Application for Incidental Harassment Authorization for Apache Alaska Corporation 3D Seismic Program Cook Inlet, Alaska

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Acronyms and Abbreviations

3D	three dimensional
2D	two dimensional
ADF&G	Alaska Department of Fish and Game
BA	Biological Assessment
BiOp	Biological Opinion
CFR	Code of Federal Regulations
CIMMC	Cook Inlet Marine Mammal Council
cui	cubic inches
dB re 1 µPa	decibel referenced to one microPascal
DGPS/RTK	differential global positioning system/roving units
DPS	Distinct Population Segment
EA	Environmental Assessment
ESA	Endangered Species Act
ft	feet
FR	Federal Register
Hz	Hertz
IHA	Incidental Harassment Authorization
INS	Integrated Navigation System
JASCO	JASCO Applied Sciences
KABATA	Knik Arm Bridge and Toll Authority
Kg	kilogram
kHz	kilohertz
km	kilometer
km^2	square kilometer
lbs	pounds
LOA	Letter of Authorization
m	meter
mi	mile
mi^2	square mile
MMPA	Marine Mammal Protection Act
MTR	Marine Terminal Redevelopment
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
OBRL	Ocean Bottom Receiver Location
OSP	Optimum Sustainable Population
POA	Port of Anchorage
PSO	Protected Species Observer
PTS	permanent threshold shift
RL	received levels
rms	root-mean-squared
SEL	sound energy level
SPL	sound pressure level
SSC	sound source characterization
SSV	sound source verification
TS	threshold shift
TTS	temporary threshold shift
USBL	Ultra-Short BaseLine
USC	United States Code
USCG	United Stated Coast Guard

1.0 Introduction

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) governs the issuance of Incidental Harassment Authorizations (IHAs) and Letters of Authorization (LOAs) permitting the incidental, but not intentional, take of marine mammals under certain circumstances are codified in 50 Code of Federal Regulations (CFR) Part 216, Subpart I (Sections 216.101 - 216.108). The Marine Mammal Protection Act (MMPA) defines take as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 United States Code [USC] Chapter 31, Section 1362 (13)). Section 216.104 sets out 14 specific items that must be addressed in requests for rulemaking and renewal of regulations pursuant to Section 101(a)(5) of the MMPA. The 14 items are addressed in Sections 2 through 15 of this application.

Apache Alaska Corporation (Apache) plans to acquire three-dimensional (3D) seismic surveys throughout Cook Inlet, Alaska over the course of the next five years. Apache applied for and received two IHAs to operate a 3D seismic survey in Cook Inlet, between April 30, 2012 - April 30, 2013 and March 1, 2013 - March 1, 2014 (77 Federal Register [FR] 27720, 78 FR 12720). In this application, Apache seeks an IHA to perform a 3D seismic program in Cook Inlet starting on March 1, 2014.

2.0 Description of Activities

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

2.1 Project Purpose

Apache has acquired over 800,000 acres of oil and gas leases in Cook Inlet since 2010 with the primary objective to explore for and develop oil and gas resources in Cook Inlet. In the spring of 2011, Apache conducted a seismic test program to evaluate the feasibility of using new nodal (no cables) technology seismic recording equipment for operations in Cook Inlet. This test program found and provided important input to assist in finalizing the design of the 3D seismic program in Cook Inlet (the nodal technology was determined to be feasible). Apache began seismic onshore acquisition on the west side of Cook Inlet in September 2011 and offshore acquisition in May 2012 under an IHA issued by NMFS for April 30, 2012 through April 30, 2013 (77 FR 27720) (Figure 1). Apache planned to continue acquisition activities under a second IHA application effective March 1, 2013. Apache plans to continue acquisition activities in Cook Inlet under a third IHA application, effective when the second (the current) IHA expires.

Two marine mammal species in the two previous IHAs and this IHA application are listed under the Endangered Species Act (ESA), requiring a Biological Assessment (BA). Apache prepared a BA, and in February 2012 NMFS issued a Biological Opinion (BiOp) for three years of seismic operations (NMFS 2012a). The February 2012 BiOp has been modified twice by NMFS, resulting in BiOps dated May 2012 (NMFS 2012b) and February 2013 (NMFS 2013a). The February 2012 BiOp divided the three years of operations into three general areas based on the planned operations at the time of the BA submittal. The overall area of operations included in this IHA application is the same area covered in the BA and three associated BiOps. The existing BiOps expires December 31, 2014, so Apache requests the effective dates of this IHA to be from March 1, 2014 to December 31, 2014 to align with the dates of the BiOp.

Apache proposes to conduct their acquisition plan in the proposed area as shown in Figure 2. The total proposed area (Zone 1 and Zone 2) encompasses approximately 4,238 square kilometers (km^2) (1,636 square miles [mi^2]) of intertidal and offshore areas. Apache is requesting the area in this IHA application to allow for operational flexibility in utilizing specific areas within Cook Inlet. There are numerous factors that influence the areas that need to be surveyed by Apache, including the geology of the Cook Inlet area, other permitting restrictions (i.e., commercial fishing, Alaska Department of Fish and Game [ADF&G] refuges), seismic imaging of leases held by other entities with whom Apache has agreements (e.g., data sharing), overlap of sources and receivers to obtain the necessary seismic imaging data, and general operational restrictions (ice, weather, environmental conditions, marine life activity, etc.). Therefore, Apache is requesting an IHA to operate anywhere within the proposed area, but intends to survey only a portion of the total area in the requested IHA.

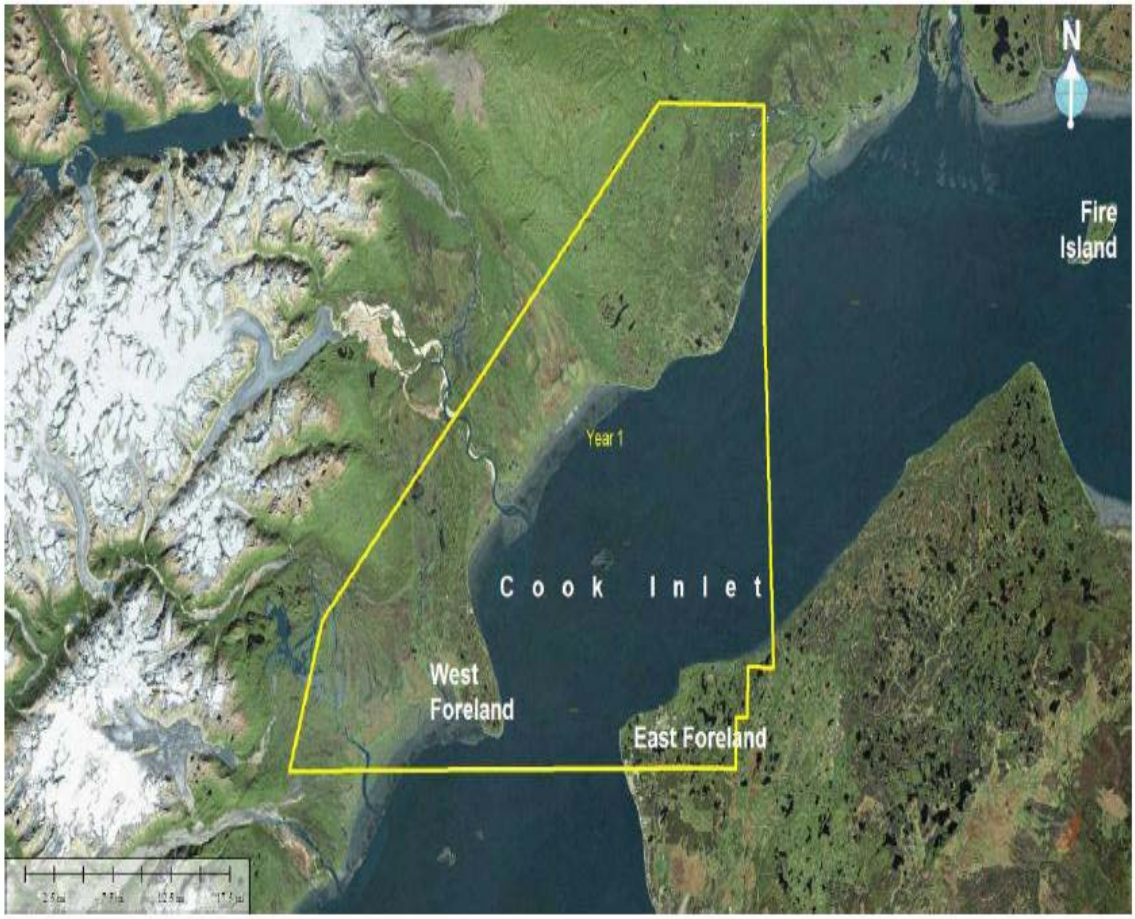

Figure 1. Location of Acquisition Plan Under First IHA

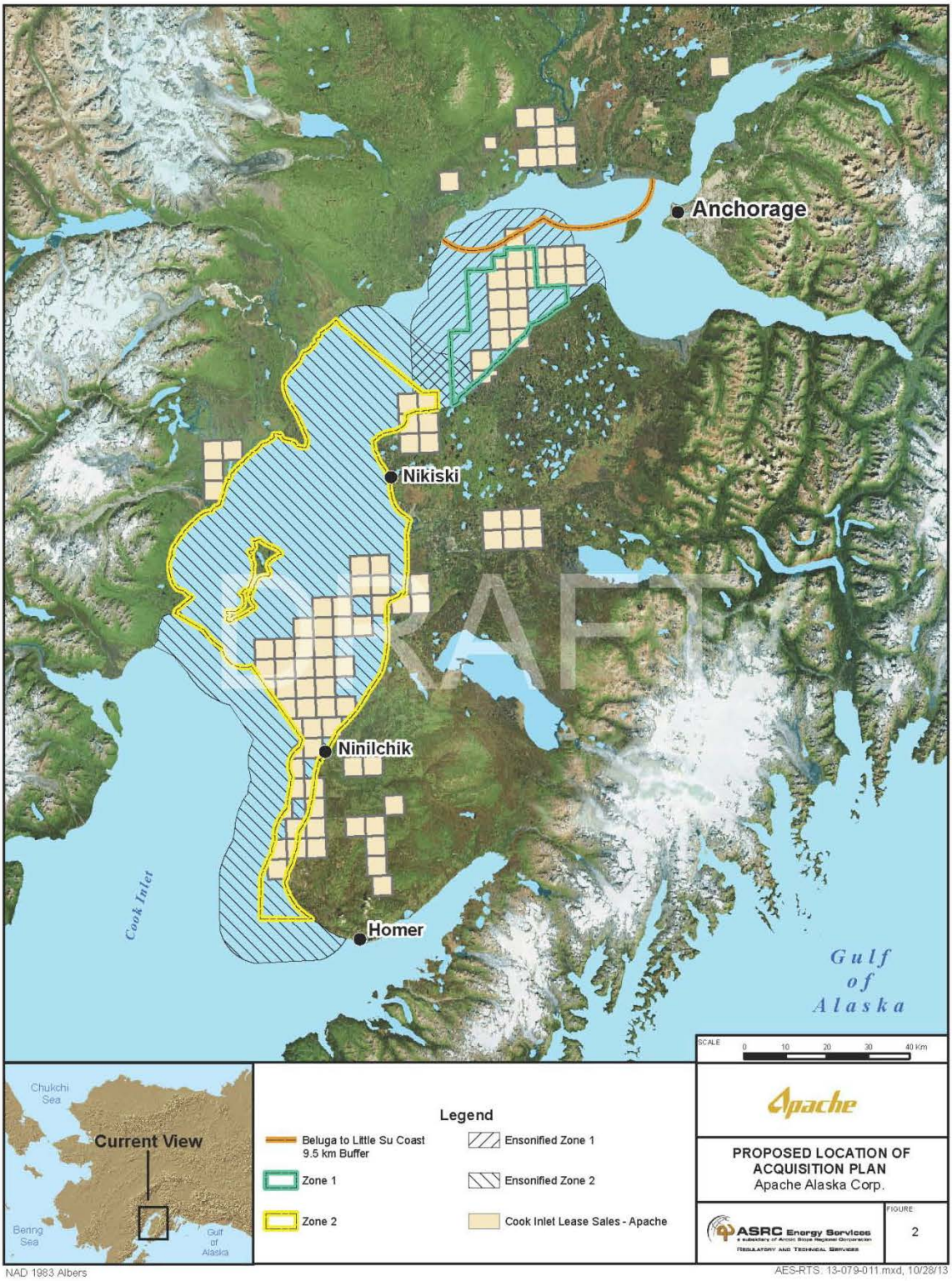

Figure 2. Proposed Location of Acquisition Plan

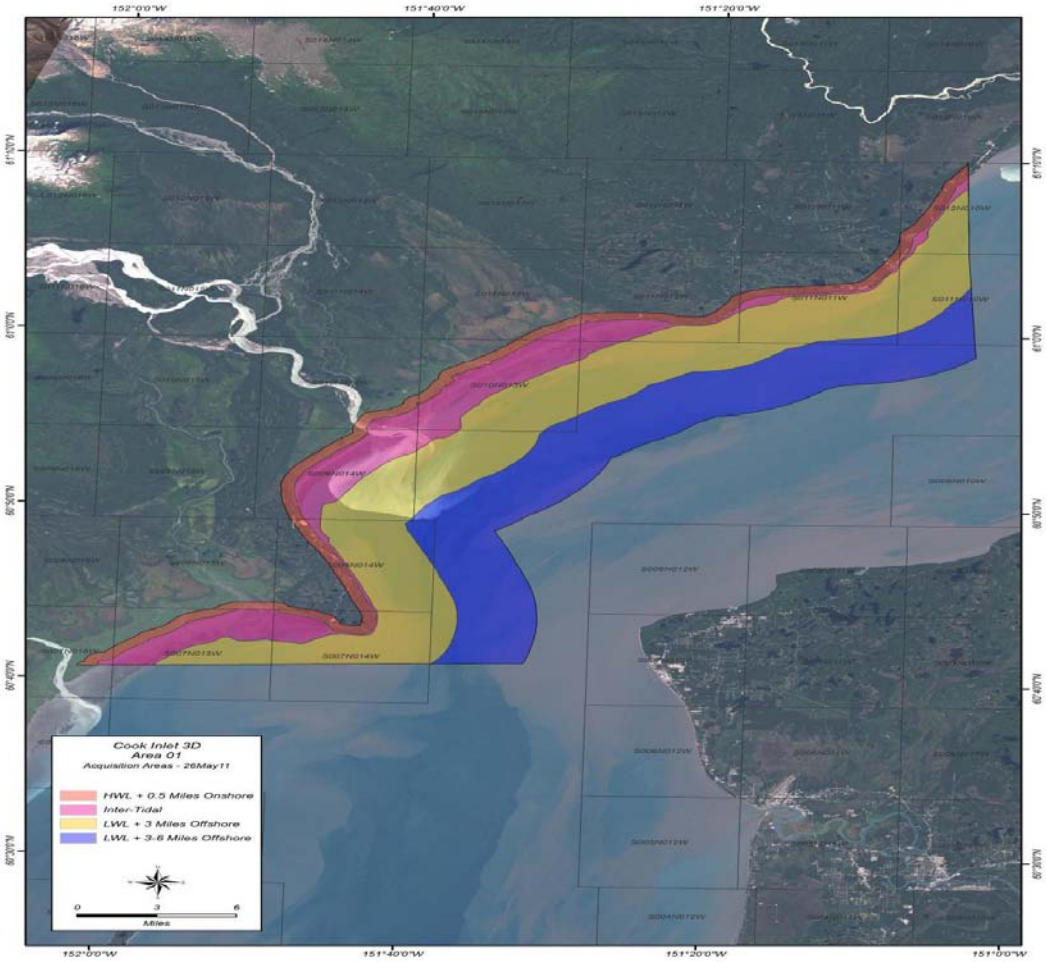

Figure 3. Offshore and Transition Components

Each phase of the Apache program encounters land, inter-tidal transition zone, and marine environments. This application includes activities only in the transition zone and marine environments, as the land-based portion of the program is not anticipated to result in underwater sound levels exceeding NMFS thresholds. Transition zone and offshore acquisition will include areas below the mean high tide line as depicted in Figure 3. The entire operation will be active 24 hours per day during some, but not all, of the IHA's time period; however, airgun activity can only occur during slack tides (low and high) because of the swift tidal currents. The currents during ebb and flood tides limits the operations and safety of the vessels deploying the airguns, as well as decreases the signal-to-noise ratio of the seismic signal to below background levels. In general, there are four slack tides in a 24-hour period; vessels can typically operate approximately 2-3 hours around each slack tide. So the total time of airgun operations in a 24-hour period is 8-12 hours (2-3 hours x 4 slack tides).

Vessels will lay and retrieve the nodal sensors on the sea floor in periods of low current or, in the case of the intertidal area, during high tide over the entire 24-hour period. The offshore and transition zone source effort will include the use of input/output sleeve airguns in two different configurations of arrays: 440 and 2,400 cubic inches [cui]. Although the 2,400 cui airgun is anticipated to be utilized most frequently, Apache may also utilize a 1,200 cui configuration when possible. The seismic source vessels expected to be used are the *M/V Peregrine Falcon* and *M/V Arctic Wolf*, or similar vessels. Cable/Nodal deployment and retrieval operations will be supported by three shallow draft vessels (*M/V*

Miss Diane I, *M/V Mark Steven*, and *M/V Maxime*), or similar vessels. The mitigation/chase vessel, which will also house the Protected Species Observers (PSO) will be the *M/V Dreamcatcher*, or a similar vessel. The node re-charging and housing vessel will be the *M/V Westward Wind*, or similar vessel. Two smaller boats will be used for personnel transport and node support in the extremely shallow water in the intertidal area. Water depths for the program will range from 0 to 128 meters (m), (0 to 420 feet [ft]).

2.2 Proposed Program Overview – General

Each phase of the Apache program encounters land, inter-tidal transition zone, and marine environments. The following provides a general overview of the work plan employed for the seismic survey.

2.2.1 Recording System

The recording system is an autonomous system "nodal" (i.e., no cables), made up of at least two types of nodes; one for the land and one for the intertidal and marine environment. For the land operator, a single-component sensor land node will be used (Figure 4); the inter-tidal and marine zone operators, will use a submersible multi-component system made up of three velocity sensors and a hydrophone (Figure 5). These systems have the ability to record continuous data. Inline receiver intervals for the node systems will be 50 m (165 ft). The nodes are deployed in *patches* for the seismic source and deployed for up to 15 days. The deployment length is limited by battery length and data storage capacity.

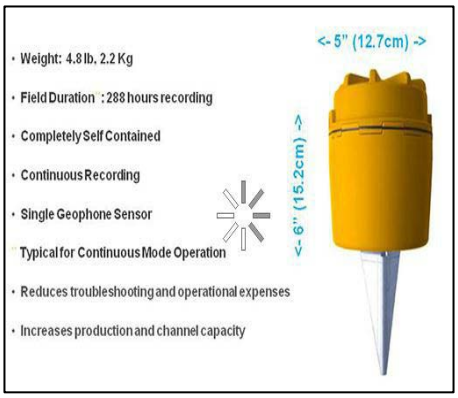

Figure 4. Onshore Nodal Recording System

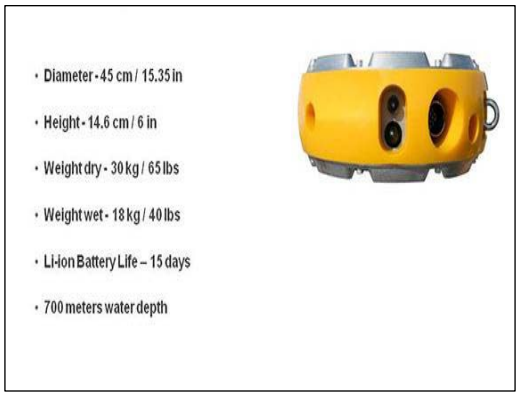

Figure 5. Offshore Nodal Recording System

The geometry methodology that Apache will gather seismic data which is called *patch shooting*. This type of seismic survey requires the use of multiple vessels for cable layout/pickup, recording, and sourcing. Operations begin by laying node lines on the seafloor parallel to each other with a node line spacing of approximately 402 m (1,320 ft). Apache's patch will have 6-8 node lines (receivers) that generally run perpendicular to the shoreline for transition zones and parallel to the shoreline for offshore areas. The node lines will be separated by either 402 or 503 m (1,320 or 1,650 ft). Inline spacing between nodes will be 50 m (165 ft). The node vessels will lay the entire patch on the seafloor prior to the airgun activity. Individual vessels are capable of carrying up to 400 nodes. With three node vessels operating simultaneously, a patch can be laid down in a single 24-hour period, weather permitting. A sample transition zone patch is depicted in Figure 6. A sample offshore patch is depicted in Figure 7. Apache is requesting authorization to place nodes north of the beluga whale critical habitat area 1 line (see Figure 14).

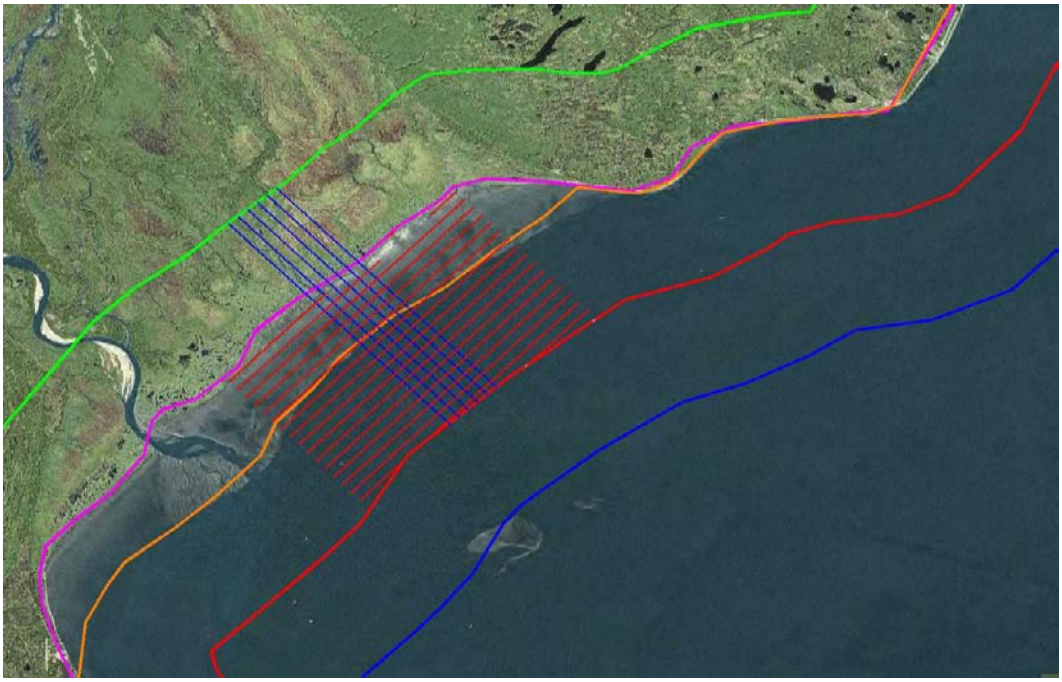

Figure 6. A Single Transition Zone Patch, Six Lines of Nodes (Blue), 16 Source Lines (Red)

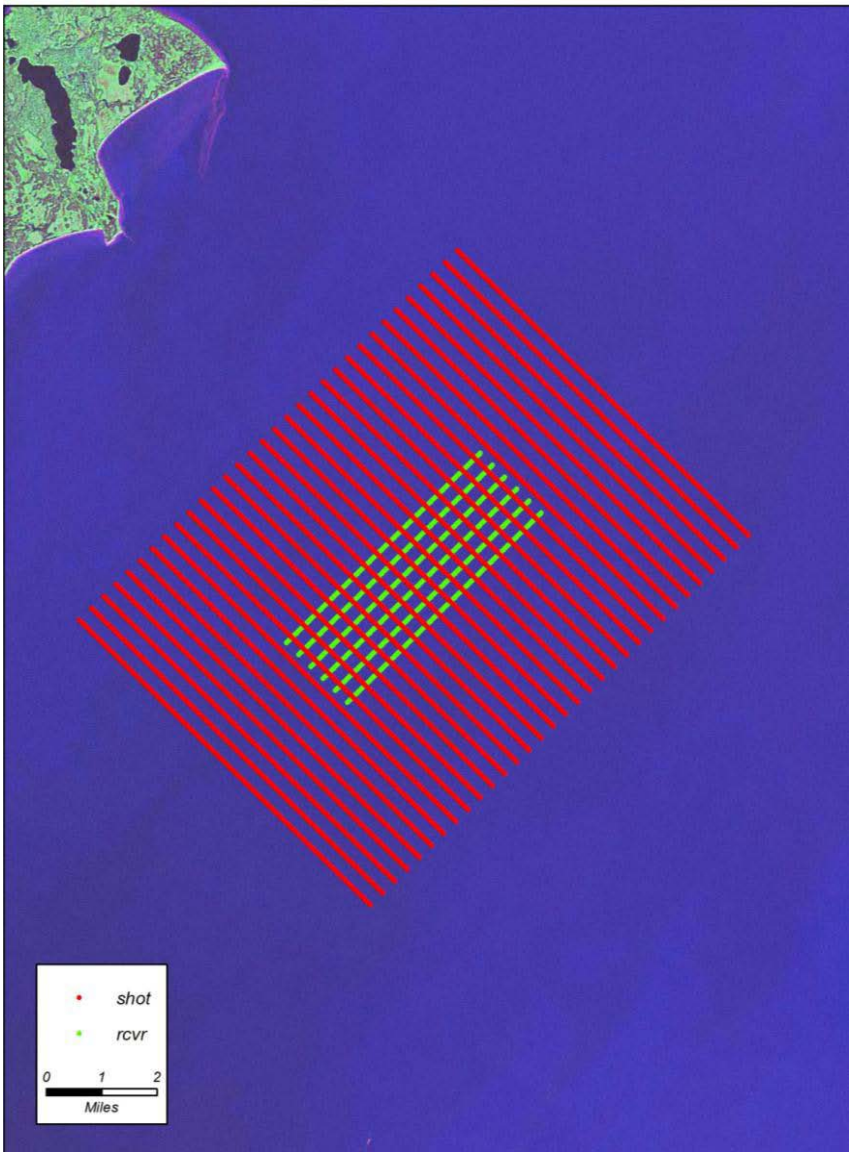

Figure 7. A Single Offshore Patch, Six Lines of Nodes (Green), 16 Source Lines (Red)

As the patches are acquired, the node lines will be moved either side to side or inline to the next patch's location. Figure 8 depicts multiple side to side patches that are acquired individually but when seamed together at the processing phase, create continuous coverage along the coastline.

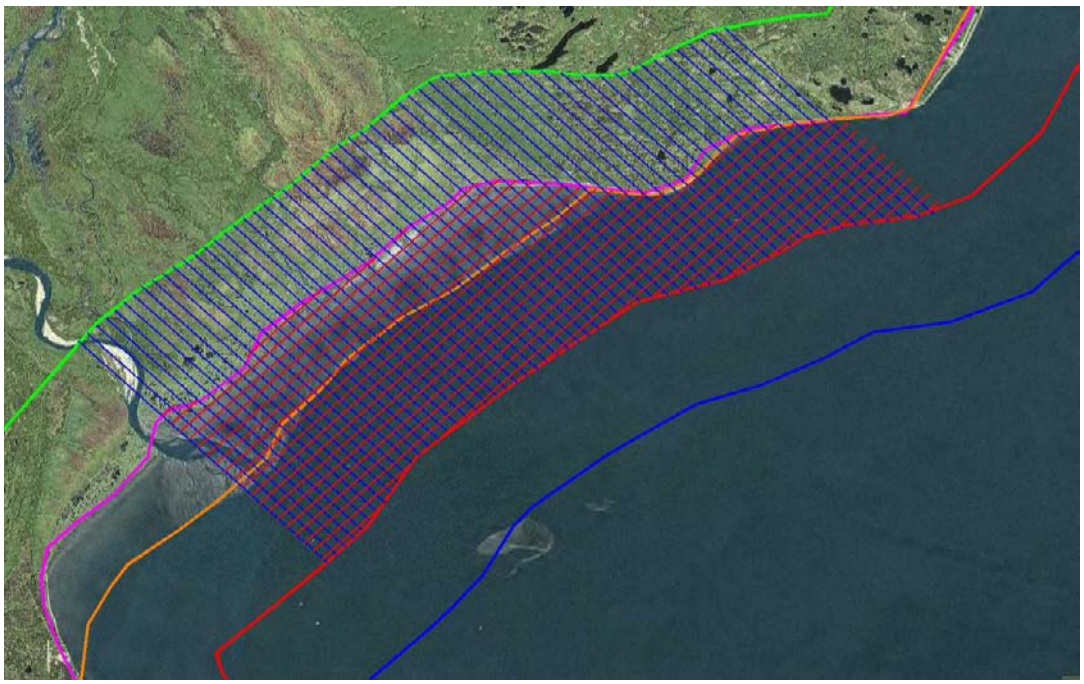

Figure 8. Multiple Intertidal Patches

2.2.2 Sensor Positioning

2.2.2.1 Transition Zone/Offshore Components

Once the nodes are in place on the seafloor, the exact position of each node is required. There are several techniques used to locate the nodes on the seafloor, depending on the depth of the water. In very shallow water, the node positions are either surveyed by a land surveyor when the tide is low, or the position is accepted based on the position at which the navigator has laid the unit.

In deeper water, there are two recognized techniques, known as Ocean Bottom Receiver Location (OBRL) and Ultra-Short Baseline (USBL) methods. For sensor positioning, Apache will employ the USBL method by using a hull or pole mounted pinger to send a signal to a transponder which is attached to each node. The transponders are coded and the crew knows which transponder goes with which node prior to the layout. The transponder's response (once pinged) is added together with several other responses to create a suite of ranges and bearings between the pinger boat and the node. Those data are then calculated to precisely position the node. In good conditions, the nodes can be interrogated as they are laid out. It is also common for the nodes to be pinged after they have been laid out. The pinger that will be used is a Sonardyne Shallow Water Cable Positioning system. The two instruments used are a Scout USBL Transceiver that operates at a frequency of 33-55 kilohertz (kHz) at a max source level of 188 decibels referenced to one micro Pascal (dB re 1 µPa) at 1 m; and a LR USBL Transponder that operates at a frequency of 35-50 kHz at a source level of 185 dB re 1 µPa at 1 m.

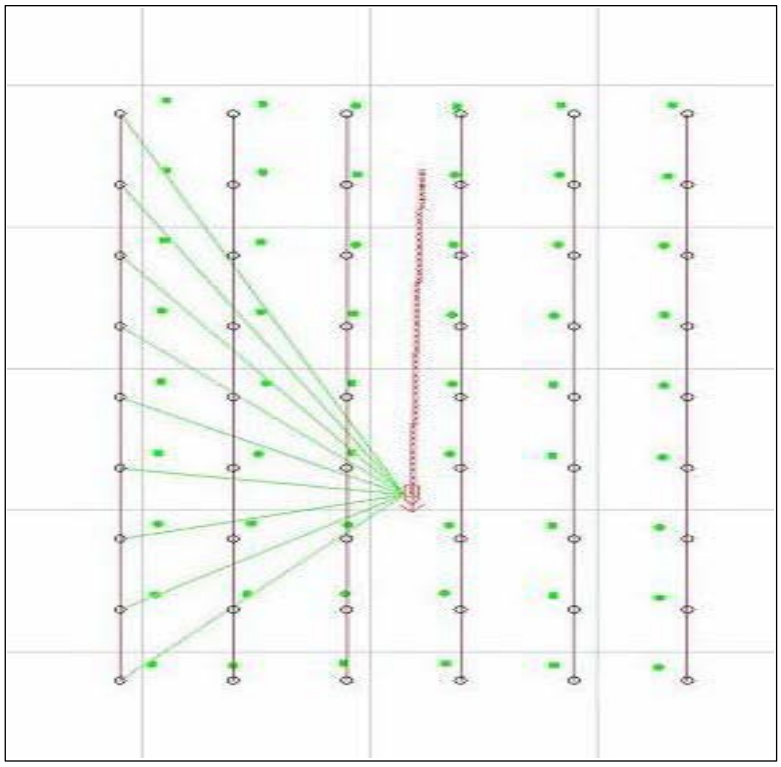

Figure 9. Pinger or OBRL Vessel Interrogating a Patch of 6 Lines

2.2.2.2 Onshore/Intertidal Components

Onshore and intertidal locating of source and receivers will be accomplished with Differential Global Positioning System/roving units (DGPS/RTK) equipped with telemetry radios which will be linked to a base station established on the *M/V Arctic Wolf* or similar vessel. Survey crews will have both helicopter and light tracked vehicle support. Offshore source and receivers will be positioned with an integrated navigation system (INS) utilizing DGPS/RTK link to the land located base stations. The integrated navigation system will be capable of many features that are critical to efficient safe operations. The system will include a hazard display system that can be loaded with known obstructions, or exclusion zones. Typically the vessel displays are also loaded with the day-to-day operational hazards, buoys, etc. This display gives a quick reference when a potential question regarding positioning or tracking arises. In the case of inclement weather, the hazard display can and has been used to vector vessels to safety.

2.2.3 Seismic Source

2.2.3.1 Transition Zone/Offshore Components

Apache will use two synchronized source vessels in time. The source vessels, *M/V Peregrine Falcon* and the *M/V Arctic Wolf* (or similar vessels), will be equipped with compressors and 2,400 cui airgun arrays (1,200 cui, if feasible). The *M/V Peregrine Falcon*, or similar, will be equipped with a 440 cui shallow water source which it can deploy at high tide in the intertidal area in less than 1.8 m (6 ft) of water. Source lines are orientated perpendicular to the node lines and parallel to the beach (see red lines on Figure 6). The two source vessels will traverse source lines of the same patch using a shooting technique called *ping/pong*. The ping/pong methodology will have the first source boat commence the source effort. As the first airgun pop is initiated, the second gun boat is sent a command and begins a countdown to pop its guns 12 seconds later than the first vessel. The first

source boat would then take its second pop 12 seconds after the second vessel has popped and so on. The vessels try to manage their speed so that they cover approximately 50 m (165 ft) between pops. The objective is to generate source positions for each of the two arrays close to a 50 m (165 ft) interval along each of the source lines in a patch. Vessel speeds range from 2-4 knots. The source effort will average 10-12 hours per day.

Each source line is approximately 12.9 km (8 mi) long. A single vessel is capable of acquiring a source line in approximately 1 hour. With two source vessels operating simultaneously, a patch of approximately 3,900 source points can be acquired in a single day assuming a 10-12 hour source effort. When the data from the patch of nodes have been acquired, the node vessels pick up the patch and roll it to the next location. The pickup effort takes approximately 18 hours.

2.2.3.2 Onshore/Intertidal Components

The onshore source effort will be shot holes. These holes are drilled every 50 m (165 ft) along source lines which are orientated perpendicular to the receiver lines and parallel to the coast. To access the onshore drill sites, Apache would use a combination of helicopter portable and tracked vehicle drills. At each source location, Apache will drill to the prescribed hole depth of approximately 10 m (35 ft) and load it with 4 kilograms (kg) (8.8 pounds [lbs]) of explosive (likely Orica OSX Pentolite Explosive). The hole will be capped with a “smart cap” that will make it impossible to detonate the explosive without the proper blaster. At the request of NMFS, Apache conducted a sound source characterization (SSC) of the onshore shot hole to determine if underwater received sound levels exceeded the NMFS thresholds. The results of the SSC verified received sound levels did not exceed NMFS thresholds (Appendix A), therefore, onshore source are not discussed further in this application.

2.2.4 Vessels

The *M/V Peregrine Falcon*, *M/V Arctic Wolf*, *M/V Miss Diane I*, *M/V Mark Steven*, *M/V Maxime*, *M/V Dreamcatcher*, and *M/V Westward Wind*, or similar vessels, will serve as the primary offshore acquisition platforms. The onshore crew will be housed in commercial facilities local near the project site. Offshore staff will be housed on the vessels, which are certified for housing 24-hour crews. Details of the vessels likely to be used are as follows:

M/V Arctic Wolf (Source Vessel)
- Size: 41 m X 9 m (135 ft X 30 ft)
- Documentation: #687450
- Gross Tonnage: 251
- Berths: 32

M/V Peregrine Falcon (Source Vessel)
- Size: 26 m X 6 m (85 ft X 24 ft)
- Documentation: #950245
- Call sign: WCZ6285
- Gross tonnage: 197
- Berths: 10

M/V Westward Wind (Node Charging / Crew Housing Vessel)
- Size: 47 m X 10 m (155 ft X 34 ft)
- Documentation: #774367
- Call sign: WCX9055
- Gross tonnage: 131
- Berths: 29

M/V Miss Diane I (Node Vessel)
Size: 26 m X 6 m (85 ft X 20 ft)
Documentation: #1210779
Call sign: WAV0779
Gross tonnage: 53
Berths: 6

M/V Mark Steven (Node Vessel)
Size: 26 m X 6.7 m (85 ft X 22 ft)
Documentation: #1238385
Call sign: WAV1238
Gross tonnage: 83
Berths: 16

M/V Maxime (Node Vessel)
Size: 21 m X 4.9 m (70 ft X 16 ft)
Documentation: #1196716
Call sign: WAV6716
Gross tonnage: 48
Berths: 4

M/V Dreamcatcher (Mitigation /chase boat)
Size: 26 m X 7.1 m (85 ft X 23 ft)
Documentation: #963070
Call sign: WBN5411
Gross tonnage: 100
Berths: 32

2.2.5 Fuel Storage

Any fuel storage will be located away from waterways and lakes and positioned in modern containment enclosures. The capacity of the containment will be 110 percent of the total volume of the fuel stored in the bermed enclosures. All storage fuel sites will be equipped with additional absorbent material and spill clean-up tools. Any transfer or bunkering of fuel for offshore activities will either occur dock side or comply with United States Coast Guard (USCG) bunkering at sea regulations.

3.0 Dates, Duration, and Geographical Region of Activities

The dates and duration of such activity and the specific geographical region where it will occur.

3.1 Dates and Durations of Activities

Apache proposes to acquire offshore/transition zone operations for approximately eight to nine months during a year. Offshore areas will be acquired in open water periods from March 1st through December 31st. For the proposed acquisition area in Cook Inlet, anticipated windows of operations will be defined by regulatory requirements with respect to agency coordination, subsistence, the presence of endangered species, and appropriate weather conditions. Refer to Figure 2 for area of proposed operations.

During each 24-hour period, seismic support activities may be conducted throughout the entire period; however, in-water airguns will only be active for approximately 2-3 hours during each of the slack tide periods. There are approximately four slack tide periods in a 24-hour period; therefore, airgun operations will be active during approximately 8-12 hours per day, if weather conditions allow. Two airgun source vessels will work concurrently on the spread, acquiring source lines approximately 12 km (7.5 mi) in length. Apache anticipates that a crew can acquire approximately 6.2 km^2 (2.4 mi^2) per day, assuming a crew can work 8-12 hours per day. Thus, the actual survey duration will take approximately 160 days over the course of eight to nine months.

The vessels will be mobilized out of Homer or Anchorage with resupply runs occurring multiple times per week out of Homer, Anchorage, or Nikiski.

4.0 Type and Abundance of Marine Mammals in Project Area

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

4.1 Species and Number in the Project Area

Of the 15 marine mammal species with documented occurrences in Cook Inlet, only five species are commonly observed in the project area: beluga whale (*Delphinapterus leucas*), harbor seal (*Phoca vitulina*), killer whale (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), and Steller sea lion (*Eumetopiaa jubatus*) (Shelden et al. 2003). Table 1 provides a summary of the abundance and status of the species likely to occur in the project area. While killer whales and Steller sea lions have been sighted in upper Cook Inlet, their occurrence is considered rare. Cook Inlet beluga whales, harbor porpoises, and harbor seals are the species most likely to be sighted during the seismic program. Recent passive acoustic monitoring research has indicated that harbor porpoises occur more frequently in the project area than expected from previous visual observations (Small 2010). A more detailed description of these five species is provided in Section 5.

There are several species of mysticetes that have been observed infrequently in lower Cook Inlet, including minke whale (*Balaenoptera acutorostrata*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), and gray whale (*Eschrichtius robustus*). Because of their infrequent occurrence, they are not included in this IHA application. However, monitoring and mitigation techniques for these species would be performed to avoid Level A and Level B takes.

Table 1. Marine Mammal Species in Cook Inlet

Species	Abundance	Comments
Beluga whale (*Delphinapterus leucas*)	283 [1]	Occurs in the project area. Listed as Depleted under the MMPA, endangered under ESA, critical habitat in project area.
Harbor seal *(Phoca vitulina richardsi)*	22,900 [2]	Occurs in the project area. No special status or ESA listing.
Killer whale *(Orcinus orca)*	1,123 Resident 552 Transient[3]	Occurs rarely in the project area. No special status or ESA listing.
Harbor porpoise *(Phocoena phocoena)*	25,987 [4]	Occurs in the project area. No special status or ESA listing.
Steller sea lion (*Eumetopias jubatus*)	45,916 [5]	Occurs infrequently in the project area. Listed as Depleted under the MMPA, endangered under ESA.

Notes: MMPA = Marine Mammal Protection Act, ESA = Endangered Species Act

[1] Abundance estimate for the Cook Inlet stock (Allen and Angliss 2013)

[2] Abundance estimate for the Cook Inlet/Shelikof stock (Allen and Angliss 2013)

[3] Resident estimate from Alaska resident stock; transient estimate from Gulf of Alaska, Aleutian Islands, and Bering Sea transient stock (Allen and Angliss 2013)

[4] Abundance estimate for the Gulf of Alaska stock (Allen and Angliss 2013)

[5] Abundance estimate for the western stock (Allen and Angliss 2013)

5.0 Description of Marine Mammals in Project Area

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

5.1 Harbor Seal

Harbor seals range from Baja California north along the west coasts of Washington, Oregon, California, British Columbia, and Southeast Alaska; west through the Gulf of Alaska, Prince William Sound, and the Aleutian Islands; and north in the Bering Sea to Cape Newenham and the Pribilof Islands. In 2010, NMFS and the Alaska Harbor Seal Commission decided to separate the three previous harbor seal stocks (Gulf of Alaska, Southeast Alaska, and Bering Sea) into 12 new stocks. The Cook Inlet/Shelikof stock is the one most likely to occur in Apache's project area and is estimated to have 22,900 individuals (Allen and Angliss 2013). Harbor seals are taken incidentally during commercial fishery operations at an estimated annual mortality of 24 individuals (Allen and Angliss 2010).

Harbor seals inhabit the coastal and estuarine waters of Cook Inlet. Harbor seals are more abundant in lower Cook Inlet than in upper Cook Inlet, but they occur in the upper inlet throughout most of the year (Rugh et al. 2005 a, b). A tagging study indicated that breeding and molting likely peak in Cook Inlet in June and August (respectively), with most of these behaviors occurring in the lower portion of Cook Inlet south of the forelands (Boveng et al. 2007). These important harbor seal life functions may occur within the southern portion of Apache's proposed survey in June and August, but the co-occurrence is expected to be minimal. From November through January, harbor seals leave Cook Inlet to forage in Shelikof Strait, so Apache's proposed operations would not interfere with foraging behavior (Boveng et al. 2007).

Harbor seals haul out on rocks, reefs, beaches, and drifting glacial ice, and feed on capelin, eulachon, cod, pollock, flatfish, shrimp, octopus, and squid in marine, estuarine, and occasionally fresh waters. Harbor seals movements are associated with tides, weather, season, food availability, and reproduction.

The major haulout sites for harbor seals are located in lower Cook Inlet. The presence of harbor seals in upper Cook Inlet is seasonal. Harbor seals are commonly observed along the Susitna River and other tributaries within upper Cook Inlet during eulachon and salmon migrations (NMFS 2003). During aerial surveys of upper Cook Inlet in 2001, 2002, and 2003, harbor seals were observed at the Chickaloon, Little Susitna, Susitna, Ivan, McArthur, and Beluga Rivers (Rugh et al. 2005a). The closest traditional haulout side to the project area is located on Kalgin Island, which is about 22 km (14 mi) south of the McArthur River.

Harbor seals respond to underwater sounds from approximately 1 to 80 kHz with the functional high frequency limit around 60 kHz and peak sensitivity at about 32 kHz (Kastak and Schusterman 1995). Hearing ability in the air is greatly reduced (by 25 to 30 dB); harbor seals respond to sounds from 1 to 22.5 kHz, with a peak sensitivity of 12 kHz (Kastak and Schusterman 1995). Figure 10 is an in-air audiogram and Figure 11 is an in-water audiogram for the harbor seal (taken from Nedwell et al. 2004). An audiogram shows the lowest level of sounds that the animal can hear (hearing threshold) at different frequencies (pitch). The y-axis of the audiogram is sound levels expressed in dB (either in-air or in-water) and the x-axis is the frequency of the sound expressed in kHz.

