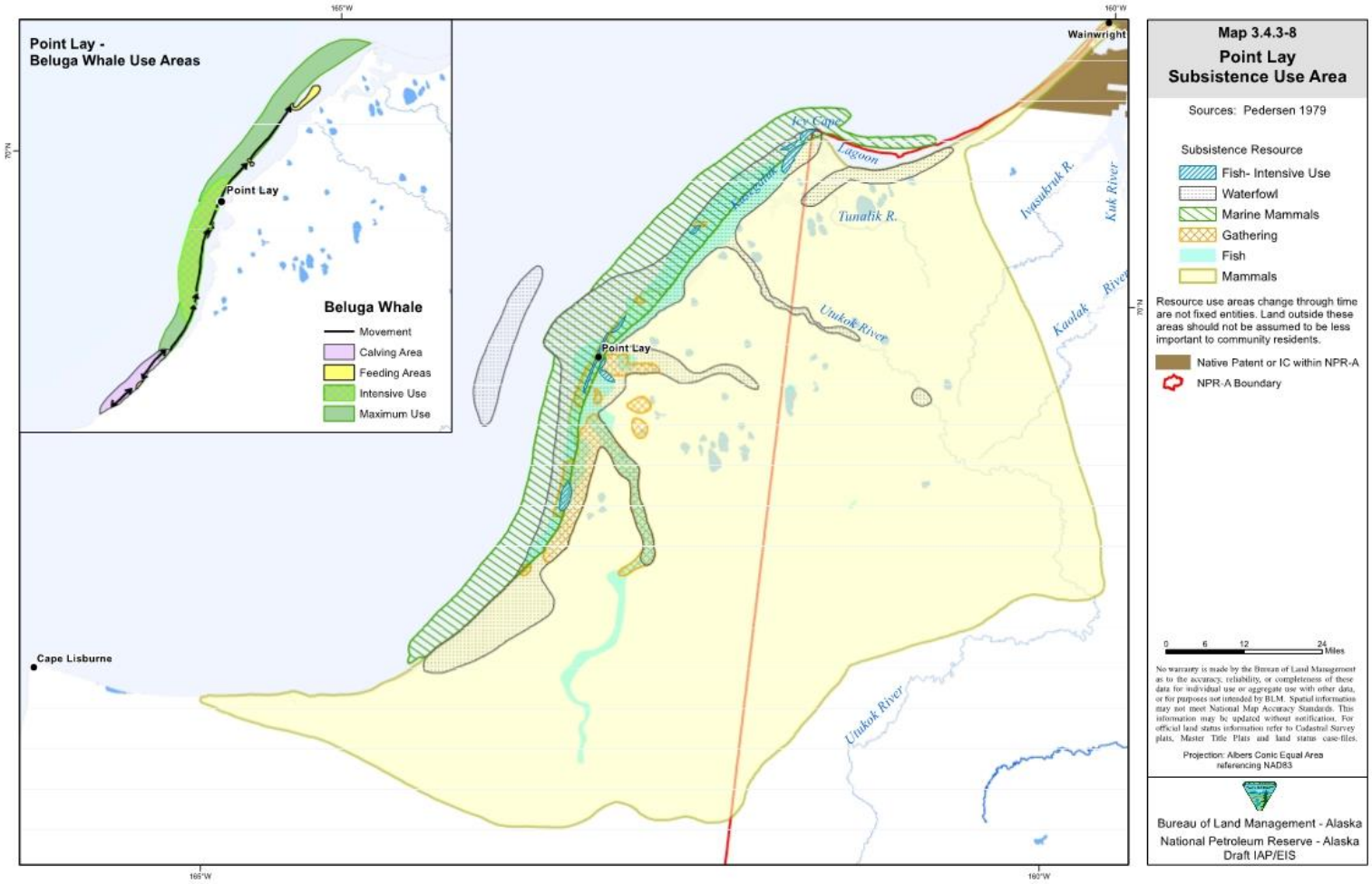

Figure A-9. Point Lay subsistence use areas.

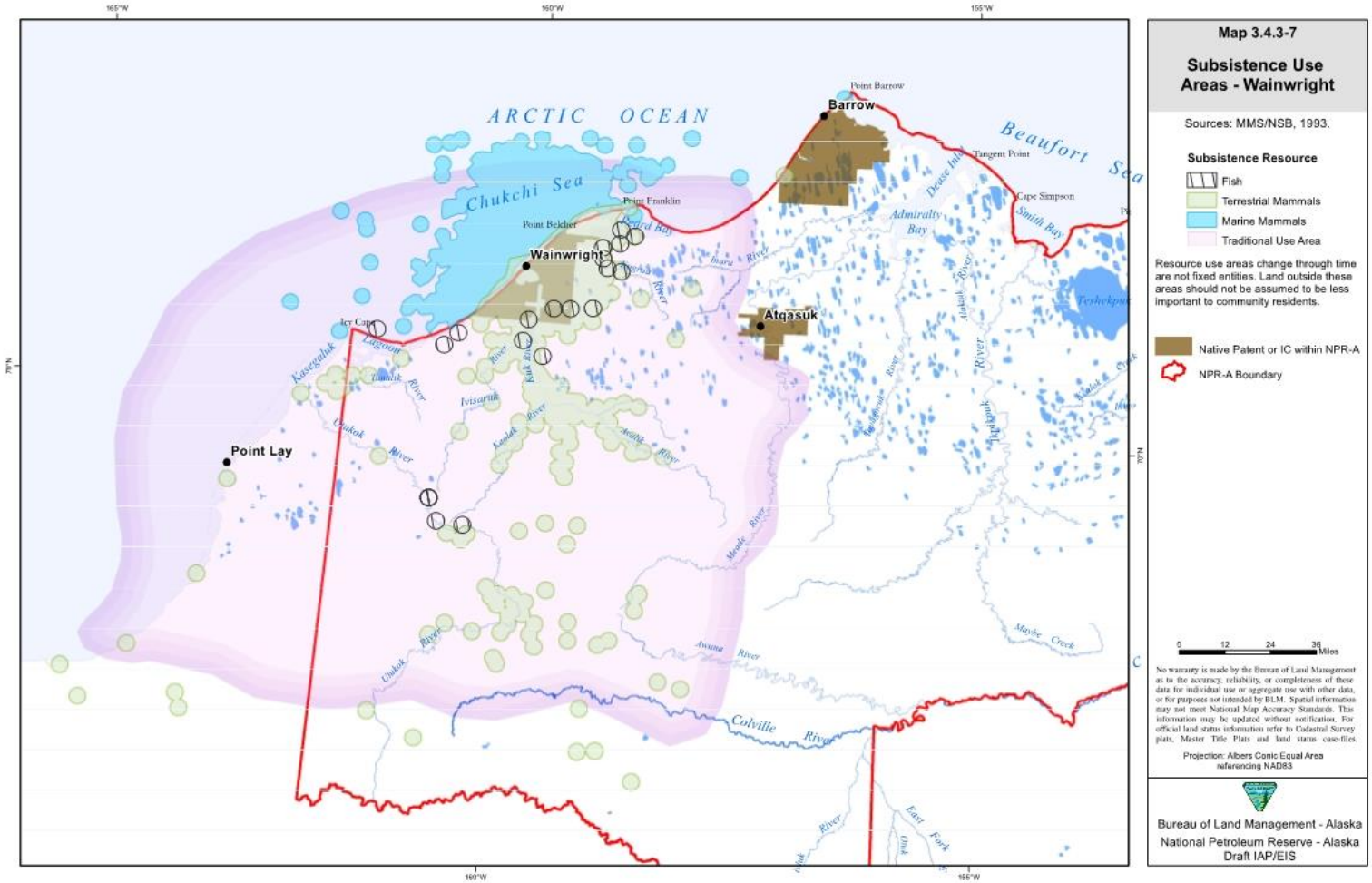

Figure A-10. Wainwright subsistence use areas.

Appendix B
Tables

Table B-1 – Acquisition parameters associated with TGS' proposed two-dimensional (2D) seismic operations.

ACQUISITION PARAMETERS	
Recording Instrument	TBA
Seismic Source	Bolt – 3,280 cubic inches (in^3)
Source Depth	6 meters (m)
Source Operating Pressure	2000 pounds per square inch (psi)
Hydrophone Solid Streamer Depth	10 m
Hydrophone Solid Streamer Length	8,100 m
Acquisition Interval	25 m
Group Interval	12.5 m
Recording Channels	648
Record Length	10 seconds
Sample Interval	2 milliseconds
Nominal Fold	162

Table B-2. Barrow Marine Mammal Subsistence Species, Estimated Location, Harvest Season

Species	Estimated Location	Harvest Season
Bowhead Whale (*Balaena mysticetus*)	Ice leads offshore of the community; 15 miles (mi) (24 kilometers [km]) southwest to 30 mi (48 km) northeast of community and up to 15 mi (24 km) offshore. Some years, hunting has taken place as far south as Icy Cape. East of the community and northwest of Peard Bay.	Spring: Between late April to late May Fall: October
Beluga (*Delphinapterus leucas*)	Along the coastal lagoons.	June to August
Pacific Walrus (*Odobenus rosmarus*)	Local haulouts near Milliktagvik and as far north as Point Franklin.	Mid-June to August August to September
Bearded Seal (*Erignathus barbatus*)	Along the coastal shore of Wainwright and south to the mouth of the Kuk Lagoon	April to August and December to January
Ringed Seal (*Phoca hispida*)	This species is rarely harvested; Spring and Fall hunts take place within close proximity of shore from Point Lay to Point Franklin	April to August and December to January
Spotted Seal (*Phoca largha*)	Along the coastal shore as far southwest as Point Lay northeast to Point Franklin; most taken at Kuk Lagoon	September to October
Ribbon Seal (*Histriophoca fasciata*)	Along the coastal shore as far southwest as Point Lay northeast to Point Franklin	April to August
Polar Bear (*Ursus maritimus*)	Near Icy Cape, from Point Belcher to Point Franklin; also at Seahorse Island	Between August and March

Source: Bacon, et al. 2009

Table B-3. Wainwright Marine Mammal Subsistence Species, Estimated Location, Harvest Season

Species	Estimated Location	Harvest Season
Bowhead Whale (*Balaena mysticetus*)	Ice leads offshore of the community; 15 mi (24 km) southwest to 30 mi (48 km) northeast of community and up to 15 mi (24 km) offshore. Some years hunting has taken place as far south as Icy Cape East of the community and northwest of Peard Bay	Spring: Between late April to late May Fall: October
Beluga (*Delphinapterus leucas*)	Along the coastal lagoons	June to August
Pacific Walrus (*Odobenus rosmarus*)	Local haulouts near Milliktagvik and as far north as Point Franklin	Mid-June to August August to September
Bearded Seal (*Erignathus barbatus*)	Along the coastal shore of Wainwright and south to the mouth of the Kuk Lagoon	April to August And December to January
Ringed Seal (*Phoca hispida*)	This species is rarely harvested; Spring and Fall hunts take place within close proximity of shore from Point Lay to Point Franklin	April to August And December to January
Spotted Seal (*Phoca largha*)	Along the coastal shore as far southwest as Point Lay northeast to Point Franklin; most taken at Kuk Lagoon	September to October
Ribbon Seal (*Histriophoca fasciata*)	Along the coastal shore as far southwest as Point Lay northeast to Point Franklin	April to August
Polar Bear (*Ursus maritimus*)	Near Icy Cape, from Point Belcher to Point Franklin; also at Seahorse Island	Between August and March

Source: Bacon, et al. 2009

Table B-4. Point Lay Marine Mammal Subsistence Species, Estimated Location, Harvest Season

Species	Estimated Location	Harvest Season
Bowhead Whale (*Balaena mysticetus*)	Ice leads offshore of Point Lay. Whale landed in 2009 was taken from an ice lead 10 miles (mi) (16 kilometers [km]) northwest of community.	Spring: Between April and June
Beluga (*Delphinapterus leucas*)	South of Point Lay, hunters herd whales from Naokak and Kukpowruk passes into the shallow waters of Kasegaluk Lagoon. Waters are also used as far north as Icy Cape and as far south as Cape Beaufort; up to 20 mi (32 km) offshore.	Mid-June to Mid-July
Pacific Walrus (*Odobenus rosmarus*)	Between Cape Beaufort and Icy Cape and as far as 25 mi (40 km) offshore	June to August
Bearded Seal (*Erignathus barbatus*)	Between Cape Beaufort and Icy Cape; up to 25 mi (40 km) offshore	June
Ringed Seal (*Phoca hispida*)	Between Cape Beaufort and Icy Cape; up to 20 mi (32 km) offshore	March to May
Spotted Seal (*Phoca largha*)	Between 10 mi (16 km) east of Cape Lisburne and as far west as Icy Cape; up to 25 mi (40 km) offshore	July to September
Ribbon Seal (*Histriophoca fasciata*)	Between Cape Beaufort and Icy Cape and as far as 25 mi (40 km) offshore	March to May
Polar Bear (*Ursus maritimus*)	As far out as 10 mi (16 km) offshore between Cape Beaufort and Icy Cape	January to April