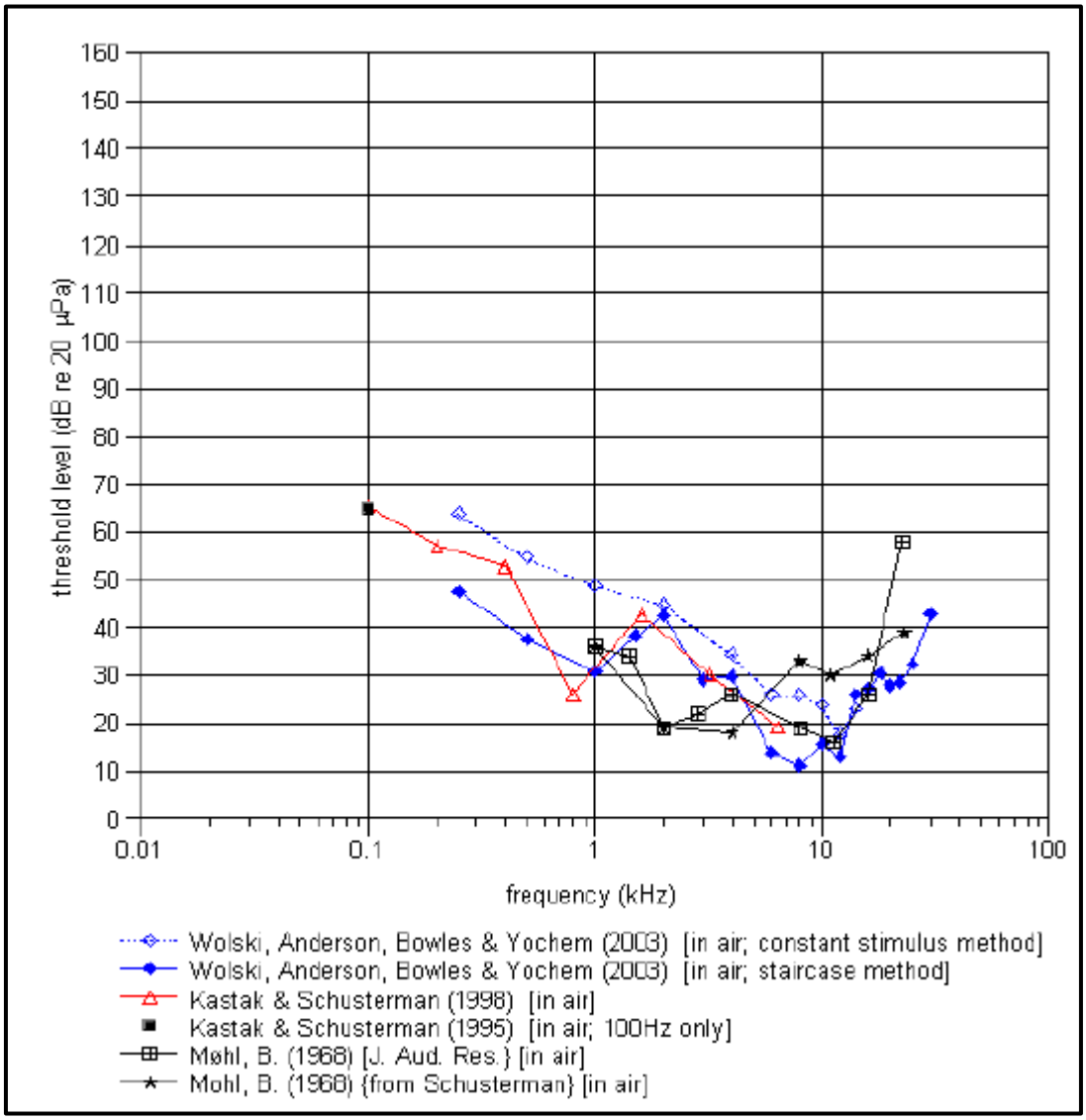

Figure 10. Harbor Seal In-air Audiogram (taken from Nedwell et al. 2004)

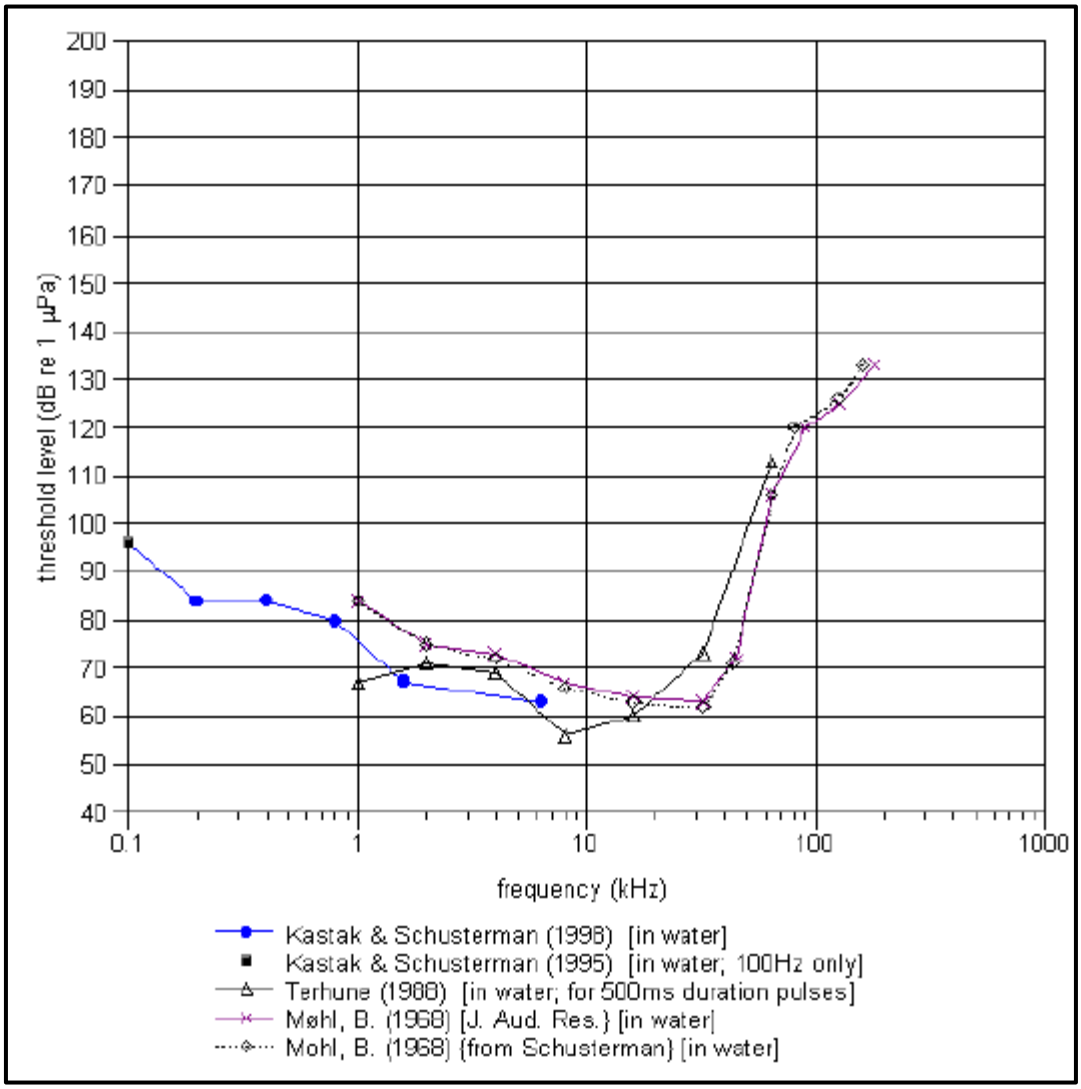

Figure 11. Harbor Seal In-water Audiogram (taken from Nedwell et al. 2004)

5.2 Killer Whale

The population of the North Pacific stock of killer whales contains an estimated 1,123 animals in the resident group and 552 animals in the transient group (Allen and Angliss 2013). Numbers of killer whales in Cook Inlet are small compared to the overall population and most are recorded in the lower Cook Inlet. Killer whales are rare in upper Cook Inlet, where transient killer whales are known to feed on beluga whales, and resident killer whales are known to feed on anadromous fish (Shelden et al. 2003). The availability of these prey species largely determines the likeliest times for killer whales to be in the area. Twenty-three sightings of killer whales were reported in the lower Cook Inlet between 1993 and 2004 in aerial surveys by Rugh et al. (2005a). Surveys over 20 years by Shelden et al. (2003) reported 11 sightings in upper Cook Inlet between Turnagain Arm, Susitna Flats, and Knik Arm. No killer whales were spotted during recent surveys by Funk et al. (2005), Ireland et al. (2005), Brueggeman et al. (2007a, 2007b, 2008), or Prevel Ramos et al. (2006, 2008). Eleven killer whale strandings have been reported in Turnagain Arm, six in May 1991, and five in August 1993. Very few killer whales, if any, are expected to approach or be in the vicinity of the project area.

The hearing of killer whales is well developed. Szymanski et al. (1999) found that they responded to tones between 1 and 120 kHz, with the most sensitive range between 18 and 42 kHz. Their greatest sensitivity was at 20 kHz, which is lower than many other odontocetes, but it matches peak spectral energy reported for killer whale echolocation clicks. Figure 12 is an audiogram for the killer whale (taken from Nedwell et al. 2004).

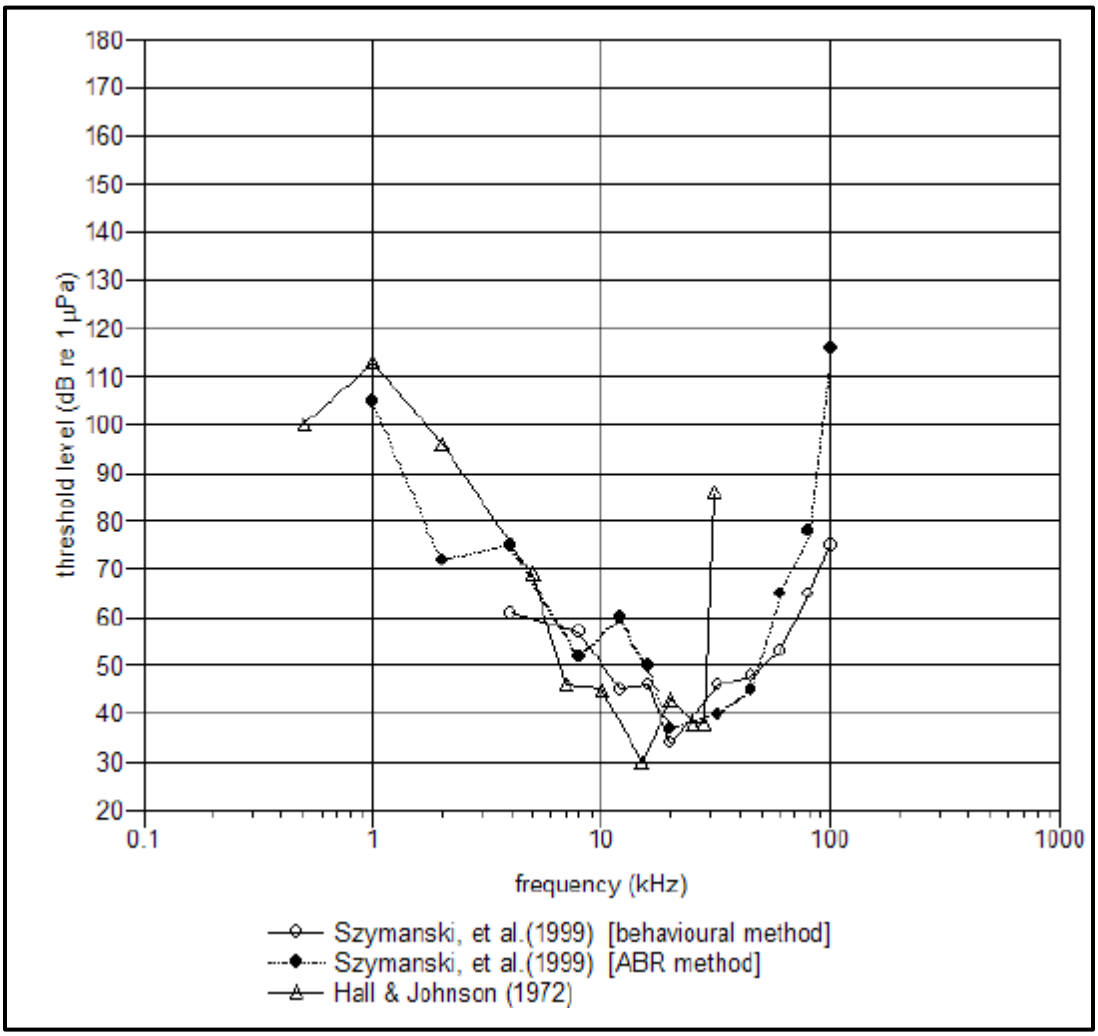

Figure 12. Killer Whale In-water Audiogram (taken from Nedwell et al. 2004)

5.3 Harbor Porpoise

Harbor porpoise stocks in Alaska are divided into three stocks: the Bering Sea stock, the Southeast Alaska stock, and the Gulf of Alaska stock. The Gulf of Alaska stock is currently estimated at 25,987 individuals (Allen and Angliss 2013). A recent estimated density of animals in Cook Inlet is 7.2 per 1,000 km^2 (386 mi^2) (Dahlheim et al. 2000) indicating that only a small number use Cook Inlet. Harbor porpoise have been reported in lower Cook Inlet from Cape Douglas to the West Foreland, Kachemak Bay, and offshore (Rugh et al. 2005a). Small numbers of harbor porpoises have been consistently reported in the upper Cook Inlet between April and October, except for a recent survey that recorded higher numbers than typical (Prevel Ramos et al. 2008). Highest monthly counts include 17 harbor porpoises reported for spring through fall 2006 by Prevel Ramos et al. (2008), 14 for spring of 2007 by Brueggeman et al. (2007a), 12 for fall of 2007 by Brueggeman et al. (2008), and 129 for spring through fall in 2007 by Prevel Ramos et al. (2008) between

Granite Point and the Susitna River during 2006 and 2007; the reason for the recent spike in numbers (129) of harbor porpoises in the upper Cook Inlet is unclear and quite disparate with results of past surveys, suggesting it may be an anomaly. The spike occurred in July, which was followed by sightings of 79 harbor porpoise in August, 78 in September, and 59 in October in 2007. The number of porpoises counted more than once was unknown indicating that the actual numbers are likely smaller than reported.

Recent passive acoustic research in Cook Inlet by ADF&G and National Marine Mammal Laboratory (NMML) have indicated that harbor porpoises occur more frequently than expected, particularly in the West Foreland area in the spring (NMML 2011, personal communication), although overall numbers are still unknown at this time.

The harbor porpoise has the highest upper-frequency limit of all odontocetes investigated. Kastelein et al. (2002) found that the range of best hearing was from 16 to 140 kHz, with a reduced sensitivity around 64 kHz. Maximum sensitivity (about 33 dB re 1 µPa) occurred between 100 and 140 kHz. This maximum sensitivity range corresponds with the peak frequency of echolocation pulses produced by harbor porpoises (120-130 kHz). Figure 13 is an audiogram for the harbor porpoise (taken from Nedwell et al. 2004).

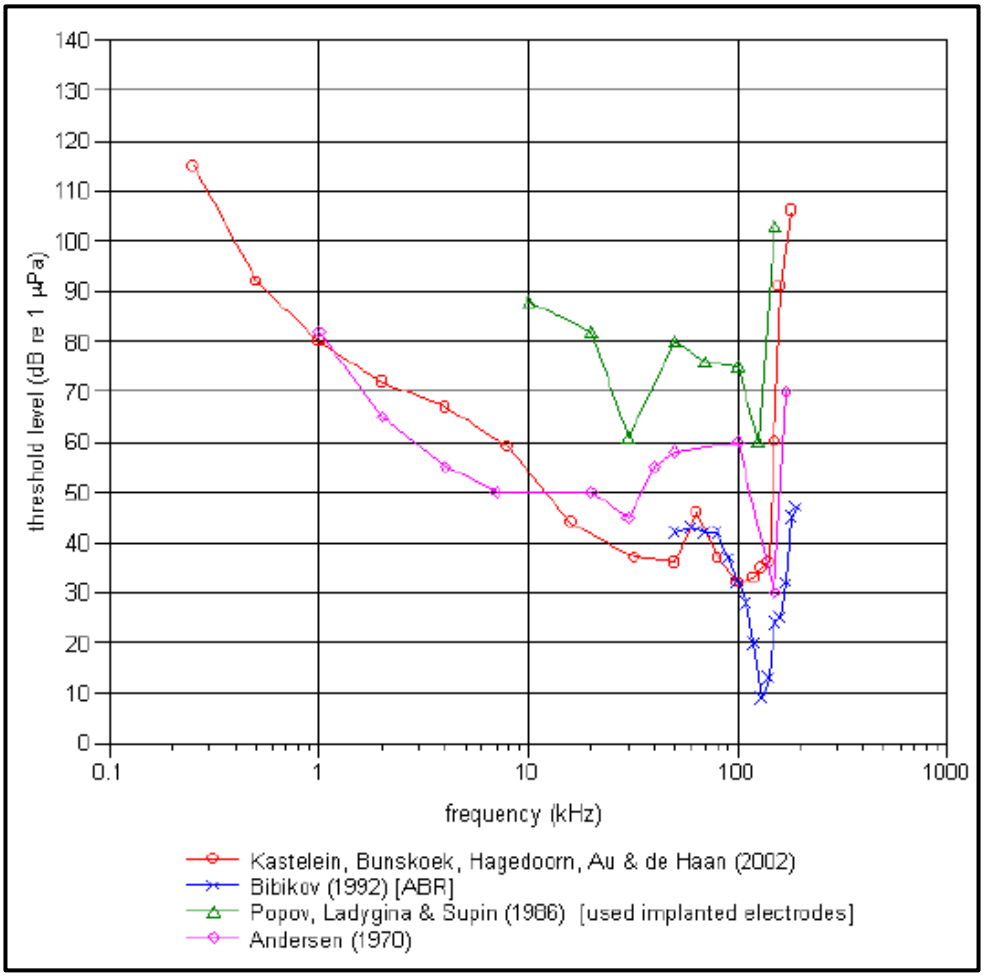

Figure 13. Harbor Porpoise In-water Audiogram (taken from Nedwell et al. 2004)

5.4 Beluga Whale

Beluga whales appear seasonally throughout much of Alaska, except in the Southeast region and the Aleutian Islands. Five stocks are recognized in Alaska: Beaufort Sea stock, eastern Chukchi Sea stock, eastern Bering Sea stock, Bristol Bay stock, and Cook Inlet stock (Allen and Angliss 2010). The Cook Inlet stock is the most isolated of the five stocks, as it is separated from the others by the Alaska Peninsula and resides year round in Cook Inlet (Laidre et al. 2000). Only the Cook Inlet stock inhabits the project area.

5.4.1 Population

Cook Inlet beluga whales may have numbered fewer than several thousand animals but there were no systematic population estimates prior to 1994. Although ADF&G conducted a survey in August 1979, it did not include all of upper Cook Inlet, the area where almost all beluga whales are currently found during summer. However, it is the most complete survey of Cook Inlet prior to 1994 and incorporated a correction factor for beluga whales missed during the survey. Therefore, the ADF&G summary (Calkins 1989) provides the best available estimate for the historical beluga whale abundance in Cook Inlet. For management purposes, NMFS has adopted 1,300 beluga whales as the numerical value for the carrying capacity to be used in Cook Inlet (65 FR 34590).

NMFS began comprehensive, systematic aerial surveys on beluga whales in Cook Inlet in 1994. Unlike previous efforts, these surveys included the upper, middle, and lower inlet. These surveys documented a decline in abundance of nearly 50 percent between 1994 and 1998, from an estimate of 653 to 347 whales (Rugh et al. 2000). In response to this decline, NMFS initiated a status review on the Cook Inlet beluga whale stock pursuant to the MMPA and the ESA in 1998 (63 FR 64228). The annual abundance surveys conducted each June since 1999 provide the following abundance estimates: 367 beluga whales in 1999, 435 beluga whales in 2000, 386 beluga whales in 2001, 313 beluga whales in 2002, 357 beluga whales in 2003, 366 beluga whales in 2004, 278 beluga whales in 2005, 305 beluga whales in 2006, 375 beluga whales in 2007; 321 beluga whales in 2009; 340 beluga whales in 2010; 284 belugas in 2011; and 312 belugas in 2012 (Hobbs et al. 2000; Rugh et al. 2003, 2004a, 2004b, 2005a, 2005b, 2005c, 2006, 2007; Hobbs et al. 2011; Shelden et al. 2012).

These results show the population is not growing and is exhibiting a decline of 1.1 percent per year (Hobbs et al. 2011). The Cook Inlet beluga whale population has been designated as depleted under the MMPA (65 FR 34590). This designation is because the current minimum population estimate (283 – Allen and Angliss 2013) places it at about 36 percent of the Optimum Sustainable Population (OSP) of 780 whales (60 percent of the estimated carrying capacity of 1,300 whales). The estimate has remained below half of the OSP, which is the threshold NMFS is required to use to designate the population as depleted under the MMPA (Angliss and Outlaw 2008).

In 1999, NMFS received petitions to list the Cook Inlet beluga whale stock as an endangered species under the ESA (64 FR 17347). However, NMFS determined that the population decline was due to over harvest by Alaska Native subsistence hunters and, because the Native harvest was regulated in 1999, listing this stock under the ESA was not warranted at the time (65 FR 38778). This decision was upheld in court. In 2006, NMFS announced initiation of another Cook Inlet beluga whale status review under the ESA (71 FR 14836) and received another petition to list the Cook Inlet beluga whale under the ESA (71 FR 44614). NMFS issued a decision on the status review on April 20, 2007 concluding that the Cook Inlet beluga whale is a distinct population segment that is in danger of extinction throughout its range; NMFS issued a proposed rule to list the Cook Inlet beluga whale as an endangered species (72 FR 19821). Public hearings were conducted in July 2007, and the comment period extended to August 3, 2007. On April 22, 2008, NMFS announced that it would delay the decision on the proposed rule until after it had assessed the population status in the summer of 2008, moving the deadline for the decision to October 20, 2008 (73 FR 21578). On October 17, 2008, NMFS

announced that the population is listed as endangered under ESA (73 FR 62919). On April 11, 2011, NMFS announced the two areas of critical habitat (76 FR 20180) comprising 7,800 km^2 (3,013 mi^2) of marine habitat (Figure 14). NMFS also released the Final Conservation Plan (NMFS 2008b).

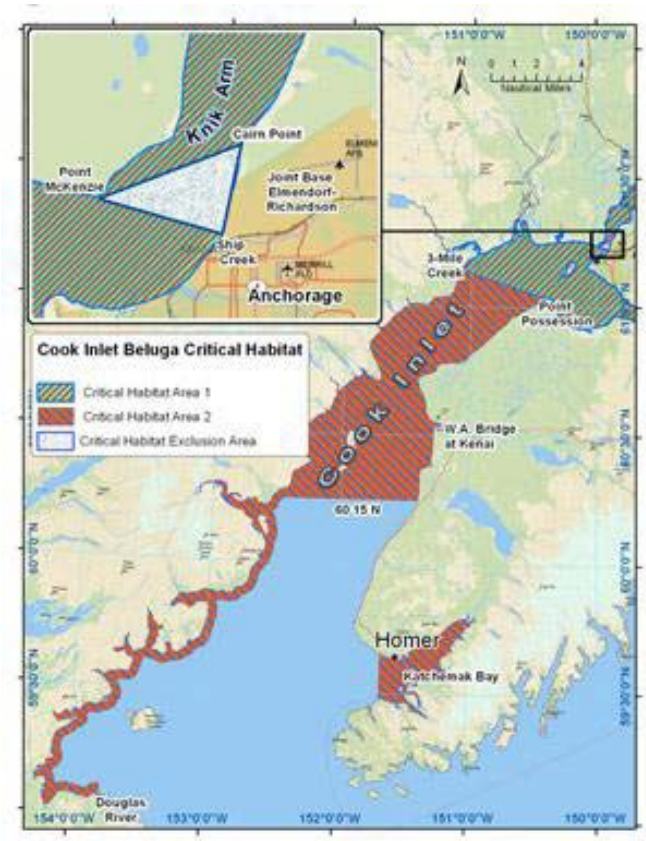

Figure 14. Final Critical Habitat of Cook Inlet Beluga Whales (76 FR 20180, April 11, 2011)

5.4.2 Hearing Abilities

In terms of hearing abilities, beluga whales are one of the most studied odontocetes because they are a common marine mammal in public aquariums around the world. Although they are known to hear a wide range of frequencies, their greatest sensitivity is around 10 to 100 kHz (Richardson et al. 1995), well above sounds produced by most industrial activities (<100 Hz or 0.1 kHz) recorded in Cook Inlet. Average hearing thresholds for captive beluga whales have been measured at 65 and 121 dB re 1 µPa at frequencies of 8 kHz and 125 Hz, respectively (Awbrey et al. 1988). Masked hearing thresholds were measured at approximately 120 dB re 1 µPa for a captive beluga whale at three frequencies between 1.2 and 2.4 kHz (Finneran et al. 2002a; Finneran et al. 2002b). Beluga whales do have some limited hearing ability down to ~35 Hz, where their hearing threshold is about 140 dB re 1 µPa (Richardson et al. 1995). Thresholds for pulsed sounds will be higher, depending on the specific durations and other characteristics of the pulses (Johnson 1991). An audiogram for beluga whales from Nedwell et al. (2004) is provided in Figure 15.

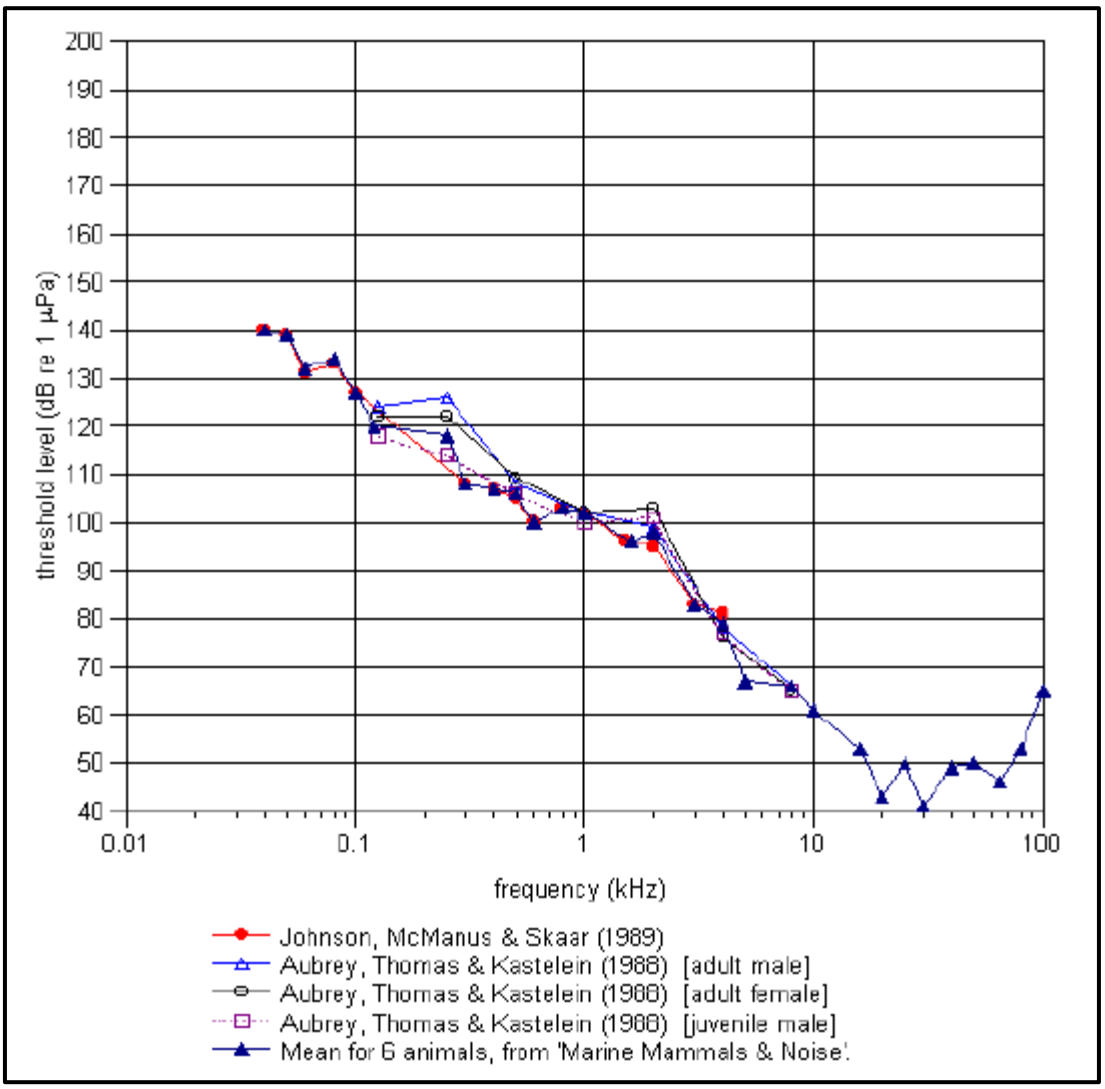

Figure 15. Beluga Whale In-water Audiogram (taken from Nedwell et al. 2004)

5.4.3 Distribution

The Cook Inlet beluga whale has been historically distributed throughout Cook Inlet, with occasional sightings in the Gulf of Alaska (Huntington 2000; Laidre et al. 2000; Rugh et al. 2000). In recent years the range of the Cook Inlet beluga whale has contracted to the upper reaches of Cook Inlet (Rugh et al. 2010).

The following discussion of the distribution of beluga whales in upper Cook Inlet is based upon NMML data including NMFS aerial surveys (Figure 16); NMFS data from satellite-tagged belugas and opportunistic sightings (NMML 2004); baseline studies of beluga whale occurrence in Knik Arm conducted for Knik Arm Bridge and Toll Authority (KABATA) (Funk et al. 2005); Marine Mammal Monitoring at the Port of Anchorage (POA) (Cornick and Kendall 2008a, 2008b; Cornick et al. 2010; Markowitz et al. 2007; Prevel Ramos et al. 2006; Širović and Kendall 2009); baseline studies of beluga whale occurrence in Turnagain Arm conducted in preparation for Seward Highway improvements (Markowitz et al. 2007); marine mammal surveys conducted at Ladd Landing to assess a coal shipping project (Prevel Ramos et al. 2008); marine mammal surveys off Granite Point, the Beluga River, and further down the inlet at North Ninilchik

(Brueggeman et al. 2007a, 2007b, 2008); passive acoustic monitoring of beluga whales in Cook Inlet (Small 2010); and Apache 2D Seismic Test Program (Apache monthly reports).

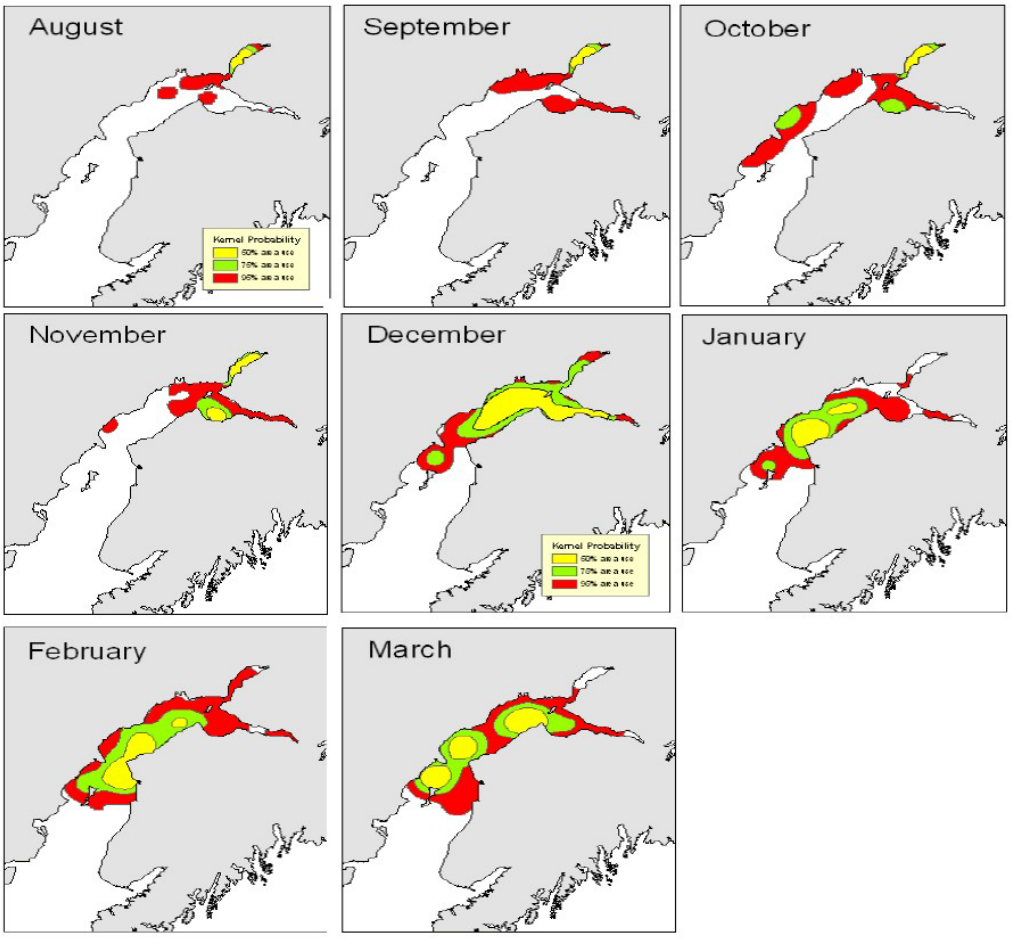

Figure 16. Predicted beluga distribution by month based upon known locations of 14 satellite tagged belugas (predictions derived via kernel probability estimates; Hobbs et al. 2005). Note the large increase in total area use and offshore locations beginning in December and continuing through March. The red area (95 percent probability) encompasses the green (75 percent) and yellow (50 percent) regions. From NMFS 2008b.

5.4.3.1 NMFS Aerial Surveys

Since 1993, NMFS has conducted annual aerial surveys in June or July to document the distribution and abundance of beluga whales in Cook Inlet. In addition, to help establish beluga whale distribution in Cook Inlet throughout the year, aerial surveys were conducted every one to two months between June 2001 and June 2002 (Rugh et al. 2004a). These annual aerial surveys for beluga whales in Cook Inlet have provided systematic coverage of 13 to 33 percent of the entire inlet each June or July since 1994 including a 3 km (1.9 mi) wide strip along the shore and approximately 1,000 km (621 mi) of offshore transects (Rugh et al. 2000, 2005a, 2005b, 2006, 2007). Surveys designed to coincide with known seasonal feeding aggregations (Table 1.3 in Rugh et al. 2000) were generally conducted on two to four days per year in June or July at or near low tide in order to reduce the search area (Rugh et al. 2000). However, from June 2001 to June 2002, surveys were conducted during most months in an effort to assess seasonal variability in beluga whale distribution in Cook Inlet (Rugh et al. 2005a).

The collective survey results show that beluga whales have been consistently found near or in river mouths along the northern shores of upper Cook Inlet (i.e., north of East and West Foreland). In particular, beluga whale groups are seen in the Susitna River Delta, Knik Arm, and along the shores of Chickaloon Bay. Small groups had also been recorded farther south in Kachemak Bay, Redoubt Bay (Big River), and Trading Bay (McArthur River) prior to 1996, but very rarely thereafter. Since the mid-1990s, most (96 to 100 percent) beluga whales in upper Cook Inlet have been concentrated in shallow areas near river mouths, no longer occurring in the central or southern portions of Cook Inlet (Hobbs et al. 2008). Based on these aerial surveys, the concentration of beluga whales in the northernmost portion of Cook Inlet appears to be fairly consistent from June to October (Rugh et al. 2000, 2004a, 2005a, 2006, 2007; Shelden et al. 2008, 2009, 2010; Shelden et al. 2012).

5.4.3.2 NMFS Satellite Tag Data

In 1999, one beluga whale was tagged with a satellite transmitter, and its movements were recorded from June through September of that year. Since 1999, 18 beluga whales in upper Cook Inlet have been captured and fitted with satellite tags to provide information on their movements during late summer, fall, winter, and spring. Hobbs et al. (2005) described: 1) the recorded movements of two beluga whales (tagged in 2000) from September 2000 through January 2001; 2) the recorded movements of seven beluga whales (tagged in 2001) from August 2001 through March 2002; and 3) the recorded movements of eight beluga whales (tagged in 2002) from August 2002 through May 2003.

The concentration of beluga whales in upper Cook Inlet appears to be fairly consistent from June to October based on aerial surveys (Rugh et al. 2000, 2004a, 2005a). Studies for KABATA in 2004 and 2005 confirmed the use of Knik Arm by beluga whales from July to October (Funk et al. 2005). Data from tagged whales (14 tags between July and March 2000 through 2003) show beluga whales use upper Cook Inlet intensively between summer and late autumn (Hobbs et al. 2005). As late as October, beluga whales tagged with satellite transmitters continued to use Knik Arm and Turnagain Arm and Chickaloon Bay, but some ranged into lower Cook Inlet south to Chinitna Bay, Tuxedni Bay, and Trading Bay (McArthur River) in the fall (Hobbs et al. 2005). In November, beluga whales moved between Knik Arm, Turnagain Arm, and Chickaloon Bay, similar to patterns observed in September (Hobbs et al. 2005). By December, beluga whales were distributed throughout the upper to mid-inlet. From January into March, they moved as far south as Kalgin Island and slightly beyond in central offshore waters. Beluga whales also made occasional excursions into Knik Arm and Turnagain Arm in February and March in spite of ice cover greater than 90 percent (Hobbs et al. 2005). While they moved widely around Cook Inlet, there was no indication that tagged whales (Hobbs et al. 2005) had a seasonal migration in and out of Cook Inlet.

5.4.3.3 Opportunistic Sightings

Opportunistic sightings of beluga whales in Cook Inlet have been reported to the NMFS since 1977. Beluga whale sighting reports are maintained in a database by NMML. Their high visibility and distinctive nature make them well-suited for opportunistic sightings along public access areas (e.g., the Seward Highway along Turnagain Arm and the public boat ramp at Ship Creek). Opportunistic sighting reports come from a variety of sources including: NMFS personnel conducting research in Cook Inlet, ADF&G, commercial fishermen, pilots, and the general public. Location data range from precise locations (e.g., GPS-determined latitude and longitude) to approximate distances from major landmarks. In addition to location data, most reports include date, time, approximate number of whales, and notable whale behavior (Rugh et al. 2000, 2004a, 2005a). Since opportunistic data are collected any time, and often multiple times a week, these data often provide an approximation of beluga whale locations and movements in those areas frequented by natural resource agency personnel, fishermen, and others.

Depending upon the season, beluga whales can occur in both offshore and coastal waters. Although they remain in the general Cook Inlet area during the winter, they disperse throughout the upper and mid-inlet areas. Data from NMFS aerial surveys, opportunistic sighting reports, and satellite-tagged beluga whales confirm they are more widely dispersed throughout Cook Inlet during the winter months (November - April), with animals found between Kalgin Island and Point Possession. Based upon monthly surveys (e.g., Rugh et al. 2000), opportunistic sightings, and satellite-tag data, there are generally fewer observations of these whales in the Anchorage and Knik Arm area from November through April (NMML 2004; Rugh et al. 2004a).

During the spring and summer, beluga whales are generally concentrated near the warmer waters of river mouths where prey availability is high and predator occurrence is low (Moore et al. 2000). Most beluga whale calving in Cook Inlet occurs from mid-May to mid-July in the vicinity of the river mouths, although Native hunters have described calving as early as April and as late as August (Huntington 2000).

Beluga whale concentrations in upper Cook Inlet during April and May correspond with eulachon migrations to rivers and streams in the northern portion of upper Cook Inlet (NMFS 2003; Angliss and Outlaw 2005). Data from NMFS aerial surveys, opportunistic sightings, and satellite-tagged beluga whales confirm that they are concentrated along the rivers and nearshore areas of upper Cook Inlet (Susitna River Delta, Knik Arm, and Turnagain Arm) from May through October (NMML 2004; Rugh et al. 2004a). Beluga whales are commonly seen from early July to early October at the mouth of Ship Creek where they feed on salmon and other fish, and also in the vicinity of the Port (e.g., alongside docked ships and within 91m [300 ft] of the docks) (Blackwell and Greene 2002; NMML 2004). Beluga whales have also been observed feeding immediately offshore of the tidelands north of the Port and south of Cairn Point (NMFS 2004).

5.4.3.4 KABATA 2004 - 2005 Baseline Study

To assist in the evaluation of the potential impact of a proposed bridge crossing of Knik Arm north of Cairn Point, KABATA initiated a study to collect baseline environmental data on beluga whale activity and the ecology of Knik Arm. Boat and land-based observations were conducted in Knik Arm from July 2004 through July 2005. Land-based observations were conducted from nine stations along the shore of Knik Arm. The three primary stations were located at Cairn Point, Point Woronzof, and Birchwood. The majority of the beluga whales were observed north of Cairn Point. Temporal use of Knik Arm by beluga whales was related to tide height. During the study period, most beluga whales using Knik Arm stayed in the upper portion of Knik Arm north of Cairn Point. Approximately 90 percent of observations occurred from August through November, and only during this time were whales consistently sighted in Knik Arm. The relatively low number of sightings in Knik Arm throughout the rest of the year suggested the whales were using other portions of Cook Inlet. In addition, relatively few beluga whales were sighted in the spring and early to mid-summer months. Beluga whales predominantly frequented Eagle Bay (mouth of Eagle River), Eklutna, and the stretch of coastline in between, particularly when they were present in greater numbers (Funk et al. 2005).

5.4.3.5 Marine Mammal Monitoring at the Port of Anchorage

To meet the permit requirements for the POA Marine Terminal Redevelopment (MTR) Project, land-based visual surveys have been conducted in Knik Arm near Cairn Point north of the MTR Project since 2005 (Prevel Ramos et al. 2006; Markowitz et al. 2007; Cornick and Kendall 2008a, 2008b; Cornick et al. 2010). The results from these studies are consistent with the results from the NMFS's aerial surveys and KABATA's baseline studies, indicating beluga whales are commonly observed in Knik Arm in late summer through the fall (August through mid-November). The results also

indicate that belugas are most often observed along the eastern shoreline adjacent to the MTR Project.

In addition to land-based surveys, the POA was required to conduct a passive acoustic marine mammal monitoring program adjacent to the MTR Project. The passive acoustic monitoring program was conducted for 20 days in August and September, 2009 (Širović and Kendall 2009). Four moored sonobuoys were deployed in a rhomboid formation at the beginning of each day of monitoring and data were collected in real-time at a land-based observation station. Acoustic monitoring continued for approximately 8-10 hours per day. Beluga whales were detected 14 out of the 20 days of monitoring (6 days in August and 8 days in September), most commonly on the sonobuoys located near the center of Knik Arm, adjacent to the deep channel (Širović and Kendall 2009).

5.4.3.6 Seward Highway Study along Turnagain Arm

Markowitz et al. (2007) documented habitat use and behavior of beluga whales along the Seward Highway in Turnagain Arm from May through November 2006. This study was focused around the high tides when whales regularly traverse the near-shore channels to the mouths of rivers and streams, where they feed on fish. Most of the observations of whales occurred between the end of August and the end of October. No beluga whales were sighted in the study area in May, June, or July. The age composition of all whales observed was 58 percent adults, 17 percent subadults, 8 percent calves, and 17 percent unknown. Most beluga whale observations were in the upper Turnagain Arm, east of Bird Creek. The observation station closest to the Port was at Potter Creek but few beluga whales were sighted in the lower Turnagain Arm section of the project area. About 80 percent of all beluga whale sightings were within 1,100 m (3,600 ft) of shore. About a third of all sightings in September were less than 50 m (164 ft) from shore while two-thirds of all sightings in October were within 50 m (164 ft) of shore. Most beluga whale movements were with the tide: eastward into the upper Turnagain Arm on the rising tide and westward out of Turnagain Arm on the falling tide. The few observations of beluga whales in the lower Turnagain Arm were close to the mid-tide, indicating that beluga whales may use these areas closer to the low tide rather than the high tide pattern observed in the upper Turnagain Arm.

5.4.3.7 Marine Mammal Surveys at Ladd Landing

Prevel Ramos et al. (2008) conducted surveys near Ladd Landing on the north side of upper Cook Inlet between Tyonek and the Beluga River from April through October in 2006 and July through October 2007. The results from 2006 indicated that July through October had the least amount of beluga whale activity in the project area. Relatively few beluga whales were observed during the 2007 surveys near Ladd Landing, with three groups of one or two whales observed in July, two groups of three whales in September, and two groups averaging seven whales in October. Two groups of 20 whales were observed near the Susitna Flats in August. Some of these whales may have been recorded more than once. Most of the whales sighted were close to shore. Of the whales seen in 2006 and 2007, 60 to 75 percent were white, 16 to 18 percent were gray, and the color of 10 to 22 percent was unknown.