Source: Bacon, et al. 2009

Table B-5. Point Hope Marine Mammal Subsistence Species, Estimated Location, Harvest Season

Species	Location	Harvest Season
Bowhead Whale (*Balaena mysticetus*)	South and southeast of the point to the extent that reaches Point Thompson. Hunting rarely takes place more than 15 miles (mi) (24 kilometers [km]) offshore.	Spring: Mid-April to Early June
Beluga (*Delphinapterus leucas*)	Same area as bowhead and open water near the shorelines and as far north as Cape Dyer.	March to June July to August
Pacific Walrus (*Odobenus rosmarus*)	Between Cape Thompson and Cape Lisburne and as far east as Ayugatak Lagoon (up to 20 mi [32 km] offshore).	May to July
Bearded Seal (*Erignathus barbatus*)	Between Cape Thompson and Cape Lisburne and as far east as Ayugatak Lagoon (up to 20 mi [32 km] offshore).	January to June
Ringed Seal (*Phoca hispida*)	Between Cape Thompson and Cape Lisburne and as far east as Ayugatak Lagoon (up to 20 mi [32 km] offshore).	January to June November to December
Spotted Seal (*Phoca largha*)	Between Cape Thompson and Cape Lisburne and as far east as Ayugatak Lagoon (up to 20 mi [32 km] offshore).	January to June November to December
Ribbon Seal (*Histriophoca fasciata*)	Between Cape Thompson and Cape Lisburne and as far east as Ayugatak Lagoon (up to 20 mi [32 km] offshore).	January to June November to December
Polar Bear (*Ursus maritimus*)	South of the point as far out as 10 mi (16 km) offshore.	January to April and October to January

Source: Bacon, et al. 2009

Appendix C
JASCO Applied Sciences Acoustic Monitoring Report

Modeling of Underwater Sound from TGS's Proposed 2013 Chukchi Sea Seismic Survey Program

Submitted to: Zig Doborzynski,
Marine Surveys, Arcis

Authors: Zizheng Li
Mikhail Zykov Terry
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2013 February 28
Version 1.1
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1. Introduction

An acoustic modeling study has been performed to provide estimates of sound levels generated by a 3280 in^3 airgun array that is proposed for use in the Chukchi Sea during TGS's 2013 seismic survey program. All acoustic modeling was performed using models by JASCO Applied Sciences.

The goal of this modeling study was to provide sound level information for defining appropriate marine mammal exclusion zones for the 2013 seismic survey. The exclusion zones would be implemented by marine mammal observers during the initial period of seismic surveying until in-situ measurements can be made. The levels of specific interest are 190, 180, and 160 and 120 dB re 1 μPa root-mean-square (RMS).

The proposed seismic survey covers a large area of the eastern and northern part of the Chukchi Sea off the north-west coast of Alaska (Figure 1). The total length of 24 proposed production survey lines is about 8,000 km (5000 mi). The number of production lines inside the MMS lease sale area is 13 with the combined length of 5,600 km. The range of water depths inside the lease area varies from 20 m to more than 3000 m.

The majority of the production lines are located in the water depths between 40 and 100 m. Only a small fraction of the lines extends to deeper water which is primarily in the northeast corner of the lease area.

Available geological information shows that the seabed of the Chukchi Sea is generally acoustically-reflective. Previous measurements of seismic survey sounds in the Chukchi have shown some spatial variability in reflectivity. Two possible geoacoustical profiles were established based on the previous information: typical and reflective.

Distances to sound level thresholds are generally strongly dependent on water depth for depths less than 100 m. Three modeling sites were chosen with depths of 20 m, 40 m, and 100 m. At each site both geoacoustic models were applied, thereby giving a total of six modeling scenarios (3 depths × 2 bottom types).

The ocean sound velocity profiles were estimated for each modeling location based on GDEM database (NOO, 2003). Since the potential timing of the survey could span the entire open water season (late June to mid-November, sound velocity profiles for each month were extracted for the model locations inside the lease area. We selected a conservative (most upward-refracting) profile from this set of profiles to carry out the model runs. Upward-refracting profiles reduce the fraction of sound energy incident on, and transmitted into the seabed, thereby maintaining more sound energy in the water column. This generally results in higher in-water sound levels at distance from the source.

The bathymetry data were obtained from SRTM 30+ v6 database (Becker, et al., 2009).

Several sound measurements have been performed during seismic survey programs in the area of interest between 2006 and 2010. The data from those studies show that the environmental properties (bottom geoacoustics, sound speed profiles, water depth) found at the Chukchi Sea are favorable for supporting low- to mid-frequency sound propagation (50 Hz to 500 Hz). It is not

unusual for distances to 120 dB RMS threshold level from airgun arrays in the 3000 in^3 to 4000 in^3 range to extend to more than 70 km from the source when measured using bottom-moored acoustic recorders. While the models are expected to produce realistic sound level estimates within a few kilometers from the source, the acoustic field at distances greater than 10 km is dependent on many tens of seabed sound reflections. A receiver at 10 km range is typically more than 200 water depths distance from the source. While distances to lower sound level thresholds are provided based on model results, those numbers should be treated as having a high level of uncertainty. The modeling approach used here examines variability from just two possible seabed types. The true variability may exceed the differences noted here at long distances.

2. Objectives

The objectives of the modeling study were as follows:

- Estimate the source level and directionality of an airgun array of 26 active airguns with the total volume 3280 in^3,
- Determine the spatial extent of ensonification resulting from the airgun source at three locations with different water depths in the Chukchi Sea using two geoacoustic bottom types, and
- Estimate the maximum distances from the source that received underwater sound pressure levels from 190, 180, 160 and 120 dB re 1 μPa (RMS) for each scenario.
- Propose appropriate zones for marine mammal safety/exclusion and potential behavioral impact.

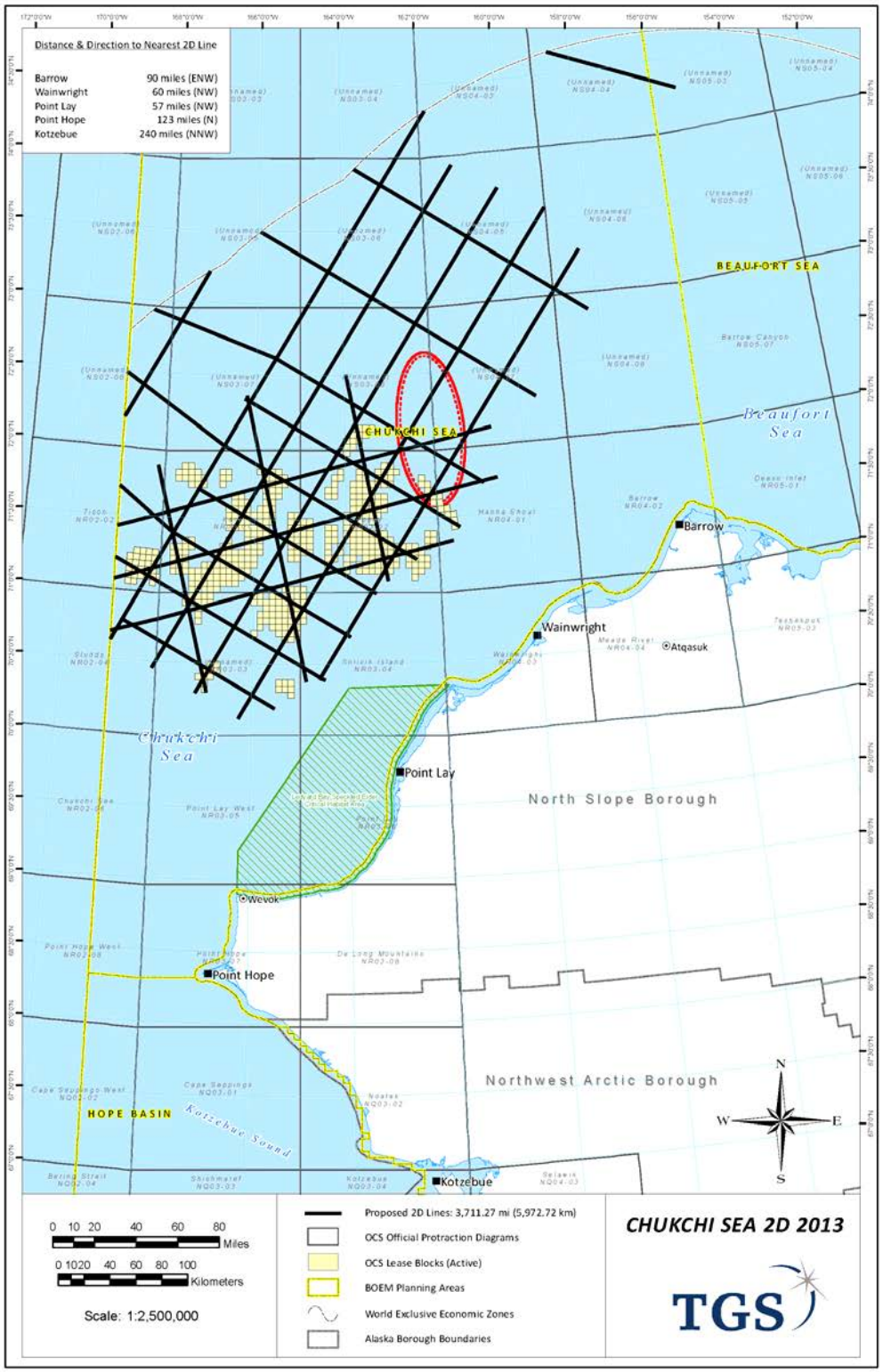

Figure 1: Overview map of TGS's proposed 2013 seismic survey lines in the northeastern Chukchi Sea.

3. Sound source

The acoustic source level of the 3280 in^3 airgun array was predicted using JASCO Applied Science's airgun array source model (AASM). AASM simulates the expansion and oscillation of the air bubbles generated by each airgun within a seismic array, taking into account pressure interaction effects between bubbles from different airguns. It includes effects from surface-reflected pressure waves, heat transfer from the bubbles to the surrounding water, and the movements of bubbles due to their buoyancy. The model outputs high-resolution airgun pressure signatures for each airgun. These signatures are superimposed with the appropriate time delays to yield the overall array source signature in any direction. Third-octave band source levels for the array are obtained by filtering the far-field array signature into third-octave pass bands.

The array geometry is shown in Figure 2. The array consists of 40 airguns with individual volumes between 40 in^3 and 250 in^3. The layout is comprised of four sub-arrays of 9 or 11 guns each, where some of them are spare guns. The overall volume is 3280 in^3 from 26 active airguns.

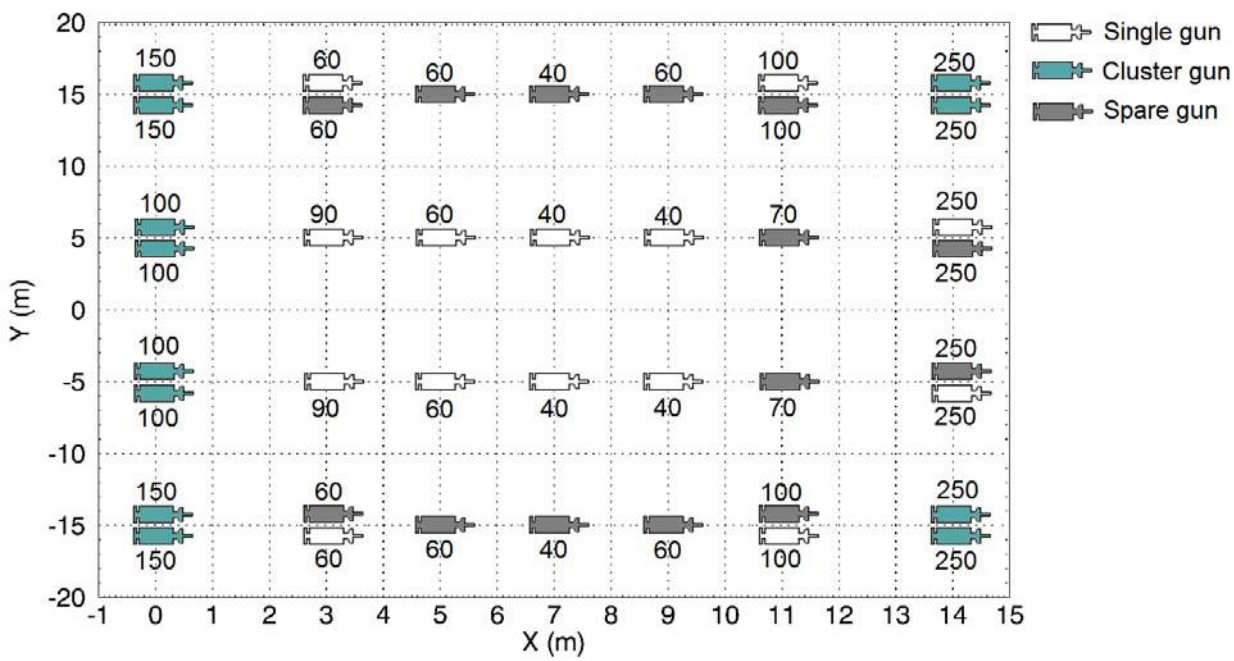

Figure 2: Geometry layout of 3280 in^3 array. Tow direction is to the right; tow depth is 6.0 m; the volume of each airgun is indicated in cubic inches.

The airgun array is expected to be operated at a constant depth of 6 m during the course of the survey. The modeling of the airgun array signature was carried out for a towing depth of 6 meters with a firing pressure of 2000 psi.

AASM was used to characterize the spectral and directional attributes of the array's composite pressure signature in all directions as described above. The overpressure signatures and the power spectra for the broadside (perpendicular to tow) and forward endfire (parallel to tow)

directions are shown in Figure 3. Table 1 shows the pertinent specifications for the modeled pressure signatures computed with AASM.

The general trend is for spectral levels to decrease with increasing frequency. Most of the airgun energy near the source is contained in frequencies below 200 Hz, but significant energy extends to several kilohertz. Source directivity is insignificant at 60 Hz or less, but is quite prominent for higher frequencies. The horizontal directivity of the array as a function of frequency is presented in Figure 4.

It has been found that AASM tends to slightly overestimate the source levels for clustered airguns, especially in low frequencies. Therefore, these modeling results can be considered conservative.

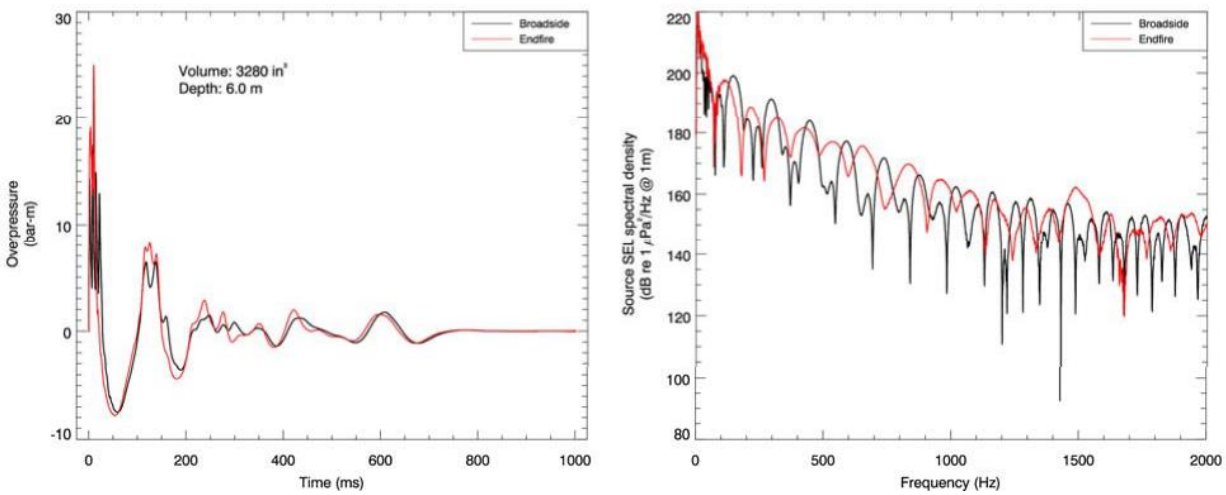

Figure 3: Overpressure signature and power spectrum for the 3280 in^3 array in the broadside and endfire directions. Surface ghosts are excluded in these signatures.

Table 1: The 3280 in^3 airgun array pressure specifications from AASM model for towing depth of 6 m. Surface ghost effects are excluded.

Metric	ForwardEndfire	Broadside
Zero-PeakPressure[dBre1μPa//1m]	248.0	244.8
90%RMSlevel[dBre1μPa//1m]	235.6	233.5
90%RMSduration[ms]	224.8	244.4
SEL(broadband0.01–2kHz)[dBre1μPa^2//1m]	225.0	222.1
SEL(0.01-1kHz)[dBre1μPa^2//1m]	225.0	222.1
SEL(1-2kHz)[dBre1μPa^2//1m]	184.6	183.1

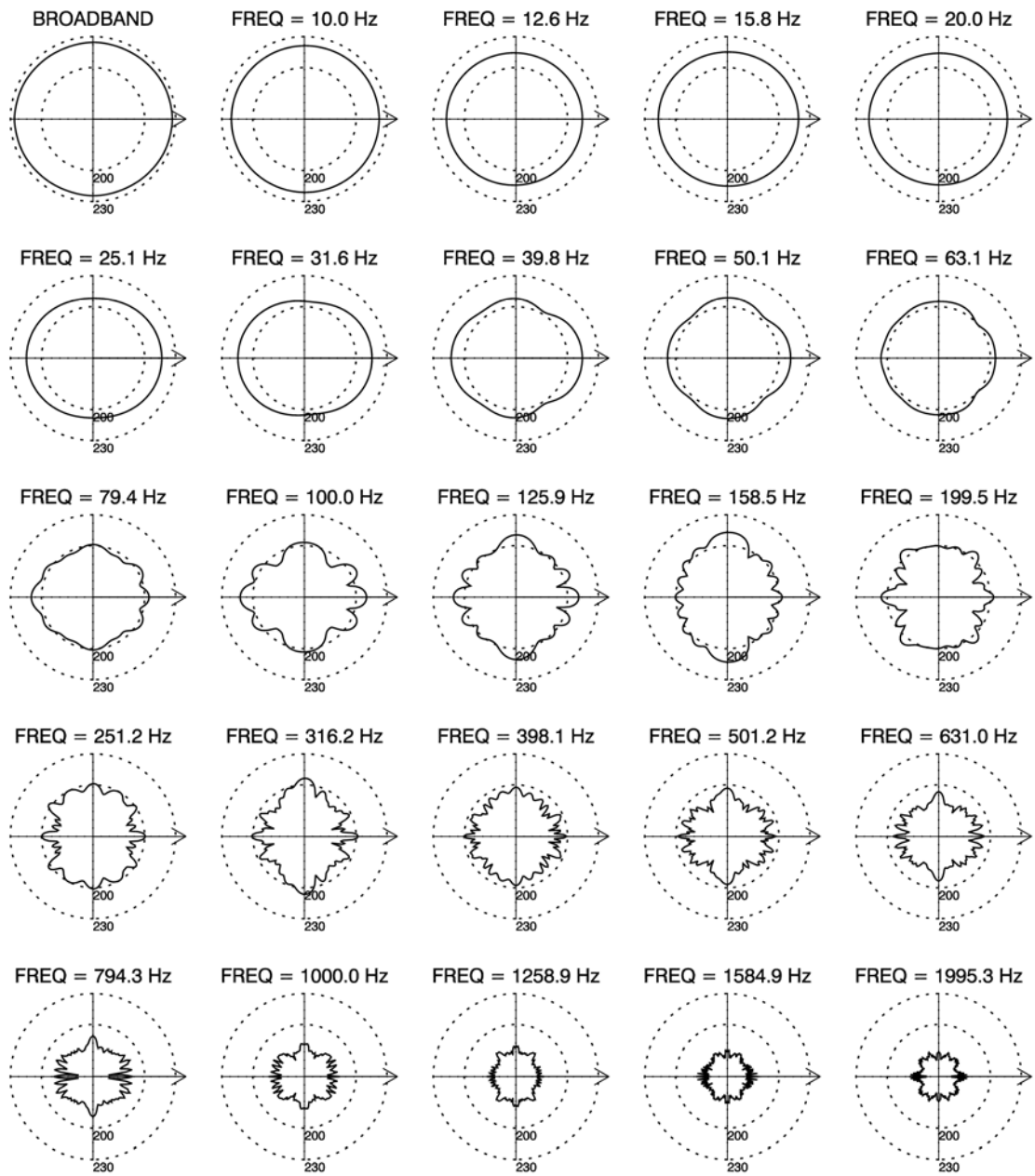

Figure 4: Azimuthal directivity pattern of source level (dB re 1 $\mu Pa^2 \cdot s$) for the 3280 in^3 array towed at 6 m depth, broadband and in 1/3-octave bands with center frequencies from 10 Hz to 2 kHz. The right-pointing arrow indicates the array tow axis direction.

4. Modeling Approach

4.1. Acoustic propagation model

The acoustic propagation model used in this study is JASCO Applied Science's Marine Operations Noise Model (MONM). MONM computes received per-pulse Sound Exposure Level (SEL) at many receiver positions distributed in depth and range away from the airgun array source. MONM uses the output of the airgun array model AASM described in Section 3.

MONM treats sound propagation in range-varying acoustic environments through a wide-angled parabolic equation (PE) solution to the acoustic wave equation. The PE code used by MONM is based on a version of the Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for an elastic seabed. The PE method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins, 1993).

MONM computes acoustic fields in three dimensions by modeling transmission loss along evenly spaced 2-D radial traverses covering a 360° swath from the source, an approach commonly referred to as N×2-D. The model fully accounts for depth and/or range dependence of several environmental parameters including bathymetry and sound speed profiles in the water column and the sea floor. It also accounts for the additional reflection loss at the seabed that is due to partial conversion of incident compressional waves to shear waves at the seabed and sub- bottom interfaces. It includes wave attenuations in all layers. The acoustic environment is sampled at a fixed range step along radial traverses.

MONM treats frequency dependence by computing acoustic transmission loss at the center frequencies of 1/3-octave bands between 10 Hz and 2 kHz. This frequency range includes the important bandwidth of noise emissions for airgun array systems. 1/3-octave band received levels are computed by subtracting band transmission loss values from the corresponding directional source levels. Broadband received levels are then computed by summing the received band levels. MONM's sound level predictions have been validated extensively against other models and experimental data (Hannay & Racca, 2005). The airgun array source levels computed with AASM were input to MONM to determine the predicted received levels in the environment surrounding the airgun array.

4.2. SEL to RMS conversion

The MONM model outputs sound field levels in SEL units. National Marine Fisheries Service (NMFS) presently uses root-mean-square (RMS) sound pressure levels (SPL) to assess specific marine mammal noise effects. Hence there was a need to apply conversion factors to convert between the different units. The RMS SPL is conventionally based on an integration interval corresponding to the pulse length of the received signal, generally defined as the shortest time window containing 90% of the pulse energy (90% RMS). Computation of RMS levels from SEL requires knowledge of this pulse length, which in shallow water can be quite variable and dependent on several factors such as seabed composition, water sound speed profile, and distance from the source. Often, in order to simplify the problem of converting units, a nominal conversion offset of +10 dB is applied to SEL to obtain RMS SPL. This corresponds with a pulse arrival duration of 100 ms. That simple approach has limited accuracy in shallow water where reverberation from bottom reflections strongly influences the actual pulse length. In fact, most

measurements in shallow water (<500 m) indicate that pulse length generally increases with increasing distance from the source. Therefore, the 10 dB constant conversion factor is likely too conservative for distances beyond 2 km in the Chukchi. We used a different conversion method that was based on examining the actual differences between SEL and RMS SPL determined from seismic sound source verification studies in the Chukchi Sea (e.g., Funk et al., 2008). A conversion function from SEL to RMS was defined as indicated by the solid line segments in Figure 5, which also shows the differences between RMS and SEL levels from several seismic verification measurements in the Chukchi. The function is defined as follows: +12 dB in the range interval 0 km to 1 km; linear decrease from +12 dB to +5 dB in the range interval 1 km to 5 km from the source; +5 dB for distances greater than 5 km from the source. The function could be as much as 9 dB too conservative at distances near 5 km to 20 km, but the high degree of variability in the previous measurement results necessitates this approach.