5.4.3.8 Marine Mammal Surveys at Granite Point, Beluga River, and North Ninilchik

Brueggeman et al. (2007a, 2007b, 2008) conducted vessel and aerial surveys in 2007 near the Beluga River between April 1 and May 15, Granite Point between September 29 and October 21, and North Ninilchik between October 25 and November 7. They recorded 148 to 162 belugas near the Beluga River with most observed during early May, 35 belugas near Granite Point with most observed in

early to mid-October, and no belugas recorded off North Ninilchik. Most of the whales were observed near the shore. In addition, the movements indicated they were transiting to the head of the upper inlet. Small percentages of calves and yearlings were recorded with adults during the spring and early fall surveys. No belugas were observed at North Ninilchik which is considered marginal habitat because of a lack of habitat structure (bays, inlets, etc.) combined with easy public access, typical of the eastern shore of the inlet.

5.4.3.9 Passive Acoustic Monitoring of Cook Inlet Beluga Whales (ADF&G)

An ongoing study by Small (2010) deployed acoustic recording devices throughout Cook Inlet in May 2009. The acoustic recording devices were deployed in Knik Arm (three in Eagle Bay and one near Cairn Point), near Fire Island, near Beluga and Kenai Rivers, in Trading Bay, Tuxedni Bay and Kachemak Bay. Results from June - October 2009 (summer, fall) identify beluga whales at the following locations: Knik Arm, Fire Island, Beluga and Kenai Rivers and Trading Bay. Results from October 2009 - May 2010 (fall, winter, spring) identify beluga whales in the same areas. These results indicate beluga whales are generally distributed throughout the middle to upper Cook Inlet.

5.4.3.10 2011 Apache 2D Seismic Test Program

Apache conducted a two-dimensional (2D) seismic test program along the west coast of Redoubt Bay, lower Cook Inlet from March 17 - April 2, 2011. The objective of the Cook Inlet 2D Seismic Test Program was to evaluate new nodal technology seismic recording equipment for operations in this environment and test seismic acquisition parameters in order to finalize the design for a planned 3D seismic program in Cook Inlet. The test had an onshore, transition zone and offshore component that included the use of input/output sleeve airguns in four different configurations of arrays (880, 1,200, 1,760, and 2,400 cui). The seismic operation was active 24 hours per day, although the in-water airguns were only active during the daylight slack tide periods. During the Cook Inlet 2D Seismic Test Program, beluga whales were sighted on three different occasions: once from the vessels and twice during aerial observations. A total of 33 beluga whales were sighted during the survey. On March 27, a group of 7 beluga whales were observed traveling near the West Foreland and a group of 25 belugas were observed milling near Drift River. On March 28, a lone individual was observed traveling near Drift River.

5.4.3.11 2011 and 2012 Apache Sound Source Verification Surveys

Apache also conducted a sound source verification survey (SSV) on September 17-18, 2011 to characterize underwater received sound levels resulting from land-based explosives (Appendix A). The survey took place in Trading Bay near the town of Shirleyville and extended 6.4 km (4 mi) along the northwest side of Nikolai Creek. There were no sightings of beluga whales before, during or after the survey.

Apache conducted an SSV on May 7-8, 2012 to verify underwater received sound levels from in-water airguns (Appendix B) near the town of Shirleyville in Trading Bay. On May 7, two beluga whales were observed milling, a group of three adults and three calves were observed foraging, and three adults were observed traveling near Drift River. On May 8, two adults were observed 300 m (984 ft) from shore near Tyonek dock, three adults and one juvenile were observed near Drift River.

5.4.3.12 2012 Apache 3D Seismic Program

Apache conducted a 3D seismic program with a marine mammal monitoring and mitigation program between May 6 and September 30, 2012. Seismic surveys were conducted in nearshore and offshore waters during slack tides from multiple vessels. Marine mammal monitoring was conducted from

vessels, land platforms, and helicopters or small fixed wing aircraft. PSOs monitored from the seismic and mitigation vessels and land during all day time seismic operations. Aerial overflights were conducted one to two times daily of the project area and surrounding coastline, including the major river mouths to monitor for larger congregations of marine mammals in and around the project vicinity. Passive acoustic monitoring took place from the mitigation vessel during all night time seismic operations and most day time seismic operations.

Six identified species and three unidentified species of marine mammals were observed from the vessels, land, and aerial platforms during the program. The species observed include Cook Inlet beluga whale, harbor seal, harbor porpoise, Steller sea lion, gray whale (*Eschrichtius robustus*), and California sea lion (*Zalophus californianus*). PSOs also observed unidentified species including a large cetacean, pinniped and marine mammal. The gray whale and California sea lion were not included in the IHA, so mitigation measures implemented for these species were implemented at the strictest level.

There were a total of 882 sightings and an estimated 5,232 individuals. Harbor seals were the most frequently observed marine mammals at 563 sightings (~3,471 estimated individuals), followed by beluga whales with 151 sightings (~1,463 estimated individuals), harbor porpoises with 137 sightings (~190 estimated individuals), and gray whales with 9 sightings (9 estimated individuals). Steller sea lions were observed on three separate occasions (~4 estimated individuals) and California sea lions were observed once (~2 estimated individuals).

5.4.4 Feeding

Beluga whales are opportunistic feeders, foraging at the mouths of rivers and along the benthos. In Cook Inlet, the primary foraging locations for beluga whales are the Susitna River Delta (the Big and Little Susitna Rivers), Eagle Bay, Eklutna River, Ivan Slough, Theodore River, Lewis River, and Chickaloon Bay and River (NMFS 2008a). Cook Inlet belugas feed on a wide variety of prey species, particularly those that are seasonally abundant. Hobbs et al. (2008) presents the most current analysis of stomach contents derived from stranded or harvested belugas in Cook Inlet. This analysis is continuing and provides information on prey availability and prey preferences of Cook Inlet belugas which is summarized below.

In spring, the preferred prey species are eulachon and cod. Other fish species found in the stomachs of belugas may be from secondary ingestion by cods that feed on polychaetes, shrimp, amphipods, mysids, as well as other fish (e.g., walleye pollock and flatfish), and invertebrates.

From late spring and throughout summer most beluga stomachs sampled contained Pacific salmon corresponding to the timing of fish runs in the area. Anadromous smolt and adult fish concentrate at river mouths and adjacent intertidal mudflats (Calkins 1989). Five Pacific salmon species: Chinook, pink, coho, sockeye, and chum spawn in rivers throughout Cook Inlet (Moulton 1997; Moore et al. 2000). Calkins (1989) recovered 13 salmon tags in the stomach of an adult beluga found dead in Turnagain Arm. Beluga hunters in Cook Inlet reported one whale having 19 adult Chinook salmon in its stomach (Huntington 2000). Salmon, overall, represent the highest percent frequency of occurrence of the prey species in Cook Inlet beluga stomachs. This suggests that their spring feeding in upper Cook Inlet, principally on fat-rich fish such as salmon and eulachon, is very important to the energetics of these animals.

In the fall, as anadromous fish runs begin to decline, belugas return to consume fish species (cod and bottom fish) found in nearshore bays and estuaries. Bottom fish include Pacific staghorn sculpin, starry flounder, and yellowfin sole. Stomach samples from Cook Inlet belugas are not available for winter months (December through March), although dive data from belugas tagged with satellite transmitters suggest whales feed in deeper waters during winter (Hobbs et al. 2005), possibly on such prey species as flatfish, cod, sculpin, and pollock.

5.5 Steller Sea Lion

Steller sea lion habitat extends around the North Pacific Ocean rim from northern Japan, the Kuril Islands and Okhotsk Sea, through the Aleutian Islands and Bering Sea, along Alaska's southern coast, and south to California (NMFS 2008c). NMFS reclassified Steller sea lions as two distinct population segments (DPS) under the ESA based on genetic studies and phylogeographical analyses from across the sea lions range (62 FR 24345). The eastern DPS includes sea lions born on rookeries from California north through Southeast Alaska; the western DPS includes those animals born on rookeries from Prince William Sound westward (NMFS 2008c). Steller sea lions occur in Cook Inlet but south of Anchor Point around the offshore islands and along the west coast of the upper Cook Inlet in the bays (Chinitna Bay, Iniskin Bay, etc.) (Rugh et al. 2005a). Portions of the southern reaches of the lower inlet are designated as critical habitat, including a 20-nautical mile buffer around all major haul out sites and rookeries. Rookeries and haulout sites in lower Cook Inlet include those near the mouth of the inlet, which are far south of the project area. It is unlikely that any Steller sea lion would be in the project area during operations.

5.5.1 Hearing Abilities

Steller sea lions have similar hearing thresholds in-air and underwater to other otariids. In-air hearing range from 0.250-30 kHz, with a region of best hearing sensitivity from 5-14.1 kHz (Muslow and Reichmuth 2010). The underwater audiogram shows the typical mammalian U-shape. The range of best hearing was from 1-16 kHz. Higher hearing thresholds, indicating poorer sensitivity, were observed for signals below 16 kHz and above 25 kHz (Kastelein et al. 2005).

6.0 Requested Type of Incidental Taking Authorization

The type of incidental taking authorization that is being requested and the method of incidental taking.

Apache requests an IHA from NMFS for the incidental take by harassment (Level B as defined in 50 CFR 216.3) of a small number of marine mammals during its planned third year of 3D seismic survey operations in Cook Inlet. The operations outlined in Sections 2 and 3 have the potential to result in takes by harassment of marine mammals by acoustic disturbance during seismic operations. The effects will depend on the species and the distance and received level of the sound (Section 8). Temporary disturbance or localized displacement reactions are most likely to occur. With implementation of the mitigation and monitoring measures described in Sections 12 and 14, no takes by injury or mortality (Level A) are anticipated, and takes by disturbance (Level B) are expected to be minimized.

7.0 Number of Incidental Takes by Activities

By age, sex, and reproductive condition, the number of marine mammals [by species] that may be taken by each type of taking, and the number of times such takings by each type of taking are likely to occur.

The proposed seismic survey operations outlined in Sections 2 and 3 have the potential to temporarily disturb or displace small numbers of marine mammals in Cook Inlet. These potential effects, as summarized in Section 8, will not exceed MMPA Level B harassment, as defined by 30 CFR 213.6. The mitigation measures to be implemented during the survey are based on Level B harassment criteria using the 160 dB re 1 µPa rms threshold defined below. No take by injury or death is anticipated with implementation of the mitigation and monitoring measures. The following sections provide information on the applicable noise criteria and a description of the methods used to calculate numbers of marine mammals that may be potentially encountered during the seismic program.

7.1 Applicable Noise Criteria

Under the MMPA, NMFS has defined levels of harassment for marine mammals. Level A harassment is defined as "…any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." Level B harassment is defined as "…any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

Since 1997, NMFS has been using generic sound exposure thresholds to determine when an activity in the ocean that produces sound might result in impacts to a marine mammal such that a take by harassment might occur (70 FR 1871). NMFS is developing new science-based thresholds to improve and replace the current generic exposure level thresholds, but the criteria have not been finalized (Southall et al. 2007). The current Level A (injury) threshold for impulse noise is 180 dB re 1 µPa rms for cetaceans (whales, dolphins, and porpoises) and 190 dB re 1 µPa rms for pinnipeds (seals, sea lions). The current Level B (disturbance) threshold for impulse noise is 160 dB re 1 µPa rms for cetaceans and pinnipeds.

7.2 Calculation of 24-Hour Acoustic Footprints

A computer modeling study was performed to predict 24-hour acoustic footprints of airgun arrays for Apache's planned Cook Inlet seismic surveys. The modeling study report is attached as Appendix C. The modeled results account for the operation over a 24-hour period, including slack tide-only operations and longest seismic source line. In late April/early May 2012, SSV was conducted of the various airgun configurations at different water depths. The results of the SSV (Appendix D) indicated the largest 160 dB re 1 µPa (rms) ensonified area for the three different aspects of a 2400 in^3 airgun array was 9.50 km. The safety zones derived from the SSV results will be used for mitigation and monitoring (discussed in Section 12 and 14).

Apache also expects that this documentation will reduce the 10 mile exclusion zone around the Susitna Delta to 9.5 km (Figure 2); as allowed in the February 14, 2013 Biological Opinion, page 110. In February 2013, NMFS established an exclusion zone for airgun activities within 16 km (10 mi) of the mean high waterline of the Susitna Delta ("Susitna Delta" being defined as shoreline between the mouth of the Beluga River to the mouth of the Little Susitna River). Airgun activities within this exclusion zone are prohibited from mid-April to mid-October. This exclusion was contingent on (as stated in the February 14, 2013 Biological Opinion), '*Once results of the sound source verification study in the upper Cook Inlet are available, Apache will contact NMFS AKR* [Alaska Region] *to determine if a new minimum setback distance is required for this area during*

this time' (NMFS 2013a). The results of the new SSV in upper Cook Inlet indicate a distance of 9.50 km is a more appropriate setback distance to protect beluga whales.

The modeled study considered seismic survey activities at nearshore locations at the sides of Cook Inlet having sloping bottoms and in the Inlet's main channel where depth is relatively constant. The nearshore locations were sub-divided into three depth intervals of 5-21 m (16-69 ft), 21-38 m (69-125 ft), and 38-54 m (125-177 ft). The channel scenario had constant water depth 80 m (262 ft) to correspond approximately with the mean channel depth over the region of Cook Inlet that Apache plans to survey. The nearshore survey depth interval subdivisions are based on the zones that can be surveyed in 24-hour periods based on anticipated nominal survey line length: 16.1 km (10 mi), and survey line spacing: 503 m (1,650 ft). Adjacent lines will be surveyed sequentially. Apache estimates that it can complete 12-14 survey lines per day based on a normal survey vessel speed of 3.5 knots (4 mph). The depth intervals listed above each correspond with 14 adjacent parallel lines based on the rate of depth increase with distance from shore. The anticipated survey effort included in the acoustic model was provided to JASCO (acoustic contractor) for the first IHA and is considered a worst-case effort. The modeled effort does not match the actual anticipated effort discussed in Section 2, but because the modeled effort is greater than the actual, this is considered a worst-case estimate. The different depth intervals were considered separately because the size of the airgun array sound footprint varies with water depth.

The largest possible airgun array configuration of 2,400 cui was considered by the modeling study to provide conservative estimates of noise footprints; smaller arrays may be used and those would produce smaller footprints.

The nearshore modeling scenarios were examined by placing the source at three distances offshore corresponding with water depths: 5, 25, and 45 m (16, 82, and 148 ft). For each source position, the model predicted distances to the 160 dB re 1 µPa rms threshold in multiple directions. These distances were subsequently interpolated to predict threshold distances for survey source positions at all depths between 5 m (16 ft) and 54 m (177 ft) depth. The deep channel survey scenario, with constant water depth of 80 m (262 ft), was modeled to predict the distances in the endfire and broadside directions relative to the array that sound levels attenuated to 160 dB re 1 µPa rms.

The 24-hour composite acoustic footprints were calculated from the footprints of the individual survey lines. Each survey line footprint was estimated using a rectangle that encompassed the 160 dB broadside (inshore and offshore directions) and endfire (along-shore) extents for all airgun pulses on that line. The union of the 14 survey line footprints created the 24-hour composite acoustic footprint. The union of the single line footprints is smaller than their sum because of overlap.

7.2.1 Nearshore Survey Results

The distances to the 160, 180, and 190 dB re 1 µPa rms sound level thresholds for the nearshore survey locations are given in Table 2. Distances correspond to the three transects modeled at each site in the onshore, offshore, and parallel to shore directions. To estimate take, Apache used the most conservative (largest) value from each category in Table 2. The 160 dB re 1 µPa footprints for one day of nearshore surveying in shallow, mid-depth, and deep water are shown in Figure 17; the corresponding areas of the footprints are listed in Table 3.

Table 2. Distances to Sound Level Thresholds for the Nearshore Surveys

Sound Level Threshold (dB re 1 µPa)	Water Depth at Source Location (m)	Distance in the Onshore Direction (km)	Distance in the Offshore Direction (km)	Distance in the Parallel to Shore Direction (km)
160	5	1.03	4.73	2.22
	25	5.69	7.77	9.5
	45	6.75	5.95	9.15
180	5	0.46	0.6	0.54
	25	1.06	1.07	1.42
	45	0.7	0.83	0.89
190	5	0.28	0.33	0.33
	25	0.35	0.36	0.44
	45	0.1	0.1	0.51

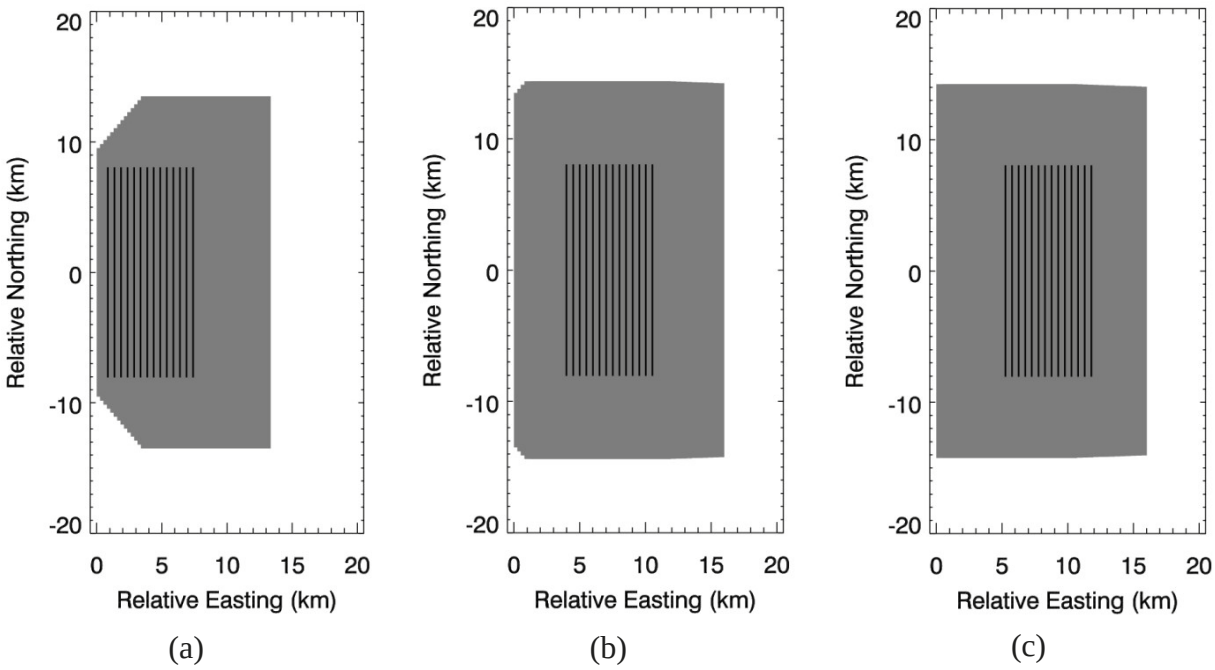

Figure 17. Daily footprints for (a) shallow, (b) mid-depth, and (c) deep water nearshore surveys. The ensonified areas are shown in gray and survey lines are shown in black.

Table 3. Areas Ensonified to 160 dB re 1 µPa for Nearshore Surveys in 24 Hours

Nearshore Survey Depth Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 µPa (km^2)
Shallow	5-21	462
Mid-depth	21-38	629
Deep	38-54	623

7.2.2 Channel Survey Results

The distances to the 160, 180, and 190 dB re 1 µPa rms sound level thresholds for the channel surveys are shown below in Table 4. Distances correspond to the broadside and endfire directions. The 160 dB re 1 µPa rms footprint for 24 hours of seismic survey in the inlet channel is shown in Figure 18; the corresponding area of the footprint is 517 km^2.

Table 4. Distances to Sound Level Thresholds for the Channel Surveys

Sound Level Threshold (dB re 1 µPa)	Water Depth at Source Location (m)	Distance in the Broadside Direction (km)	Distance in the Endfire Direction (km)
160	80	5.14	7.33
180	80	0.91	0.98
190	80	0.15	0.18

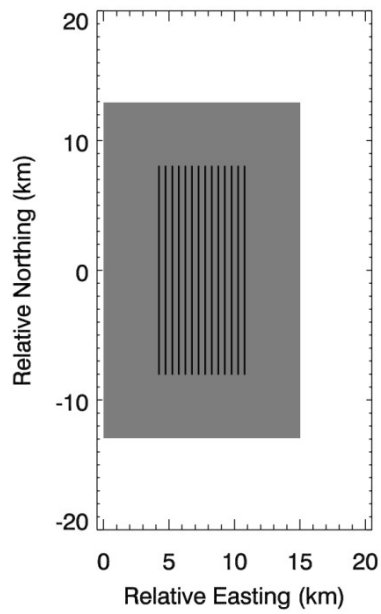

Figure 18. Daily footprint for channel surveys. The ensonified area is shown in gray and the survey lines are shown in black.

7.2.3 Positioning pinger

As described in Section 2.2.2, the maximum source level of the pinger is 188 dB re µPa at 1 m rms (at 33 - 55 kHz). Assuming a simple spreading loss of 20 log R (where R is radius) with a source level of 188 dB, the distance to the 190, 180, and 160 dB isopleths would be 1, 3, and 25 m (3.28, 9.8, and 82 ft), respectively. This spreading loss is appropriate for high-frequency pulsed systems. The reason is that the multipaths (direct path, surface reflection, bottom reflection, etc.) of short duration pulses arrive at the receivers spaced in time. The rms level therefore should be computed for the strength of the strongest multipath, which will be the direct path. The use of 20 log R is fully appropriate because this path does not interact with surface or bottom (otherwise it would have an even higher coefficient than 20).

7.3 Estimates of Marine Mammal Density

During the intergovernmental consultation process for Apache's second IHA application, NMFS consulted with the NMML for an independent review of the marine mammal density in Cook Inlet. The NMML responded with a predictive beluga habitat model (Goetz et al. 2012a). For consistency purposes, the NMML beluga model was used to predict beluga takes for this IHA application, and other marine mammal takes were predicted using traditional techniques described below.

To develop NMML's estimated densities of belugas, Goetz et al. (2012a) developed a model based on aerial survey data, depth soundings, coastal substrate type, environmental sensitivity index, anthropogenic disturbance, and anadromous fish streams to predict beluga densities throughout Cook Inlet. The result of this work is a beluga density map of Cook Inlet, which easily sums the belugas predicted within a given geographic area.

Estimated densities of other marine mammals in the proposed project area were estimated from the annual aerial surveys conducted by NMFS for Cook Inlet beluga whale between 2000 and 2012 in June (Rugh et al. 2000, 2001, 2002, 2003, 2004b, 2005b, 2006, 2007; Shelden et al. 2008, 2009, 2010, 2012; Hobbs et al. 2011). These surveys were flown in June to collect abundance data of beluga whales, but sightings of other marine mammals are also reported. Although these data are only collected in one month each year, these surveys provide the best available relatively long term data set for sighting information in the proposed project area. The general trend in marine mammal sighting is that beluga whales and harbor seals are seen most frequently in upper Cook Inlet, with higher concentrations of harbor seals near haul out sites on Kalgin Island and of beluga whales near river mouths, particularly the Susitna River. The other marine mammals of interest for this IHA (killer whales, harbor porpoises, Steller sea lions) are observed infrequently in upper Cook Inlet and more commonly in lower Cook Inlet. In addition, these densities are calculated based on a relatively large area that was surveyed, much larger than the proposed seismic area. Furthermore, these annual surveys are conducted only in June (numbers from August surveys were not used because the area surveyed was not provided), so it does not account for seasonal variations in distribution or habitat use of each species. Therefore, the use of these data to estimate density is extremely conservative and likely provides much higher estimate of the probability of observing these animals in the project area.

Table 5 provides a summary of the results of each annual survey conducted in June from 2000 to 2012. This table has some corrections from the Table 5 of Apache's second IHA application process, resulting in slight changes to subsequent calculations. The total number of individuals sighted for each survey by year is reported, as well as total hours for the entire survey and total area surveyed. To estimate density of marine mammals, total number of individuals (other species) observed for the entire survey area by year (surveys usually last several days) was divided by the total number of hours for each aerial survey by the approximate total area surveyed for each year (density = individuals/hour/km^2). As noted previously, the total number of animals observed for the entire survey includes both lower and upper Cook Inlet, so the total number reported and used to calculate density is higher than the number of marine mammals anticipated to be observed in the project area. In particular, the total number of harbor seals observed on several surveys is very high due to several large haul outs in lower and middle Cook Inlet.

Table 5. Sightings of Marine Mammals from NMFS Annual Aerial Surveys.

Location	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Other Species*													
Harbor seal	**1800**	**1485**	**1606**	**974**	**956**	**1087**	**1798**	**1474**	**2037**	**1415**	**1156**	**1811**	**1812**
Harbor porpoise	**29**	**25**	**0**	**0**	**100**	**2**	**0**	**4**	**6**	**86**	**10**	**30**	**11**
Killer whale	**0**	**15**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**33**	**0**	**9**
Steller sea lion	**10**	**35**	**54**	**77**	**1**	**104**	**83**	**0**	**75**	**39**	**1**	**100**	**65**
Survey Details													
Number of total survey hours (hrs)	43	55	45	61	45	54.5	58.4	47.2	47.7	39.4	48.4	47	53
Total area surveyed (km^2)	6500	5200	5244	5100	6000	5500	6723	5255	7172	5766	6120	6790	6219
Density Estimates (no. animals / no. survey hrs / km^2 surveyed)													
Harbor seal**	0.00644	0.00519	**0.00681**	0.00313	0.00354	0.00363	0.00458	0.00594	0.00595	0.00623	0.00390	0.00567	0.005497
Harbor porpoise**	0.00010	0.00009	0.00000	0.00000	0.00037	0.00001	0.00000	0.00002	0.00002	**0.00038**	0.00003	0.00009	0.000033
Killer whale**	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	**0.00011**	0.00000	0.000027
Steller sea lion**	0.00004	0.00012	0.00023	0.00025	0.00000	**0.00035**	0.00021	0.00000	0.00022	0.00017	0.00000	0.00031	0.000197

Bold numbers indicate highest counts per year per species and used in density estimates.

* Counts indicate total observed per year

** Total number observed animals per year were used to estimate density

Table 6. Summary of Density Estimates of Marine Mammals

	Density	
Species	**Maximum**	**Average**
Harbor seal*	0.00681	0.00512
Harbor porpoise*	0.00038	0.00009
Killer whale*	0.00011	0.00001
Steller sea lion*	0.00035	0.00016

Density = no. animals / survey effort (hrs) / area surveyed (km^2)

* Total number observed animals per year were used to estimate density on Table 5.

7.4 Calculation of Takes

In October 2012, plaintiffs requested motion for a summary judgment from the U.S. District Court for the District of Alaska, challenging NMFS methods for estimating takes issued under the first Apache IHA (effective April 30, 2012 – April 30, 2013). The court concluded that NMFS take calculations were erroneous because they combined corrected population abundance figures with uncorrected (raw) survey density estimates (USDC 2013). The raw survey density estimates are derived from sightings during monthly aerial surveys and provide the best long-term data for sightings in the project area, but they do not correct for missed animals or seasonal variations in distribution (NMFS 2013b).

During the second Apache IHA application process a correction factor was applied to the sightings data, which prompted NMFS to seek a review from the National Marine Mammal Laboratory (NMML). NMML developed and applied a predictive habitat model (Goetz et al. 2012a) of beluga density estimates to Apache's 2013 survey area and found that a total of 21.5 belugas could be taken by Level B harassment, which was lower than Apache's original estimates (NMFS 2013b).

As a result of discussions with NMFS, Apache has used the NMML model (Goetz et al. 2012a) for the calculation of takes in this IHA. Apache has established two zones (Zone 1 and Zone 2) and proposes to conduct seismic surveys within all, or part of these zones; to be determined as weather, ice, and priorities dictate.

Using the NMML model, Apache summed the expected number of beluga takes in each zone (including the 160 dB buffer), the total area of each zone (including the 160 dB buffer), and calculated the average take density of beluga whale for each zone (Table 7). At this time the 160 dB buffer is 9.50 km, if Apache conducts another SSV which has a different 160 dB buffer, the new buffer will be used with the same methodology outlined below.

Table 7: Expected Belugas Takes, Total Area of Zone, and Average Take Density

	Expected Beluga Takes from NMML model (including the 160 dB buffer)	Total Area of Zone (km^2) (including the 160 dB buffer)	Average Take Density (d_x)
Zone 1	28	1319	$d_1 = 0.0212$

Zone 2	29	5160	d_2 = 0.0056

To maintain fewer than 30 takes, Apache will limit surveying in the zones to satisfy the following equation:

Equation 1:

* d_x = ——————————————————————

* A_x = Actual Area Surveyed (km^2) including 160 dB buffer in Zone X

This formula will allow Apache to maintain less than 30 calculated beluga whale takes as calculated under the NMML model. The formula also allows Apache to have flexibility to prioritize survey locations in response to local weather, ice, and operational constraints. Apache may choose to survey portions of a zone or a zone in its entirety. The use of this formula will ensure the Apache seismic program, including the 160 dB buffer, stays below 30 calculated beluga takes.

Apache proposes to initially limit actual survey areas, including 160 dB buffer zones, to satisfy Equation 1. Apache will operate in Zone 1 or Zone 2 until the 30 calculated takes of belugas has been met or the IHA expires. If Apache reaches the calculated 30 takes, Apache will initiate consultation with NMFS to continue seismic operations in lower Cook Inlet where beluga whales have been rarely documented in recent years (Hobbs et al. 2000; Rugh et al. 2003, 2004a, 2004b, 2005a, 2005b, 2005c, 2006, 2007; Hobbs et al. 2011; Shelden et al. 2012, Goetz et al. 2012b).

Apache reasserts their goal is to have no beluga takes during the entire survey period due to the mitigation measures described in this IHA request. The takes authorized by the IHA are observed takes during operations, not calculated takes from the NMML model. While the NMML model provides informative densities for operational planning, the authorized IHA takes will be for observed beluga whale takes, not predicted takes. This reflects NMFS having the legal authority to regulate the number of takes (rather than activities) to ensure the survival of this important species.

The estimated number of other Cook Inlet marine mammals that may be potentially harassed during the seismic surveys was calculated by multiplying the density estimates discussed in the previous section (in individuals/hr/km^2) by the anticipated area ensonified by levels ≥160 dB re µPa rms (Appendix C, Appendix D) by the number of expected days that will be surveyed seismically in the project area. As discussed in Section 2, Apache anticipates that a crew will collect seismic data 10 - 12 hours per day over approximately 160 days over the course of eight to nine months. It is assumed that over the course of these 160 days, 100 days would be working in the offshore region and 60 days in the shallow, intermediate, and deep nearshore region. Of those 60 days in the nearshore region, 20 days would be in each depth. It is important to note that environmental conditions (such as ice, wind, fog) will play a significant role in the actual operating days; therefore, these estimates are conservative in order to provide a basis for probability of encountering these marine mammal species in the project area.

The number of estimated takes by harassment was calculated using the following assumptions:

- The number of nearshore and shallow water survey days is 20 and daily acoustic footprint is 462 km^2 (178 mi^2).
- The number of nearshore and intermediate water depth survey days is 20 and daily acoustic footprint is 629 km^2 (243 mi^2).

- The number of nearshore and deep water depth survey days is 20 and daily acoustic footprint is 623 km^2 (241 mi^2).
- The number of offshore survey days is 100 and daily footprint is 517 km^2 (200 mi^2).

Table 8 shows the estimated maximum and average takes by species for the program with the methods and assumptions outlined above.

Table 8. Maximum and Average Encounter Probability (Maximum Level B Take Estimates) per Species

	Shallow		Intermediate		Deep		Offshore		Total	
Area Ensonified (km^2)	**462**		**629**		**623**		**517**		**2231**	
Survey days	**20**		**20**		**20**		**100**		**160**	
Species	**max**	**avg**	**max**	**avg**	**max**	**avg**	**max**	**avg**	**max**	**avg**
Harbor seals	62.9	47.3	85.6	64.4	84.8	63.8	351.9	264.5	585.2	439.9
Harbor porpoises	3.5	0.8	4.8	1.1	4.7	1.1	19.6	4.5	32.5	7.6
Killer whales	1.0	0.1	1.4	0.2	1.4	0.2	5.8	0.8	9.6	1.3
Steller sea lions	3.2	1.5	4.4	2.0	4.3	2.0	17.9	8.4	29.8	13.9

Shallow water = 5-21 m

Intermediate water = 21-38 m

Deep water = 38-54 m

Take estimates =density (from Table 6) * area ensonified ≥ 160 dB re 1 μPa rms from JASCO (Appendix C) * no.of days estimated to be seismically surveyed

Table 8 identifies the worst-case probability of encountering these marine mammal species within the 160 dB zone during the survey and does not account for seasonal distribution of these species, haul outs of harbor seals and Steller sea lions, or the rigorous mitigation and monitoring techniques implemented by Apache to reduce Level B takes to all species. The following text describes each point further.

7.4.1 Seasonal Distribution

Apache's proposed implementation of the mitigation measures (Sections 12 and 14) provides for the best incorporation of seasonal beluga density into the seismic program. Hobbs et al. (2005) was able to incorporate seasonality into their study, but it was not intended to provide density modeling. Apache has flown regular aerial surveys for Cook Inlet beluga whales in 2012 and 2013; and while conducting operations has an extensive working knowledge of where belugas are located. Both of these sources confirm that there are dramatic shifts in beluga distribution throughout the year; and that these shifts must be incorporated into operational planning. To accomplish Apache's goal of zero beluga takes, Apache will incorporate regular aerial surveys and seasonal considerations of beluga density into the prioritization of their seismic program, in addition to other factors such as weather, ice conditions, and operations.

For other marine mammals, data used to estimate probability of sightings for Cook Inlet are based on a three to four day aerial survey conducted in one month (June) of each year. This aerial survey does not take into account that marine mammal species are not evenly distributed across Cook Inlet in these numbers and that animals seen in June at those levels may not be observed in that same area two months later. Because there are no other systematic surveys for Cook Inlet that provide the level of detail for these years, this is still the best available data for estimating takes. In particular, killer whales, harbor porpoises, and Steller sea lions are expected to be observed more frequently in lower and mid-Cook Inlet; while beluga whales and harbor seals are more likely to be following the salmon and eulachon fish runs throughout Cook Inlet.

This is important because if Apache can begin conducting seismic surveys in lower Cook Inlet in the fall, when beluga whales are typically feeding in upper Cook Inlet, the likelihood of observing (and exposing) beluga whales to airguns is much lower.

7.4.2 Pinniped Haul Outs

Seismic surveys in the Trading Bay region have resulted in numerous sightings of individual harbor seals. Apache does not anticipate encountering large haul outs of seals or Steller sea lions in the project area, but expects to continue to observe curious individual harbor seals; particularly during large fish runs in the various rivers draining into Cook Inlet. These density estimates are skewed by the numbers observed in large haul outs on the aerial surveys; seals on land would not be exposed to in-water sounds during that time. Seals in the water usually travel in small groups or as singles. Therefore, although Table 8 indicates an average of 440 and maximum of 586 seals to be observed, it is highly unlikely that those numbers of seals would be taken by harassment during seismic operations.

For many of the same reasons discussed above for harbor seals, the number of actual takes by harassment of Steller sea lions are expected to be much lower than the average of 14 and maximum of 30. In all of the NMFS aerial surveys, no Steller sea lions were observed in upper Cook Inlet. Less than five Steller sea lions have been observed by the Port of Anchorage monitoring program, and those observed have been single, juvenile animals (likely male). Apache anticipates less than five Steller sea lions in the project area.

7.4.3 Monitoring and Mitigation

As described in detail in Sections 12 and 14, Apache has implemented a rigorous monitoring and mitigation program to reduce Level B harassment, particularly to beluga whales. Apache is shutting down air gun operations if any beluga whales are sighted within or approaching the 160 dB zone and have committed in the current IHA and in this IHA Application, to not taking by harassment more than 30 beluga whales in one year. The maximum probable number of sightings for beluga whales is not expected to be exposed to seismic air guns at harassment level because of the rigorous mitigation program. Given that belugas are usually transiting from one feeding area to another in lower concentrations, these estimates appear to be reasonable in assessing probability of beluga whales potentially observed. This includes conducting aerial overflights near larger river mouths where belugas are known to congregate to avoid operating in areas of important feeding times.

Furthermore, the total number of days actually surveying near river mouths is much lower than the 160 days used to estimate takes in these different water depths, so this probability sighting table is extremely conservative. Therefore, due to actual number of days and hours likely to be operating airguns near river mouths and the strict monitoring and mitigation measures to be used when operating near rivers, the actual number of takes by harassment estimated for beluga whales is expected to be much lower than the numbers in Table 8.

7.5 Summary of Requested Takes

Based on the discussion and estimates above, Apache requests the following number of takes by harassment by species for the project area (Table 9). Apache was authorized these same take levels from March 1, 2013 through March 1, 2014. Apache asks for the same numbers for all species based on the numbers of sightings and shut downs already implemented in 2012. **It is important to note that Apache understands and is not asking for additional takes per year, but will continue to operate with the assumption that 30 beluga whale takes (and relevant other species) will be authorized in a 1-year period regardless of the area of operations**. The abundance of the population, as summarized in Section 4, is also provided with the calculated percent of the population that will be temporarily behaviorally disturbed during seismic operations. As shown in the table, the percent of all species requested to be taken by harassment is less

than 10 percent of the population for all of the species, and less than 1 percent for all except the beluga whales. Therefore, Apache anticipates there will be no more than a negligible impact on small numbers of marine mammals during the seismic operations.

Table 9. Requested Number of Takes

Species	Number of Requested Takes	Cook Inlet Population Abundance	Percent of Population
Beluga whales	30	283	10.60%
Harbor seals	200	22,900	0.87%
Harbor porpoises	20	25,987	0.08%
Killer whales	10	1,123	0.89%
Steller sea lions	20	45,916	0.04%

Note: population abundance summarized in Section 3

8.0 Description of Impact on Marine Mammals

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

8.1 General Effects of Noise on Marine Mammals

Marine mammals use hearing and sound transmission to perform vital life functions. Introducing sound into their environment could be disrupting to those behaviors. Sound (hearing and vocalization/ echolocation) serves four primary functions for marine mammals, including: 1) providing information about their environment, 2) communication, 3) prey detection, and 4) predator detection. The distances to which airgun noise associated with the Cook Inlet 3D Seismic Program are audible depend upon source levels, frequency, ambient noise levels, the propagation characteristics of the environment, and sensitivity of the receptor (Richardson et al. 1995).

The effects of sounds from airguns on marine mammals might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995). In assessing potential effects of noise, Richardson et al. (1995) has suggested four criteria for defining zones of influence. These zones are described below from greatest influence to least:

Zone of hearing loss, discomfort, or injury – the area within which the received sound level is potentially high enough to cause discomfort or tissue damage to auditory or other systems. This includes temporary threshold shifts (TTS, temporary loss in hearing) or permanent threshold shifts (PTS, loss in hearing at specific frequencies or deafness). Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage.

Zone of masking – the area within which the noise may interfere with detection of other sounds, including communication calls, prey sounds, or other environmental sounds.

Zone of responsiveness – the area within which the animal reacts behaviorally or physiologically. The behavioral responses of marine mammals to sound is dependent upon a number of factors, including: 1) acoustic characteristics the noise source of interest; 2) physical and behavioral state of animals at time of exposure; 3) ambient acoustic and ecological characteristics of the environment; and 4) context of the sound (e.g., whether it sounds similar to a predator) (Richardson et al. 1995; Southall et al. 2007). However, temporary behavioral effects are often simply evidence that an animal has heard a sound and may not indicate lasting consequence for exposed individuals (Southall et al. 2007).

Zone of audibility – the area within which the marine mammal might hear the noise. Marine mammals as a group have functional hearing ranges of 10 Hz to 180 kHz, with best thresholds near 40 dB (Ketten 1998; Kastak et al. 2005; Southall et al. 2007). These data show reasonably consistent patterns of hearing sensitivity within each of three groups: small odontocetes (such as the harbor porpoise), medium-sized odontocetes (such as the beluga and killer whales), and pinnipeds (such as the harbor seal and Steller sea lion). Hearing capabilities of the species included in this Application are discussed in Section 4.0. There are no applicable criteria for the zone of audibility due to difficulties in human ability to determine the audibility of a particular noise for a particular species.

8.1.1 Potential Effects of Airgun Sounds

The following text describes the potential impacts on marine mammals due to seismic activities. Due to the mitigation measures discussed in Sections 12 and 14, it is unlikely there would be any temporary or

especially permanent hearing impairment, or non-auditory physical effects on marine mammals. In addition, most of nearshore area of Cook Inlet is a poor acoustic environment because of its shallow depth, soft bottom, and high background noise from currents and glacial silt which greatly reduces the distance sound travels (Blackwell and Greene 2002).

8.1.1.1 Tolerance

Studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers, but they do not necessarily cause behavioral disturbances. Numerous studies have shown that marine mammals at distances over a few kilometers from operating seismic vessels often show no apparent response. That is often true even when pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to temporarily react behaviorally to airgun pulses under some conditions, at other times they have shown no overt reactions. In general, pinnipeds and small odontocetes are more tolerant of exposure to airgun pulses than baleen whales.

8.1.1.2 Masking

Masking of marine mammal calls and other natural sounds are expected to be limited in the presence of seismic noise, although there are very few specific data of relevance. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004; Di Iorio and Clark 2010). Masking effects of seismic pulses are expected to be negligible in the case of the odontocete cetaceans, given the intermittent nature of seismic pulses. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are airgun sounds. Therefore, the potential problem of auditory masking for beluga whales is diminished by the small amount of overlap between frequencies produced by seismic and other industrial noise (<1 kHz) and frequencies which beluga whales call (0.26-20 kHz) and echolocate (40-60 kHz and 100-120 kHz; Blackwell and Greene 2002). Additionally, beluga whales have been known to change their vocalizations in the presence of high background noise possibly to avoid masking calls (Au et al. 1985; Lesage et al. 1999; Scheifele et al. 2005).

8.1.1.3 Disturbance Reactions

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, environmental conditions, and many other factors (Richardson et al. 1995). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a short distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, which is not anticipated in the proposed seismic program, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of sound on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound to assess behavioral disturbance. However, this procedure likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically important but unknown degree by a seismic program are based on behavioral observations during studies of several species. However, information is largely lacking for many species including those species likely to occur in the project areas. Detailed studies have been done

on other species found elsewhere in Alaska waters including gray whales, bowhead whales, and ringed seals. The criteria established for these marine mammals, which are applied to others are conservative and have not been demonstrated to significantly affect individuals or populations of marine mammals in Alaska waters. Therefore, the effect of the 3D seismic program on the behavior of marine mammals should be no more than negligible for reasons stated earlier.

Toothed Whales. Little systematic information is available about reactions of beluga whales, killer whales, and harbor porpoise to noise pulses. Beluga whales exhibit changes in behavior when exposed to strong, pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002a; Finneran et al. 2002b). However, the animals tolerated high received levels of sound (peak–peak level >200 dB re 1 μPa) before exhibiting aversive behaviors (Richardson et al. 1995). Some belugas summering in the Eastern Beaufort Sea may have avoided the specific area of seismic operations (2 arrays with 24 airguns per array), which used a larger array than the proposed program (2 arrays of 16 airguns per array), by 10 to 20 km (6.2 to 12.4 mi), although belugas occurred as close as 1,540 m (5,052 ft) to the line of seismic operations (Miller et al 2005). Observers stationed on seismic vessels operating off the United Kingdom from 1997 - 2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004). Killer whales were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. The displacement of the median distance from the array was ~0.5 km (0.3 mi) or more. Killer whales also appear to be more tolerant of seismic shooting in deeper water. Killer whales are rare to uncommon in the inlet, therefore, the planned seismic program should have no more than a negligible impact on killer whales and no effect on the population. Harbor porpoises are rarely sighted, but have been detected acoustically throughout the inlet. However, based on the relatively few animals observed, the project should have no more than a negligible impact and no effect on the population.

Pinnipeds. While there are no published data on seismic effect on sea lions or harbor seals, anecdotal data and data on arctic seals indicate that sea lions and other pinnipeds generally tolerate strong noise pulses (Richardson et al. 1995). Monitoring studies in the Alaskan and Canadian Beaufort Sea during 1996 - 2002 provided considerable information regarding behavior of arctic seals exposed to seismic pulses (Miller et al. 2005; Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 with as many as 24 airguns with total volumes 560 to 1,500 cui. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundred meters, and many seals remained within 100 to 200 m (328 to 656 ft) of the trackline as the operating airgun array passed by them. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. Miller et al. (2005) also reported higher sighting rates during non-seismic than during line seismic operations, but there was no difference for mean sighting distances during the two conditions nor was there evidence ringed or bearded seals were displaced from the area by the operations. The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data from these studies indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviors, e.g. “looked” and “dove”. Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where “looking” occurs (Miller et al. 2005; Moulton and Lawson 2002).