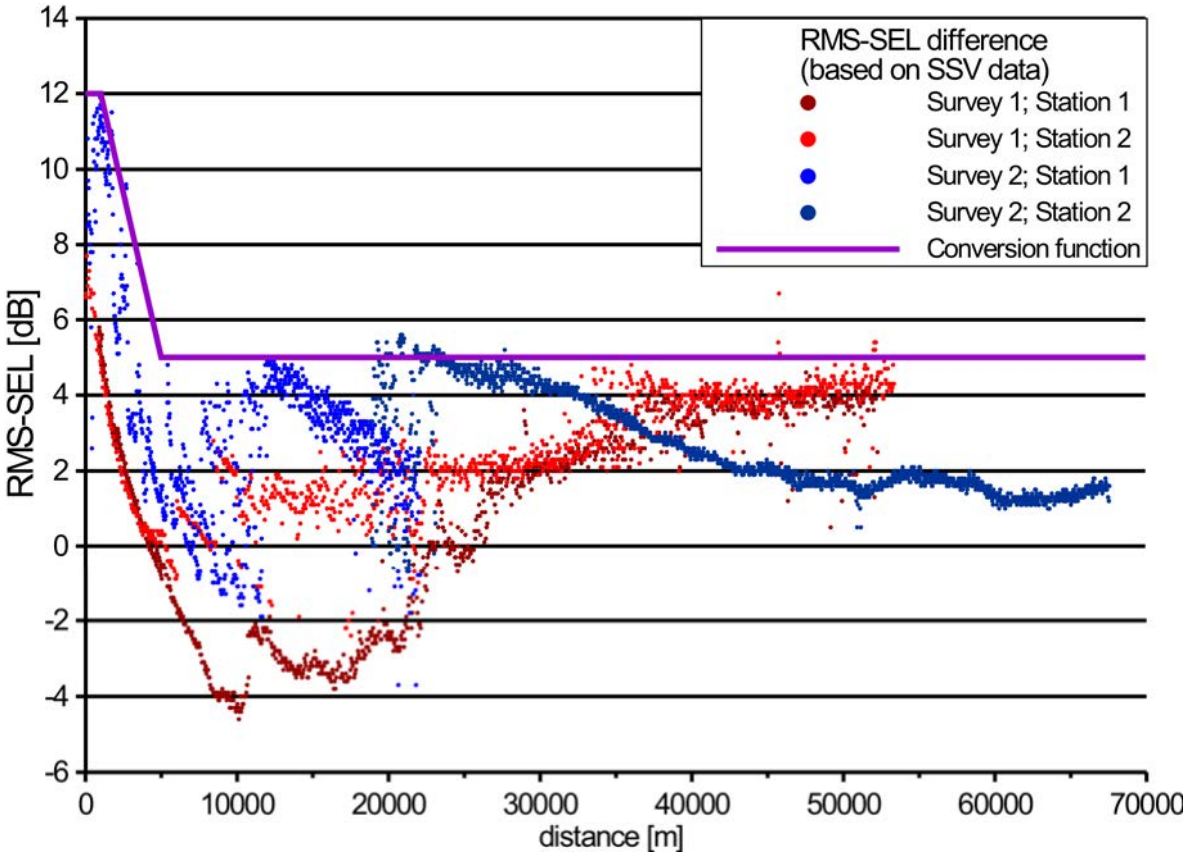

Figure 5: Difference between SEL and RMS metrics computed from empirical data recorded during sound source verification studies from seismic programs in the Chukchi Sea.

4.3. Modeling Locations

TGS's seismic survey is planned in the eastern part of the Chukchi Sea, where water depths are predominantly between 30 and 60 m. There are also some locations, such as near Hanna Shoal where water depths decrease to just under 20 m. Water depths in the far northeast corner of the lease area fall off to more than 1000 m, but that area is a small fraction of the area of interest and

sound levels at least for higher thresholds are expected to occur at shorter distances than inshallower water. As discussed previously, three modeling locations were chosen with water depths 17 m, 40 m, and 100 m (Figure 6 and Table 2). All the locations were chosen directly on proposed seismic tracks.

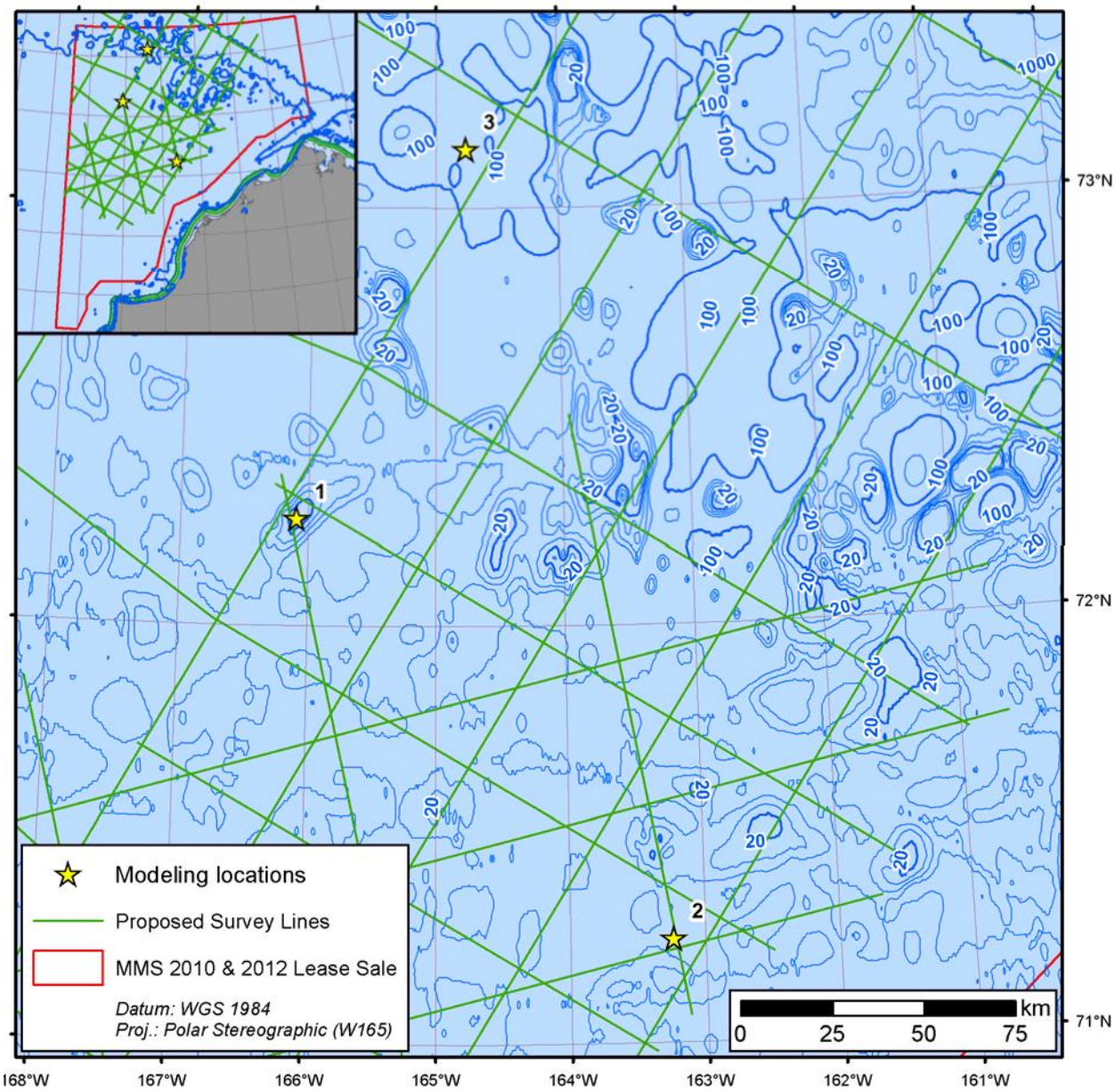

Figure 6: Acoustic modeling locations in the northeastern Chukchi Sea and nearby proposed seismic survey track-lines.

Table 2: Acoustic modeling site coordinates and water depths.

Site	Latitude/Longitude		Northing/Easting (UTM zone 3)	Water depth
1	72° 15.288'N	166° 05.466'W	8017690N 462885 E	17 m
2	71° 14.906'N	163° 13.949'W	7906031N 563409 E	40 m
3	73° 08.446'N	164° 45.319'W	8116199N 507921 E	100 m

The source at site 1 (17 m water depth) is located on top of a bottom hill that extends 10 km in the southwest – northeast direction and 5 km in southeast – northwest direction. The surrounding water depths are in the range of 50 to 60 m.

4.4. Geoacoustics

Seabed properties are important for acoustic modeling in the shallow environments present over the study area. Since the results of the modeling would be used at different locations in the Chukchi Sea, a generic geoacoustic profile was created for each water depth category, rather than site specific ones. Each geoacoustic profile reflected typical bottom properties for the specific geomorphological region.

The seismic data recorded during previous sound source verification studies allowed us to estimate the P-wave velocities for the shallow layers at two locations in the Chukchi Sea. The analysis was performed using the data recorded by JASCO Ocean Bottom Hydrophones in the common receiver geometry. Several generations of head waves were identified. It was calculated that the P-wave of the surficial sediments can be as high as 1700 m/s. Also at one location a layer with P-wave velocity of 1800 m/s were identified very close to the sea bottom. At the other location a layer with P-wave velocity of 1900 m/s was believed to occur at deeper depth. It was decided that the latter velocity profile would represent typical bottom and the former would be used for reflective bottom type.

Multiple bottom samples in the Chukchi Sea are available through Deck41 bottom samples database (NGDC, 2003). The samples show that the dominant sediment type found at the bottom is sand or silty sand.

Also several well logs are available that provides information on porosity to the depths as deep as 50 m. The porosity profile probed at several locations around the Chukchi Sea is similar to each other: 50% porosity in the range of 0 to 2 meters below the sea floor, then rapid decrease to 35 – 25% at 2 m, and constant porosity thereafter at 30 – 25% (Winters and Lee, 1984)

The missing seabed geoacoustic parameters were estimated using Buckingham's sediment grain-shearing model (Buckingham, 2005), which allows estimation of acoustic properties of the sediments from porosity and grain-size measurements. The geoacoustic parameters predicted by the grain-shearing model are as follows: density (ρ), compressional speed (V_p), compressional attenuation coefficient in decibels per wavelength (α_p), shear wave speed (V_s), and shear wave attenuation coefficient (α_s). The input parameters for the geoacoustic model were the bottom type (grain size) and sediment porosity. Two geoacoustic models were constructed based on the available data for typical and reflective bottoms (Tables 3 and 4).

Table 3: Geoacoustic model for typical bottom.

depth (m)	ρ(g/cm3)	Vp (m/s)	αp (dB/λ)	Vs (m/s)	αs (dB/λ)
0 – 1	1.87 – 2.08	1550 – 1700	0.50 – 0.54	150	0.90
1 – 25	2.08 – 2.10	1700 – 1750	0.54 – 1.30		
25 – 30	2.10 – 2.20	1750 – 1900	1.30 – 1.50		
30 – 100	2.20	1900 – 2300	1.50 – 1.90		
>100	2.20	2300	1.90		

Table 4: Geoacoustic model for reflective bottom.

depth (m)	ρ(g/cm3)	Vp (m/s)	αp (dB/λ)	Vs (m/s)	αs (dB/λ)
0 – 1	1.87 – 2.08	1600 – 1700	0.50 – 0.54	200	1.10
1 – 5	2.08 – 2.20	1700 – 1800	0.54 – 0.72		
5 – 100	2.20	1800 – 2300	0.72 – 1.90		
>100	2.20	2300	1.90		

4.5. Bathymetry

The accuracy of sound propagation model results depends on the quality of bathymetry data used. For the purpose of the modeling study a bathymetrical grid was created with the cell size of 500 m× 500 m. The bathymetry grid was in the WGS 84 UTM Zone 3 projection. The grid covered the area approximately 800 km× 700 km around the proposed survey operations area. It was derived from the bathymetry data referred to as SRTM 30+, version 6.0 (Becker, et al., 2009), which has a resolution of 30 arc seconds.

4.6. Sound Speed Profile

Water column sound speed profiles (SSPs) for each of the three locations (Figure 6) were computed from temperature and salinity profiles from the U.S. Naval Oceanographic Office's Generalized Digital Environmental Model (GDEM) database (Teague, *et al.*, 1990). The latest release of the GDEM database (version 3.0) provides average monthly profiles of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution. Profiles in GDEM are provided at 78 fixed depth points up to a maximum depth of 6800 m (where the ocean is that deep), including 55 standard depths at ≤2000 m. The profiles in GDEM are based on historical observations of global temperature and salinity from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). GDEM provides historical average profiles that extend to the deepest depth in a given 15-arc-minute square.

Temperature-salinity profiles from GDEM were converted to sound-speed profiles (SSPs) using the equations of Coppens, 1981:

$$c(z,T,S) = 1449.05 + 45.7T - 5.21t^2 - 0.23t^3$$

$$+(1.333 - 0.126t + 0.009t^2)(S - 35) + \Delta$$

$$\Delta = 16.3Z + 0.18Z^2$$

$$Z = (z/1000)(1 - 0.0026\cos(2\phi))$$

$$t = T/10$$

where z is depth in meters, T is temperature in degrees Celsius, S is salinity in psu, and $\varphi$is latitude (in radians).

Figure 7 through Figure 9 show the mean SSP derived from the GDEM data for each of the modeled locations for the months of July through November, which are the anticipated months when the seismic survey operations will occur. The SSP for the month of November was selected for the purpose of this study because the implied propagation conditions at that time are more strongly upward-refracting, which is typically favorable for supporting longer-range underwater acoustic propagation. The November SSPs were selected for the propagation modeling to be conservative and precautionary.

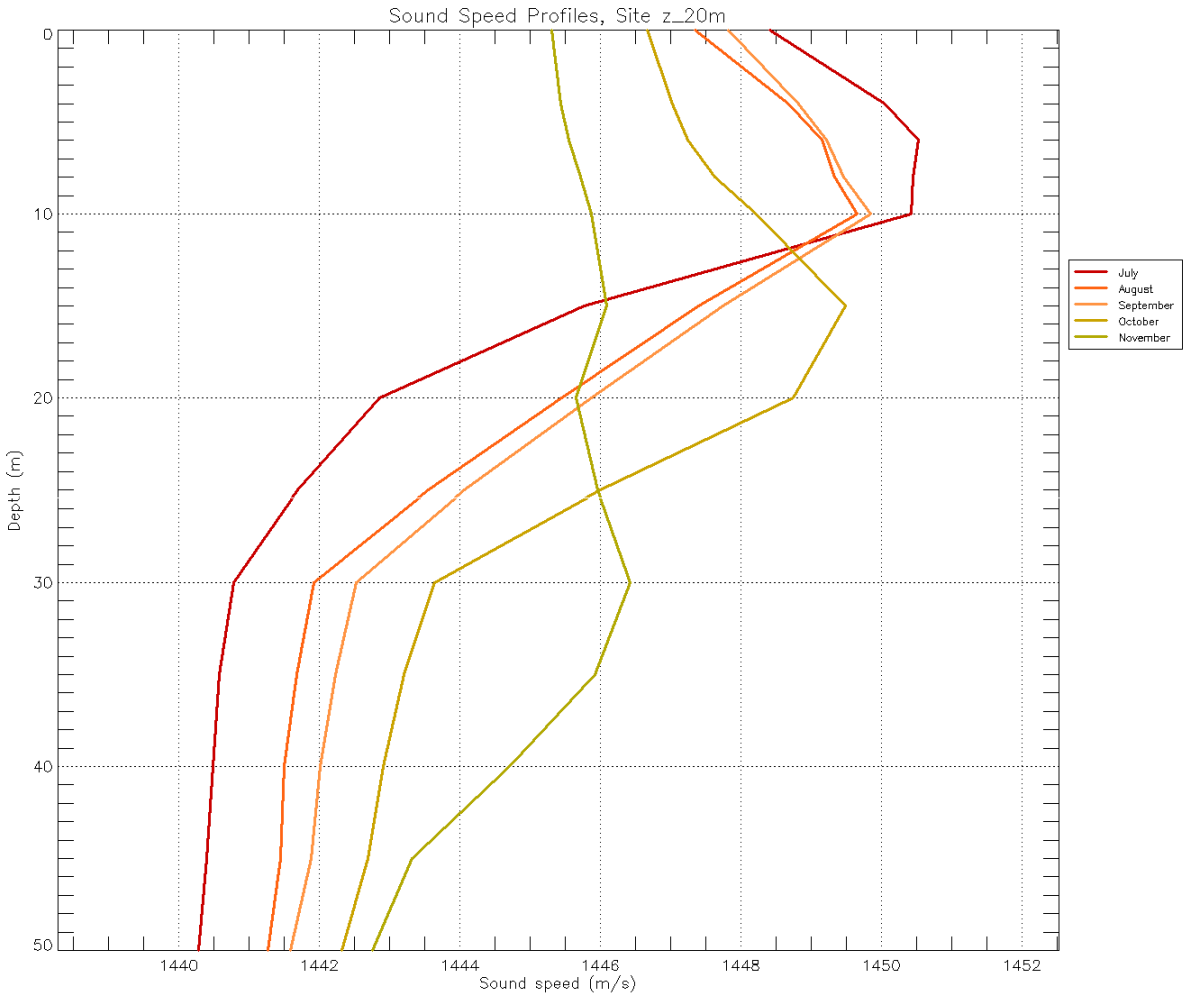

Figure 7: Mean sound velocity profiles at the 20 m depth location for the months of July to November.

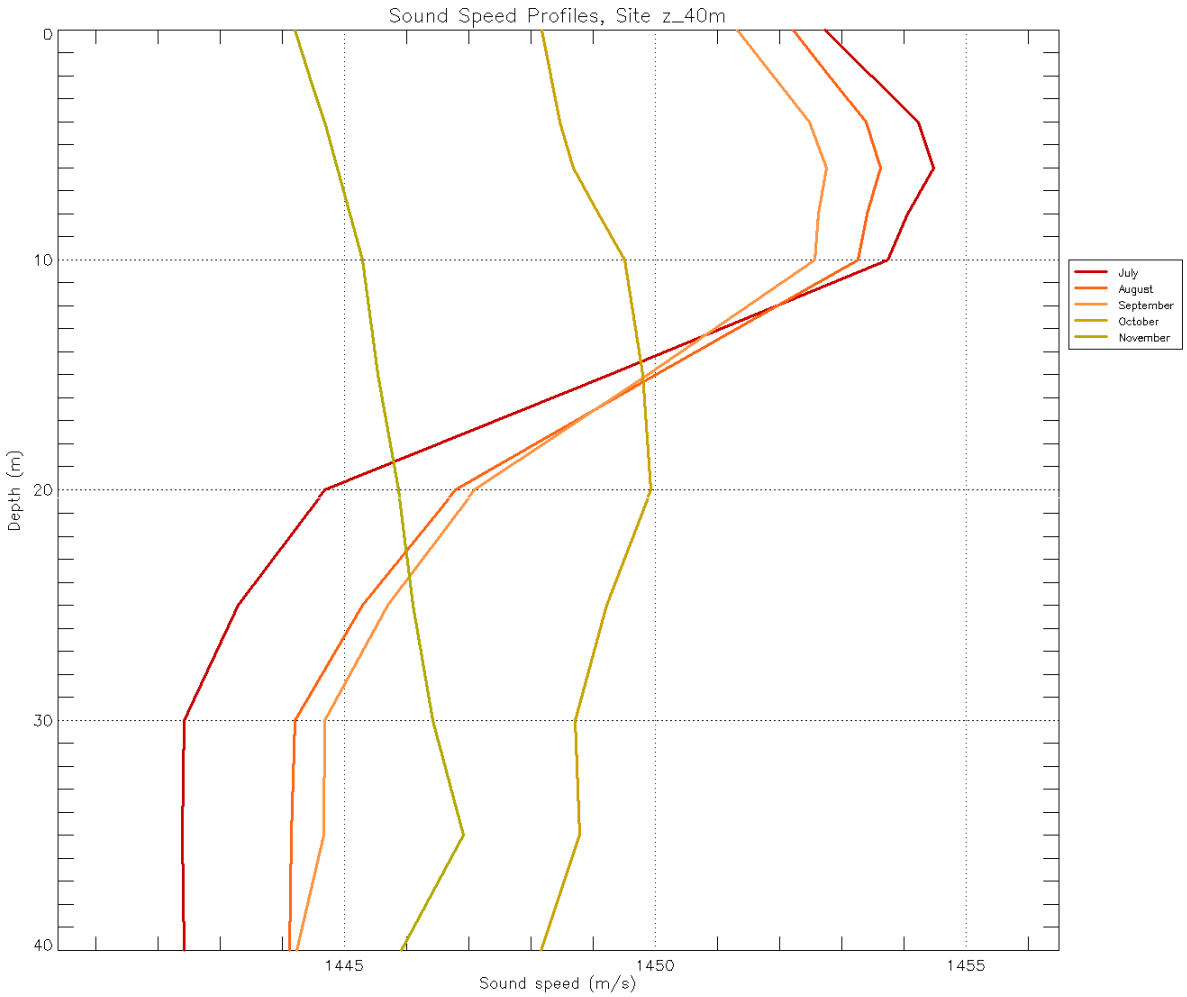

Figure 8: Mean sound velocity profiles at the 40 m depth location for the months of July to November.

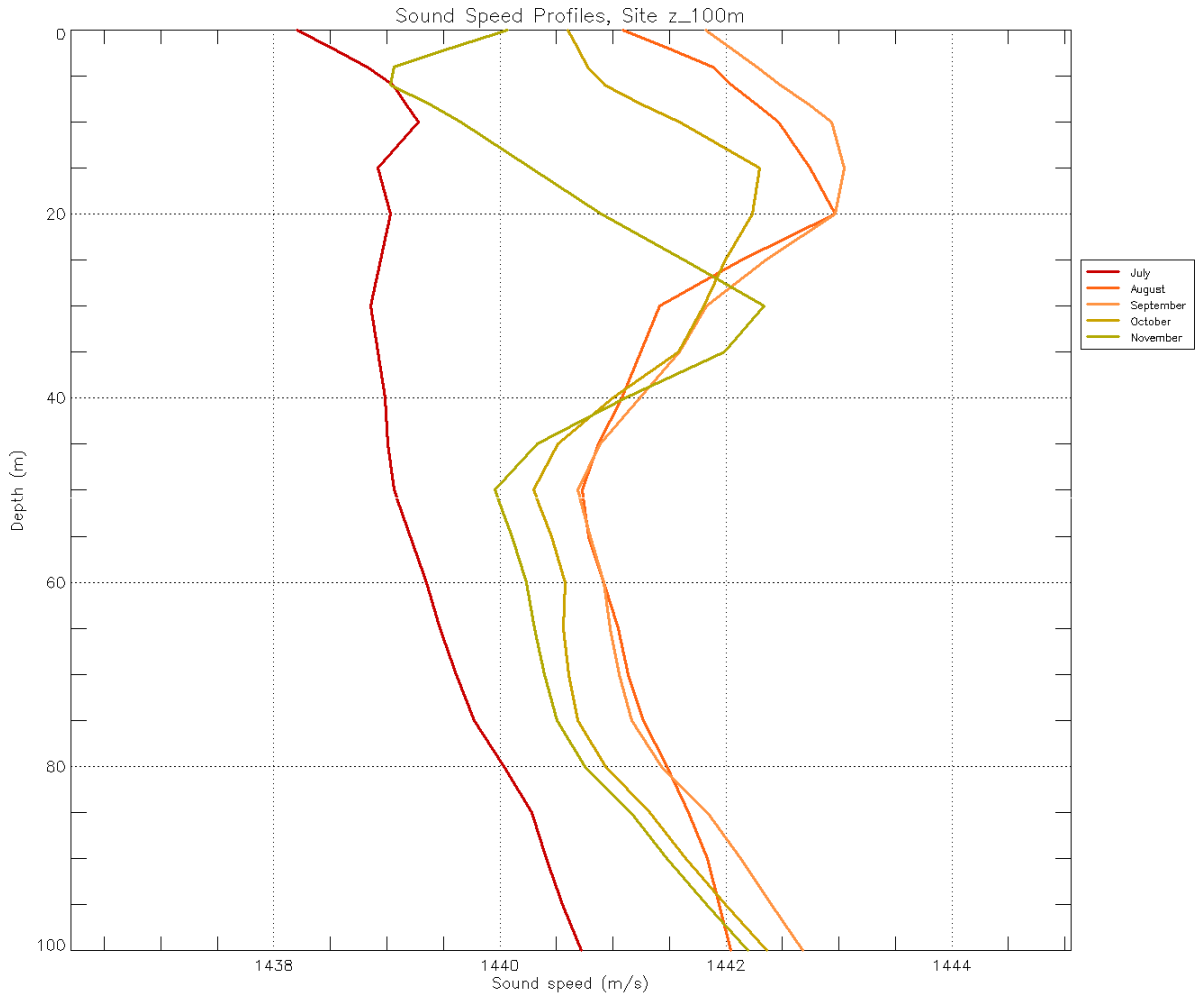

Figure 9: Mean sound velocity profiles at the 100 m depth location for the months of July to November.