Consequently, by using the responses of bearded, ringed, and spotted seals (least amount of data on reaction to seismic operations) to seismic operations as surrogates for harbor seals and sea lions, it is reasonable to conclude that the relatively small numbers relative to the population size (see Table 9) of harbor seals and the even smaller numbers of Steller sea lions possibly occurring in the project area during seismic operations are not likely to show a strong avoidance reaction to the proposed airgun sources. Pinnipeds frequently do not avoid the area within a few hundred meters of operating airgun arrays, even for airgun arrays much larger than that planned for the proposed project (e.g., Harris et al. 2001). Reactions are expected to be very localized and confined to relatively small distances and durations, with no long-term effects on individuals or populations.

8.1.1.4 Strandings and Mortality

There is no evidence in the literature that airgun pulses can cause serious injury, death, or stranding of marine mammals even in the case of larger airgun arrays than planned for the proposed program (76 FR 58473). Seismic surveys have been referenced as possible causes of marine mammal strandings (Engel et al. 2004; Taylor et al. 2004), but the evidence is inconclusive (71 FR 43112). While strandings have been associated with military mid-frequency sonar pulses (Jepson et al. 2003; Fernández et al. 2004; Hildebrand 2005), Apache does not plan to use such sonar systems during the Cook Inlet 3D Seismic Program. Seismic pulses and military mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy below 1 kHz. In addition, strandings associated with sound exposure have not been documented in Cook Inlet (76 FR 58473).

8.1.1.5 Noise Induced Threshold Shift

There is sometimes confusion when reporting sound levels. It is important to not only say "dB" but to also add the reference level. This is often written as "dB re 1 μPa" for sounds in water that are measured relative (re) to 1 μPa and "dB re 20 μPa" for sounds in air that are measured relative (re) to 20 μPa. All sound measurements in this document are for measurements made in water, and are specified in terms of dB re 1 μPa.

The different references in air and water leads to confusion not only because the reference is different by a factor of 20, but also because the sound intensity is a function of both the density of the medium (water and air are obviously different), and the velocity of sound in the medium (air at about 350m/sec and water at about 1500 m/sec). The net result of this is that sound levels expressed in dB in water, are about 60 dB less (61.5dB) than the same dB levels in air. A 60-dB difference in relative intensity represents a million-fold difference in power. Sound levels of 120 dB (re 1 μPa) in water are roughly equivalent to sound levels of 60 dB (re 20 μPa) in air. A sound level of 60 dB re 20 μPa in air is roughly equivalent to the level of sound in conversational speech.

Animals exposed to intense sound may experience reduced hearing sensitivity for some period of time following exposure. This increased hearing threshold is known as noise induced threshold shift (TS). The amount of TS incurred in the animal is influenced by a number of noise exposure characteristics, such as amplitude, duration, frequency content, temporal pattern, and energy distribution (Kryter 1985; Richardson et al. 1995; Southall et al. 2007). It is also influenced by characteristics of the animal, such as behavior, age, history of noise exposure and health. The magnitude of TS generally decreases over time after noise exposure and if it eventually returns to zero, it is known as TTS. If TS does not return to zero after some time (generally on the order of weeks), it is known as “permanent threshold shift” (PTS). Temporary threshold shift is not considered to be auditory injury and does not constitute “Level A Harassment” as defined by the MMPA. Sound levels associated with TTS onset are generally considered to be below the levels that will cause PTS, which is considered to be auditory injury.

Temporary threshold shift has been studied in captive odontocetes and pinnipeds (reviewed in Southall et al. 2007). Data are available for three cetacean species (bottlenose dolphin, *Tursiops truncatus*; beluga whale, and harbor porpoise) and three pinniped species (harbor seal, California sea lion, *Zalophus californianus*; Northern elephant seal, *Mirounga angustirostris*). However, these data have all been collected from captive animals and no documentation exists of TTS or PTS in free ranging marine mammals exposed to airgun pulses. Inner ears of beluga and bowhead whales examined shortly after being taken in subsistence hunts show little and no evidence of auditory trauma sustained pre-mortem. Beluga whales show some acoustic trauma, though not substantial enough to have caused deafness and not attributed to a specific sound source (Thewissen et al. 2011).

The current NMFS policy regarding exposure of marine mammals to impulsive sound is that cetaceans should not be exposed to impulsive sounds >180 dB re 1 µPa rms and that pinnipeds should not be exposed to impulsive sounds >190 dB re 1µPa rms (NMFS 2000). These criteria were established before information was available about minimum received levels of sound that would cause auditory injury in marine mammals. They are likely lower than necessary and are intended to be precautionary estimates below which no physical injury will occur (Southall et al. 2007). Many marine mammal species avoid ships and/or seismic operations. This behavior in and of itself should be sufficient to avoid TTS onset. In addition, monitoring and mitigation measures often implemented during seismic surveys are designed to detect marine mammals near the airgun array and avoid exposing them to sound pulses that may cause hearing impairment. For example, it is standard protocol for many seismic operators to ramp up airgun arrays, which should allow animals near the airguns at startup time to move away from the source and thus avoid TTS. If animals do incur TTS, it is a temporary and reversible phenomenon unless exposure exceeds the TTS-onset threshold by an amount sufficient to cause PTS. The following subsections summarize the available data on noise-induced hearing impairment in marine mammals.

Sound Exposure Level (SEL)

Sound exposure level is a measure of sound energy, calculated as 10 times the logarithm of the integral (with respect to duration) of the mean-square sound pressure, referenced to 1 $\mu Pa^2 s$ (Kastak et al. 2005; Southall et al. 2007). It is useful for assessing the cumulative level of exposure to multiple sounds because it allows sounds with different durations and involving multiple exposures to be compared in terms of total energy. This type of comparison assumes that sounds with equivalent total energy will have similar effects on exposed subjects, even if the sounds differ in SPL, duration and/or temporal exposure patterns. Sound exposure level likely over estimates TTS and PTS arising from complex noise exposures because it does not take varying levels and temporal patterns of exposure and recovery into account (Southall et al. 2007). Some support for the use of SEL to evaluate TTS and PTS has been shown for marine mammals (e.g., Finneran et al. 2002a; Finneran et al. 2002b, 2005), and this measure will be referred to in the following sections of this document.

Temporary Threshold Shift

Temporary threshold shift is the mildest form of hearing impairment that can occur during exposure to loud sound (Kryter 1985). It is not considered to represent physical injury, as hearing sensitivity recovers relatively quickly after the sound ends. It is, however, an indicator that physical injury is possible if the animal is exposed to higher levels of sound. The onset of TTS is defined as a temporary elevation of the hearing threshold by at least 6 dB (Schlundt et al. 2000). Several physiological mechanisms are thought to be involved with inducing TTS. These include reduced sensitivity of sensory hair cells in the inner ear, changes in the chemical environment in the sensory cells, residual middle-ear muscular activity, displacement of inner ear membranes, increased blood flow, and post-stimulatory reduction in efferent and sensory neural output (Kryter 1994; Ward 1997).

Very few data are available regarding the sound levels and durations that are necessary to cause TTS in marine mammals. Data are available for only three species of cetaceans and three species of pinnipeds. No data are available for mysticete species. No data are available for any free ranging marine mammals or for exposure to multiple pulses of sound during seismic surveys.

TTS in Odontocetes

Most studies of TTS in odontocetes have focused on non-impulsive sound, and all have been carried out on captive animals. A detailed review of all TTS data available for marine mammals can be found in Southall et al. (2007). The following is a summary of key results.

Finneran et al. (2005) measured TTS in bottlenose dolphins exposed to 3 kHz tones with various durations and SPL levels in a quiet pool. The amount of TTS was positively correlated with the SEL, and statistically significant amounts of TTS were observed for SELs > 195 dB re 1μPa^{2}s. These data agree with those reported by Schlundt et al. (2000) and Nachtigall et al. (2004) and support the use of 195 dB re 1μPa^{2}s as a threshold for TTS onset in dolphins and belugas exposed to mid-frequency sounds. Finneran et al. (2005) also found that each additional dB of SEL produced an additional 0.4 dB of TTS and that for TTS of 3-4 dB, recovery was nearly complete within 10 minutes post-exposure. For larger TTS, longer recovery times were required. The authors caution, however, that interpretation of TTS growth and recovery curves is hampered by the very small amounts of TTS measured relative to the variability of the measurements. They also note that not all exposures above a certain TTS threshold will cause TTS. For example, only 18 percent of exposures to an SEL of 195 dB re 1μPa^{2}s resulted in measurable TTS.

Mooney et al. (2009a) measured TTS in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130-178 dB re 1μPa for 1.88 to 30 min. The results of this study showed a strong positive relationship between SEL and the amount of TTS, however, the relationship was not a simple equal energy relationship. When SEL was kept constant and exposure duration decreased, TTS did not stay constant, as expected by the equal energy rule. The amount and occurrence of TTS decreased as the duration of sound exposure decreased, so relative to longer duration exposures, shorter duration exposures required greater SELs to induce TTS. Recovery time also varied with both SPL and duration of sound exposure and followed a logarithmic function according to the amount of TTS. Similar results were reported by Mooney et al (2009b). The results of this work illustrate the importance of reporting both SPL and duration of sound exposure when evaluating TTS in odontocetes.

The TTS threshold for odontocetes exposed to a single impulse from a watergun appears to be lower than that for exposure to non-impulse sound (Finneran et al. 2002a; Finneran et al. 2002b). An exposure SEL of 186 dB re 1μPa^{2}s resulted in mild TTS in a beluga whale. However, these measurements were made in the presence of band-limited white noise (masking noise), which may have resulted in a lower TTS than would have been observed in the absence of masking noise. Data from terrestrial mammals also show that broadband pulsed sounds with rapid rise times have a greater auditory effect than do non-impulse sounds (Southall et al. 2007). The rms level of an airgun pulse is typically 10-15 dB higher than the SEL for the same pulse when received within a few km of the airguns. A single airgun pulse might therefore need to have a received level of approx 196-201 dB re 1 μPa rms to produce brief, mild TTS. Exposure to several strong seismic pulses, each with a flat-weighted received level near 190 dB rms (175-180 dB SEL) could result in cumulative exposure of approximately 186 dB SEL and thus slight TTS in a small odontocete.

While the majority of TTS research has been conducted on bottlenose dolphins and beluga whales, one study involved another odontocete species, the harbor porpoise (Lucke et al. 2009). The TTS threshold for this harbor porpoise was lower than that measured for the larger odontocetes. TTS occurred in the harbor porpoise upon exposure to one airgun pulse with a received level of approximately 200 dB re 1 μPa peak-peak or an SEL of 164.3 dB re 1μPa^{2}s.

When estimating the amount of sound energy required for the onset of TTS, it is generally assumed that the effect of a given cumulative SEL from a series of pulses is the same as if that amount of sound energy were received as a single strong sound (Southall et al. 2007). However, some recovery may occur between pulses and it is not currently known how this may affect TTS threshold. In addition, more data are needed in order to determine the received levels at which odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. For example, the total energy received by an animal will be a function of received levels of airgun pulses as an airgun array approaches, passes at various distances and moves away (e.g., Erbe and King 2009). Finally, as TTS threshold was lower for the harbor porpoise than for bottlenose dolphins or beluga whales, more data are needed regarding TTS thresholds in other odontocete species.

TTS in Pinnipeds

Temporary threshold shift has been measured for only three pinniped species: harbor seals, California sea lions, and northern elephant seals, and only one study has examined TTS in response to exposure to underwater pulses (Finneran et al. 2003). Of the three species for which data are available, the harbor seal exhibits TTS onset at the lowest exposure levels to non-pulsed sounds. A 25 minute exposure to a 2.5 kHz sound elicited TTS in a harbor seal at an SPL of 152 dB re 1 µPa (SEL 183 dB re 1µPa^{2}s), as compared to 174 dB re 1 µPa (SEL 206 dB re 1µPa^{2}s) for the California sea lion and 172 dB re 1 µPa (SEL 204 dB re 1µPa^{2}s) for the elephant seal (Kastak et al 2005).

The auditory response of pinnipeds to underwater pulsed sounds has been examined in only one study. Finneran et al. (2003) measured TTS onset in two captive California sea lions exposed to single underwater pulses produced by an arc-gap transducer. No measurable TTS was observed following exposures up to a maximum level of 183 dB re 1 µ Pa peak-to-peak (SEL 163 dB re 1µPa^{2}s). Finneran et al. (2003) suggest that the equal energy rule may apply to pinnipeds, however Kastak et al. (2005) found that for harbor seals, California sea lions and elephant seals exposed to prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer. For example, for a non-impulse sound, doubling the exposure duration from 25 to 50 min (a 3 dB increase in SEL) had a greater effect on TTS than an increase of 15 dB (95 vs. 80 dB) in exposure level. These results are similar to those reported by Mooney et al. (2009a, b) for bottlenose dolphins and emphasize the need for taking both SPL and duration into account when evaluating the effect of sound exposure on marine mammal auditory systems.

Permanent Threshold Shift (PTS)

Permanent threshold shift is defined as 'irreversible elevation of the hearing threshold at a specific frequency' (Yost 2000). It involves physical damage to the sound receptors in the ear and can be either total or partial deafness or impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Some causes of PTS are severe extensions of effects underlying TTS (e.g. irreparable damage to sensory hair cells). Others involve different mechanisms, for example exceeding the elastic limits of certain tissues and membranes in the middle and inner ears and resultant changes in the chemical composition of inner ear fluids (Ward 1997; Yost 2000). The onset of PTS is determined by pulse duration, peak amplitude, rise time, number of pulses, inter-pulse interval, location, species and health of the receivers ear (Ketten 1994).

The relationships between TTS and PTS thresholds have not been studied in marine mammals and there is currently no evidence that exposure to airgun pulses can cause PTS in any marine mammal, however there has been speculation about that possibility (e.g. Richardson et al. 1995; Gedamke et al. 2008). In terrestrial mammals, prolonged exposure to sounds loud enough to elicit TTS can cause PTS. Similarly, shorter term exposure to sound levels well above the TTS threshold can also cause PTS (Kryter 1985). Terrestrial mammal PTS thresholds for impulse sounds are thought to be at least 6 dB higher than TTS thresholds on a peak-pressure basis (Southall et al. 2007). Also, pulses with rapid rise times can result in PTS even when peak levels are only a few dB higher than the level causing slight TTS.

Southall et al. (2007) used available marine mammal TTS data and precautionary extrapolation procedures based on terrestrial mammal data to estimate exposures that may be associated with PTS onset. For terrestrial mammals, TTS exceeding 40 dB generally requires a longer recovery time than smaller TTS, which suggests a higher probability of irreversible damage (Ward 1970) and possibly different underlying mechanisms (Kryter 1994; Nordman et al. 2000). Based on this, and the similarities in morphology and functional dynamics among mammalian cochleae, Southall et al. (2007) assumed that PTS would be likely if the hearing threshold was increased by more than 40 dB and assumed an increase of 2.3 dB in TTS with each additional dB of sound exposure. This translates to an injury criterion for pulses that is 15 dB above the SEL of exposures causing TTS onset. Finneran et al. (2002a) found TTS onset in belugas exposed to a single pulse of sound at an SEL of 183 dB re 1μPa^{2}s. Therefore, according to the assumptions above, the PTS threshold would be approximately 198 dB re 1μPa^{2}s for a single pulse.

There are no data on the sound level of pulses that would cause TTS onset in pinnipeds. Southall et al. (2007) therefore assumed that known pinniped-to-cetacean differences in TTS-onset for non-pulsed sounds also apply to pulse sounds. Harbor seals experience TTS onset at received levels that are 12 dB lower than those required to elicit TTS in beluga whales (Kastak et al. 2005; Finneran 2002a). Therefore, TTS onset in pinnipeds exposed to a single underwater pulse was estimated to occur at an SEL of 171 dB re 1μPa^{2}s. Adding 15 dB results in a PTS onset of 186 dB re 1μPa^{2}s for pinnipeds exposed to a single pulse. This is likely to be a precautionary estimate as the harbor seal is the most sensitive pinniped species studied to date and these results are based on measurements taken from a single individual (Kastak et al. 1999, 2005).

It is unlikely that a marine mammal would remain close enough to a large airgun array long enough to incur PTS. Some concern arises for bowriding dolphins, however the auditory effects of seismic pulses are reduced by Llyod's mirror and surface release effects. In addition, the presence of the ship between the bowriding animals and the airgun array may also reduce received levels (e.g. Gabriele and Kipple 2009). As discussed in the TTS section, the levels of successive pulses received by a marine mammal will increase and then decrease gradually as the seismic vessel approaches, passes and moves away, with periodic decreases also caused when the animal goes to the surface to breath, reducing the probability of the animal being exposed to sound levels large enough to elicit PTS.

9.0 Description of Impact on Subsistence Uses

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

The Cook Inlet beluga whale has traditionally been hunted by Alaska Natives for subsistence purposes. For several decades prior to the 1980s, the Native Village of Tyonek residents were the primary subsistence hunters of Cook Inlet beluga whales. During the 1980s and 1990s, Alaska Natives from villages in the western, northwestern, and North Slope regions of Alaska either moved to or visited the south central region and participated in the yearly subsistence harvest (Stanek 1994). From 1994 to 1998, NMFS estimated 65 whales per year (range 21-123) were taken in this harvest, including those successfully taken for food, and those struck and lost. NMFS has concluded that this number is high enough to account for the estimated 14 percent annual decline in population during this time (Hobbs et al. 2008). Actual mortality may have been higher, given the difficulty of estimating the number of whales struck and lost during the hunts. In 1999, a moratorium was enacted (Public Law 106-31) prohibiting the subsistence take of Cook Inlet beluga whales except through a cooperative agreement between NMFS and the affected Alaska Native organizations. Since the Cook Inlet beluga whale harvest was regulated in 1999 requiring cooperative agreements, five beluga whales have been struck and harvested. Those beluga whales were harvested in 2001 (one animal), 2002 (one animal), 2003 (one animal), and 2005 (two animals). The Native Village of Tyonek agreed not to hunt or request a hunt in 2007, when no co-management agreement was to be signed (NMFS 2008a).

The 2008 Cook Inlet Beluga Whale Subsistence Harvest Final Supplemental Environmental Impact Statement (NMFS 2008a) authorizes how many beluga whales can be taken during a five-year interval based on the five-year population estimates and ten-year measure of the population growth rate. Based on the 2008 - 2012 five-year abundance estimates, no hunt occurred between 2008 and 2012 (NMFS 2008a). The Cook Inlet Marine Mammal Council, which managed the Alaska Native Subsistence fishery with NMFS, was disbanded by a unanimous vote of the Tribes' representatives on June 20, 2012. At this time, no harvest is expected in 2013 or 2014.

Residents of the Native Village of Tyonek are the primary subsistence users in Knik Arm area. The project should not have any effect because no beluga harvest will take place in 2013 or 2014 and the area is not an important native subsistence site for other subsistence species of marine mammals.

Data on the harvest of other marine mammals in Cook Inlet are lacking. Some data are available on the subsistence harvest of harbor seals, harbor porpoises, and killer whales in Alaska in the marine mammal stock assessments. However, these numbers are for the Gulf of Alaska including Cook Inlet, and they are not indicative of the harvest in Cook Inlet. Because the relatively small proportion of marine mammals utilizing Cook Inlet, the number harvested is expected to be extremely low. Therefore, because the proposed program would result in only temporary disturbances, the seismic program would not impact the availability of these other species for subsistence uses.

Some detailed information on the subsistence harvest of harbor seals is available from past studies conducted by ADF&G (Wolfe et al. 2009). In 2008, only 33 harbor seals were taken for harvest in the Upper Kenai-Cook Inlet area. In the same study, reports from hunters stated that harbor seal populations in the area were increasing (28.6%) or remaining stable (71.4%). The specific hunting regions identified were Anchorage, Homer, Kenai, and Tyonek, and hunting generally peaks in March, September, and November (Wolfe et al. 2009). The timing and location of subsistence harvest of Cook Inlet harbor seals may coincide with Apache's project, but because this subsistence hunt is conducted opportunistically and at such a low level (NMFS 2013c), Apache's program is not expected to have an impact on the subsistence use of harbor seals.

10.0 Description of Impact on Marine Mammal Habitat

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

Fish are the primary prey species for marine mammals in upper Cook Inlet. Beluga whales feed on a variety of fish, shrimp, squid, and octopus (Burns and Seaman 1986). Common prey species in Knik Arm include salmon, eulachon and cod. Harbor seals feed on fish such as pollock, cod, capelin, eulachon, Pacific herring, and salmon as well as a variety of benthic species, including crabs, shrimp, and cephalopods. Harbor seals are also opportunistic feeders with their diet varying with season and location. The preferred diet of the harbor seal in the Gulf of Alaska consists of pollock, octopus, capelin, eulachon, and Pacific herring (Calkins 1989). Other prey species include cod, flat fishes, shrimp, salmon, and squid (Hoover 1988). Harbor porpoises feed primarily on Pacific herring, cod, whiting (hake), pollock, squid, and octopus (Leatherwood et al. 1982). In the upper Cook Inlet area, harbor porpoise feed on squid and a variety of small schooling fish, which would likely include Pacific herring and eulachon (Bowen and Siniff 1999; NMFS unpublished data). Killer whales feed on either fish or other marine mammals depending on genetic type (resident versus transient respectively). Killer whales in Knik Arm are typically the transient type (Shelden et al. 2003) and feed on beluga whales and other marine mammals, such as harbor seal and harbor porpoise.

While there may be few definitive studies on the use of the nearshore shallow coastal areas in the upper inlet, use of this type of habitat elsewhere by salmon and other species in Cook Inlet is supported in literature (NMFS 2008b). In general, fish perceive underwater sounds in the frequency range of 50 to 2,000 Hz, with peak sensitivities below 800 Hz (Popper and Carlson 1998; Department of the Navy 2001). However, fish are sensitive to underwater impulsive sounds due to swimbladder resonance. As the pressure wave passes through a fish, the swimbladder is rapidly squeezed as the high pressure wave, and then the under pressure component of the wave, passes through the fish. The swimbladder may repeatedly expand and contract at the high sound pressure levels (SPL), creating pressure on the internal organs surrounding the swimbladder.

Permanent injury to fish from acoustic emissions has been shown for high-intensity sounds of several hours long. In a review on the effects of low-frequency noise to fish, a threshold of 180 dB peak sound level was used to define the potential injury to fish. Sound pressure levels greater than an average of 150 dB rms are expected to cause temporary behavioral changes such as a startle response or behaviors associated with stress. Although these SPLs are not expected to cause direct injury to a fish, they may decrease the ability of a fish to avoid predators.

Carlson (1994), in a review of 40 years of studies concerning the use of underwater sound to deter salmonids from hazardous areas at hydroelectric dams and other facilities, concluded that salmonids were able to respond to low-frequency sound and to react to sound sources within a few feet of the source. He speculated that the reason that underwater sound had no effect on salmonids at distances greater than a few feet is because they react to water particle motion/acceleration, not sound pressures. Detectable particle motion is produced within very short distances of a sound source, although sound pressure waves travel farther.

Hastings and Popper (2005) reviewed all pertinent peer-reviewed and unpublished papers on noise exposure of fish through early 2005. They proposed the use of SEL to replace peak SPL in pile driving criteria. This report identified interim thresholds based on SEL or sound energy.

The interim thresholds for injury were based on exposure to a single pile driving pulse. The report also indicates that there was insufficient evidence to make any findings regarding behavioral effects associated with these types of sounds. Interim thresholds were identified for pile driving consisting of a single-strike peak sound pressure and a single strike SEL for onset of physical injury. A peak pressure criterion was retained to function in concert with the SEL value for protecting fishes from potentially damaging aspects of

acoustic impact stimuli. The available scientific evidence suggested that a single-strike peak pressure of 208 dB and a single strike SEL of 187 dB were appropriate thresholds for the onset of physical injury to fishes.

Following the Hasting and Popper (2005) paper, NMFS developed their version of the dual criteria that included the single strike peak pressure threshold of 208 dB, but addressed the accumulation of multiple strikes through accumulation of sound energy by setting a criterion of 187 dB SEL. The accumulated SEL is calculated using an equal energy hypothesis that combines the SEL of a single strike to 10 times the 10-based logarithm of the number of pile strikes.

Only a small fraction of the potentially available habitat in Cook Inlet would be impacted by noise from the Cook Inlet 3D Seismic Program at any given time during the seismic survey. Furthermore, the constant movement of the seismic vessel and the short duration of actual seismic activity would result in short-term, temporary, and very localized acoustic impacts on fish and other prey species. Thus, the seismic program is not expected to have any effects on habitat or prey that could cause permanent or long-term consequences for marine mammals.

11.0 Description of Impact from Loss or Modification to Habitat

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

The proposed Cook Inlet 3D Seismic Program will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. Direct impacts are physical destruction or alteration of habitat, which will not occur from the seismic program. Indirect impacts are primarily caused by ensonification of habitat from noise, which will be very localized and short term, because the proposed Cook Inlet 3D Seismic Program will be of short duration and confined to one area. Ensonification from seismic operations should have no more than a negligible effect on marine mammal habitat because:

- No studies have demonstrated that seismic noise affects the life stages, condition, or amount of food resources (fish, invertebrates, eggs) comprising habitats used by marine mammals, except when exposed to sound levels within a few meters of the seismic source or in a few very isolated cases. Where fish or invertebrates did respond to seismic noise, the effects were temporary and of short duration. Consequently, disturbance to fish species would be short-term and fish would return to their pre-disturbance behavior once the seismic activity ceases. Thus, the proposed survey would have little, if any, impact on marine mammals to feed in the area where seismic work is planned.
- The seismic area covers a small percentage of the potentially available habitat used by marine mammals in Cook Inlet allowing beluga and other marine mammals to move away from any seismic program sounds.

Thus, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, since operations will be limited in duration, location, timing, and intensity.

12.0 Measures to Reduce Impacts to Marine Mammals

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 primary marine mammal species potentially exposed to seismic sounds during the seismic program will be beluga whales, harbor seals, and harbor porpoises. There are no known rookeries, mating grounds, or areas of similar significance in the project area. The following text describes the proposed measures to minimize takes by harassment. The monitoring plan is discussed in more detail in Section 14.

12.1 Seasonal Exclusion Zone

NMFS established an exclusion zone for airgun activities within 16 km (10 mi) of the mean high waterline of the Susitna Delta ("Susitna Delta" being defined as shoreline between the mouth of the Beluga River to the mouth of the Little Susitna River). Airgun activities within this exclusion zone are prohibited from mid-April to mid-October. This exclusion was contingent on (as stated in the February 14, 2013 Biological Opinion), '*Once results of the sound source verification study in the upper Cook Inlet are available, Apache will contact NMFS AKR* [Alaska Region] *to determine if a new minimum setback distance is required for this area during this time'* (NMFS 2013a). The results of the SSV (Appendices B, C, and D) in upper Cook Inlet indicate a distance of 9.50 km is a more appropriate setback distance to protect beluga whales.

Apache is limited to 30 takes of beluga whales in one year, irrespective of location or seasonality. Therefore, Apache does not believe this exclusion zone is warranted. Apache has confirmed the ability to lay marine nodes north of the exclusion zone. Based on the results from the Upper Cook Inlet SSV, historic marine mammal data and data collected during the 2012 and 2013 field seasons, Apache will develop a program which will have minimal to no impact on beluga whales within the Susitna Delta region.

12.2 Vessel-Based Monitoring

Vessel-based observers will monitor marine mammals at the seismic program during all daytime airgun operations. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated shut down safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, airgun operations will be powered down (or shut down if necessary) immediately. Mitigation measures will be communicated by the PSO on the source vessel to the airgun operators and vessel captain/crew.

During daytime operations, vessel-based observers will watch for marine mammals at the project location during all periods of seismic operations and for a minimum of 30 minutes prior to the planned start of airgun operations after an extended shut down (10 minutes). PSOs will also observe opportunistically during daylight hours when no seismic activity is taking place.

Apache proposes to conduct both daytime and nighttime seismic operations. Hours surveyed during periods of low visibility will depend on the time of year and tidal cycles. Apache only conducts their surveys during periods of slack tide, which in Cook Inlet occur twice over a 24 hour period and last 4-6 hours each, totaling 8-12 hours of potential survey time per 24 hour period. Nighttime operations can be initiated only if a mitigation gun has been continuously operational from the time that the PSO monitoring ended. Seismic activity will not ramp up from an extended shut down during nighttime operations. PSOs will not monitor

during seismic operations at night. Vessel captain and crew will watch for marine mammals (insofar as practical at night) and will call for the airgun(s) to be shut down if marine mammals are observed in or about to enter the safety radii. After a shut down during night operations, seismic activity will be suspended until the following day and the full safety zone is visible for at least 30 minutes.

12.3 Proposed Safety Radii

In order to avoid any takes by injury (Level A), Apache proposes to shut down airguns or positioning pingers in the event a marine mammal approaches the 180 or 190 dB injury sound level zone and monitor the 160 dB harassment sound level zone to shut down if large groups of animals approach. Apache proposes to shut down if a group of more than five beluga whales or a group of five or more harbor porpoises is sighted within the 160 dB harassment sound level zone. Apache also proposes to shut down if a beluga whale calf is sighted approaching or within the 160 dB harassment zone. As discussed in detail in Appendix C, received sound levels for determining safety zones were estimated for the first IHA application. Distances to the 190, 180, and 160 dB with the 440 and 2,400 cui airgun configurations were measured in late April 2013, the results of which are provided in Appendix B. The estimated safety zones were used to estimate probability of occurrence for marine mammals, but the measured safety zones will be used to monitor. These distances are provided in Table 10.

Table 10. Summary of Distance to NMFS Sound Level Thresholds

Source	190 dB	180 dB	160 dB
Pinger	1 m	3 m	25 m
10 cui air gun	10 m	10 m	280 m
400 cui air gun	100 m	310 m	2500 m
2400 cui air gun (nearshore)	380 m	1400 m	9500 m
2400 cui air gun (offshore)	290 m	910 m	8700 m

Apache proposes to monitor these zones for marine mammals before, during, and after the operation of the offshore airguns and pingers. Monitoring will be conducted using qualified PSOs on three vessels, as discussed in Section 14.

12.4 Power Down Procedure

A power down procedure involves reducing the number of airguns in use such that the radius of the 180 dB (or 190 dB) injury zone is decreased to the extent that marine mammals are not in the harassment zone. In contrast, a shut down procedure occurs when all airgun activity is suspended. During a power down, a mitigation airgun, typically the 10 cui, is operated. Operation of the mitigation gun allows the safety radii to decrease to 10 m, 10 m, and 280 m (33 ft, 33 ft, and 919 ft) for the 190 dB, 180 dB, and 160 dB zones, respectively. If a marine mammal is detected outside the safety radius (either injury or harassment) but is likely to enter that zone, the airguns may be powered down before the animal is within the safety radius, as an alternative to a complete shut down. Likewise, if a marine mammal is already within the harassment zone when first detected, the airguns will be powered down immediately if this is a reasonable alternative to a complete shut down. If a marine mammal is already detected within the injury zone when first detected, the airguns will be shut down immediately.

Following a power down, airgun activity will not resume until the marine mammal has cleared the injury zone. The animal will be considered to have cleared the safety zone if it:

- Is visually observed to have left the injury zone,
- Has not been seen within the injury zone (190dB) for 15 min in the case of pinnipeds and harbor porpoise, or
- Has not been seen within the injury zone (180 dB) for 30 min in the case of cetaceans.

12.5 Shut Down Procedure

As noted previously, a shut down occurs when all airgun activity is suspended. The operating airgun(s) and/or pinger will be shut down completely if a marine mammal approaches the applicable injury zone. The shut down procedure will be accomplished within several seconds (of a "one shot" period) of the determination that a marine mammal is either in or about to enter the injury zone.

Airgun activity will not resume until the marine mammal has cleared the safety radius. Following a shut down, airgun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the injury zone if it:

- Has not been seen within the injury zone (180 dB for cetaceans and 190 dB for pinnipeds) for 15 minutes in the case of species with shorter dive durations (small odontocetes and pinnipeds), or
- Has not been seen within the injury zone (180 dB) for 30 minutes in the case of species with longer dive durations (large odontocetes, including killer whales and beluga whales).

After a shut down during night operations, seismic survey activities will be suspended until the full injury zone is visible for at least 30 minutes.

12.6 Ramp Up Procedure

A "ramp up" procedure gradually increases airgun volume at a specified rate. Ramp up is used at the start of airgun operations, including a power down, shut down, and after any period greater than 10 minutes in duration without airgun operations. The airgun array begins operating after a specified-duration period without airgun operations. NMFS normally requires that the rate of ramp up be no more than 6 dB per 5-minute period. Ramp up will begin with the smallest gun in the array that is being used for all airgun array configurations. During the ramp up, the safety zone for the full airgun array will be maintained.

If the complete safety radius has not been visible for at least 30 minutes prior to the start of operations, ramp up will not commence unless the mitigation gun has been operating during the interruption of seismic survey operations. This means that it will not be permissible to ramp up the 24-gun source from a complete shut down in thick fog or at other times when the outer part of the safety zone is not visible. Ramp up of the airguns will not be initiated if a marine mammal is sighted within or near the applicable safety radii at any time.

12.7 Speed or Course Alteration

If a marine mammal is detected outside the injury zone (180 or 190dB) and, based on its position and the relative motion, is likely to enter the injury zone, the vessel's speed and/or direct course may, when practical and safe, be changed that also minimizes the effect on the seismic program. This can be used in coordination with a power down procedure. The marine mammal activities and movements relative to the seismic and support vessels will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations, power down, or shut down of the airgun(s).

12.8 Distance Estimation of Marine Mammal to Source Vessel(s)

12.8.1 Calculation of Marine Mammal Distance to Source Vessel(s)

When a marine mammal is sighted from the shore-based observation station and/or mitigation vessel, PSOs will radio in a shut down immediately by calling "Shut down, shut down, shut down." Personnel on the source vessels will respond that they are shut down. PSOs on the source vessels will record shut down request time and implementation time (both to the second). PSOs and the on-duty ship's navigator then will utilize the 10 minute shut down window to estimate distance of the marine mammal to the source vessel(s). These distance estimations will be calculated by range and bearing from the observing platform (land based observation location and/or vessel). The navigator on the source vessel(s) will graphically estimate the mammal's location on the "Nav" computer by dragging a line away from the observation platform at the range and bearing given, drag a line from that spot to the source vessel(s) to get the desired mammal-source distance. These distances are given in feet and will then be converted by the PSO into meters using the program "Convert." In the event that the marine mammal is determined to be within the 160 dB safety zone, PSOs will maintain the shut down for the specified duration (15 minutes for pinnipeds and harbor porpoise and 30 minutes for larger cetaceans). In the event that the marine mammal is determined to be outside the 160 dB zone the seismic operations will be restarted at full volume. If the shut down of seismic operations is greater than the allowed 10 minute window, a full ramp up will be implemented following the defined ramp up procedure.

13.0 Measures to Reduce Impacts to Subsistence Users

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.

Since November 2010, Apache has met and continues to meet with many of the villages and traditional councils throughout the Cook Inlet region. During these meetings, no concerns have been raised regarding potential conflict with subsistence harvest.

Additionally, Apache met with the Cook Inlet Marine Mammal Council (CIMMC) to describe the Project activities and discuss subsistence concerns from March 2011 - February 2012. The meeting provided information on the time, location, and features of the proposed 3D program, opportunities for involvement by local people, potential impacts to marine mammals, and mitigation measures to avoid impacts. Discussions regarding marine seismic operations continued with the CIMMC until its disbandment.

The features of the 3D program should prevent any adverse effects on the availability of marine mammals for subsistence.

- In-water seismic activities will follow mitigation and monitoring procedures as described in Sections 12 and 14 of this application to minimize effects on the behavior of marine mammals and; therefore, opportunities for harvest by Alaska Native communities.
- Regional subsistence representatives may support recording marine mammal observations along with marine mammal biologists during the monitoring program and be provided annual reports.
- The size of the affected area, mitigation measures, and input from the CIMMC should result in the 3D program having no effect on the availability of marine mammals for subsistence uses.

[1] Meetings have been held with Alexander Creek, Knikatnu, Native Village of Tyonek, Salamatof, Tyonek Native Corporation, Ninilchik Traditional Council, Ninilchik Native Association, Village of Eklutna, Kenaitze Indian Tribe, and Cook Inlet Region, Inc.

14.0 Monitoring and Reporting

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. Guidelines for developing a site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources.

14.1 Monitoring

Apache's proposed Monitoring Plan is described below. Apache understands that this Monitoring Plan will be subject to review by NMFS and others, and that refinements may be required.

14.1.1 Visual Boat-Based Monitoring

Three vessels will employ PSOs to identify marine mammals during all daytime hours of airgun operations: the two source vessels (*M/V Peregrine Falcon* and *M/V Arctic Wolf*) and one support vessel (*M/V Dreamcatcher*). Two PSOs will be on the source vessels and two PSOs on the support vessel in order to better observe the safety, power down, and shut down areas. On each vessel, one PSO will be on watch for four hours before being relieved by the second PSO for four hours. Therefore, between all three vessels, six PSOs will be on board with three on watch at any given time. When marine mammals are about to enter or are sighted within designated safety zones, airgun or pinger operations will be powered down (when applicable) or shut down immediately. The vessel-based observers will watch for marine mammals at the seismic operation during all periods of source effort and for a minimum of 30 minutes prior to the planned start of airgun or pinger operations after an extended shut down. Apache personnel will also watch for marine mammals (insofar as practical) and alert the observers in the event of a sighting. Apache personnel will be responsible for the implementation of mitigation measures only when a PSO is not on duty (e.g., nighttime operations).

Seismic operations will not be initiated or continue when adequate observation of the designated safety zone is not possible due to environmental conditions such as high sea state, fog, ice and low light. Termination of seismic operations will be at the discretion of the lead PSO based on continual observation of environmental conditions and communication with other PSOs.

With NMFS consultation, PSOs will be hired by Apache or its designee. Apache will provide the curriculum vitae and references for all PSOs. PSOs will follow a schedule so observers will monitor marine mammals near the seismic vessel during all ongoing operations and air-gun ramp ups. PSOs will normally be on duty in shifts no longer than four hours with two hour minimum breaks to avoid observation fatigue. The vessel crew will also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction on how to do so.

The source and support vessels are suitable platform for marine mammal observations. When stationed on the third deck and/or flying bridge, the observer will have an unobstructed view around the entire vessel. If surveying from the bridge, the observer's eye level will be about 6 m (20 ft) above sea level. During operations, the PSO(s) will scan the area around the vessel systematically with reticule binoculars (e.g., 7×50 or equivalent) and with the naked eye. Laser range finders (Leica LRF 1200 laser rangefinder or equivalent)

will be available to assist with distance estimation. They are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly.

PSOs observing from the mitigation vessel will be equipped with big eye (20x100) binoculars.

All observations and/or mitigation measures will be recorded in a standardized format. Data will be entered into a custom database using a notebook computer. The accuracy of the data entry will be verified by computerized validity data checks as the data are entered and by subsequent manual checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical, or other programs for further processing and archiving.

Results from the vessel-based visual observations will provide:

- The basis for real-time mitigation (airgun shut down, power down, and ramp up).
- Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
- Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
- Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

14.1.2 Visual Shore-Based Monitoring

In addition to the vessel-based PSOs, Apache proposes to utilize a shore-based station when possible. The shore-based station will follow all safety procedures, including bear safety. The shore-based location will need to have sufficient height to observe marine mammals; the PSO would be outfitted with big-eye (20x100) binoculars. The PSO would scan the area prior to, during, and after the airgun operations. The PSO would be in contact with the other PSOs on the vessels, as well as the source vessel operator via radio to be able to communicate the sighting of a marine mammal approaching or sighted within the project area.

14.1.3 Aerial-Based Monitoring

Apache proposes, safety and weather permitting, to conduct daily aerial surveys when there are any seismic-related activities (including but not limited to node laying/retrieval or airgun operations) occurring north or east of a line from Tyonek across to the eastern side of Number 3 Bay of the Captain Cook State Recreation Area, Cook Inlet. Safety and weather permitting, surveys are to be flown even if the air guns are not being fired.

Apache also proposes, safety and weather permitting, and when operating north or east of a line from Tyonek to the eastern side of Number 3 Bay of the Captain Cook State Recreation Area, Cook Inlet, to fly daily aerial surveys around the most important beluga whale foraging and reproductive areas of the upper Inlet. Flights are to be conducted with a plane with adequate viewing capabilities, i.e., view not obstructed by wing or other part of the plane. Flight paths should encompass areas from Anchorage, along the coastline of the Susitna Delta to Tyonek, across the inlet to Point Possession, around the coastline of Chickaloon Bay to Burnt Island, and across to Anchorage (or in reverse order). The surveys will continue daily when Apache has any activities north or east of a line from Tyonek across to the eastern side of Number 3 Bay of the Captain Cook State Recreation Area (Figure 19).

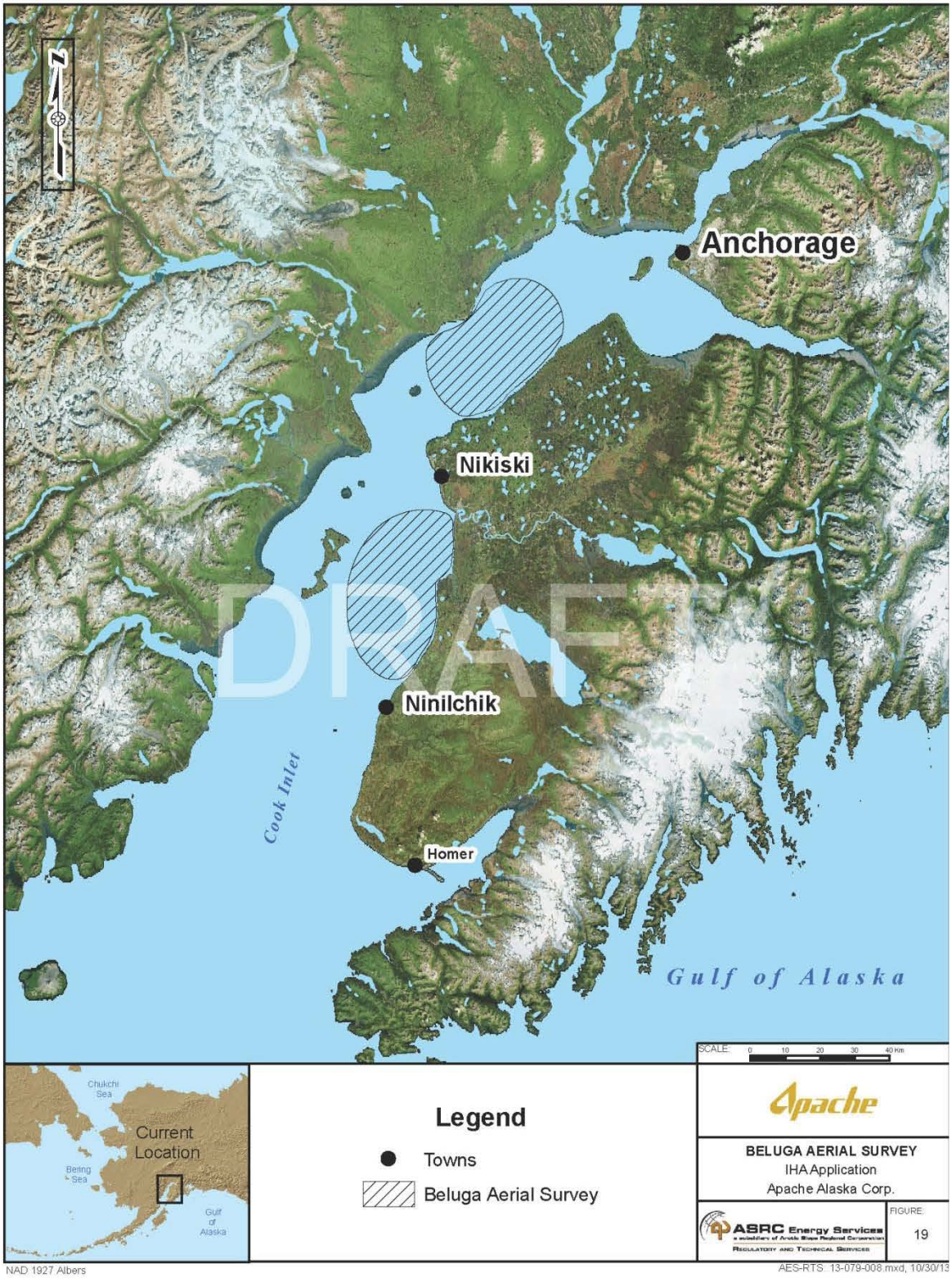

Figure 19. Beluga Aerial Survey Locations

Apache also proposes to, safety and weather permitting, conduct aerial surveys when operating near river mouths to identify large congregations of beluga whales and harbor seal haul outs.

In the event of a marine mammal sighting, aircraft will attempt to maintain a radial distance of 457 m (1,500 ft) from the marine mammal(s). Aircraft will avoid approaching marine mammals from head-on, flying over or passing the shadow of the aircraft over the marine mammals. Using these operational requirements, sound levels underwater are not expected to reach NMFS harassment thresholds (Richardson et al. 1995).