5. Results

Acoustic propagation modeling was performed at three different sites using two geoacoustic models at each site, giving a total of six scenarios. For each of the six scenarios considered we used two spatial modeling resolutions: (a) a 10 km × 10 km computation space centered on each of the three modeling locations, using a 5 m step size in horizontal range, and (b) a 300 km × 300 km computation space centered on each of the three modeling locations, using a 20 m step size in horizontal range. The higher resolution model provided a more detailed sound field in the vicinity of the source where steep angle propagation requires smaller step sizes, while the lower resolution model over a larger area provided appropriate detail for long-range sound fields where the usage of the high resolution step size was computationally prohibitive.

The ensonification values in the vertical direction were obtained at 24 different depths ranging from 1 m to 220 m below the sea surface (extending into the bottom) for the modeling runs at the 17 m and 40 m water depth sites and at 31 different depths ranging from 1 m to 1200 m below the

sea surface for the modeling runs at the 100 m water depth site. The towing direction of the seismic source was assumed to be along the proposed seismic lines: 107°, 101°, and 108° (relative to UTM 3 North) for the three source locations at 17 m, 40 m, and 100 m water depths respectively. At each source position the modeling was performed for the suggested source depth of 6.0 m.

Processing of the output data from the modeling code involved gridding of all the data points in each horizontal plane separately (i.e., at each modeling depth). The resulting stack of grids was collapsed into a single grid using a maximum-over-depth rule; the sound level at each location was taken to be the maximum value that occurred over all modeled depths for that location.
A 3 dB safety factor was added to the modeled sound levels to add a degree of conservatism. The resulting sound level isopleth maps are presented in Figures 11–16.

The calculations of threshold distances were performed based on the grids of the modeled sound field for each scenario. Two grids were used per scenario, representing the maximum-over-depth sound level and the sound level at the bottom. For each threshold, two distances are reported: (a) R_{max} – the maximum distance at which the threshold sound level was registered in the modeled field; (b) $R_{95\%}$ – the maximum distance to a grid point at which the specific sound level was registered after exclusion of 5% furthest points. The distances to specific sound levels for six modeling scenarios are summarized in Tables 5–7. We have also provided the original SEL value corresponding to each specified RMS SPL.

The reason for examining sound levels at multiple depths is that levels can vary significantly with depth. This is especially true at long distances from the source where destructive interference with surface and bottom can reduce levels near the interfaces. At long distances the maximum levels occur at mid-water depths. Figure 10 shows the horizontal and vertical distribution of broadband SEL produced by the airgun array source at the 17 m water depth location with reflective bottom type. This vertical slice is oriented perpendicular to the source tow direction (broadside). At distances beyond about 60 km the sound levels at the bottom and surface can be more than 10 dB lower than the maximum level at the same distance in the mid- water depth.

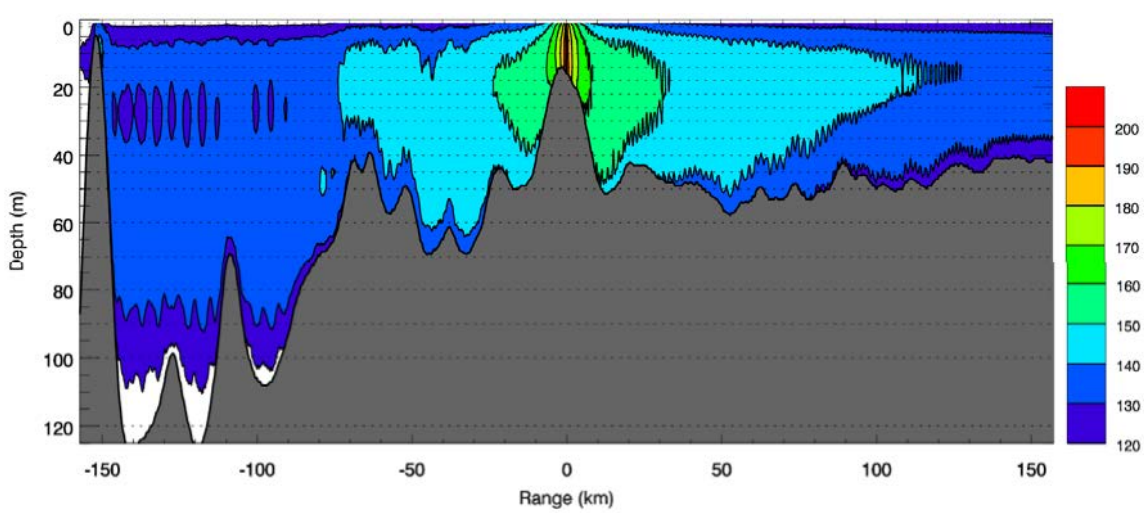

Figure 10: 2-D distribution of RMS SPL (dB re 1 μPa) at the 17 m water depth location with reflective bottom..

Table 5: Threshold distances (in km) from the source at 17 m water depth to the specified levels.

RMS SPL (dB re 1 μPa)	SEL (dB re 1 μPa^2·s)	Reflective bottom				Typical bottom			
		Max over depths		At bottom		Max over depths		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.20	0.15	0.20	0.15	0.16	0.15	0.16	0.15
190	178	0.93	0.71	0.90	0.69	0.83	0.66	0.74	0.63
180	170	2.21	1.72	1.97	1.60	1.99	1.65	1.97	1.53
170	164	4.11	3.24	3.66	2.82	3.85	3.12	3.56	2.75
160	155	8.49	6.57	5.51	4.42	8.41	6.24	5.51	4.32
150	145	43.7	30.2	11.3	8.53	40.4	29.0	10.5	8.11
140	135	151.2	98.1	54.9	31.1	128.3	89.3	53.7	30.5
130	125	212.0*	165.9*	152.5	66.8	188.3*	152.2*	152.3	63.8
120	115	212.0*	179.3*	164.7*	135.7*	212.0*	178.3*	159.7*	134.0*

*thelevelswerenotfullyenclosedinsidethemodelingarea.

Table 6: Threshold distances (in km) from the source at 40 m water depth to the specified levels.

RMS SPL (dB re 1 μPa)	SEL (dB re 1 μPa^2·s)	Reflective bottom				Typical bottom			
		Max over depths		At bottom		Max over depths		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.14	0.12	0.14	0.12	0.14	0.12	0.14	0.12
190	178	0.92	0.77	0.83	0.66	0.81	0.58	0.81	0.57
180	170	2.54	1.96	2.54	1.92	2.34	1.85	2.34	1.72
170	164	4.64	3.79	4.44	3.63	4.51	3.62	4.33	3.41
160	155	9.91	7.67	8.30	6.95	9.33	7.21	8.30	6.51
150	145	26.0	18.5	17.9	13.0	23.9	17.3	16.4	12.4
140	135	57.3	43.8	39.2	23.9	54.3	41.9	39.1	22.8
130	125	155.2*	127.6*	54.6	41.6	154.4*	123.9*	54.1	39.9
120	115	212.0*	172.1*	152.8	104.5	212.0*	171.3*	152.7	101.7

*thelevelswerenotfullyenclosedinsidethemodelingarea.

Table 7: Threshold distances (in km) from the source at 100 m water depth to the specified levels.

RMS SPL (dB re 1 μPa)	SEL (dB re 1 μPa^2·s)	Reflective bottom				Typical bottom			
		Max over depths		At bottom		Max over depths		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.08	0.07	0.07	0.07	0.08	0.07	0.07	0.07
190	178	0.43	0.35	0.41	0.34	0.41	0.36	0.41	0.36
180	170	2.35	1.75	2.35	1.72	2.30	1.64	2.30	1.62
170	164	5.12	3.93	5.12	3.75	5.03	3.72	5.02	3.58
160	155	14.8	9.53	14.0	8.95	14.9	8.99	11.7	8.40
150	145	28.5	22.2	25.0	21.2	26.7	20.9	24.3	19.9
140	135	105.2	53.5	56.2	37.9	104.3	51.1	55.6	34.6
130	125	179.6*	137.7*	107.4	62.1	180.1*	135.3*	107.5	60.1
120	115	212.0*	170.2*	163.3	102.8	212.0*	170.4*	163.3	99.2

*thelevelswerenotfullyenclosedinsidethemodelingarea.

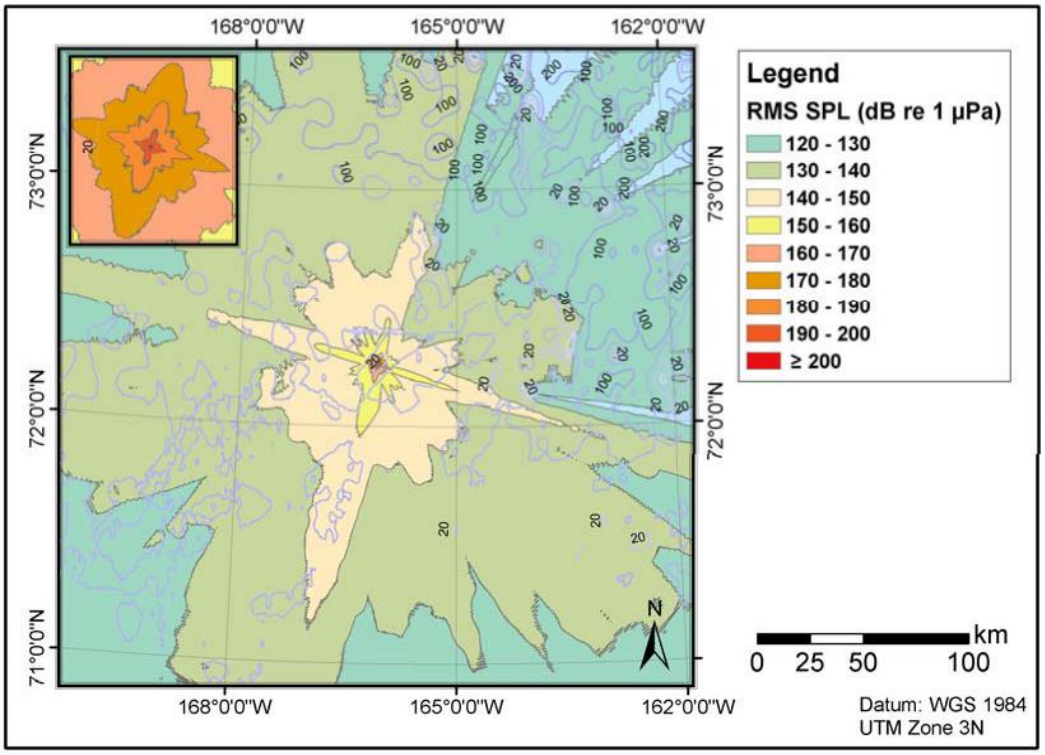

Figure 11: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 17 m water depth in the Alaskan Chukchi Sea (November, typical bottom).