Results from the aerial and shore-based observations will provide:

- The basis for real-time mitigation (airgun power down, shut down, and ramp up) (aerial observers will be in radio contact with the seismic operations personnel).
- Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
- Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.

14.2 Reporting

Immediate reports will be submitted to NMFS if 25 belugas are detected in the Level B harassment zone to evaluate and make necessary adjustments to monitoring and mitigation. If the number of detected takes is met or exceeded the amount authorized for any marine mammal species, Apache will immediately cease survey operations involving the use of active sound sources (e.g., air guns and pingers) and notify NMFS.

Weekly reports will be submitted to NMFS no later than the close of business (Alaska time) each Thursday during the weeks when in-water seismic activities take place. The field reports will summarize species detected, in-water activity occurring at the time of the sighting, behavioral reactions to in-water activities, and the number of marine mammals taken.

Monthly reports will be submitted to NMFS for all months during which in-water seismic activities take place. The monthly report will contain and summarize the following information:

1. Dates, times, locations, heading, speed, weather, sea conditions (including Beaufort sea state and wind force), and associated activities during all seismic operations and marine mammal sightings;
2. Species, number, location, distance from the vessel, and behavior of any marine mammals, as well as associated seismic activity (number of power-downs and shut downs), observed throughout all monitoring activities.
3. An estimate of the number (by species) of: (A) pinnipeds that have been exposed to the seismic activity (based on visual observation) at received levels greater than or equal to 160 dB re 1 µPa (rms) and/or 190 dB re 1 µPa (rms) with a discussion of any specific behaviors those individuals exhibited; and (B) cetaceans that have been exposed to the seismic activity (based on visual observation) at received levels greater than or equal to 160 dB re 1 µPa (rms) and/or 180 dB re 1 µPa (rms) with a discussion of any specific behaviors those individuals exhibited.
4. A description of the implementation and effectiveness of the: (A) terms and conditions of the Biological Opinion's Incidental Take Statement (ITS); and (B) mitigation measures of the IHA. For the Biological Opinion, the report shall confirm the implementation of each Term and Condition, as well as any conservation recommendations, and describe their effectiveness, for minimizing the adverse effects of the action on ESA-listed marine mammals.

An annual will be submitted to NMFS within 90 days after the end of the project. The report will summarize all activities and monitoring results conducted during in-water seismic surveys. The Technical Report will include the following:

1. Summaries of monitoring effort (e.g., total hours, total distances, and marine mammal distribution through the study period, accounting for sea state and other factors affecting visibility and detectability of marine mammals);
2. Analyses of the effects of various factors influencing detectability of marine mammals (e.g., sea state, number of observers, and fog/glare);
3. Species composition, occurrence, and distribution of marine mammal sightings, including date, water depth, numbers, age/size/gender categories (if determinable), group sizes, and ice cover;
4. Analyses of the effects of survey operations;
   - sighting rates of marine mammals during periods with and without seismic survey activities (and other variables that could affect detectability), such as:
   - initial sighting distances versus survey activity state;
   - closest point of approach versus survey activity state;
   - observed behaviors and types of movements versus survey activity state;
   - numbers of sightings/individuals seen versus survey activity state;
   - distribution around the source vessels versus survey activity state; and
   - estimates of take by Level B harassment based on presence in the 160 dB disturbance zone.

15.0 Research Coordination

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

Open-water seismic operations have been conducted in Alaska waters for over 25 years and, during this time, there have been no noticeable adverse impacts from them on the marine mammal populations or their availability for subsistence uses. This includes seismic operations involving airgun arrays more powerful and extensive than that proposed for the Cook Inlet 3D Seismic Program. Over the time period these larger airgun arrays have been used in the Chukchi and Beaufort seas, bowheads, gray whales, and other species have increased to where they are approaching or at carrying capacity of the habitat. Furthermore, the subsistence harvest of bowhead whales has been very consistent over the last 10 years among the whaling villages suggesting no decrease in their availability for harvest (Suydam and George 2004). While studies of seismic surveys on marine mammals have not been conducted in Cook Inlet, those referred above for the Alaska Arctic suggest the nearshore location, site characteristic, short time frame, and limited number and length of time of active seismic operations each day of the proposed Cook Inlet 3D Seismic Program should have no impact on the marine mammal populations.

To further ensure that there will be no adverse effects resulting from the planned seismic operations, Apache will continue to cooperate with NMFS, the Bureau of Ocean Energy Management, other appropriate federal agencies, the State of Alaska, Cook Inlet tribal entities including but not limited to the Native Village of Tyonek and Kenaitze Indian Tribe, affected communities, and other monitoring programs to coordinate research opportunities and assess all measures than can be taken to eliminate or minimize any impacts from their program.

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APPENDIX A

Sound Source Verification of Land-Based Explosives

Memorandum

TO: Katie McCafferty (USACE)

CC: Mandy Migura (NMFS), Brad Smith (NMFS), Brian Hopper (NMFS), Scott Nish (SAE), Jeff Hastings (SAE), Rick Trupp (SAE), Rick Stolz (SAE), Suzan Simonds (SAE), Mike Reblin (Apache), Steve Adiletta (Apache), Lisa Parker (Apache)

FROM: Sheyna Wisdom (Fairweather Science)

RE: Sound Source Verification of Land-Based Explosives Results

1.0 SUMMARY

SAExploration, Inc. (SAE) conducted a sound source verification (SSV) survey to characterize the underwater received sound levels resulting from land-based explosives on 17-18 September, 2011 in Trading Bay for Apache Alaska Corporation. The following summarizes the methods and results of the SSV study.

Two acoustic teams, JASCO Applied Sciences (JASCO) and Illingworth & Rodkin, Inc. (I&R), were contracted by SAE to perform the SSV test. JASCO's SSV equipment consisted of three Ocean Bottom Hydrophone (OBH) autonomous seabed acoustic recording systems, two vessel-based real-time acoustic monitoring and data logging stations, and one 4-channel particle velocity and acceleration measurement system. I&R's equipment consisted of two vessel-based single channel hydrophone measurement systems.

The SSV test consisted of a total of seven shot locations beginning in the mudflats, three locations in the lowlands and spaced every half mile for 4 miles inland, a total of 24 holes. Each location had a 1 kg charge buried at 25 ft, a 2 kg buried at 25 ft, and a 4 kg charge buried at 35 ft. Further details on methods are provided below. The detonations and measurements were performed on 17 September at low tide from approximately 3:30 – 8:30 pm. The OBHs were deployed at approximately 3:30 pm and retrieved at approximately 9:30 pm. Environmental conditions were favorable for collection of visual and acoustic data with winds less than 5 knots, calms seas, slightly overcast, and no fog or wind.

In order to ensure Cook Inlet beluga whales were not exposed to underwater received levels exceeding the National Marine Fisheries Service (NMFS) Level B harassment criteria during this test, three Protected Species Observers (PSOs) were employed on the two vessels and in a twin-engine aircraft.

Received levels reported by JASCO and I&R are well below the NMFS criterion of 160 dB re 1 Pa rms from the OBH and real-time vessel based data logging systems.

2.0 LOCATION

The SSV test was performed in Trading Bay, West Cook Inlet, Alaska. The test location is in Township Section and Range S011N011W and S011N012W, near the town of Shirleyville (Figure 1). The test line

extended 4 miles along the northwest side of Nikolai Creek. The SSV test will consist of a total of eight shot locations beginning in the mudflats, three locations in the lowlands and spaced every half mile for 4 miles inland, a total of 24 holes. Locations of the test shots and vessels are provided in Appendix A.

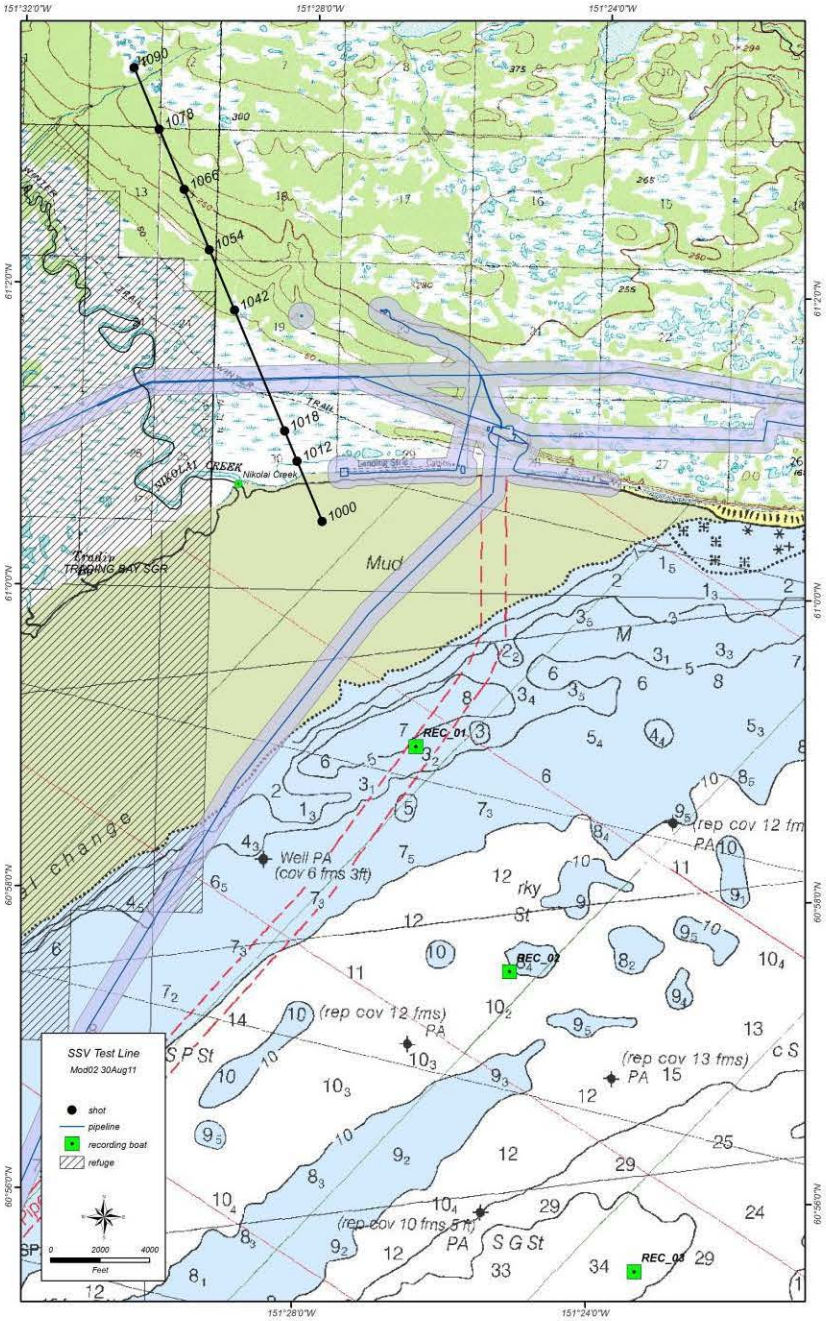


Figure 1. SSV test shothole location and OBH locations.

3.0 VESSELS

Two cable laying vessels, *the M/V Maxime* and *M/V Peregrine Falcon* were used for acoustic equipment deployment and retrieval (Figure 2). The *M/V Peregrine Falcon* is a 25 feet (ft) x 90 ft aluminum landing craft with a 32 inch draft and the *M/V Maxime* is a 16 ft x 70 ft aluminum landing craft. During the detonations, a Fast Response Craft (FRC) (e.g., 20-ft inflatable) was anchored at approximately 1 km from the last shothole on the test line. The particle sensor was deployed from the FRC. The *M/V Peregrine Falcon* was drifting at approximately 3 km from the last shothole on the test line. The JASCO real-time data logging system and I&R single channel hydrophone were deployed over the side of the vessel. The *M/V Maxime* was driving at approximately 6 km from the last shothole on the test line. The JASCO real-time data logging system and I&R single channel hydrophone were deployed over the side of the vessel. The actual locations of the vessels during the detonation are shown on Figure 3.

Figure 2. M/V Peregrine Falcon (left), M/V Maxime (right).

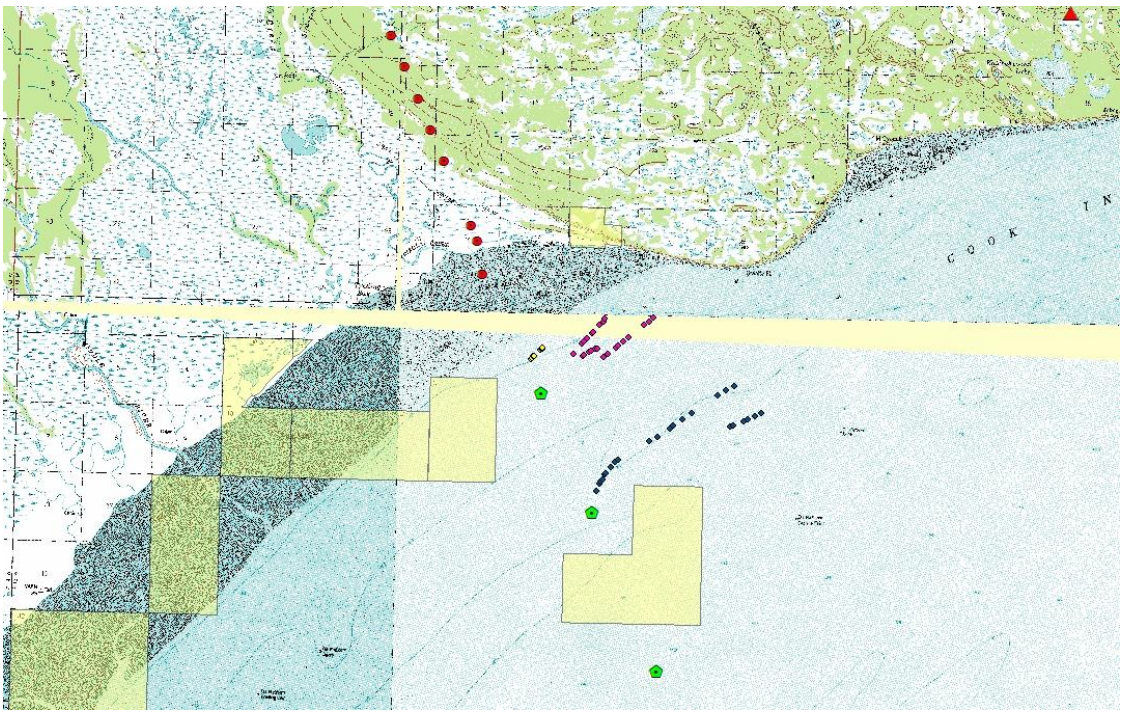


Figure 3. Locations of vessels during shothole detonations.
Yellow is zodiac with particle sensor, pink is *M/V Peregrine Falcon*, and gray is *M/V Maxime*.

4.0 PERSONNEL

The vessel crew was comprised of a captain and two deck hands for each vessel and one cook. The scientific team on the vessels consisted of three JASCO personnel (Caitlin O'Neil, Jennifer Wladichuk, Melanie Austin), two I&R personnel (James Reyff, Ryan Pommerenck), two PSOs (Sasha McFarland, Bridget Watts), and two project managers (Rick Stolz, Sheyna Wisdom). One PSO (Christa Koos) was on the aircraft (BN2 Islander twin turboprop) that flew over the site prior to the detonation to ensure there were no Cook Inlet beluga whales in the area.

5.0 ACOUSTIC MONITORING

Methods - JASCO

JASCO-operated equipment consisted of:

1. Three JASCO OBH autonomous seabed acoustic recording systems (Figures 4 and 5) deployed at 3 km, 6 km, and 10 km from the last shothole on the test line.

2. Two JASCO ADAMS/SpectroPlotter vessel-based real-time acoustic monitoring and data logging stations (Figure 6) deployed from vessels located at 3 km and 6 km from the last shothole on the testline. Vessels were drifting with engines off.

3. One 4-channel particle velocity and acceleration measurement system (Figure 7). The particle velocity sensor deployed from the FRC at approximately 1 km from the last shothole on the test line.

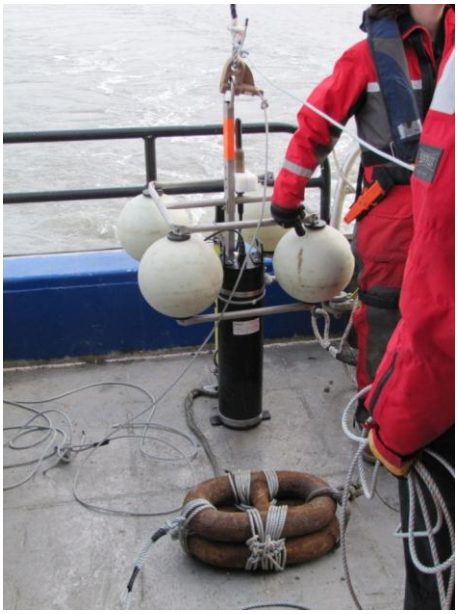


Figure 4. Ocean Bottom Hydrophone (OBH) autonomous acoustic recorders with float frames and integral acoustic releases.

Figure 5. Deployment of OBH in Cook Inlet.

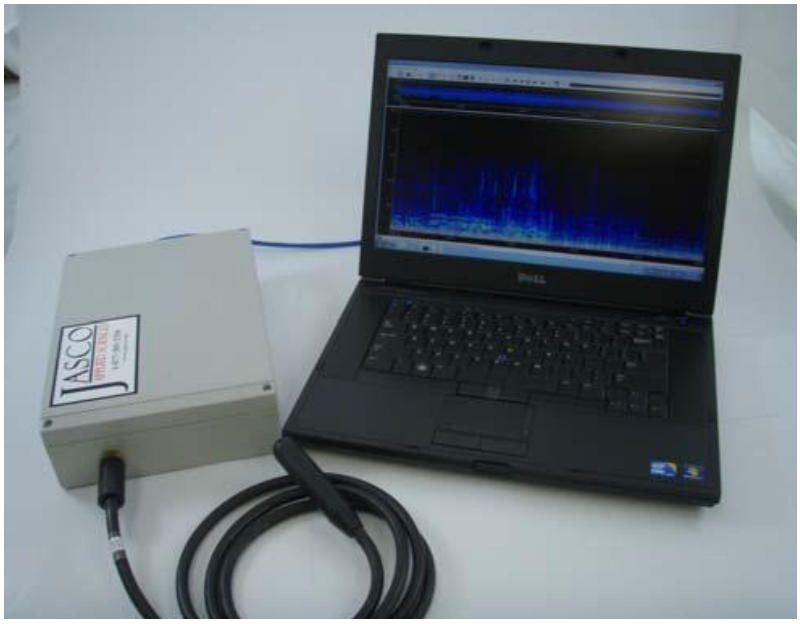


Figure 6. JASCO ADAMs digital acoustic monitoring system and SpectroPlotter real-time monitoring/logging software

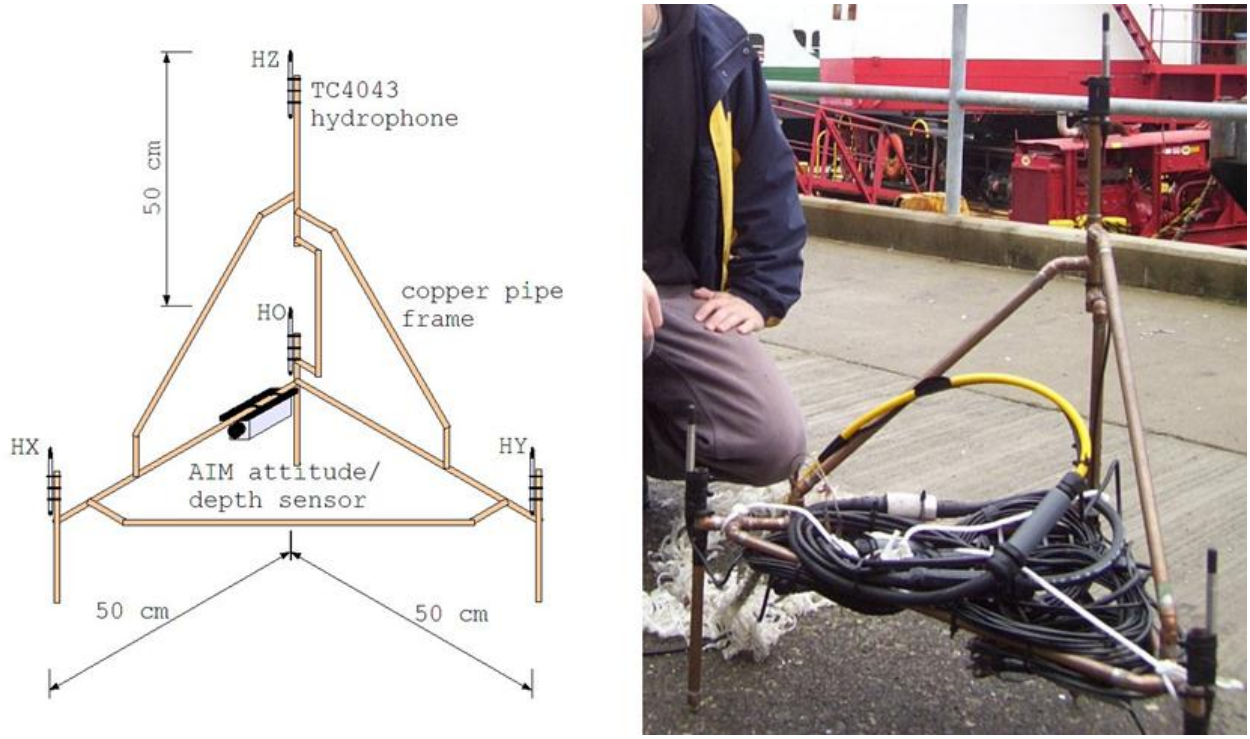


Figure 7. Four-hydrophone arrangement for particle velocity measurements using pressure gradient method.

Methods – I&R

I&R-operated equipment consisted of:

Two (2) single channel hydrophone measurement systems (Figure 8) consisting of hydrophones, signal charge converter, multigain signal conditioner, and dual channel digital audio recorder (sample rate up to 48 kHz). Sounds were recorded for subsequent analysis. The hydrophones were deployed over the side from vessels located on anchor at 3 km and 6 km from the last shothole on the test line.

On the *M/V Peregrine*, the hydrophone was a Reson TC-4103 miniature hydrophone connected to a PCB in-line charge amplifier and multi-gain power supply. The signal was split and fed into a Roland digital audio recorder and a Larson Davis Model 3000 Real Time Analyzer (RTA). The system was calibrated with a GRAS Type 42AC piston phone with a hydrophone coupler that produced a tone of 155.3 dB re 1 µPa at 250 Hz. On the *M/V Maxime*, the same system was used except a Larson Davis Model 820 Type 1 sound level meter was used instead of the RTA.

Figure 8. Two LDL Model 831 SLMs, recorder and one strung Reson TC-4033

Results – JASCO

JASCO analyzed the results from the three loudest shots recorded on the OBH and vessel-based data logging systems located 3 km from station 1000 (nearest shot to the vessels). For processing sound levels, the acoustic signals were low-pass filtered at 60 Hz to remove background noise (i.e., drilling rigs in the area) not related to the explosion shots. The over the side system was at a depth of 2 m and the OBH was approximately at a depth of 30 m, 1.5 m above the seafloor.

The sound levels measured on the shallow, over the side hydrophone were lower than on the OBH. This is to be expected, as low-frequency sounds are strongly attenuated near the sea surface due to the proximity of the pressure-release boundary.

Tables 1 and 2 summarize results of the test shothole location and Figure 9 shows a spectrogram plot of shot ID number 9 on OBH at 3022 m receiver range.

Table 1. Land explosion shots recorded by Ocean Bottom Hydrophone (OBH) at 3 km receiver range.

Shot ID Number	Station	Source Depth (ft)	Charge Size (kg)	Range (m)	0-Peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SEL (dB re 1 µPa2s)
1	1000	25	2	3022	142	134	130
8	1000	25	2	3022	142	131	130
9	1000	25	4	3022	144	131	132

Table 2. Land explosion shots recorded by over the side system at 3 km receiver range.

Shot ID Number	Station	Source Depth (ft)	Charge Size (kg)	Range (m)	0-Peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SEL (dB re 1 µPa2s)
1	1000	25	2	2794	117	109	106
8	1000	25	2	2957	117	106	107
9	1000	25	4	2992	124	110	114

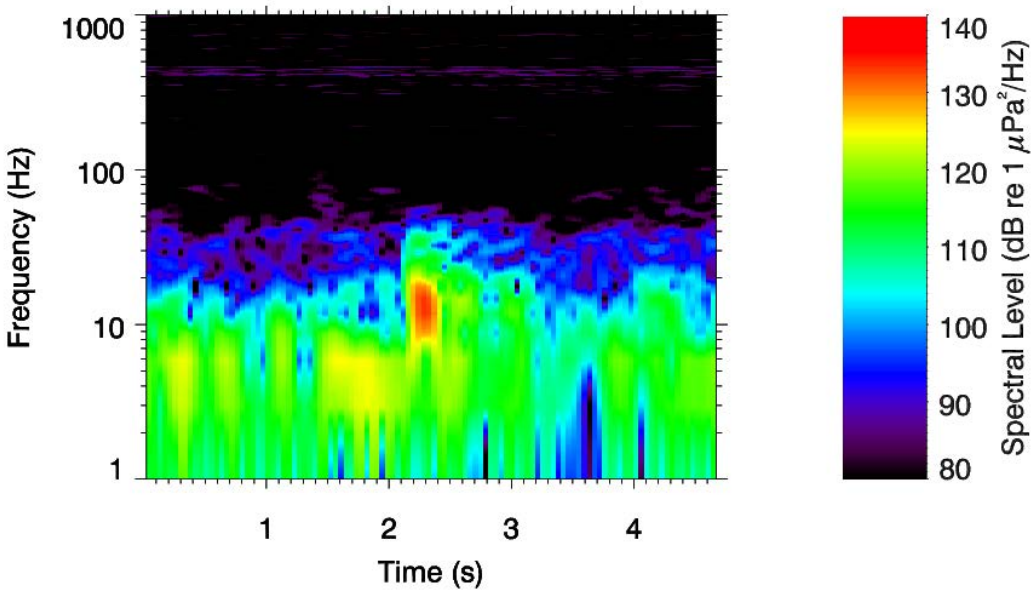


Figure 9. Spectrogram plot of land explosion shot ID number 9 on OBH at 3022 m receiver range

Results – I&R

I&R started the measurements when the project manager indicated the shots were "hot" and ended it after the shot was complete. The spectra charts shown in Appendix B show the maximum level (L_{max}) (the 1/8th of a second RMS detector) and the average equivalent energy level (L_{eq}) for the period measured. I&R reported received levels from 107-111 dB L_{eq} and 115-120 dB L_{max}, although it is important to note that these levels reported are not associated with the shot, as a signal was never detected during the study.

DISCUSSION

Received levels reported by JASCO and I&R are well below the NMFS criterion of 160 dB re 1 Pa rms from the OBH and real-time vessel based data logging systems.

MARINE MAMMAL MONITORING

Methods

Two PSOs observed from the two vessels: *M/V Peregrine* with eye height on bridge ~15 ft; visible horizon distance ~7.75km and *M/V Maxime* with eye height on bridge ~9 ft; visible horizon distance ~3km). Observers began observations 90 minutes prior to and during on-land and mudflat seismic activity. A third PSO conducted a site clearance overflight 30 minutes prior to seismic activity to ensure no beluga whales were in the area. One PSO was positioned on the port side of the bridge on each vessel and scanned the water to the horizon in the full field of view (~180 degrees forward). We recorded all marine mammal sightings. Variables recorded were: time of sighting, species, latitude and

longitude of the vessel, position relative to the vessel, distance from vessel, number of animals in the sighting, color phase of belugas (white, gray, or black), behavior (including during and after shothole activity), closest point of approach time and distance, and any mitigation measures taken. We also recorded environmental conditions every 30 minutes, including water depth, Beaufort sea state, wind direction, % ice cover, % cloud cover, tidal stage, visibility, glare amount, and glare direction. Other variables we recorded were vessel speed and direction and whether or not seismic activities were underway.

Results

The *M/V Maxime* was positioned approximately 6 km from shore and did not observe any marine mammals during the shotholes. The *M/V Peregrine* was positioned approximately 3 km from shore and had seven marine mammal observations (Table 3), all positioned closer to shore than the observation platform. Both vessels drifted with the engines off during shothole detonations, but repositioned to compensate for movement with the current.

Table 3. Marine mammal sightings during SSV test of 17 September, 2011.

Time	Species	#	Distance from vessel (m)	Charge started? Y/N	Behavior	Mitigation measures taken Y/N	Comments
1553	Harbor seal	1	400	N	Look	N	Sank out of sight
1611	Harbor seal	1	500	N	Look	N	Sank; might be first
1619	Unidentified pinniped	1	1200	N	Rest	N	Sank
1626	Harbor seal	1	200	N	Look	N	Sank; might be first
1640	Harbor seal	1	600	N	Rest	N	Sank
1652	Harbor seal	1	350	Y	Rest	N	Mudflat shot initiated
1659	Harbor porpoise	1	250	Y	Travel	N	Inland shots ongoing

No beluga whales were sighted. The single harbor porpoise was sighted for three surfacings (approximately 10 to 30 seconds between each), and then not seen again in the monitoring area. Harbor seals were noted looking at the *M/V Peregrine* or at the FRC. Of the five harbor seals seen during the SSV test, three sightings were in approximately the same area and within 34 minutes time; this may have been a single curious animal investigating the vessels in the area. None of the animals sighted exhibited changes of behavior during the encounters.

Discussion

No Cook Inlet beluga whales were sighted before, during, or after the SSV.

APPENDIX A

GPS LOCATIONS OF SHOT HOLE RELATIVE TO VESSEL

Appendix A
Apache Alaska Corporation
Land-Based Explosives SSV
Sept 17, 2011
Zodiac Measurements

Type	SP	Lat (WGS-84)	Long (WGS-84)	Month#	Day#	Year	Hour	Min	Sec	Comment	Symbol#	SymbolColor	SymbolDisplay	Altitude (Meters)	Depth (Meters)	Temp Deg C	Ref Dist	Ref units
T	1000, 2 kg, 25'	60.98991754	-151.4459912	9	18	2011	0	54	28	-9.956543	1.00E+25	1.00E+25	M	0.0045	724.0696	724.0696	0.000904	5
T	1012, 1 kg, 25'	60.98991293	-151.4459867	9	18	2011	1	0	53	-9.956543	1.00E+25	1.00E+25	M	0.0045	724.8647	724.8647	0.000904	5
T	1000, 1 kg, 15'	60.9899121	-151.4459883	9	18	2011	1	2	48	-8.995239	1.00E+25	1.00E+25	M	0.0136	725.0838	725.0838	0.002712	5
T	1012, 4 kg, 30'	60.98991126	-151.445987	9	18	2011	1	4	53	-8.995239	1.00E+25	1.00E+25	M	0.0104	725.3077	725.3077	0.002072	5
T	1012, 2 kg, 25'	60.98990983	-151.4459846	9	18	2011	1	8	38	-10.437256	1.00E+25	1.00E+25	M	0.0093	725.6802	725.6802	0.001864	5
T	1000, 1 kg, 10'	60.98990983	-151.4459847	9	18	2011	1	9	33	-9.47583	1.00E+25	1.00E+25	M	0.0104	725.7352	725.7352	0.002072	5
T	1000, 2 kg, 25'	60.98990849	-151.4459792	9	18	2011	1	15	4	-9.956543	1.00E+25	1.00E+25	M	0.0136	726.3564	726.3564	0.002712	5
T	1000, 4 kg, 25'	60.98990757	-151.445976	9	18	2011	1	19	4	-10.437256	1.00E+25	1.00E+25	M	0.0104	726.7662	726.7662	0.002072	5
T	1000, 1 kg, 25'	60.98990606	-151.4459759	9	18	2011	1	21	24	-9.956543	1.00E+25	1.00E+25	M	0.0045	727.0182	727.0182	0.000904	5
T	1018, 1 kg, 25'	60.98990682	-151.4459554	9	18	2011	1	37	59	-8.514648	1.00E+25	1.00E+25	M	0.0531	729.9043	729.9043	0.01063	5
T	1018, 4 kg, 35'	60.98992308	-151.4459197	9	18	2011	1	40	54	-8.514648	1.00E+25	1.00E+25	M	0.1071	732.5627	732.5627	0.021414	5
T	1018, 2 kg, 22'	60.98996591	-151.4458041	9	18	2011	1	46	39	-8.033936	1.00E+25	1.00E+25	M	0.1104	740.4203	740.4203	0.022072	5
T	1042, 2 kg, 25'	60.98997957	-151.4457686	9	18	2011	1	48	19	-8.514648	1.00E+25	1.00E+25	M	0.133	742.8656	742.8656	0.026606	5
T	1042, 4 kg, 35'	60.99001578	-151.4456852	9	18	2011	1	51	54	-8.514648	1.00E+25	1.00E+25	M	0.1915	748.9072	748.9072	0.038293	5
T	1042, 1 kg, 25'	60.99011192	-151.4454835	9	18	2011	1	55	15	-8.514648	1.00E+25	1.00E+25	M	0.2309	764.1707	764.1707	0.046179	5
T	1090, 1 kg, 25'	60.99050738	-151.4447552	9	18	2011	2	4	30	-8.033936	1.00E+25	1.00E+25	M	0.7245	823.1652	823.1652	0.144907	5
T	1090, 4 kg, 25'	60.99056857	-151.4446481	9	18	2011	2	6	45	-7.553101	1.00E+25	1.00E+25	M	0.5138	832.0936	832.0936	0.102766	5
T	1090, 2 kg, 25'	60.99064727	-151.4445126	9	18	2011	2	9	20	-8.033936	1.00E+25	1.00E+25	M	0.2922	843.4984	843.4984	0.058435	5
T	1078, 1 kg, 25'	60.9919603	-151.4419157	9	18	2011	3	12	20	-10.917847	1.00E+25	1.00E+25	M	0.5859	1457.1315	1457.1315	0.117177	5
T	1066, 1 kg, 25'	60.9919893	-151.4418427	9	18	2011	3	13	5	-10.917847	1.00E+25	1.00E+25	M	0.6164	1462.2217	1462.2217	0.123272	5
T	1078, 4 kg, 35'	60.99209533	-151.4415623	9	18	2011	3	15	55	-11.398438	1.00E+25	1.00E+25	M	0.7935	1481.397	1481.397	0.158691	5
T	1066, 4 kg, 35'	60.9921442	-151.441428	9	18	2011	3	16	55	-9.47583	1.00E+25	1.00E+25	M	0.6435	1490.4537	1490.4537	0.128697	5
T	1078, 2 kg, 25'	60.99224051	-151.4411628	9	18	2011	3	18	55	-11.398438	1.00E+25	1.00E+25	M	0.6908	1508.3173	1508.3173	0.138162	5
T	1066, 2 kg, 25'	60.99228267	-151.4410476	9	18	2011	3	19	50	-11.398438	1.00E+25	1.00E+25	M	0.7242	1516.1028	1516.1028	0.144837	5

Appendix A
Apache Alaska Corporation
Land-Based Explosives SSV
Sept 17, 2011
M/V Peregrine Measurements (3 km)

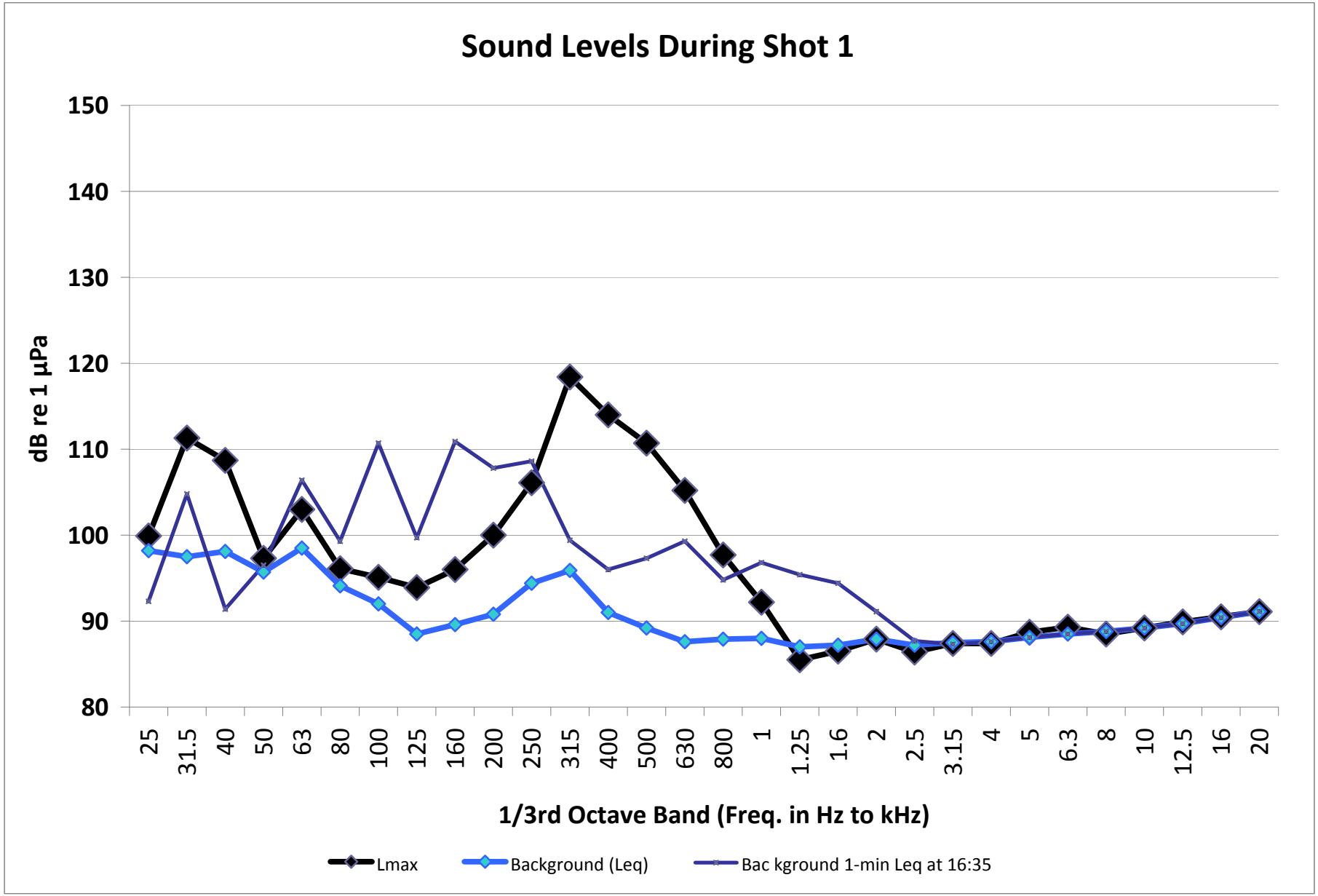
Type	SP	Lat (WGS-84)	Long (WGS-84)	Month#	Day#	Year	Hour	Min	Sec	Comment	Symbol#	SymbolColor	SymbolDisplay	Altitude (Meters)	Depth (Meters)	Temp Deg C	Ref Dist	Ref units
T	1000, 2 kg, 25'	60.99128891	-151.4275184	9	18	2011	0	54	25	-9.47583	1.00E+25	1.00E+25	M	4.3694	115.311	33279454.9	0.873877	5
T	1012, 1 kg, 25'	60.99334851	-151.4241399	9	18	2011	1	0	50	-11.398438	1.00E+25	1.00E+25	M	3.3304	418.0037	33279757.59	0.666083	5
T	1000, 1 kg, 15'	60.99389442	-151.4231465	9	18	2011	1	2	50	-11.398438	1.00E+25	1.00E+25	M	3.9199	503.4697	33279843.06	0.783979	5
T	1012, 4 kg, 30'	60.9945514	-151.4218887	9	18	2011	1	4	55	-11.398438	1.00E+25	1.00E+25	M	3.4539	605.7288	33279945.32	0.690778	5
T	1012, 2 kg, 25'	60.99560936	-151.4198625	9	18	2011	1	8	40	-12.359863	1.00E+25	1.00E+25	M	4.4164	778.0306	33280117.62	0.883288	5
T	1000, 1 kg, 10'	60.99589887	-151.419303	9	18	2011	1	9	30	-12.359863	1.00E+25	1.00E+25	M	3.0041	825.4883	33280165.07	0.60083	5
T	1000, 2 kg, 25'	60.9972953	-151.4165322	9	18	2011	1	15	5	-10.437256	1.00E+25	1.00E+25	M	2.5196	1054.324	33280393.91	0.50392	5
T	1000, 4 kg, 25'	60.99811287	-151.4151711	9	18	2011	1	19	5	-8.995239	1.00E+25	1.00E+25	M	2.2417	1181.1919	33280520.78	0.448348	5
T	1000, 1 kg, 25'	60.99861444	-151.414448	9	18	2011	1	21	25	-8.514648	1.00E+25	1.00E+25	M	2.2375	1253.7912	33280593.38	0.447505	5
T	1018, 1 kg, 25'	60.99061869	-151.4146858	9	18	2011	1	38	0	-11.398438	1.00E+25	1.00E+25	M	3.6331	2682.8585	33282022.45	0.726616	5
T	1018, 4 kg, 35'	60.99128581	-151.4130815	9	18	2011	1	40	50	-11.87915	1.00E+25	1.00E+25	M	4.306	2808.1364	33282147.72	0.861191	5
T	1018, 2 kg, 22'	60.99270101	-151.4095704	9	18	2011	1	46	35	-15.243652	1.00E+25	1.00E+25	M	2.9977	3068.359	33282407.95	0.599532	5
T	1042, 2 kg, 25'	60.99311926	-151.4085298	9	18	2011	1	48	20	-15.243652	1.00E+25	1.00E+25	M	4.1445	3144.6269	33282484.21	0.828903	5
T	1042, 4 kg, 35'	60.9940106	-151.4063459	9	18	2011	1	51	50	-13.801758	1.00E+25	1.00E+25	M	3.2603	3310.436	33282650.02	0.652058	5
T	1042, 1 kg, 25'	60.99497125	-151.4040654	9	18	2011	1	55	15	-13.321045	1.00E+25	1.00E+25	M	3.9478	3482.5438	33282822.13	0.789558	5
T	1090, 1 kg, 25'	60.99764843	-151.3973603	9	18	2011	2	4	30	-13.801758	1.00E+25	1.00E+25	M	4.0029	4002.4619	33283342.05	0.800588	5
T	1090, 4 kg, 25'	60.99834706	-151.395584	9	18	2011	2	6	45	-14.282471	1.00E+25	1.00E+25	M	4.1575	4127.1957	33283466.78	0.831508	5
T	1090, 2 kg, 25'	60.99914367	-151.3935282	9	18	2011	2	9	20	-14.282471	1.00E+25	1.00E+25	M	4.8923	4269.8134	33283609.4	0.978468	5
T	1078, 1 kg, 25'	60.99086126	-151.4237118	9	18	2011	3	12	22	-14.282471	1.00E+25	1.00E+25	M	5.1294	1552.4605	33289161.4	1.02588	5
T	1066, 1 kg, 25'	60.99102999	-151.4232123	9	18	2011	3	13	2	-13.801758	1.00E+25	1.00E+25	M	4.7472	1585.4591	33289194.4	0.949435	5
T	1078, 4 kg, 35'	60.99165168	-151.4207113	9	18	2011	3	15	57	-13.321045	1.00E+25	1.00E+25	M	4.5952	1747.0084	33289355.95	0.919035	5
T	1066, 4 kg, 35'	60.99191395	-151.419941	9	18	2011	3	16	57	-12.840454	1.00E+25	1.00E+25	M	5.3143	1798.8372	33289407.78	1.062865	5
T	1078, 2 kg, 25'	60.99229532	-151.4180942	9	18	2011	3	18	57	-12.840454	1.00E+25	1.00E+25	M	3.7352	1908.5827	33289517.52	0.747038	5
T	1066, 2 kg, 25'	60.99248459	-151.4173081	9	18	2011	3	19	47	-12.840454	1.00E+25	1.00E+25	M	5.6912	1956.4959	33289565.44	1.13825	5

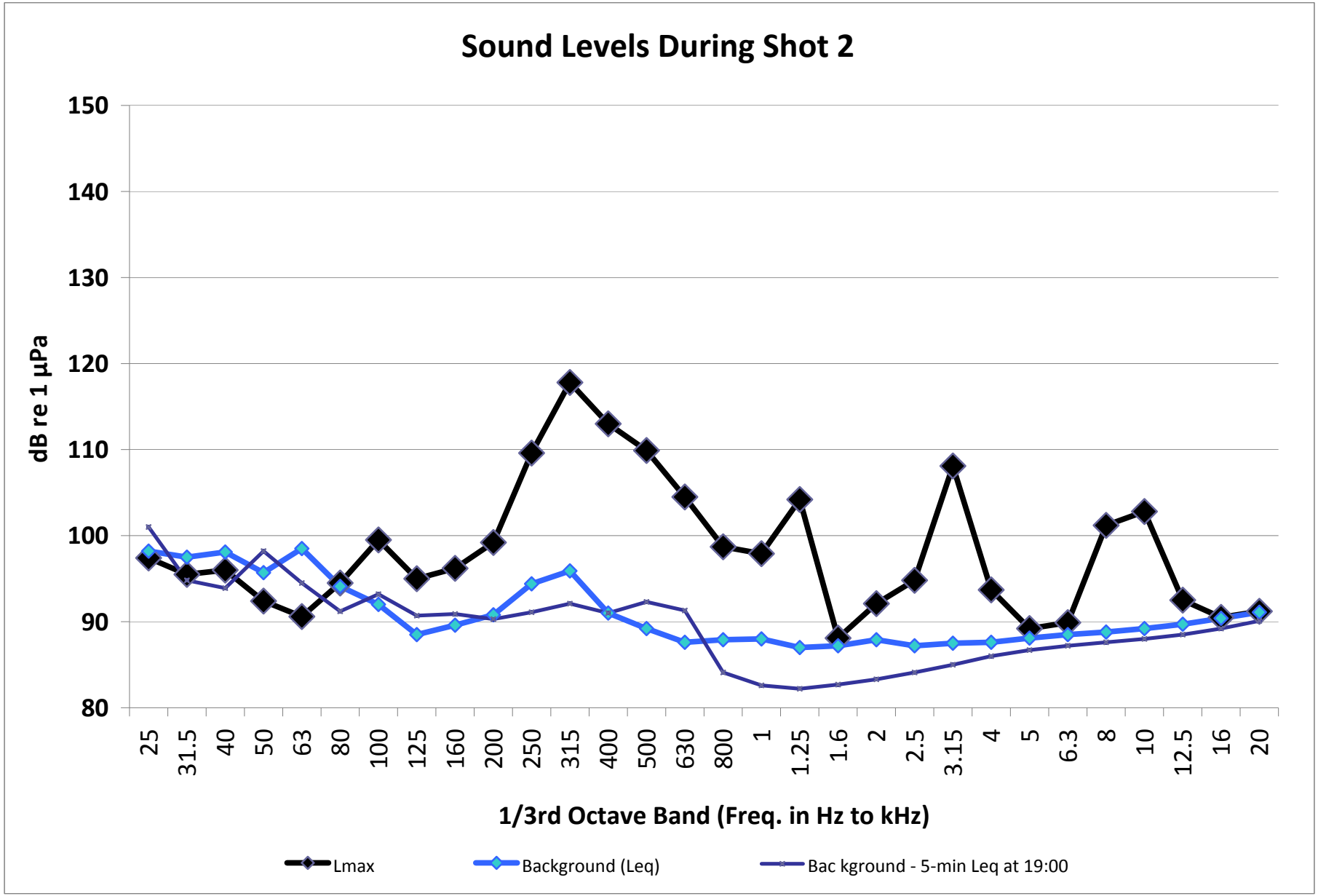
Appendix A
Apache Alaska Corporation
Land-Based Explosives SSV
Sept 17, 2011
M/V Maxime Measurements (6 km)

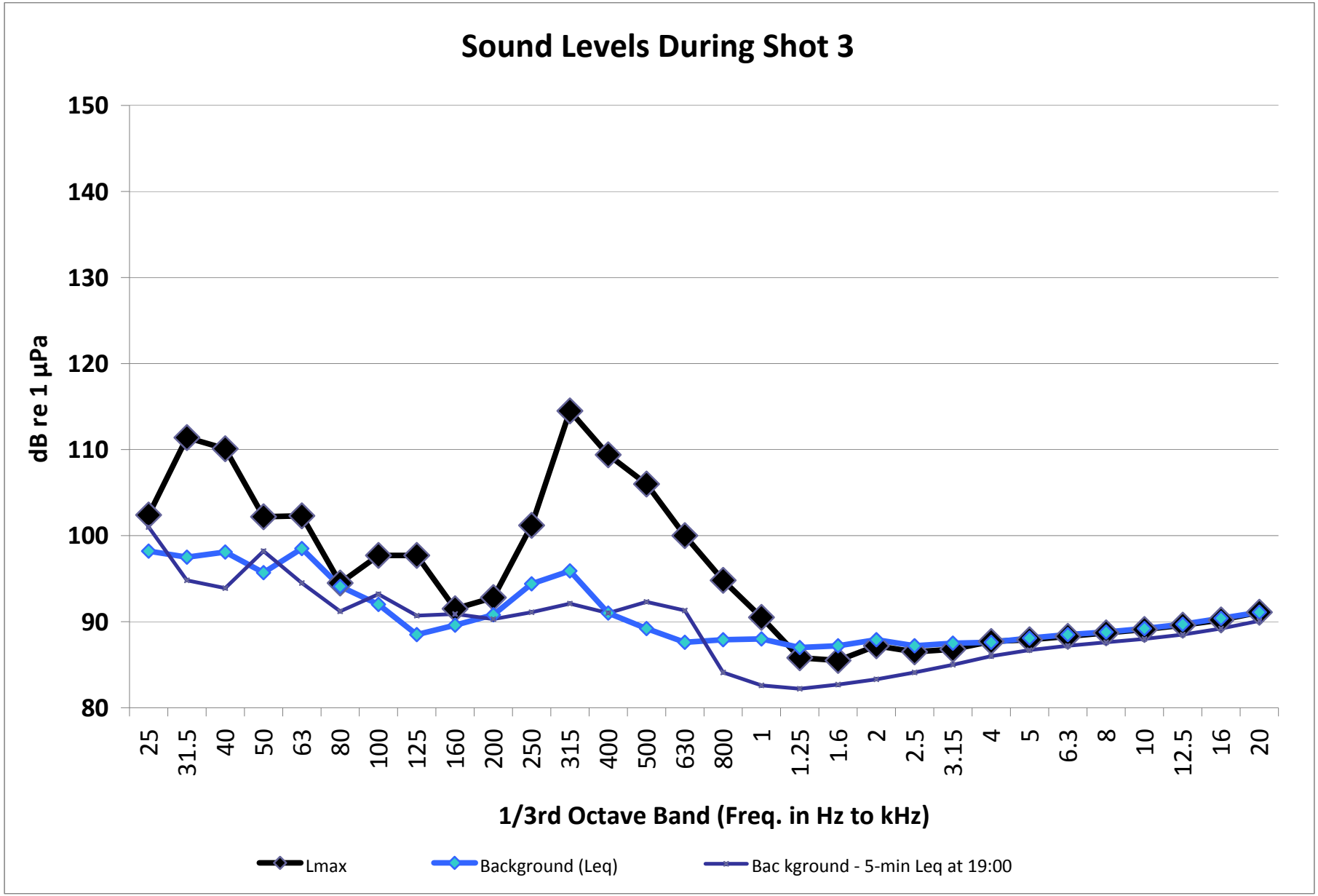
Type	SP	Lat (WGS-84)	Long (WGS-84)	Month#	Day#	Year	Hour	Min	Sec	Comment	Symbol#	SymbolColor	SymbolDisplay	Altitude (Meters)	Depth (Meters)	Temp Deg C	Ref Dist	Ref units
T	1000, 2 kg, 25'	60.96267309	-151.4163099	9	18	2011	0	54	33	16.960449	1.00E+25	1.00E+25	SM	0.0129	0.2667	3.8366	1.225251	38
T	1012, 1 kg, 25'	60.96421025	-151.4150674	9	18	2011	1	0	35	13.595825	1.00E+25	1.00E+25	SM	0.015	0.384	3.9538	1.289817	42
T	1000, 1 kg, 15'	60.96466547	-151.4146214	9	18	2011	1	2	26	10.711792	1.00E+25	1.00E+25	SM	0.0112	0.4188	3.9886	1.116323	36
T	1012, 4 kg, 30'	60.96518942	-151.4140437	9	18	2011	1	4	32	-0.343384	1.00E+25	1.00E+25	SM	0.012	0.4599	4.0298	1.053849	41
T	1012, 2 kg, 25'	60.96631846	-151.412938	9	18	2011	1	8	49	0.137451	1.00E+25	1.00E+25	SM	0.01	0.547	4.1169	1.236434	29
T	1000, 1 kg, 10'	60.96654679	-151.4127251	9	18	2011	1	9	32	2.540649	1.00E+25	1.00E+25	SM	0.0173	0.5643	4.1342	1.44979	43
T	1000, 2 kg, 25'	60.9678671	-151.4106768	9	18	2011	1	14	51	-5.149902	1.00E+25	1.00E+25	SM	0.0104	0.6787	4.2486	1.134143	33
T	1000, 4 kg, 25'	60.96891803	-151.4087569	9	18	2011	1	19	7	-5.630493	1.00E+25	1.00E+25	SM	0.0162	0.7763	4.3461	1.423388	41
T	1000, 1 kg, 25'	60.96943351	-151.4073062	9	18	2011	1	21	23	0.618042	1.00E+25	1.00E+25	SM	0.0203	0.8367	4.4065	1.623903	45
T	1018, 1 kg, 25'	60.97328542	-151.3941622	9	18	2011	1	37	49	-4.188599	1.00E+25	1.00E+25	SM	0.0192	1.3541	4.9239	2.155318	32
T	1018, 4 kg, 35'	60.97427306	-151.3908138	9	18	2011	1	41	7	-17.166382	1.00E+25	1.00E+25	SM	0.0271	1.4855	5.0554	2.4354	40
T	1018, 2 kg, 22'	60.97609168	-151.3854634	9	18	2011	1	46	41	-4.669312	1.00E+25	1.00E+25	SM	0.026	1.7046	5.2745	2.343729	40
T	1042, 2 kg, 25'	60.97661798	-151.3840703	9	18	2011	1	48	8	-3.707886	1.00E+25	1.00E+25	SM	0.0294	1.764	5.3339	2.585043	41
T	1042, 4 kg, 35'	60.97808423	-151.3803036	9	18	2011	1	51	49	-10.437256	1.00E+25	1.00E+25	SM	0.0184	1.926	5.4959	3.017529	22
T	1042, 1 kg, 25'	60.97949624	-151.3764597	9	18	2011	1	55	31	4.463257	1.00E+25	1.00E+25	SM	0.0232	2.0877	5.6576	2.089307	40
T	1090, 1 kg, 25'	60.98324094	-151.3651237	9	18	2011	2	4	17	3.982666	1.00E+25	1.00E+25	SM	0.0301	2.5946	6.1645	2.777337	39
T	1090, 4 kg, 25'	60.98422129	-151.3618725	9	18	2011	2	6	39	5.424561	1.00E+25	1.00E+25	SM	0.0504	2.723	6.2928	3.487922	52
T	1090, 2 kg, 25'	60.98530591	-151.3582288	9	18	2011	2	9	12	0.618042	1.00E+25	1.00E+25	SM	0.0452	2.8664	6.4363	3.321894	49
T	1078, 1 kg, 25'	60.97674119	-151.3594436	9	18	2011	3	12	15	5.905273	1.00E+25	1.00E+25	SM	0.0442	7.6506	11.2204	3.877627	41
T	1066, 1 kg, 25'	60.97695476	-151.3584596	9	18	2011	3	12	52	5.905273	1.00E+25	1.00E+25	SM	0.0361	7.6867	11.2566	3.515989	37
T	1078, 4 kg, 35'	60.97797149	-151.3538491	9	18	2011	3	15	44	0.137451	1.00E+25	1.00E+25	SM	0.0264	7.8566	11.4264	3.80736	25
T	1066, 4 kg, 35'	60.97837516	-151.3521358	9	18	2011	3	16	48	-2.746704	1.00E+25	1.00E+25	SM	0.0378	7.9204	11.4903	3.677114	37
T	1078, 2 kg, 25'	60.97907555	-151.3489779	9	18	2011	3	18	40	0.137451	1.00E+25	1.00E+25	SM	0.0395	8.0369	11.6067	4.061812	35
T	1066, 2 kg, 25'	60.97963211	-151.3464417	9	18	2011	3	20	6	2.540649	1.00E+25	1.00E+25	SM	0.0521	8.1302	11.7	3.830052	49

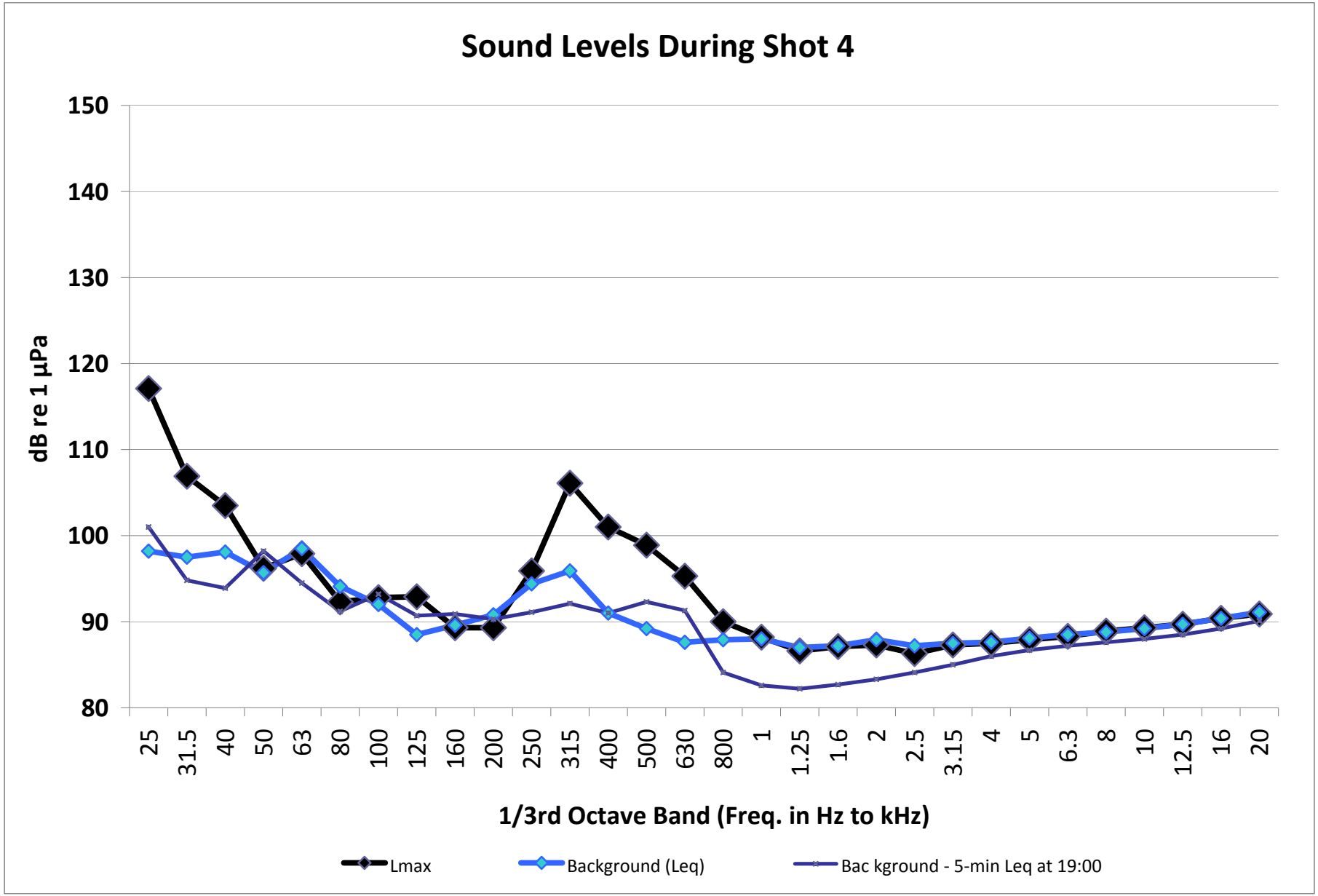
APPENDIX B

RESULTS OF I&R FROM M/V PEREGRINE


Sound Levels During Shot 1
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground 1-min Leq at 16:35


Sound Levels During Shot 2
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00


Sound Levels During Shot 3
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00


Sound Levels During Shot 4
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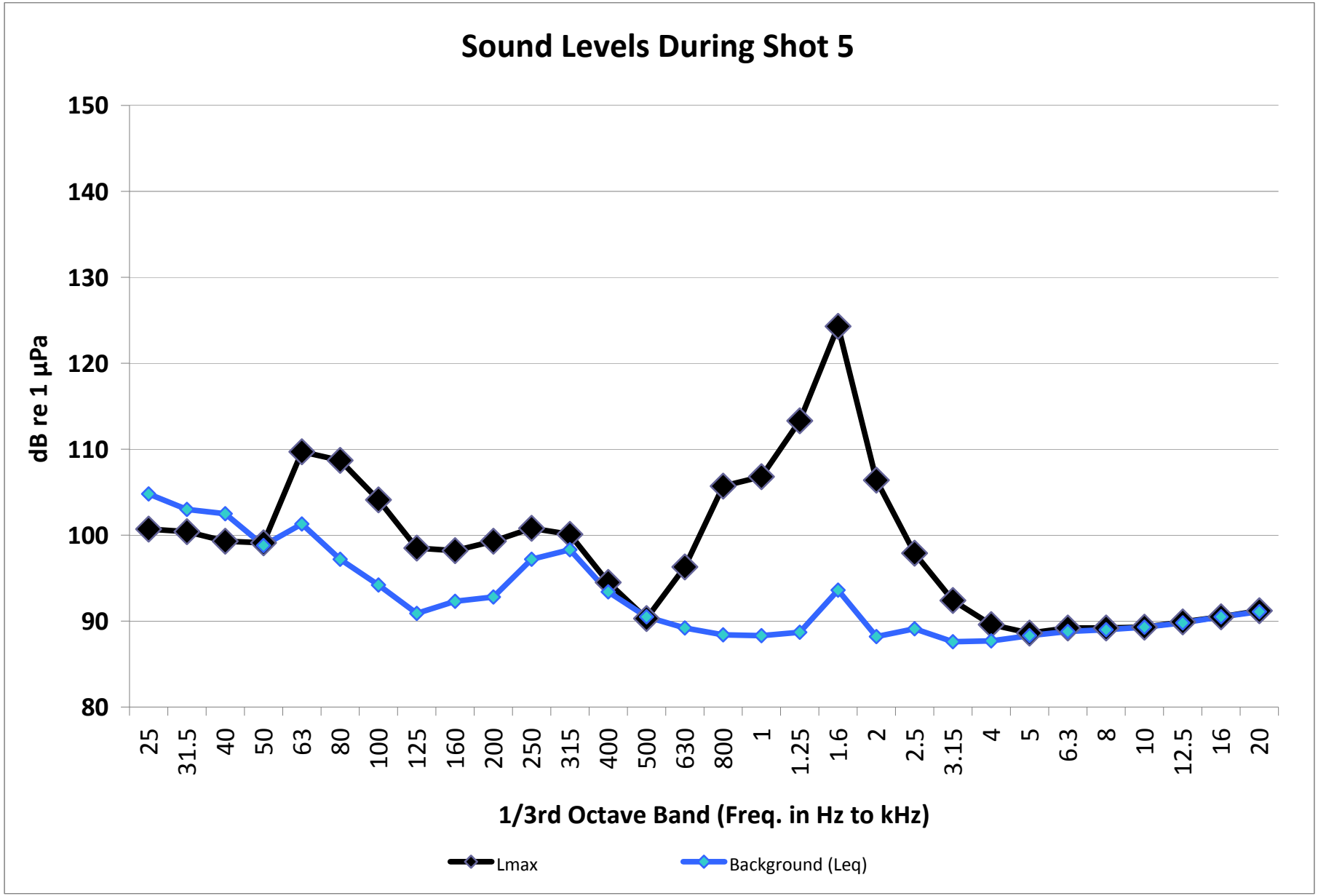
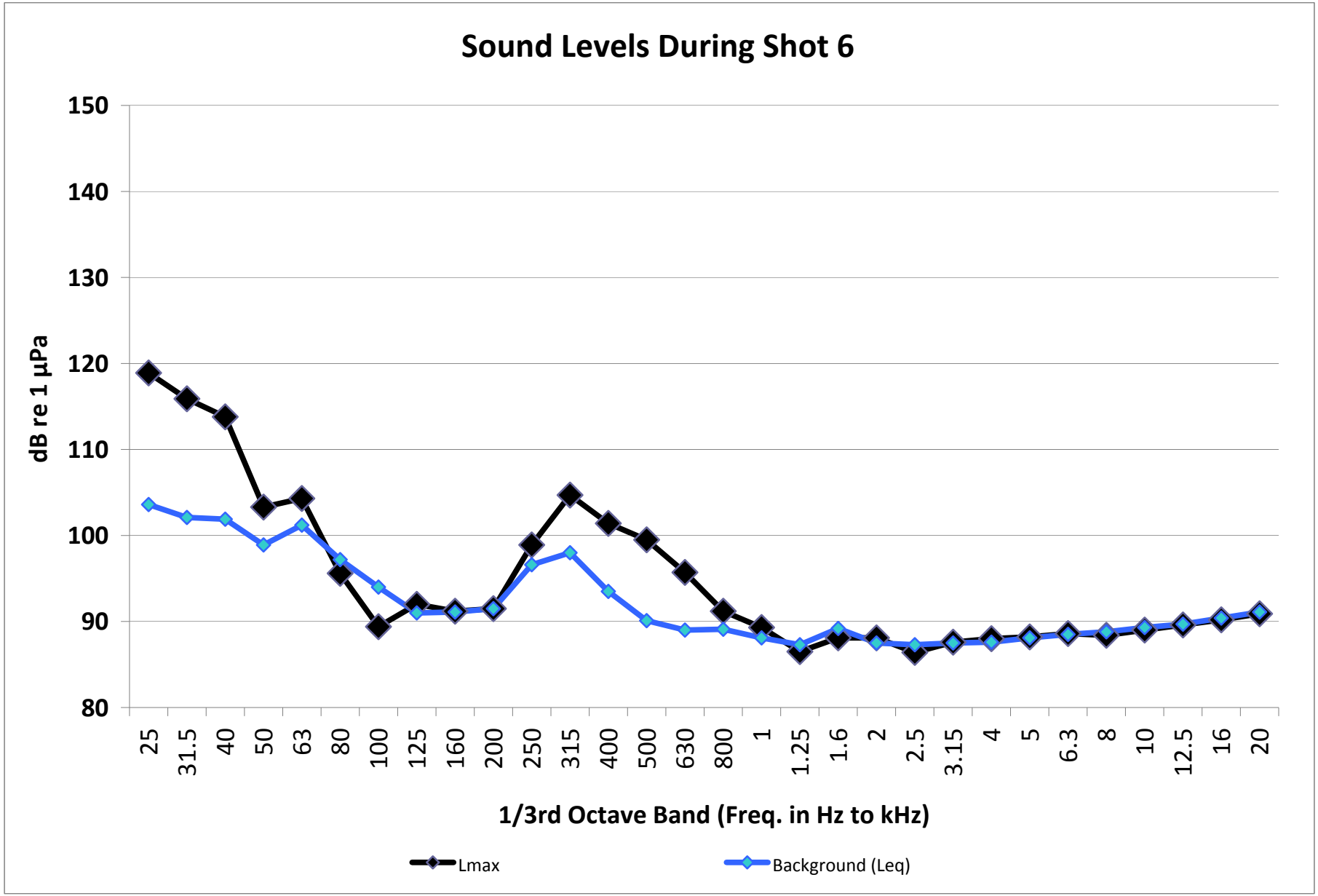
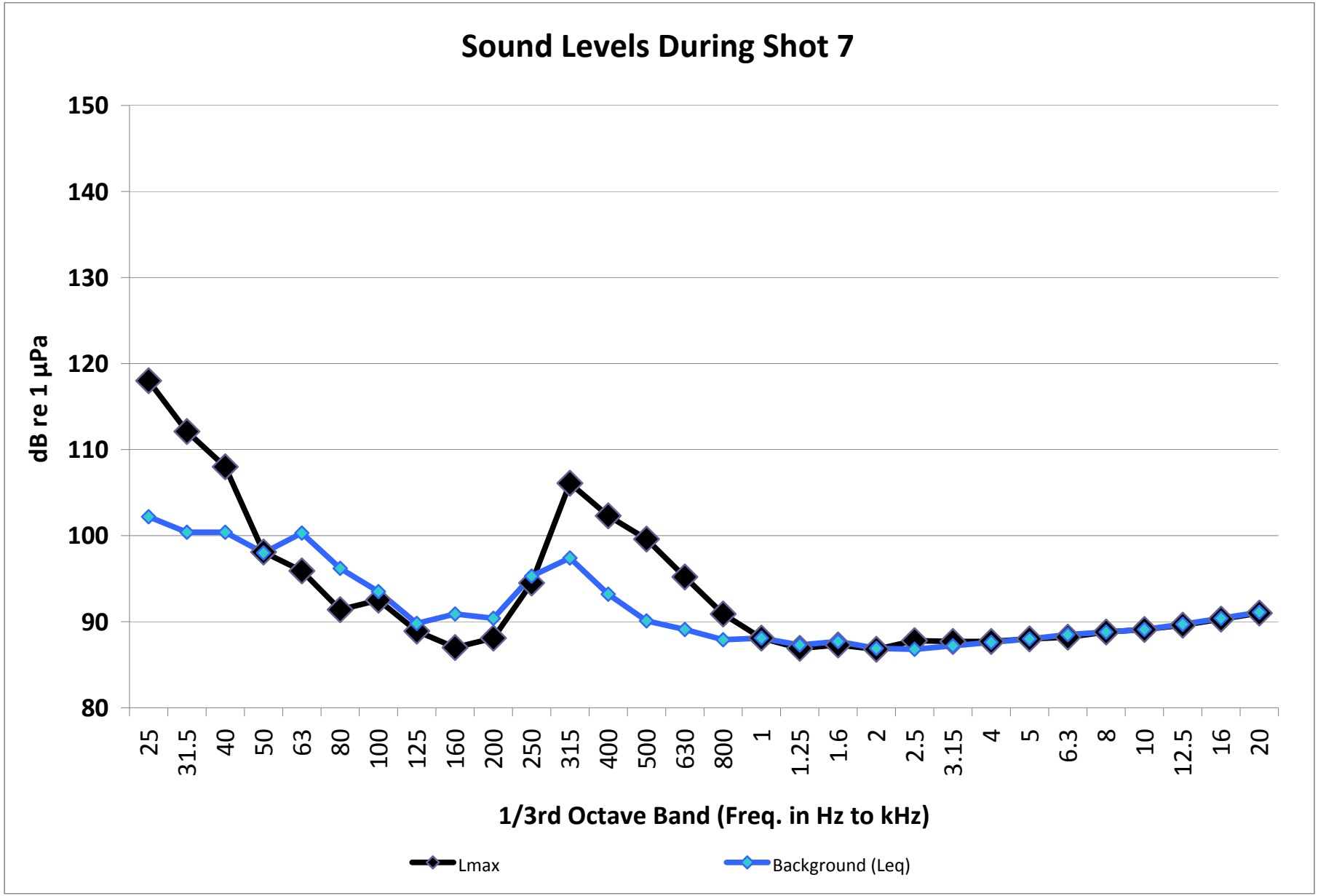
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00