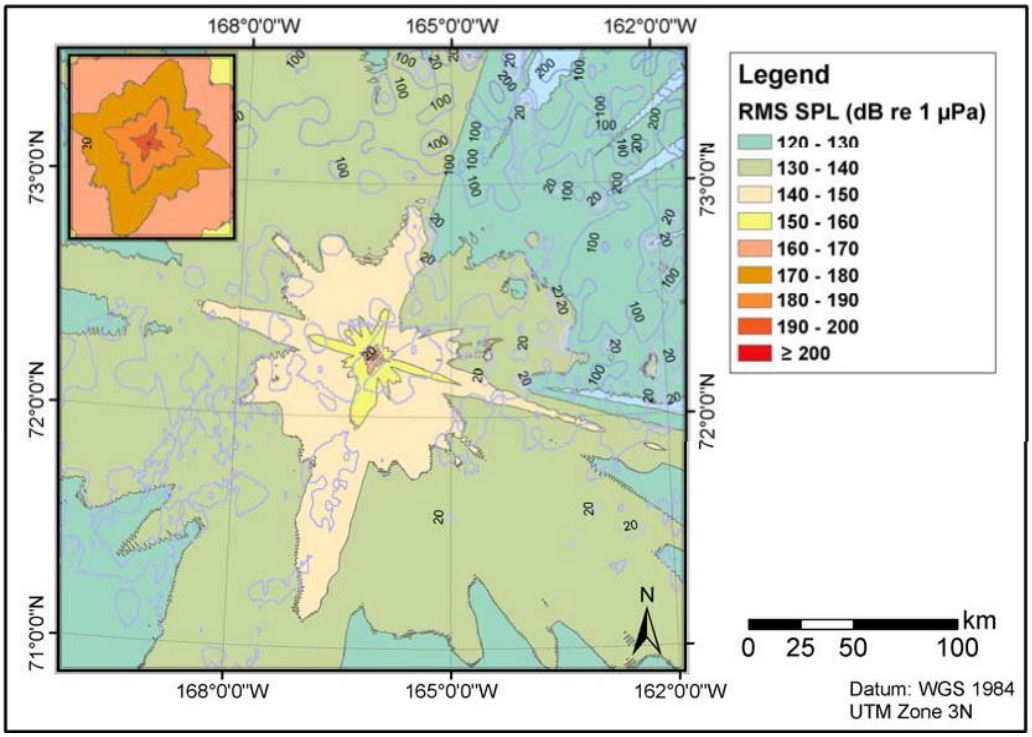

Figure 12: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 17 m water depth in the Alaskan Chukchi Sea (November, reflective bottom).

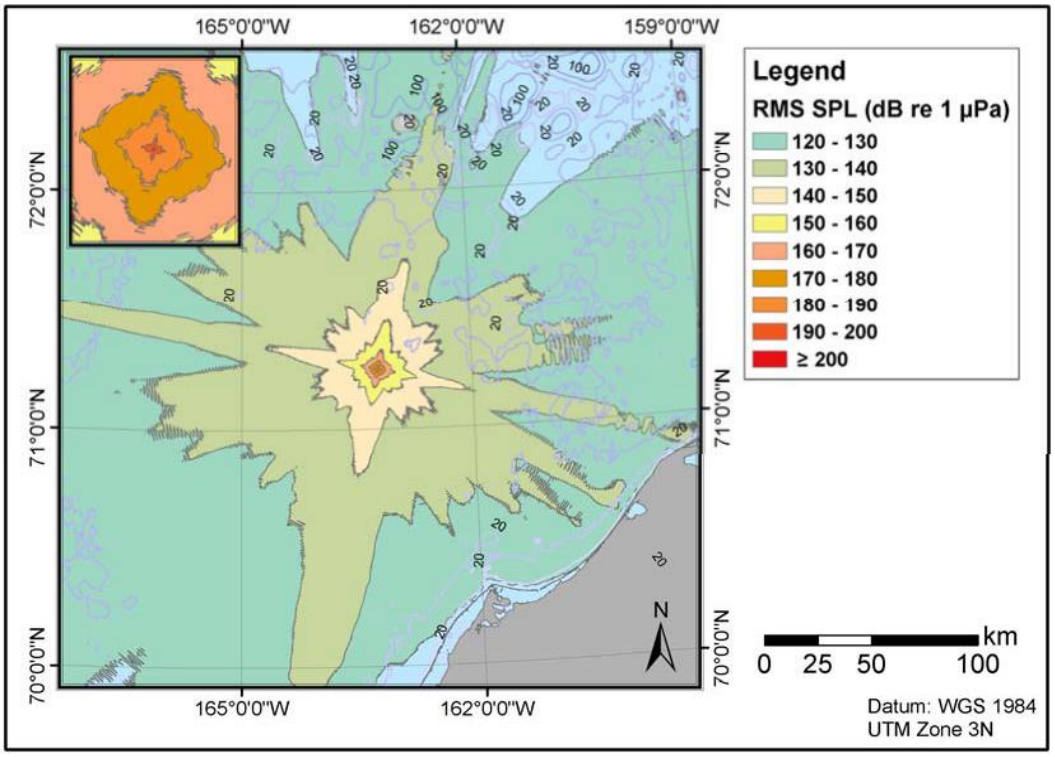

Figure 13: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 40 m water depth in the Alaskan Chukchi Sea (November, typical bottom).

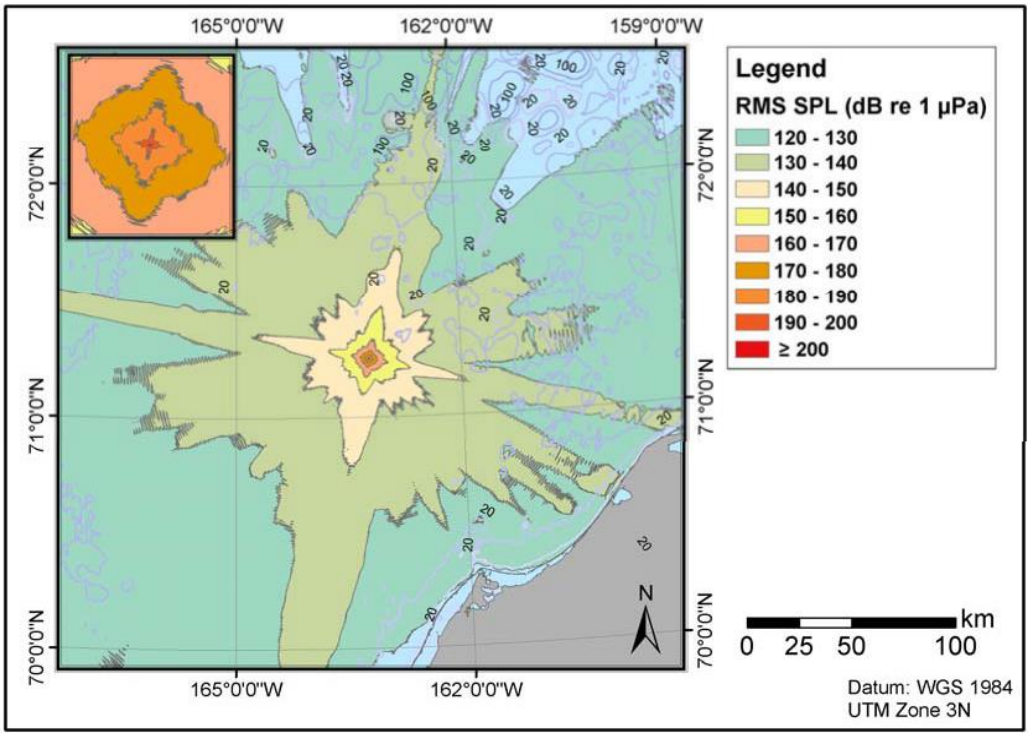

Figure 14: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 40 m water depth in the Alaskan Chukchi Sea (November, reflective bottom).

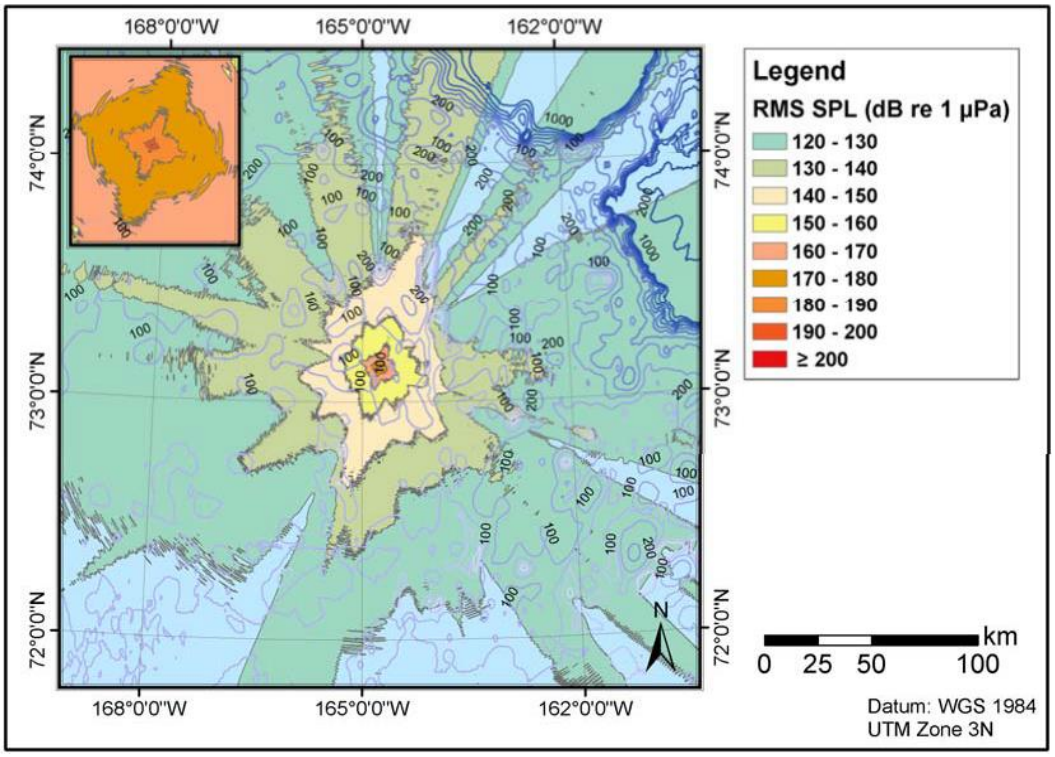

Figure 15: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 100 m water depth in the Alaskan Chukchi Sea (November, typical bottom).

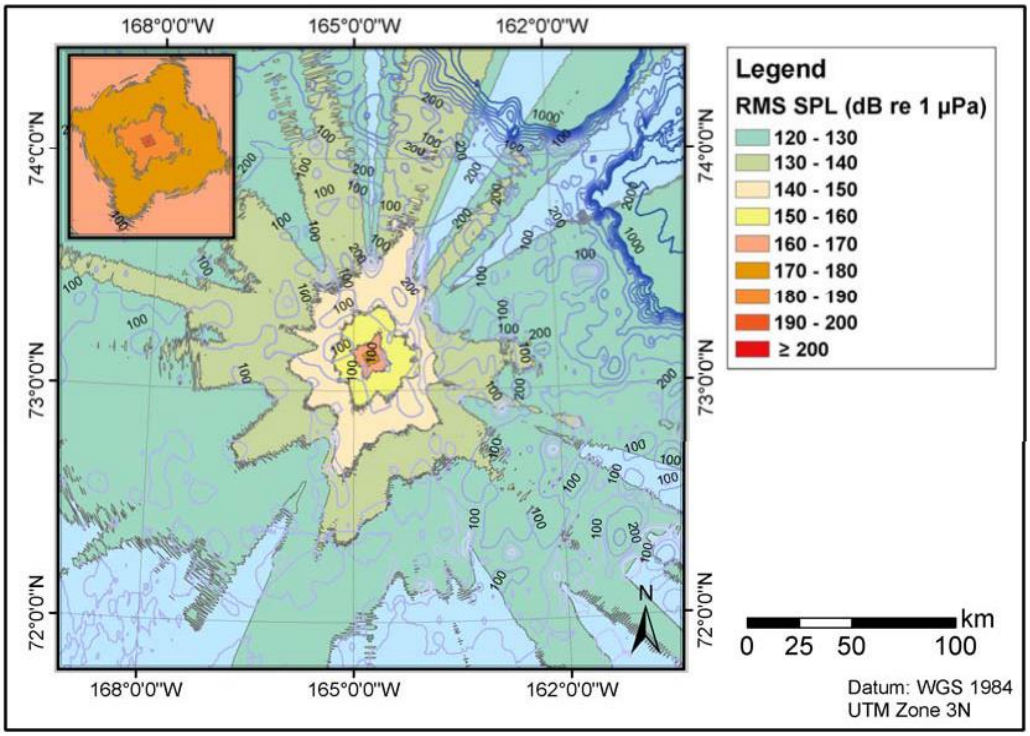

Figure 16: RMS SPL (dB re 1 µPa) around the 3280 in^3 airgun array placed at 100 m water depth in the Alaskan Chukchi Sea (November, reflective bottom).