Sound Levels During Shot 5
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 6
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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160
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400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
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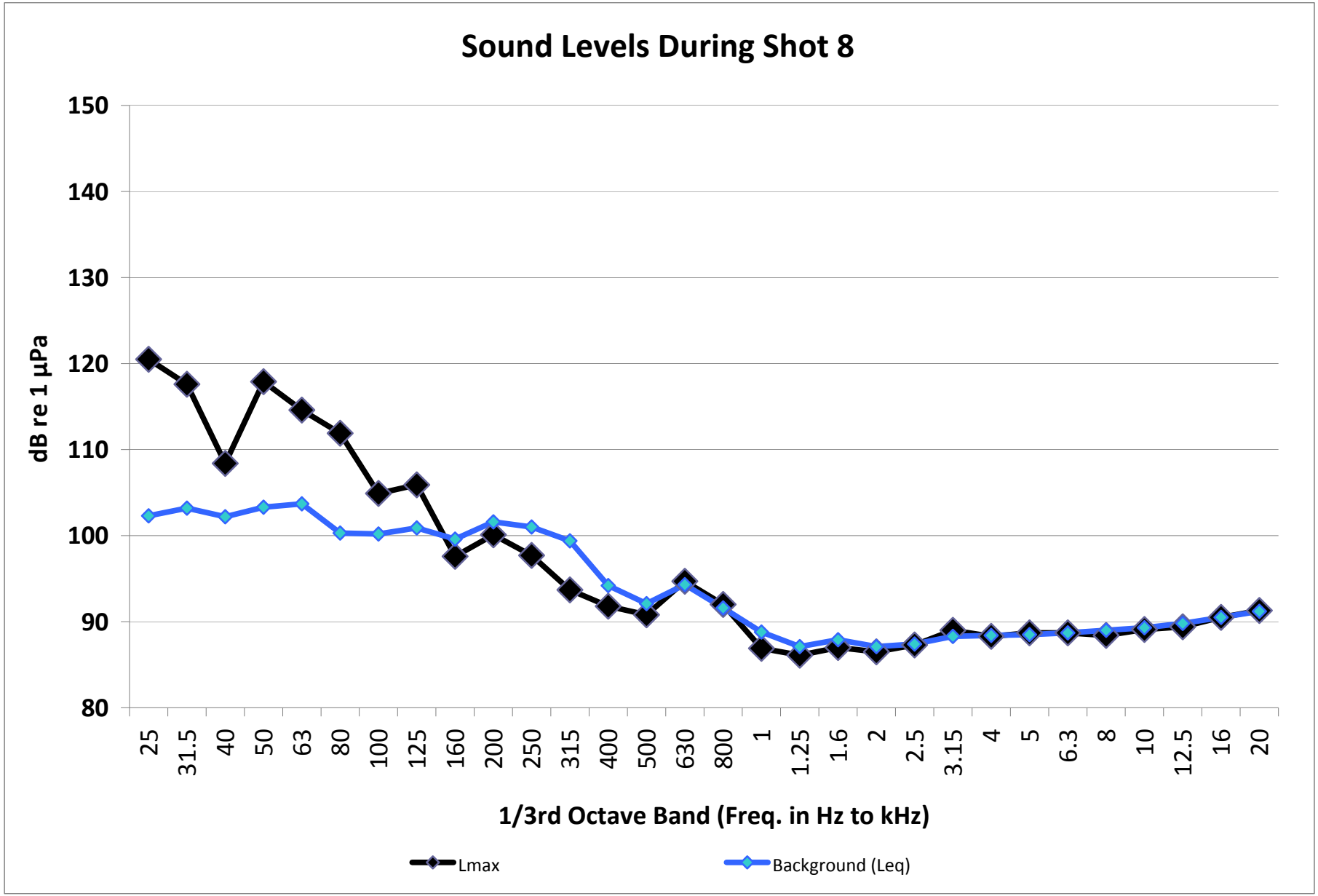
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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1
1.25
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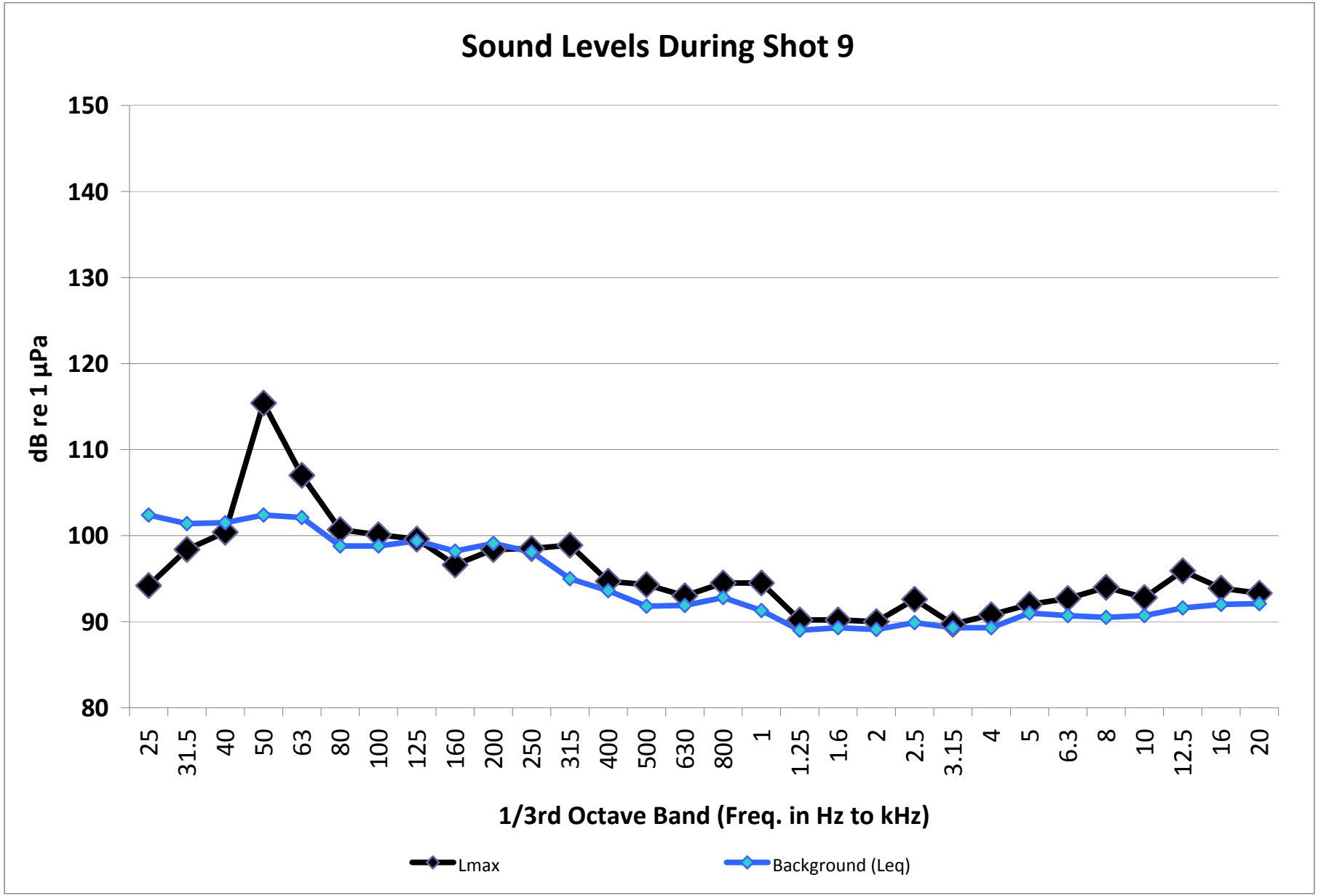
Lmax
Background (Leq)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800
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1.6
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2.5
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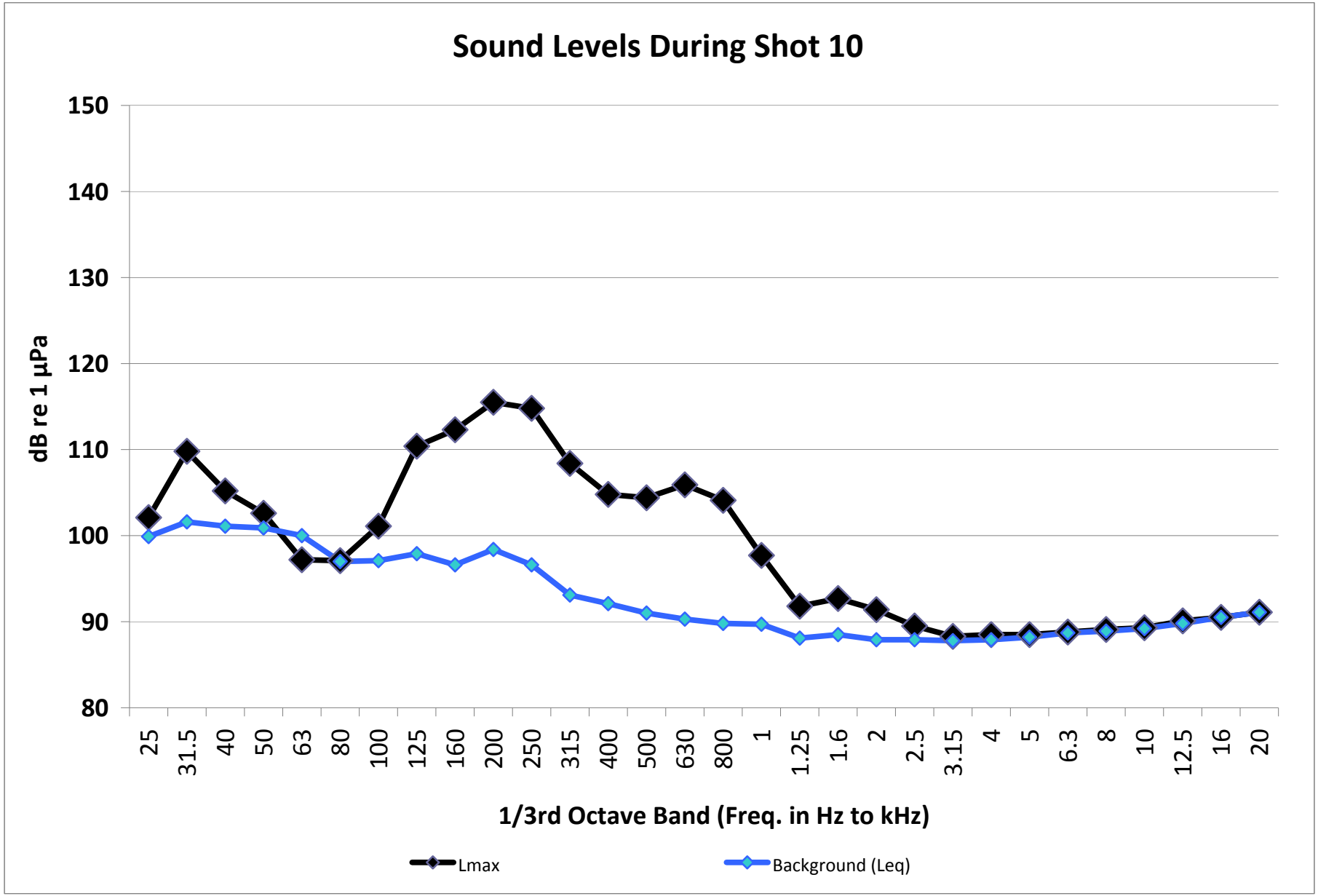
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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1.25
1.6
2
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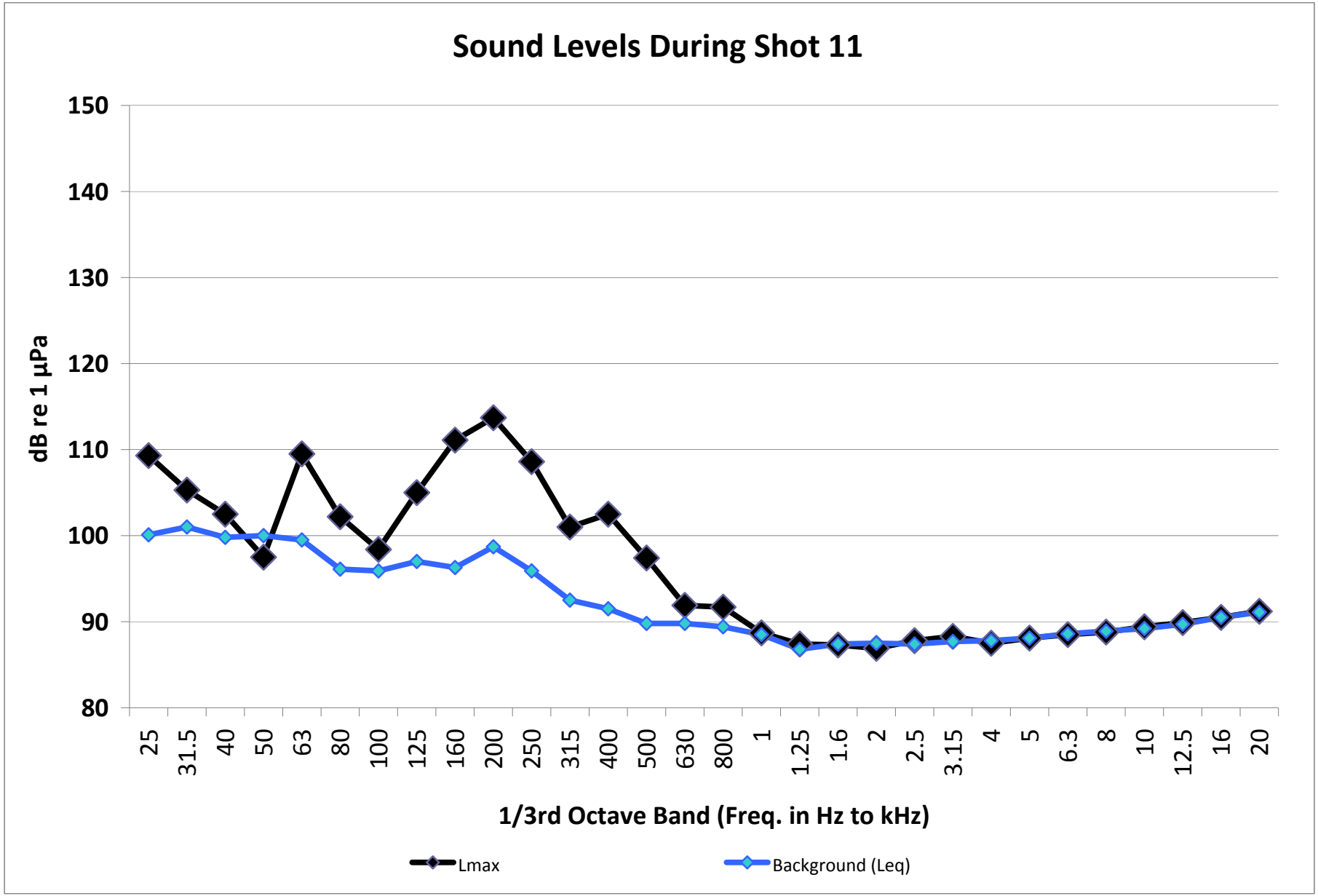
Lmax
Background (Leq)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1.25
1.6
2
2.5
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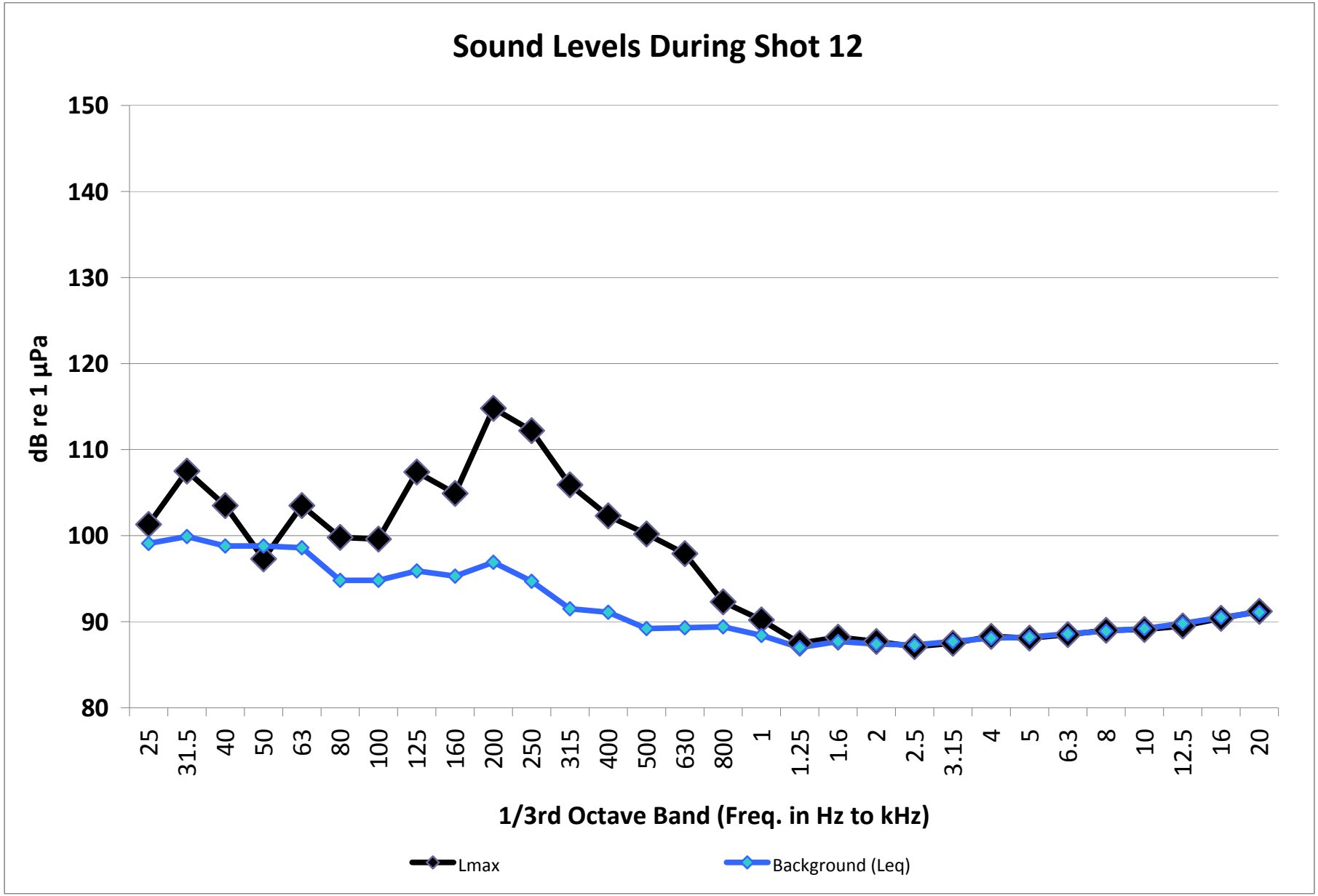
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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1.25
1.6
2
2.5
3.15
4
5
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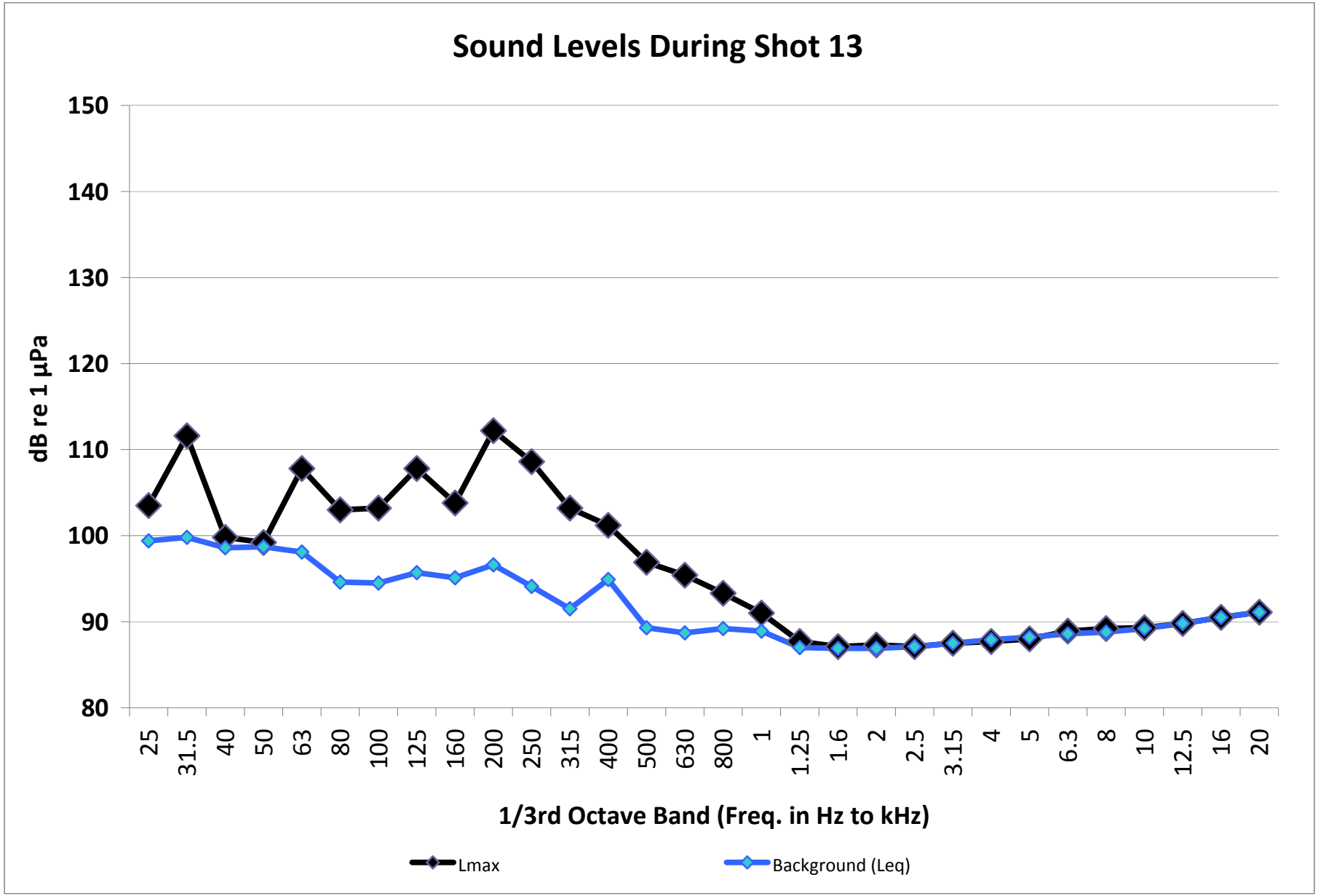
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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1.25
1.6
2
2.5
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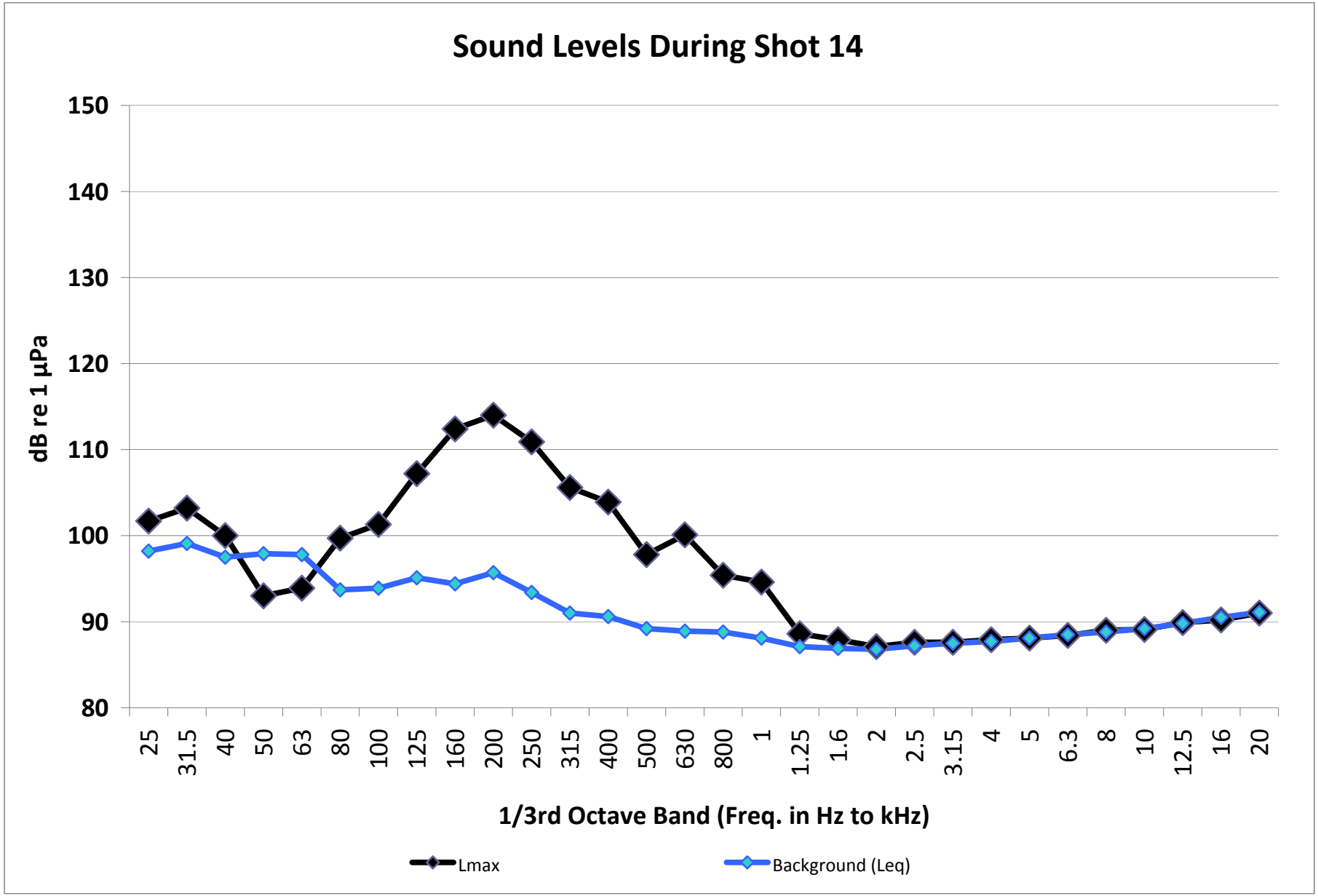
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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1.25
1.6
2
2.5
3.15
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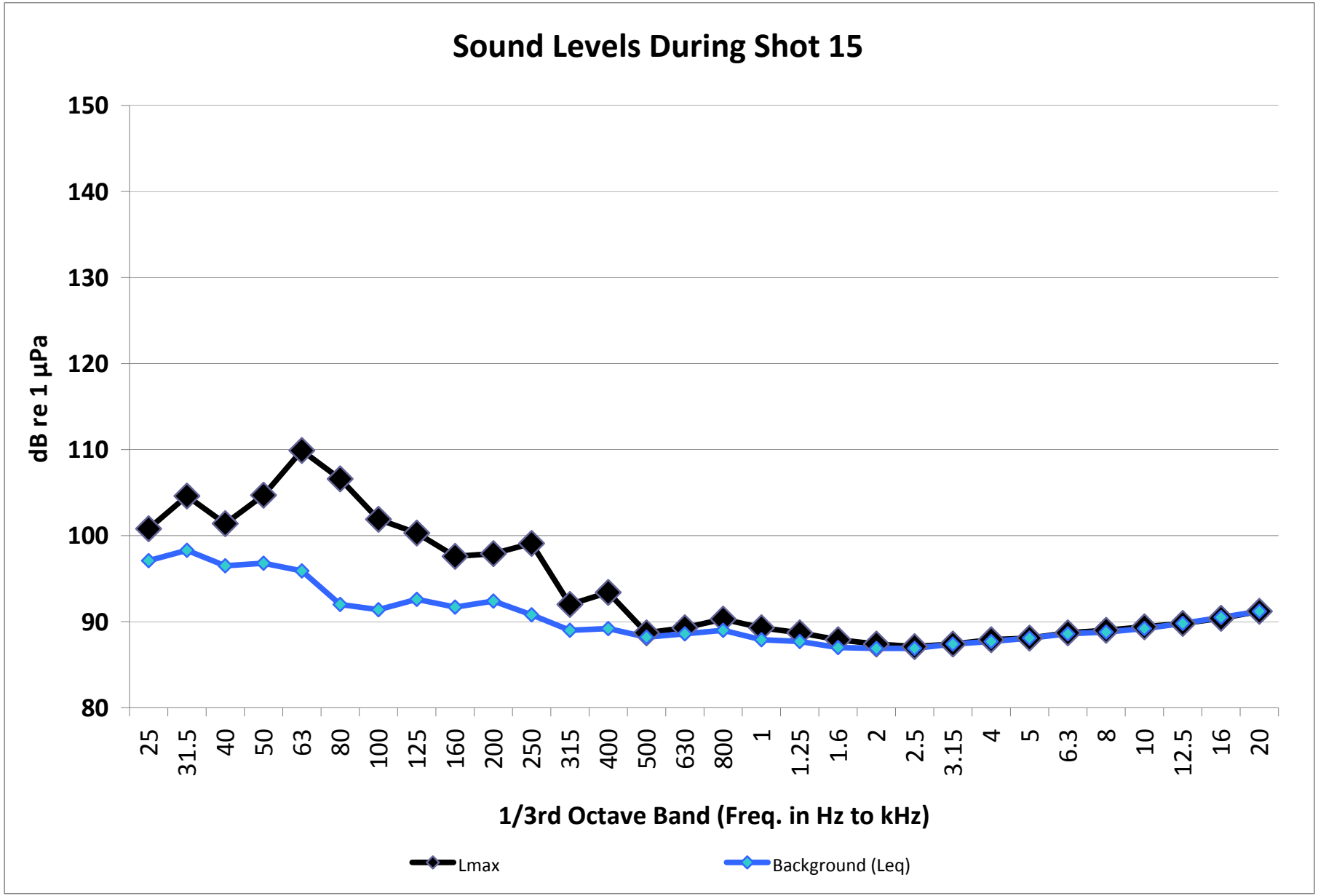
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 15
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dB re 1 µPa
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800
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1.25
1.6
2
2.5
3.15
4
5
6.3
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10
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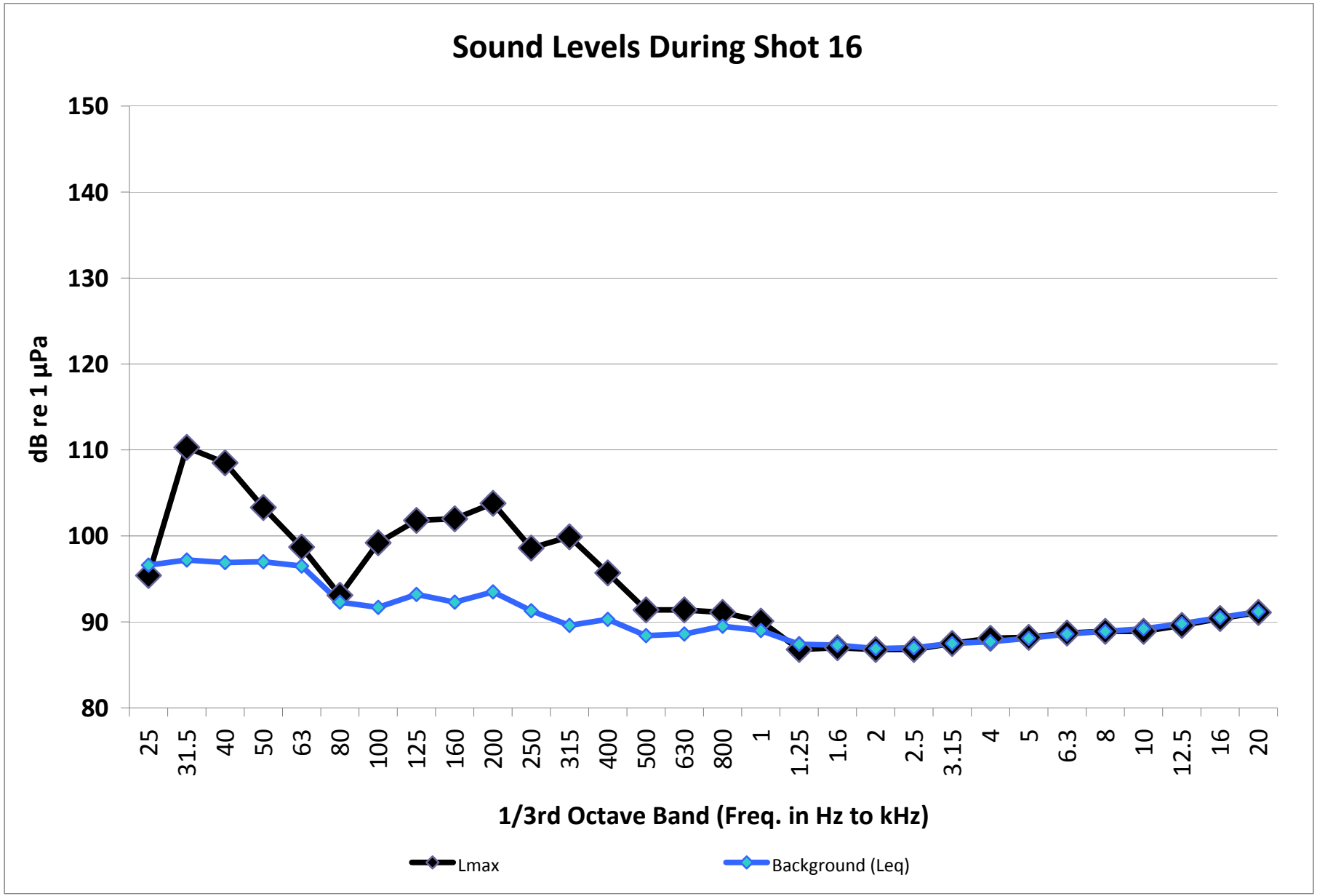
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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500
630
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1
1.25
1.6
2
2.5
3.15
4
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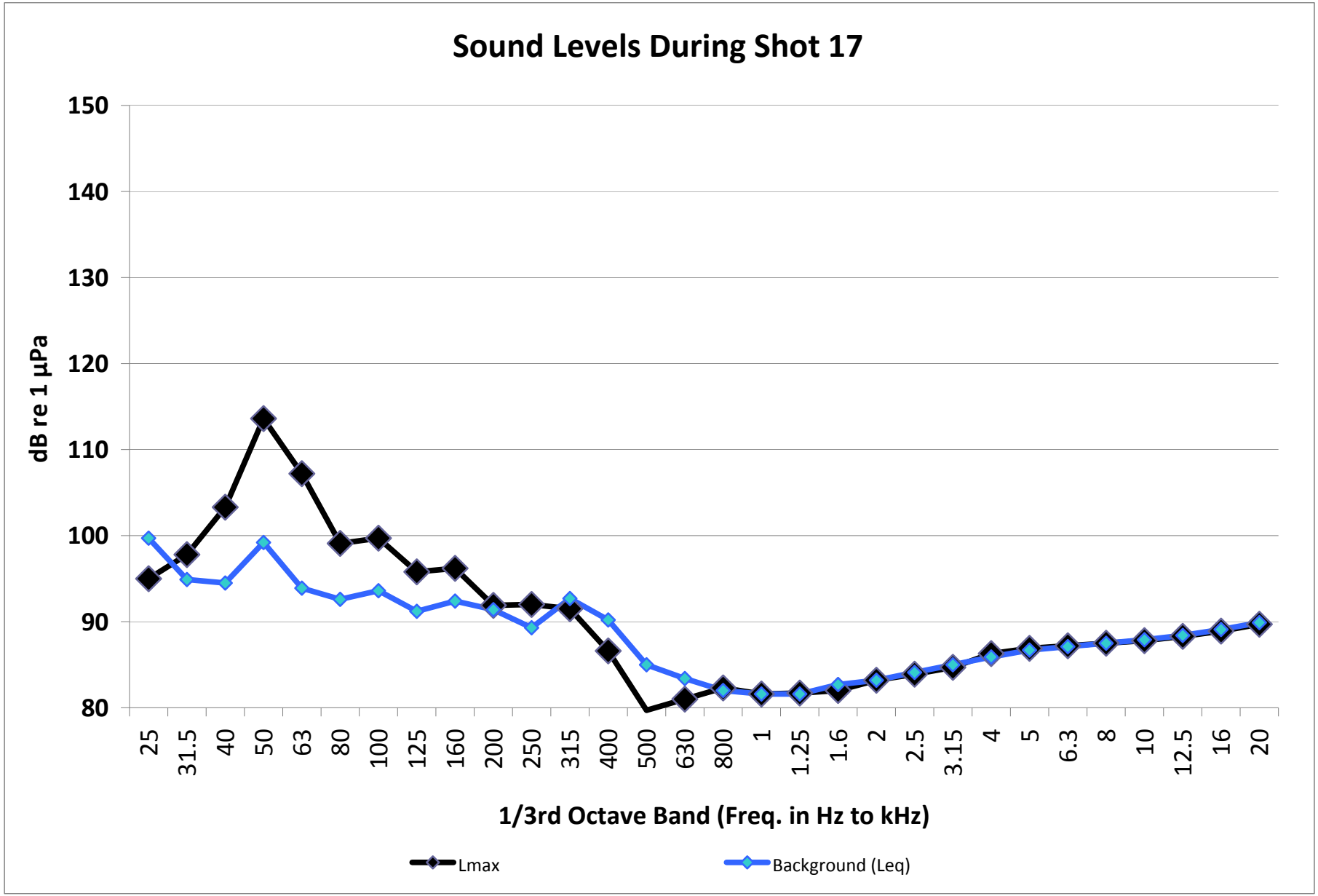
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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130
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dB re 1 µPa
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1.25
1.6
2
2.5
3.15
4
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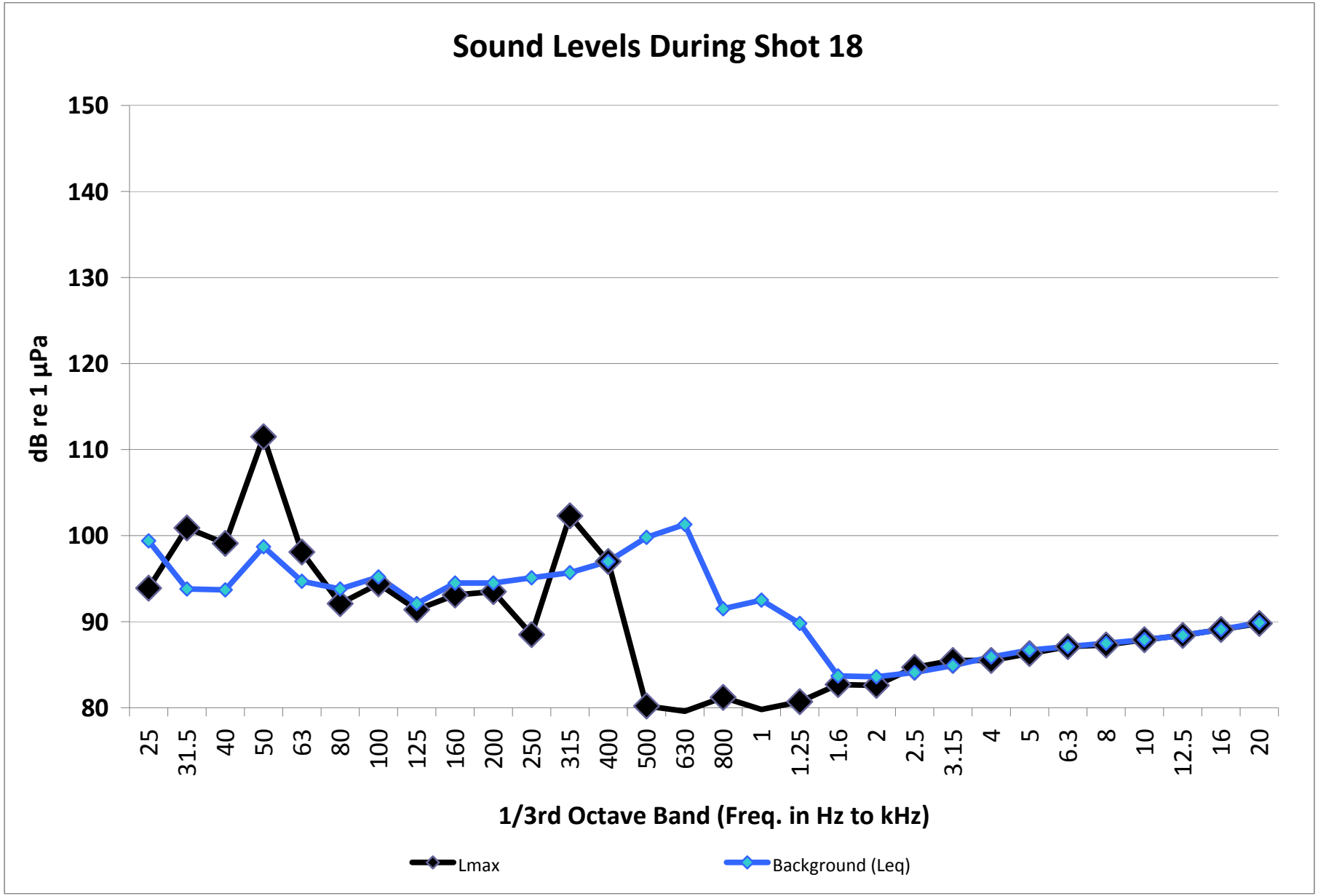
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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90
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dB re 1 µPa
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1.25
1.6
2
2.5
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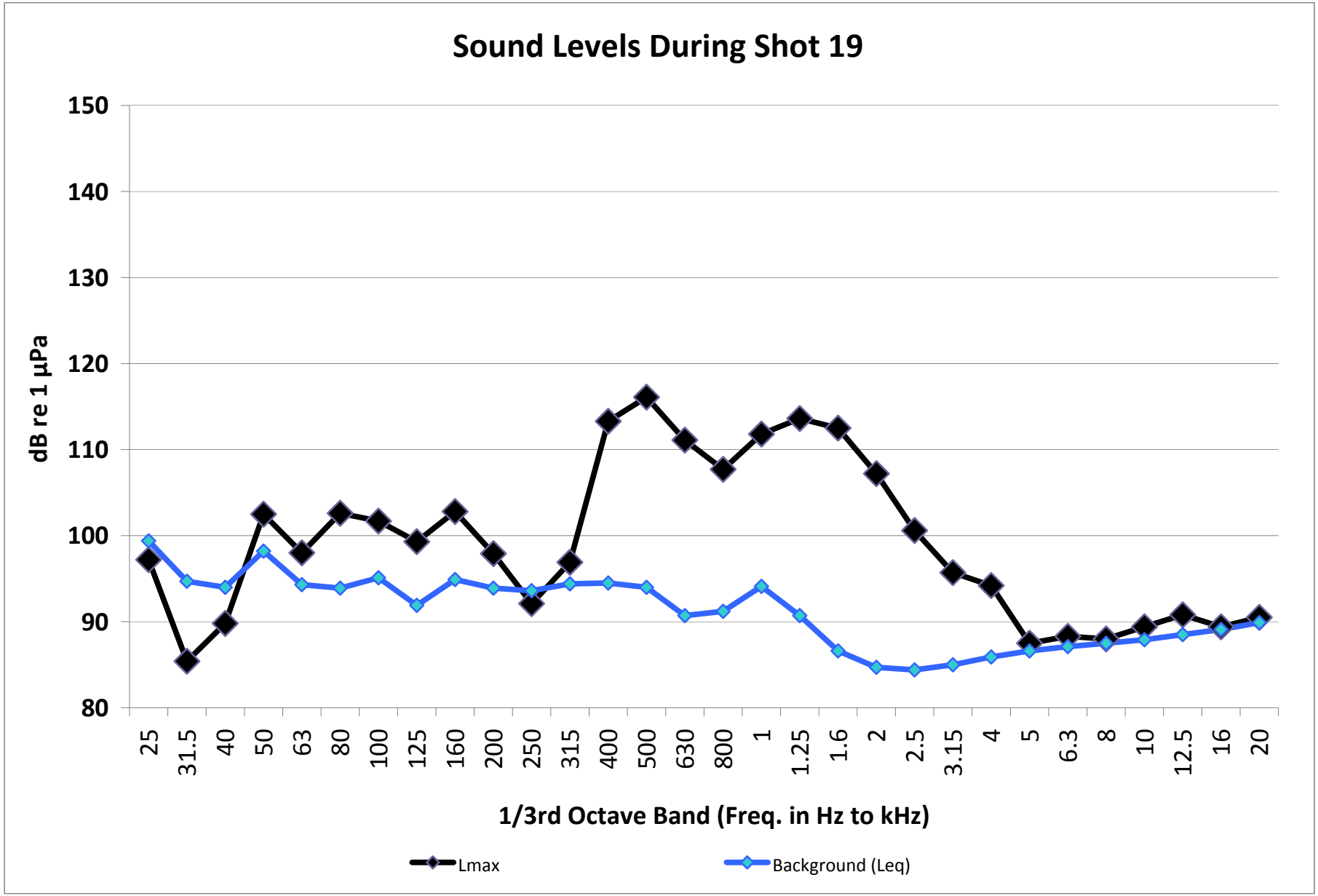
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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1.25
1.6
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2.5
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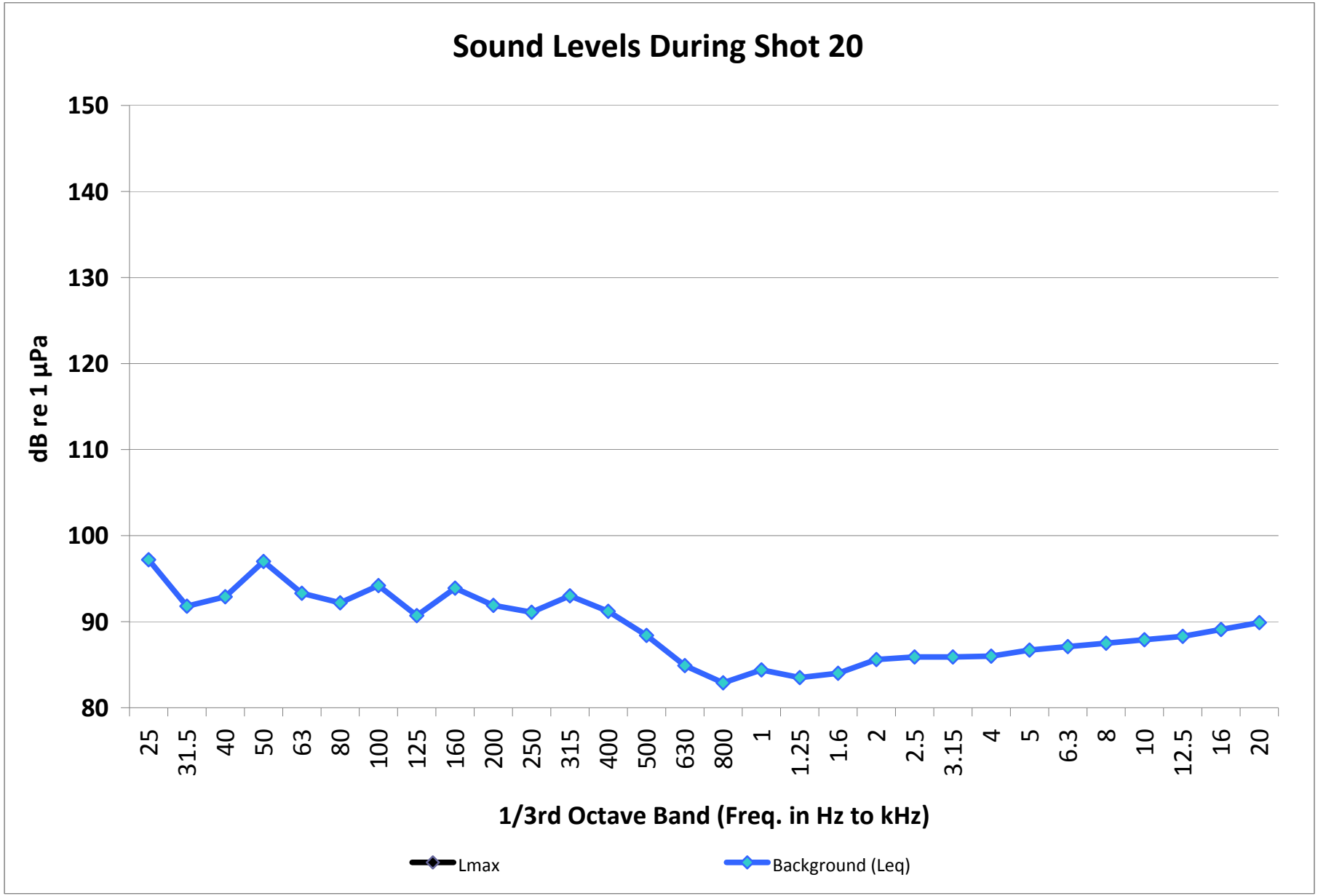
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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110
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90
80
dB re 1 µPa
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80
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1.25
1.6
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2.5
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8
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12.5
16
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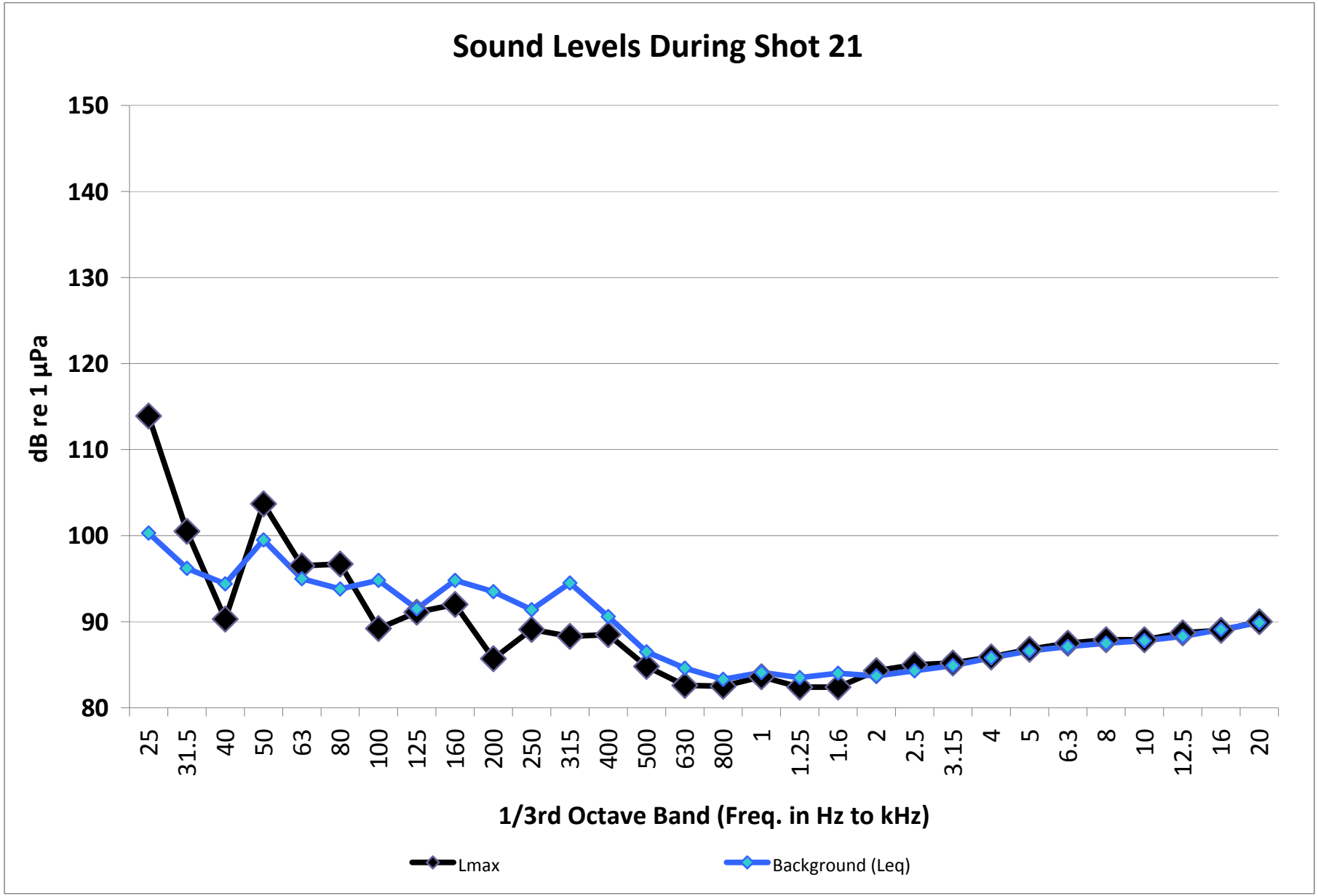
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)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dB re 1 µPa
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50
63
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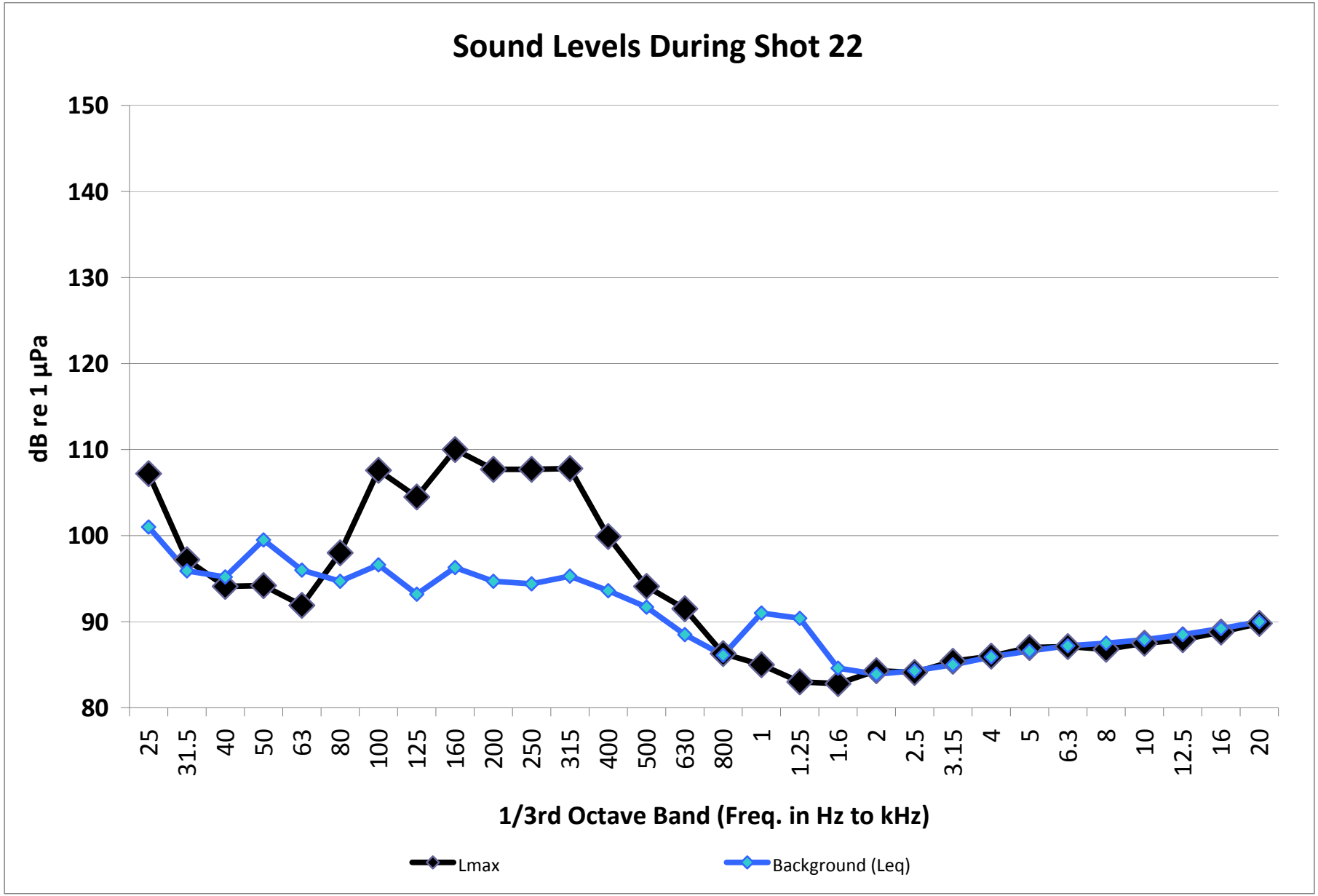
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 22
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dB re 1 µPa
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315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)

APPENDIX B

Sound Source Verification of Airguns 2012

Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey

Submitted to:
Fairweather LLC for
Apache Corporation

Authors:
Melanie Austin
Graham Warner

2013 January 4

P001134-006
Version 2.0

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Figure 8. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site. 39

Figure 8. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site. 39

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Figure 37. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration. 43

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Figure 8. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site. 47

Figure 8. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site. 47

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Figure 46: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 2400 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore sites (track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values. The endfire empirical fit was restricted to measurements at ranges less than 5 km to provide accurate distances to thresholds above 150 dB; data at ranges beyond 5 km are shown for completeness. 54

Figure 8. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site. 55
Figure 8. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site. 55
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Figure 48. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5528 m spectrogram is 2048-pt FFT, 48 kHz sample rate). 57
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Table 16 Recommended monitoring distances based on water depth. 64

1. Introduction

1.1. Study Overview

This report presents initial results of an underwater acoustic study designed to characterize the sound emissions of seismic sound sources involved in Apache's 2012 Seismic Survey in Cook Inlet. The acoustic measurement study was performed by JASCO Applied Sciences, under contract to SA Exploration, to measure underwater sound pressure levels (SPLs) as a function of distance, frequency and direction from airgun array sound sources deployed for Apache's survey. The acoustic measurements were conducted to satisfy the requirements in Apache's Incidental Harassment Authorization (IHA).

JASCO performed acoustic measurements using its Ocean Bottom Hydrophone (OBH) systems to measure underwater SPLs produced by the program's three airgun array configurations (440, 1200, and 2400 in^3) and a 10 in^3 mitigation gun. The measurements were carried out from 6 – 8 May, 2012. The data recorders were retrieved and data downloaded by 16:00 9 May, 2012 Alaska Daylight Time.

The primary goals of the acoustic measurements were as follows:

1. To measure the 190, 180, and 160 dB re 1 μPa (rms) SPL distances in the broadside and endfire directions from the full airgun arrays and 10 in^3 mitigation gun.
2. To compare the distances from the measurements with the corresponding distances in the IHA.

This report contains an explanation of the approach used to measure threshold distances for impulsive sound levels between 190 and 160 dB re 1 μPa (rms) in 10 dB steps for each source type.

2. Test Seismic Survey Description

2.1. Survey Location and recorder geometry

The test seismic survey program was carried out on the north shore of Cook Inlet at Beshta Bay. Figure 1 provides a map of the test survey area with the survey lines and acoustic monitoring stations indicated. Two separate track lines were defined to enable sound levels to be measured for source locations in shallow water (Track 1) and in deeper water (Track 2). The water depth along Track 1 is nearly constant, but there is a transition from deeper to shallower bathymetry along Track 2. Figure 2 below shows the bathymetry along the tracks during source vessel transits while the 2400 in^3 array was being measured. This figure illustrates the relative water depths along the tracks but the actual water depths varied with the tide cycle.

Sound levels were recorded using OBH-A through OBH-D (red diamonds on map) while the sources transited Track 1. The OBHs were oriented perpendicular to the source track at ranges extending toward the center of Cook Inlet. After measurements for Track 1 were complete, the OBHs were retrieved and redeployed at stations OBH-E through OBH-G for Track 2 measurements. In this case the OBHs were oriented along a line that extended toward shore.

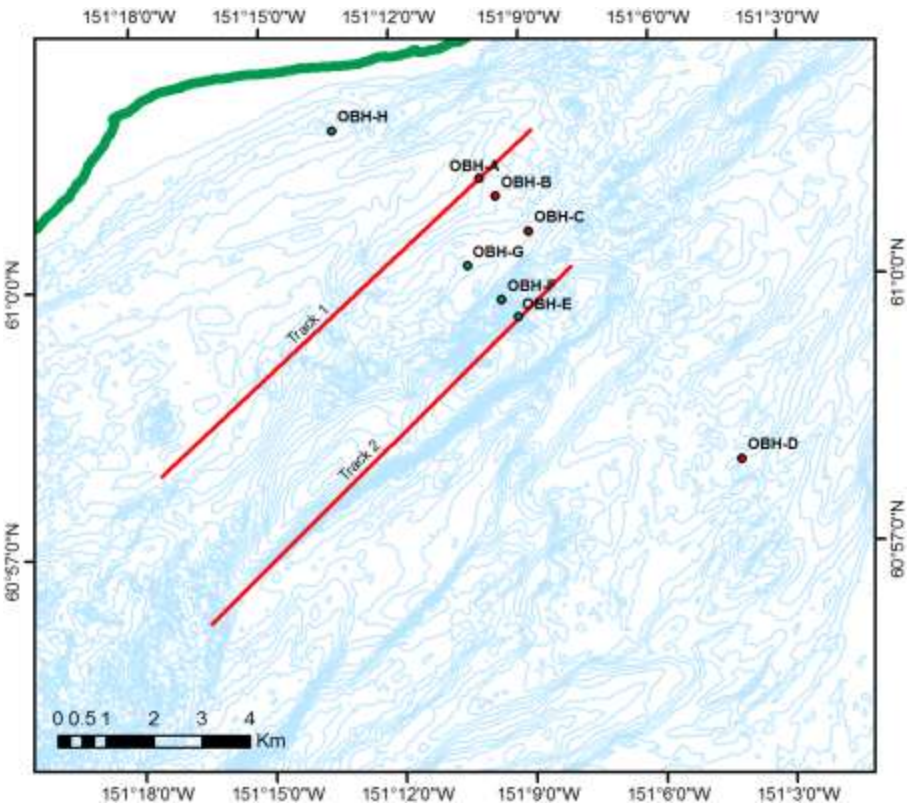


Figure 1. Map of the two acoustic survey lines and OBH locations.

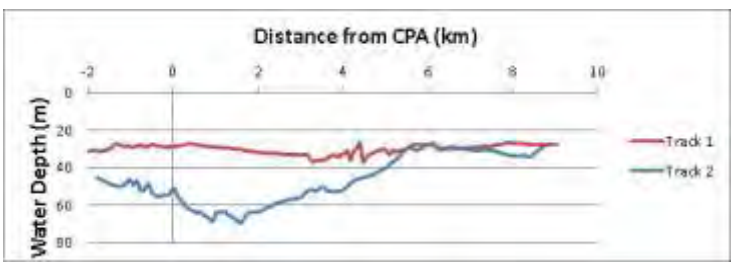


Figure 2: Water depth values along Track 2 measured during a single transit of the source vessel.