6. Discussion

The maximum distances to several SEL sound level thresholds are provided in Tables 5 to 7. The distances are dependent on the water depth at the source location and depth variations along the propagation paths at each site. Low frequency seismic sound propagation in shallow waters depends on the geoacoustic properties of the environment, the water depth, and the frequency of the sound. The frequency content of the received sound field also depends on the frequency distribution of acoustic energy emitted by the airgun array source (frequency band source levels). The source level at each frequency is generally dependent on the direction of sound emission relative to the front of the airgun array (Figure 4). The model takes into account all of the above to compute 3-dimensional sound fields (Figure 10, and Figure 11 to Figure 16).

There was not a specific model scenario that consistently caused the greatest distances for all thresholds. The largest threshold distance to 190 dB RMS re 1 μPa occurred at 930 m at the shallowest (17 m water depth) site with the reflective bottom type. The largest threshold distance for to 180 dB RMS re 1 μPa was 2.54 km and occurred at 40 m water depth with reflective bottom type. The 180 dB RMS re 1 μPa distance at the 17 m water depth was slightly shorter at at 2.21 km because some of the lowest frequency sound energy could not propagate as well in the very shallow water.

The maximum distances to thresholds 170–160 dB RMS re 1 μPa occurred for the 100 m water depth scenario. The maximum distances to thresholds 150–140 dB RMS re 1 μPa occurred for the 17 m water depth scenario. As previously mentioned, the 17 m water depth scenario had the source position at the top of an underwater hill with dimensions approximately 5 km x 10 km, and with surrounding water depths falling off to 50–60 m. Consequently sound propagation beyond 2.5 – 5 km in this scenario was in deeper water depths.

The sound level isopleths maps (Figure 11 to Figure 16) showed that received sound levels depended strongly on direction relative to the airgun array source. This type of directivity is a common feature of large airgun array sources. The actual distance to sound level thresholds below 130 dB RMS re 1 μPa varied by as much as a factor of 4 depending on direction. This large variation arises because the sound field at long distances is dominated by mid- to high-frequencies between 200 Hz to 500 Hz. Lower frequency energy is more rapidly attenuated so is less able to propagate to these distances in the shallow environments. The remaining higher frequency sound field has high variability with direction because of the correspondingly high directivity of the source at those frequencies (Figure 4).

The results of this modeling study were compared with empirical data obtained during sound source verification studies for Shell in 2007 (Funk et al., 2008). Those empirical data were collected using bottom-moored recorders at the site with nominal water depth 32 m. The 40 m depth model scenario with reflective bottom most closely matches the environment of that field measurement. Table 8 shows the corresponding model and empirical distances to levels between 180 and 120 dB RMS re 1 μPa. Since the measurements were performed with bottom-moored recorders, the near-bottom model results are presented with the modeled maximum-over-depth results.

Table 8: Comparison of threshold distance to the specified RMS SPL levels for 3147 in^3 airgun source (2007 Shell Offshore program, measured at bottom) and 3280 in^3 airgun source modeled in this study.

RMS SPL (dB re 1 μPa)	Measurement: 3147 in^3		Model: 3280 in^3 (40 m water depth, reflective bottom)			
	end-fire (km)	Broadside (km)	At bottom		Max over depths	
			R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
190	0.45	0.55	0.83	0.66	0.92	0.77
180	1.14	2.47	2.54	1.92	2.54	1.96
170	2.90	4.5	4.44	3.63	4.64	3.79
160	7.15	6.1	8.30	6.95	9.91	7.67
150		15.8	17.9	13.0	26.0	18.5
140		30.5	39.2	23.9	57.3	43.8
130		42.0	54.6	41.6	155.2*	127.6*
120	58.5	66.0	152.8	104.5	212.0*	172.1*

*the levels were not fully enclosed inside the modeling area.

The distances (R_{max}, bottom depth receiver) to thresholds for the 40 m model scenario and the empirical distances from a bottom moored recorder in 32 m water depth are quite similar. The maximum measured distance to 190 and 180 dB RMS re 1 μPa were 550 m and 2.47 km. The corresponding modeled distances were 830 m and 2.54 km. The measured and modeled distances to 160 dB were 6.1 km and 8.3 km respectively. There is a larger difference between the measured and modeled distances to 120 dB RMS re 1 μPa; the measured distance was 66 km while the modeled 152.8 km. We feel the modeled distance to 120 dB may be overly large due to the model's inability to account for energy loss due to scattering by bottom roughness and water column inhomogeneities. Those effects become important over the longer propagation paths corresponding to the lower 120 dB RMS re 1 μPa threshold. We therefore recommend the use of the modeled 95th percentile distance instead of the maximum distance for the 120 dB RMS re 1 μPa threshold. The 95th percentile distance discards the narrow coherent features of the directivity patterns observed especially at longer distances.

7. Conclusion

This report presents the results of acoustic modeling performed to estimate the distances from TGS's 3280 in^3 airgun array that sound levels reach thresholds between 190 and 120 dB RMS re 1 μPa. The model was run at 3 locations in the Alaskan Chukchi Sea where water depths were 17 m, 40 m and 100 m.

The modeled distances for 190, 180 and 160 dB RMS re 1 μPa for the 40 m model site are similar to measurements of seismic airgun array sounds made recently in the Chukchi for a slightly smaller airgun array at a nominal 32 m water depth site. The modeled distance for 120 dB RMS re 1 μPa is greater than the measured distance for that level. The difference is attributed to seabed scattering and in-water inhomogeneities, not included in the model, that reduce coherent sound propagation that leads to large distances for the 120 dB RMS re 1 μPa threshold. The model results also indicate important variation of sound levels with depth at longer distances

from the source. The sound levels in mid-water depths appear to be up to 10 dB greater than near the surface and bottom for the upward-refracting water sound speed profiles examined. The difference may be less for other sound speed profiles. Still, when comparing these model results with previous empirical results it is important to consider the depths at which the measurements were made. These measurements are often made using seabed-deployed recorders.

The results of this modeling study are summarized for use as marine mammal exclusion and potential effects zones in Table 9. The distances provided in Table 9 are based on R_{max} from Tables 5–7. The 120 dB RMS re 1 µPa threshold distance was derived from the R95% distances from Tables 5–7. At each source location the maximum model result for typical and reflective bottom types was chosen.

Table 9: Proposed marine mammal exclusion/safety zones for three water depths.

RMS (dB re 1 µPa)	Exclusion zone (m)		
	Depth: 17-40 m	Depth: 40-100 m	Depth: >100 m
190	930	920	430
180	2200	2500	2400
160	8500	9900	15000
120	179300*	172100*	170400*

* These distances are likely overestimated due to (1) the 3 dB conservative factor added to the model sound levels. (2) The model does not account for the energy loss due to the scattering by the bottom roughness and water column inhomogeneity, which affects more to the longer propagation path. (3) The conversion factor from SEL to rms SPL used in this study might be overly conservative at this longer distance.

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19.0 **Appendix A. 4100 in^3 Airgun Array Modeling Results**

TGS had originally intended to use a 4100 in^3 array for this project but this was later abandoned, in favor of the 3280 in^3 array discussed in the main sections of this report. Original model results for the larger array are included here for reference. Table A - 1 to Table A - 3 show the threshold distances from the 4100 in^3 airgun array at 17 m, 40 m and 100 m water depth to the specified levels (Zykov, et al., 2010).

Table A - 1: Threshold distances (in km) from the 4100 in^3 airgun array source at 17 m water depth to the specified levels.

RMS SPL (dB re 1 μPa)	SEL (dB re 1 μPa^2·s)	Reflective bottom				Typical bottom			
		Max over depth		At bottom		Max over depth		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.16	0.13	0.16	0.13	0.11	0.10	0.11	0.09
190	178	0.73	0.64	0.72	0.62	0.73	0.60	0.72	0.56
180	170	2.13	1.72	1.91	1.53	1.98	1.70	1.85	1.53
170	164	4.18	3.30	3.52	2.80	3.94	3.27	3.57	2.82
160	155	8.7	7.0	5.5	4.5	8.4	6.7	5.5	4.5
150	145	36.2	29.3	11.1	8.0	34.7	27.4	11.1	8.1
140	135	115.0	85.4	40.9	29.5	112.5	76.4	39.0	28.2
130	125	164.9*	142.7*	152.1	69.0	162.9*	141.1*	151.9	65.5
120	115	212.0*	170.2*	159.1*	132.3	212.0*	168.9*	158.9*	127.5*

*thelevelswerenotfullyenclosedinsidethemodelingarea.

Table A - 2: Threshold distances (in km) from the 4100 in^3 airgun array source at 40 m water depth to the specified levels.

RMS SPL (dB re 1 μPa)	SEL (dB re 1 μPa^2·s)	Reflective bottom				Typical bottom			
		Max over depth		At bottom		Max over depth		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.12	0.10	0.12	0.10	0.11	0.09	0.11	0.09
190	178	0.64	0.56	0.64	0.56	0.59	0.49	0.59	0.46
180	170	2.38	1.92	2.32	1.91	2.28	1.80	2.28	1.68
170	164	4.67	3.80	4.44	3.58	4.52	3.67	4.33	3.37
160	155	10.9	8.6	8.6	7.0	10.2	8.3	8.4	6.6
150	145	27.1	20.7	18.4	13.4	25.3	19.4	18.0	12.8
140	135	55.6	43.4	39.9	25.8	53.1	41.2	39.4	24.7
130	125	153.6	112.0	56.2	42.8	153.6	106.6	55.8	41.3
120	115	211.2*	155.1*	152.1	97.9	210.9*	153.7*	152.2	92.6

*thelevelswerenotfullyenclosedinsidethemodelingarea.

Table A - 3: Threshold distances (in km) from the 4100 in^3 airgun array source at 100 m water depth to the specified levels.

RMS SPL (dB re 1 µPa)	SEL (dB re 1 µPa^2·s)	Reflective bottom				Typical bottom			
		Max over depth		At bottom		Max over depth		At bottom	
		R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
200	188	0.07	0.06	0.06	0.05	0.07	0.06	0.06	0.05
190	178	0.39	0.33	0.39	0.33	0.39	0.35	0.39	0.35
180	170	2.17	1.70	2.17	1.68	2.15	1.48	2.15	1.40
170	164	5.30	3.79	5.12	3.59	5.02	3.60	5.02	3.48
160	155	16.5	11.6	15.4	8.6	15.3	10.9	11.7	8.0
150	145	32.2	23.9	25.1	21.1	30.9	23.3	25.1	20.2
140	135	106.0	61.8	66.0	39.8	104.9	58.6	66.1	38.4
130	125	185.4*	137.3*	105.3	60.4	186.4*	137.2*	105.8	58.8
120	115	212.0*	167.8*	159.1	91.9	212.0*	168.6*	159.2	87.3

*thelevelswerenotfullyenclosedinsidethemodelingarea.

Table A - 4 summarized the modeling results for use as marine mammal exclusion and potential effect zones from the 4100 in^3 array. The distances provided were based on R_{max} from Table A - 1 to Table A - 3 with a 10% safety factor applied to account for environmental uncertainties. The 120 dB RMS re 1 µPa threshold distance was derived from the $R_{95\%}$ distances, also with a 10% safety factor applied. At each source location the maximum model result for typical and reflective bottom types was chosen.

Table A - 4: Proposed marine mammal exclusion/safety zones for three water depths for the 4100 in^3 array. These values include a 10% safety factor applied to the model results.

RMS (dBre1µPa)	Exclusionzone(meters)		
	Depth:17-40m	Depth:40-100m	Depth:>100m
190	810	710	430
180	2400	2600	2400
160	9600	12000	18000
120	170000	155000	170000