2.2. Source Types

Four airgun array configurations were measured and are described below. These included a 2400 in^3 array, a 1200 in^3 sub-array, a 440 in^3 array and a 10 in^3 mitigation gun.

2.2.1. Seismic Airguns

The 2400 in^3 airgun array consisted of two 1200 in^3 sub-arrays, each having four pairs of 150 in^3 airguns. A single 1200 in^3 sub-array is shown in Figure 3. The 2400 in^3 airgun array was configured as illustrated in Figure 4 with the two sub-arrays separated horizontally by 4.6m. The figure shows only 12 airguns because the sub-arrays contain a pair of airguns suspended below the middle pairs (and hence not visible in these plan views). The sub-arrays were towed at 3 m depth.

Figure 3. A 1200 in^3 tri-cluster sub-array consisting of eight 150 in^3 airguns. The 2400 in^3 array consisted of two identical 1200 in^3 tri-clusters separated horizontally by 4.6 m.

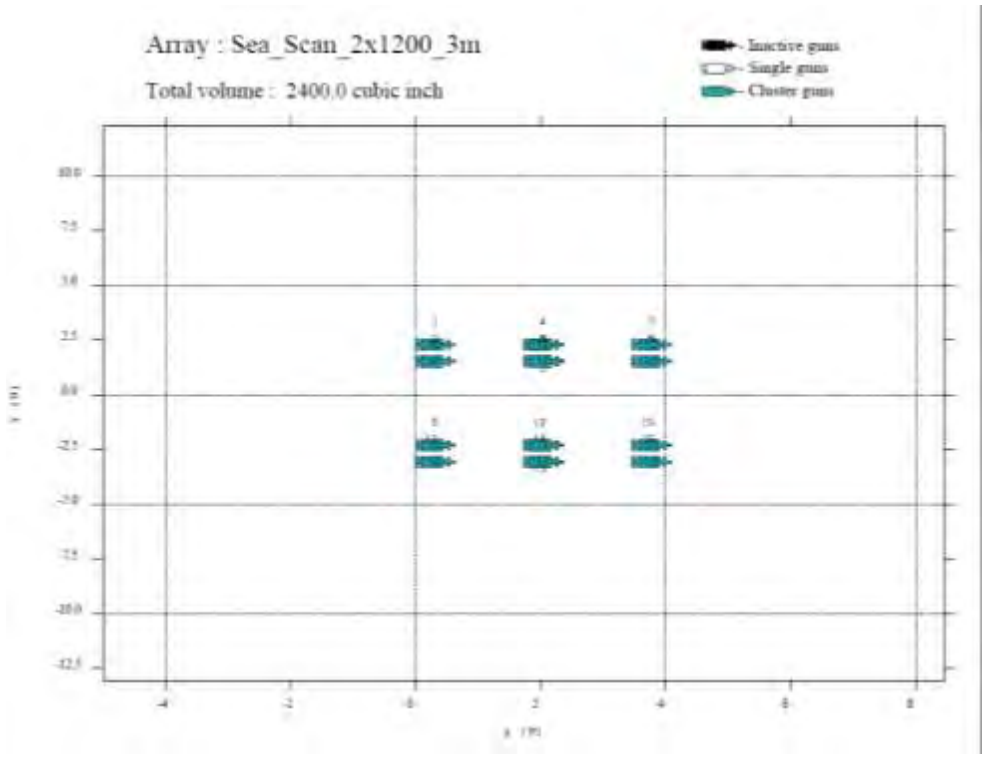


Figure 4. Geometry layout of 2400 in^3 array. Tow depth is 3.0 m; the volume of each airgun is indicated in cubic inches. This array consists of two 1200 in^3 sub-arrays separated horizontally by 4.6 m.

Additionally, a smaller 440 in^3 array (Figure 5, left) that consisted of two 70 in^3 and two 150 in^3 airguns was also measured. The 150 in^3 airguns were positioned at the front of the array and the 70 in^3 airguns were 1.2 m behind. The pairs of airguns were separated port/starboard by 1 m. The 440 in^3 array was towed at 2 m depth. A single 10 in^3 gun (Figure 5, right) was also measured and was towed at 1 m depth.

Figure 5 The 440 in^3 array sitting on the back deck before deployment (left) and the 10 in^3 mitigation airgun as it was being deployed.

2.2.2. Pre-season Estimates of Sound Threshold Radii

Table 1 shows the pre-season threshold radii as indicated in the IHA permit application for the 440 in³ airgun array, the 2440 in³ airgun array, and 10 in³ mitigation gun. Radii for the 1200 in^3 sub-array were not listed in the IHA.

Table 1: Pre-season estimates of sound threshold radii.

SPL_{rms90} (dB re 1 µPa)	2400 in³ Airgun Array (Nearshore)	2400 in³ Airgun Array (Offshore)	440 in³ Airgun Array	Mitigation Gun (10 in³)
190	510m	180m	NA	10m
180	1420m	980m	NA	33m
160	6410m	4890m	NA	330m

3. Acoustic Measurement and Analysis Methods

3.1. Measurement Apparatus and Calibration

Underwater sound level measurements were obtained using two deployments of four autonomous Ocean Bottom Hydrophone (OBH) recorder systems (see Figure 6). The OBH units provided high-resolution, digital underwater sound recordings on two channels using two different hydrophone sensitivities. The lower sensitivity channel used a calibrated Reson TC4043 hydrophone with nominal sensitivity -201 dB re V/µPa, and the higher sensitivity channel used a calibrated Reson TC4032 hydrophone with nominal sensitivity -170 dB re V/µPa. The acoustic data were recorded on calibrated Sound Devices 722 24-bit audio hard-drive

recorders at 48 kHz sampling rate for Track 1 measurements and at 96 kHz for Track 2 measurements. The sample rate was increased to 96 kHz during the second set of deployments such that sounds from a high-frequency TZ/OBC Transponder could be measured. Each time the recorders were retrieved, the data were transferred to external hard drives for backup.

The OBH systems were calibrated using a GRAS 42AC pistonphone precision sound source, which generated a 250 Hz reference tone with amplitude accurate to within ± 0.08 dB. The tone level was played directly to the hydrophone sensors using a specialized adapter. Calibrations were performed in the field immediately prior to each deployment and immediately upon each retrieval. The pistonphone reference signal was recorded by the digital recorders and was later analyzed to provide end-to-end system calibration of hydrophone, amplifiers and digitization. The pressure sensitivity obtained from the pistonphone calibration was used in the subsequent data analysis for determination of airgun sound levels.

The OBHs were fitted with floats and an acoustic release. Chain links (240 lbs total weight) were used as ballast to sink the recorders on deployment. Upon recovery, a transducer was used to trigger the acoustic release, releasing each recorder from its ballast. The recorders floated to the surface and were retrieved using a mooring hook and crane.

Global Positioning System (GPS) coordinates of deployment locations were obtained with a Garmin handheld GPS and are accurate to within 5 m. Time-stamped source and vessel navigation data were provided by the navigation team on board the source vessel.

Figure 6. Photograph of a JASCO Ocean Bottom Hydrophone (OBH) recorder.

3.2. Measurement Procedures

Deployment details for each OBH are listed in Table 2. Table 3 lists dates of operation and the track line transited for each measured sound source.

Table 2. OBH location coordinates (WGS-84) and deployment and retrieval times for the acoustic measurements. Water depths indicate the depth at time of deployment.

Station	Deployment Date and Time (AKDT)	Retrieval Date and Time (AKDT)	Latitude	Longitude	Water Depth (m)	Range from Source Track (m)
OBH-A (S-02)	6 May, 07:29	7 May, 14:09	61°01.159'N	151°09.998'W	17.2	0
OBH-B (S-05)	6 May, 07:15	7 May, 14:31	61°00.984'N	151°09.600'W	20.6	500
OBH-C (S-01)	6 May, 06:56	7 May, 14:50	61°00.554'N	151°08.854'W	29.4	1500
OBH-D (S-03)	6 May, 06:21	7 May, 15:30	60°57.978'N	151°04.108'W	26.4	8000
OBH-E (S-03)	7 May, 18:36	9 May, 06:04	60°59.586'N	151°09.184'W	52.1	0
OBH-F (S-05)	7 May, 18:46	9 May, 06:31	60°59.798'N	151°09.596'W	56.7	500
OBH-G (S-01)	7 May, 18:55	9 May, 06:50	61°00.195'N	151°10.356'W	33.0	1500
OBH-H (S-02)	7 May, 19:19	9 May, 07:25	61°01.748'N	151°13.360'W	15.8	5500

Table 3. Sound sources monitored during Apache's 3D seismic survey program, 6 – 9 May, 2012. Dates are in AKDT.

Source	Start Date (2012) and Time (AKDT)	End Date (2012) and Time (AKDT)	acoustic Track
10 in^3 airgun	6 May, 09:54	6 May, 12:10	Track 1
1200 in^3 airgun array	6 May, 17:34	6 May, 18:23	Track 1
2400 in^3 airgun array	6 May, 19:50	6 May, 21:05	Track 1
440 in^3 airgun array	7 May, 09:37	7 May, 13:09	Track 1
440 in^3 airgun array	7 May, 20:43	8 May, 03:15	Track 2
1200 in^3 airgun array	8 May, 08:22	8 May, 10:49	Track 2
10 in^3 airgun	8 May, 14:59	8 May, 16:01	Track 2
2400 in^3 airgun array	8 May, 16:43	8 May, 17:42	Track 2

3.3. Data Analysis Procedures

3.3.1. SPL Threshold Radii

Acoustic data were analyzed using custom processing software, to determine peak and *rms* SPLs and sound exposure levels (SELs) versus range from the airgun arrays and explosive shots. The data processing steps were as follows:

1. Airgun pulses (or explosive shots) in the OBH recordings were identified using automated detection algorithm.
2. Waveform data were converted to units of μPa using the calibrated hydrophone sensitivity of each OBH system.
3. For each pulse/shot, the distance to the airgun array was computed from the GPS deployment coordinates of the OBH systems and the time referenced navigation logs of the survey vessel.
4. The airgun pulses were processed to determine peak sound pressure level (Peak SPL), 90% *rms* sound pressure level (SPL_{rms90}) and sound exposure level (SEL).

In order to estimate distances to the different *rms* SPL threshold levels, the SPL data were fit to an empirical propagation loss curve of the following form:

$$RL = SL - A\log_{10} R - BR, \; or \tag{1}$$

$$RL = SL - A\log_{10} R \tag{2}$$

where R is the horizontal range from the source to the OBH, RL is the received sound level, SL is the estimated source level term, A is the geometric spreading loss coefficient and B is the absorptive loss coefficient. This equation was fit to the SPL data by minimizing (in the least-squares sense) the difference between the trend line and the measured level-range samples. In order to provide precautionary estimates of the threshold radii, the best fit line was shifted upwards (by increasing the constant SL term) so that the trend line encompassed 90% of all the data. The 90th percentile best-fit values for SL, A, and B are shown in the SPL plot annotations in the following sections.

The empirical fits for the endfire levels along the offshore line (Track 2) were restricted to measurements at ranges less than 5km to avoid the influence of the site-specific reduction in sound levels resulting from the shoaling bathymetry along the track (see Figure 2). Restricting the measurements to ranges less than 5km excluded the influence from absorptive loss effects that tend to be observed at longer ranges, and the threshold radii were calculated from extrapolated linear-fits in the form of Equation (2) above.

4. Results

4.1. 10 in^3 Mitigation Gun

4.1.1. Track 1

Peak SPL, 90% rms SPL and SEL for each shot along the nearshore line (Track 1) were computed from acoustic data recorded on OBH-A. Figure 7 shows sound levels from the 10 in³ mitigation gun versus slant range measured in the endfire direction on OBH-A as the source transited the line. This plot only shows levels received within 200 m of the source due to the low signal-to-noise ratio at longer measurement ranges for this track. Sound levels shown were recorded on the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 4 lists ranges to several rms SPL thresholds for each of the fits in Figure 7. Figure 8 illustrates how rms pulse duration varied with range over the track line (left), with the rms SPL (right) for comparison. Figure 9 presents spectrograms of 10 in³ airgun pulses measured near CPA at 26 m and at 192 m. Figure 10 shows waveforms and SEL spectral density plots of these same pulses. A contour plot of 1/3-octave band levels versus range and frequency is shown in Figure 11. Sound levels near the source were highest between 40 and 50 Hz.

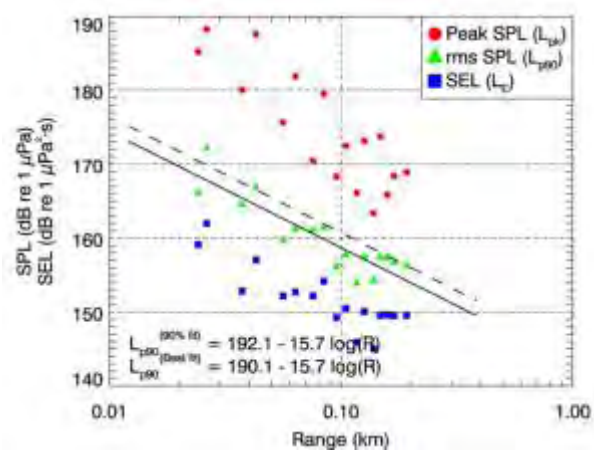


Figure 7: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 10 in^3 mitigation airgun pulses in the endfire direction for the nearshore track. Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Table 4: Threshold radii for the 10 in^3 mitigation airgun from the nearshore line as determined from empirical fits to SPL_{rms90} versus distance data in Figure 7.

SPL_{rms90} Threshold (dB re 1 μPa)	Range (m) in endfire direction	
	Best fit	90th percentile fit
190	<10	<10
180	<10	<10
170	19	26
160	83	110

*Extrapolated beyond measurement range.

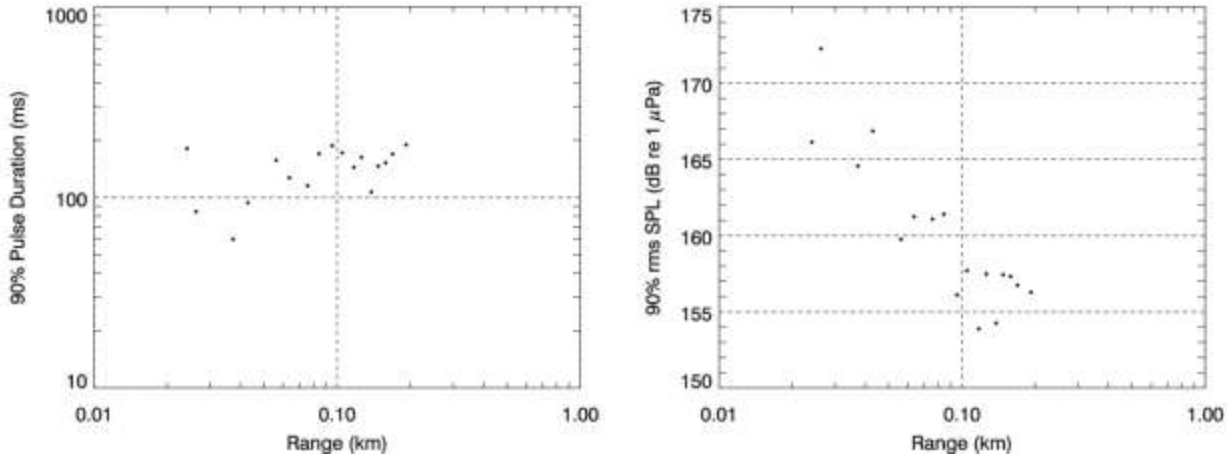


Figure 8. 10 in³ airgun array 90% pulse duration (left) and rms SPL (right) as a function of range at the nearshore site.

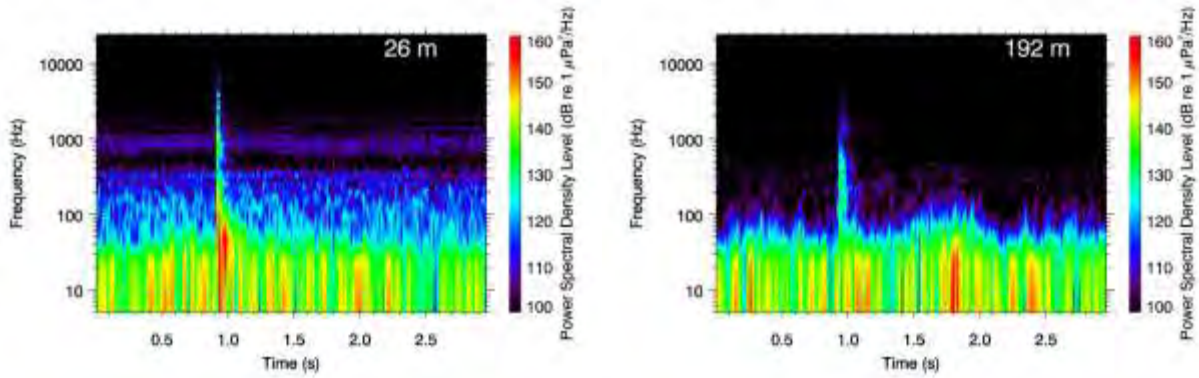


Figure 9. Spectrograms of airgun pulses from the 10 in³ airgun array at two distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

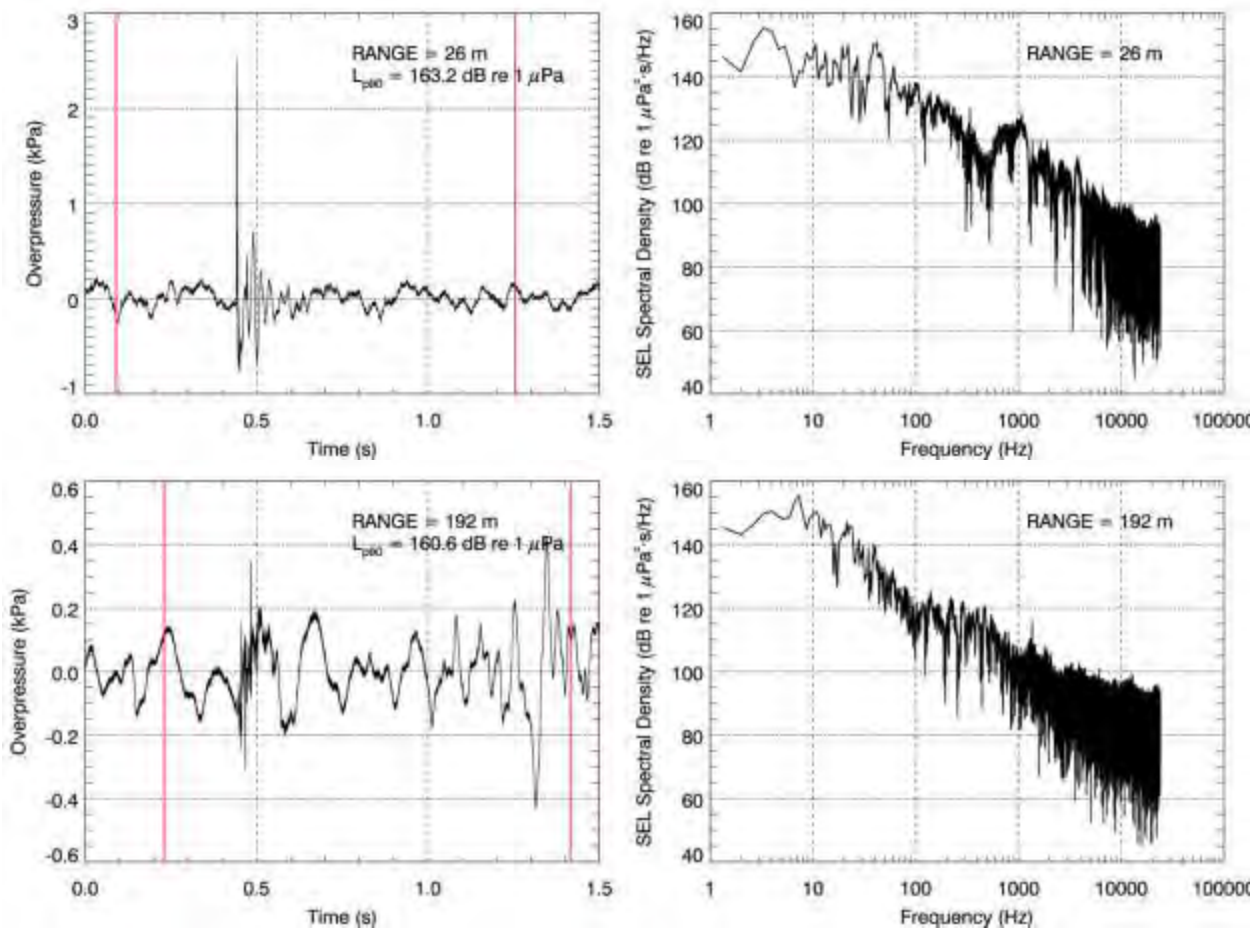


Figure 10. Waveform (left) and corresponding SEL spectral density (right) plots of 10 in³ airgun array pulses at two distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

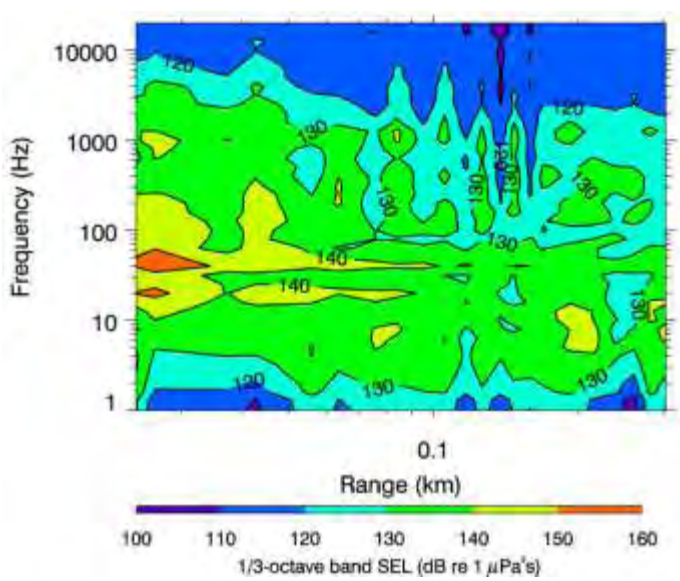


Figure 11. 1/3 octave band SEL levels as a function of range and frequency for the 10 in³ airgun array in the endfire direction at the nearshore site.

4.1.2. Track 2

Peak SPL, 90% rms SPL and SEL for each shot along the offshore line (Track 2) were computed from acoustic data recorded on OBH-E. Figure 12 shows sound levels from the 10 in³ mitigation gun versus slant range measured in the endfire direction on OBH-E as the source transited the line. Sound levels shown were recorded on the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 5 lists ranges to several rms SPL thresholds for each of the fits in Figure 12. Figure 13 illustrates how rms pulse duration varied with range over the track line (left), with the rms SPL (right) for comparison. Figure 14 presents spectrograms of 10 in³ airgun pulses measured near CPA at 18 m and at 493 m, 1522 m, and 4993 m. Figure 15 shows waveforms and SEL spectral density plots of these same pulses. A contour plot of 1/3-octave band levels versus range and frequency is shown in Figure 16. Sound levels near the source were highest between 70 and 150 Hz.

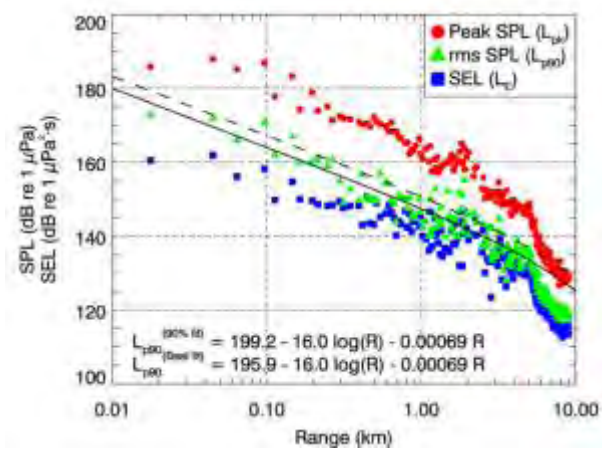


Figure 12: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 10 in^3 mitigation airgun pulses in the endfire direction for the offshore track. Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Table 5: Threshold radii for the 10 in^3 mitigation airgun from the offshore line as determined from empirical fits to SPL_{rms90} versus distance data in Figure 12.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction	
	Best fit	90th percentile fit
190	<10	<10
180	<10	<10
170	42	67
160	180	280

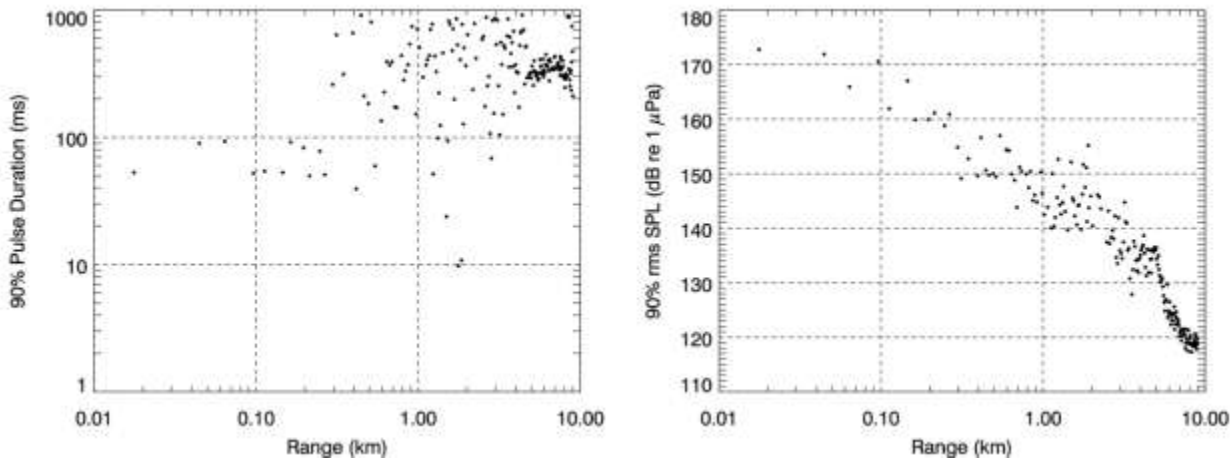


Figure 13. 10 in³ airgun array 90% pulse duration (left) and rms SPL (right) as a function of range at the offshore site.

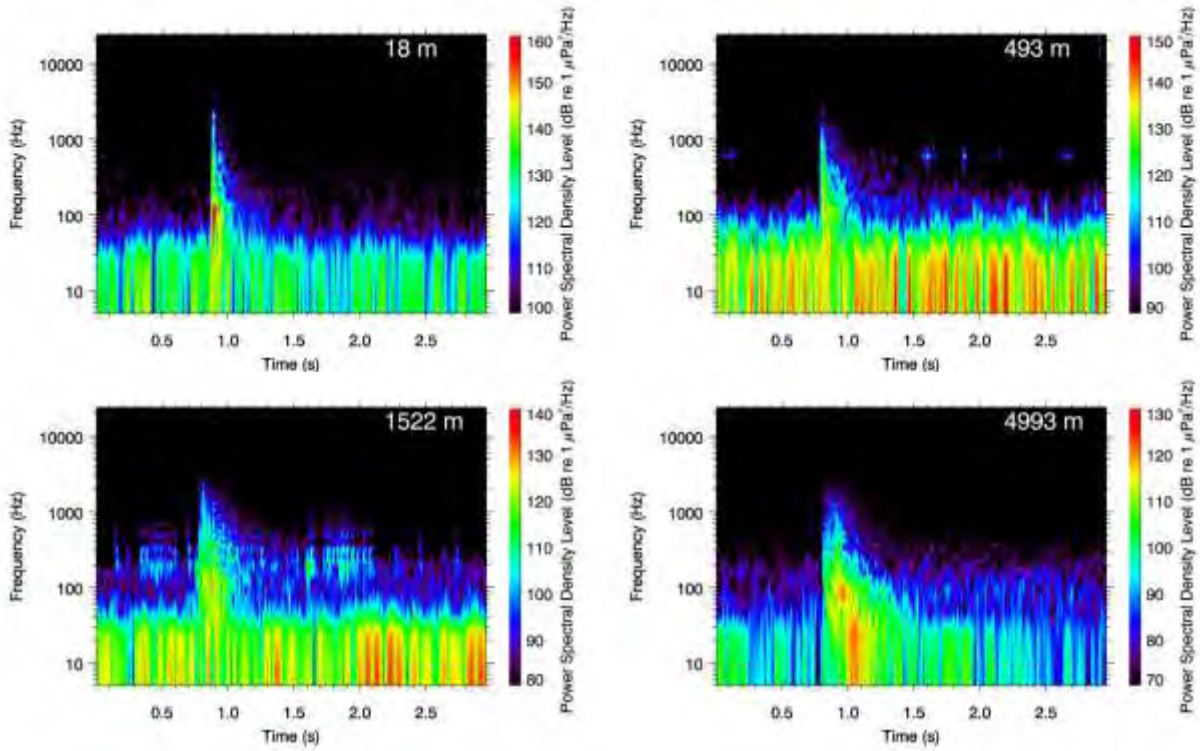
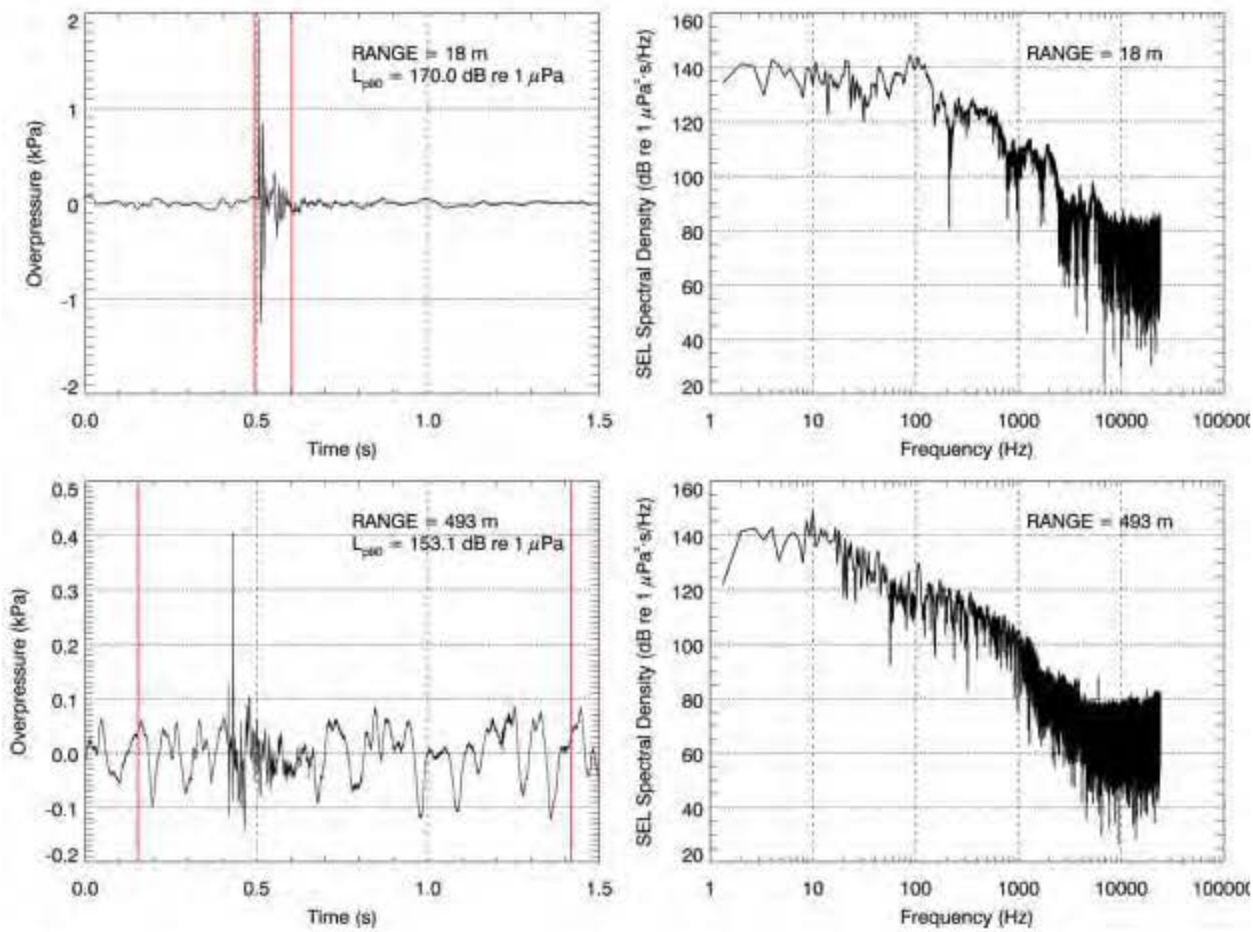


Figure 14. Spectrograms of airgun pulses from the 10 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.


RANGE = 18 m
L_{pk0} = 170.0 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 18 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 493 m
L_{pk0} = 153.1 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 493 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

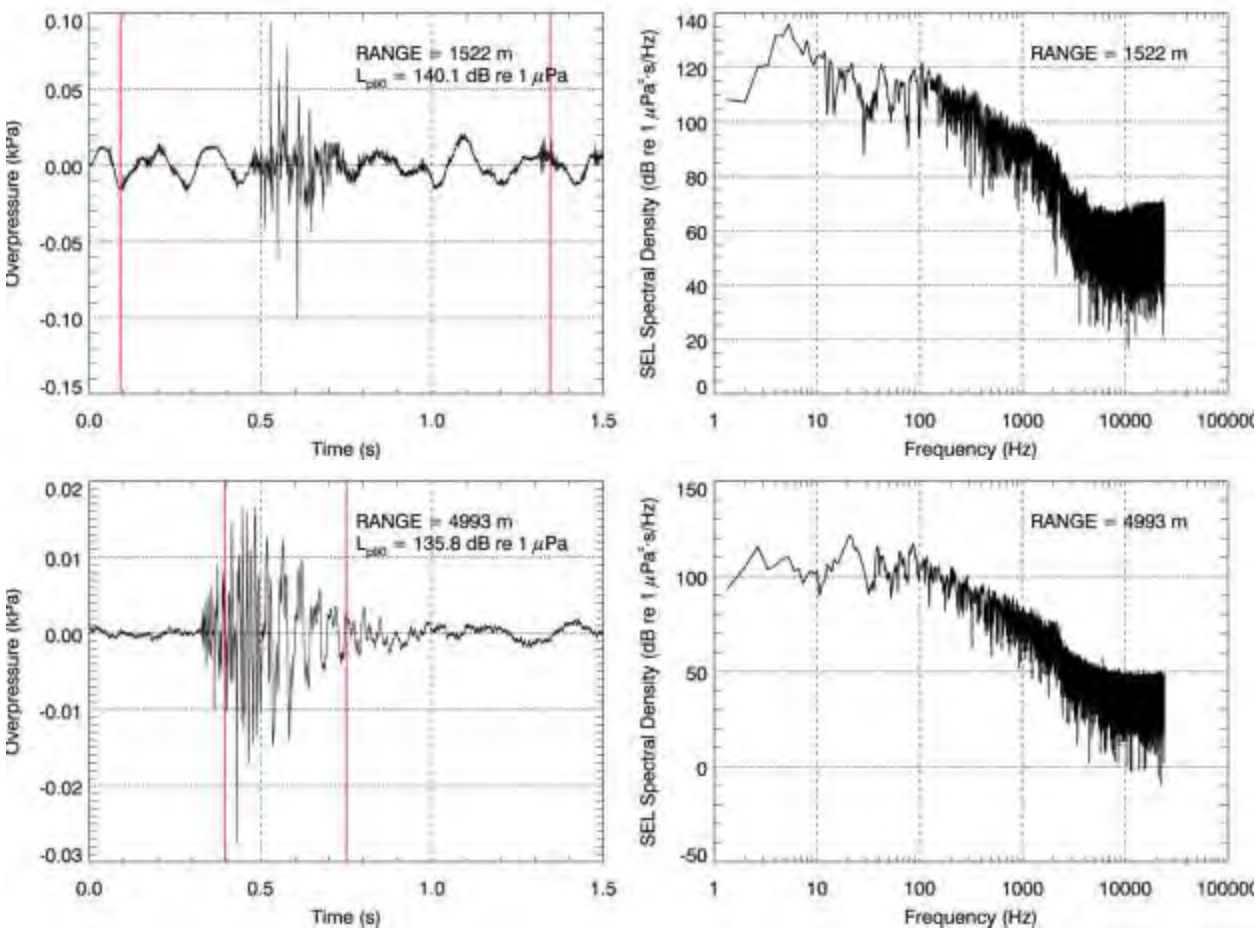


Figure 15. Waveform (left) and corresponding SEL spectral density (right) plots of 10 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

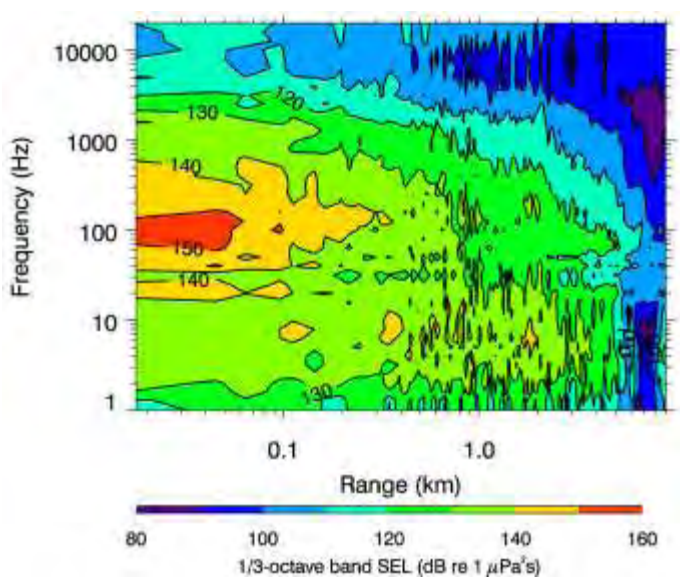


Figure 16. 1/3 octave band SEL levels as a function of range and frequency for the 10 in³ airgun array in the endfire direction at the offshore site.

4.2. 440 in^3 Airgun Array

4.2.1. Track 1

Peak SPL, 90% rms SPL and SEL for each shot along the nearshore line (Track 1) were computed from acoustic data recorded on OBHs A-D. Figure 17 shows sound levels from the 440 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. A 25 Hz high pass filter was applied to recordings on OBH D prior to SPL calculations to isolate airgun sounds from flow noise. Table 6 lists ranges to several rms SPL thresholds for each of the fits in Figure 17. Figures Figure 18 and Figure 19 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 20 presents spectrograms of 440 in³ airgun array pulses in the endfire direction at 471 m, 1537 m, and 7934 m. Pulses in the broadside direction near CPA at 22 m, 477 m, 1524 m, and 7936 m are shown in Figure 21. Figures Figure 22 and Figure 23 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 24. Sound levels near the source were highest between 30 and 300 Hz in the endfire direction and between 20 and 300 Hz in the broadside direction.

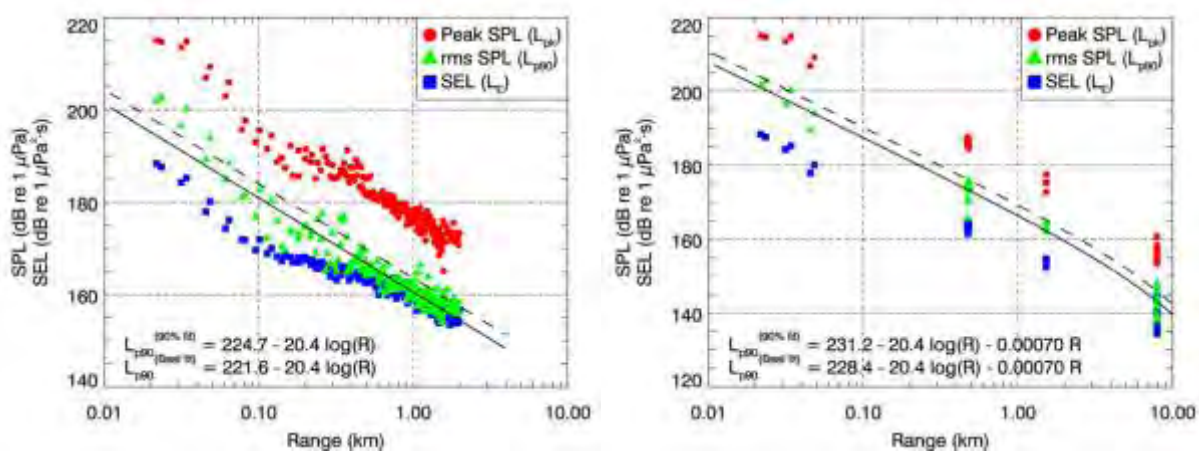


Figure 17: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 440 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured for the nearshore line (Track 1). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Table 6: Threshold radii for the 440 in^3 airgun array at the nearshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 17.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	36	50	75	100
180	110	160	230	310
170	340	480	680	920
160	1100	1500	1900	2500

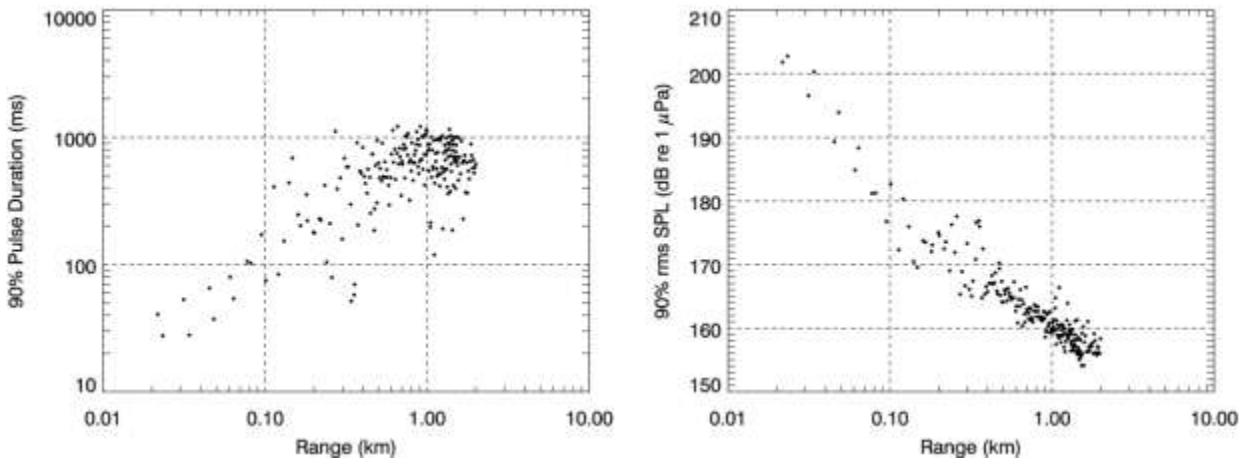


Figure 18. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

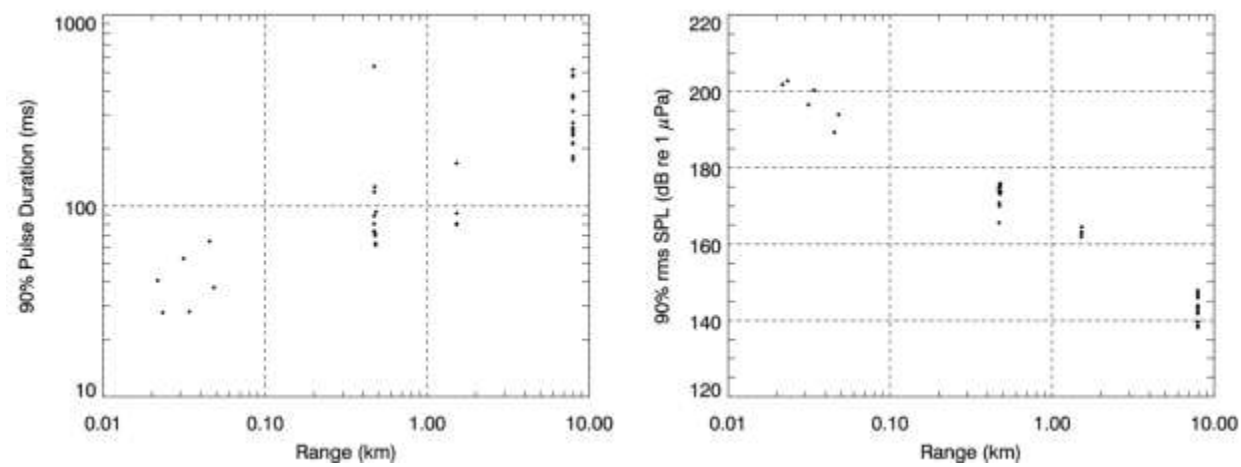


Figure 19. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

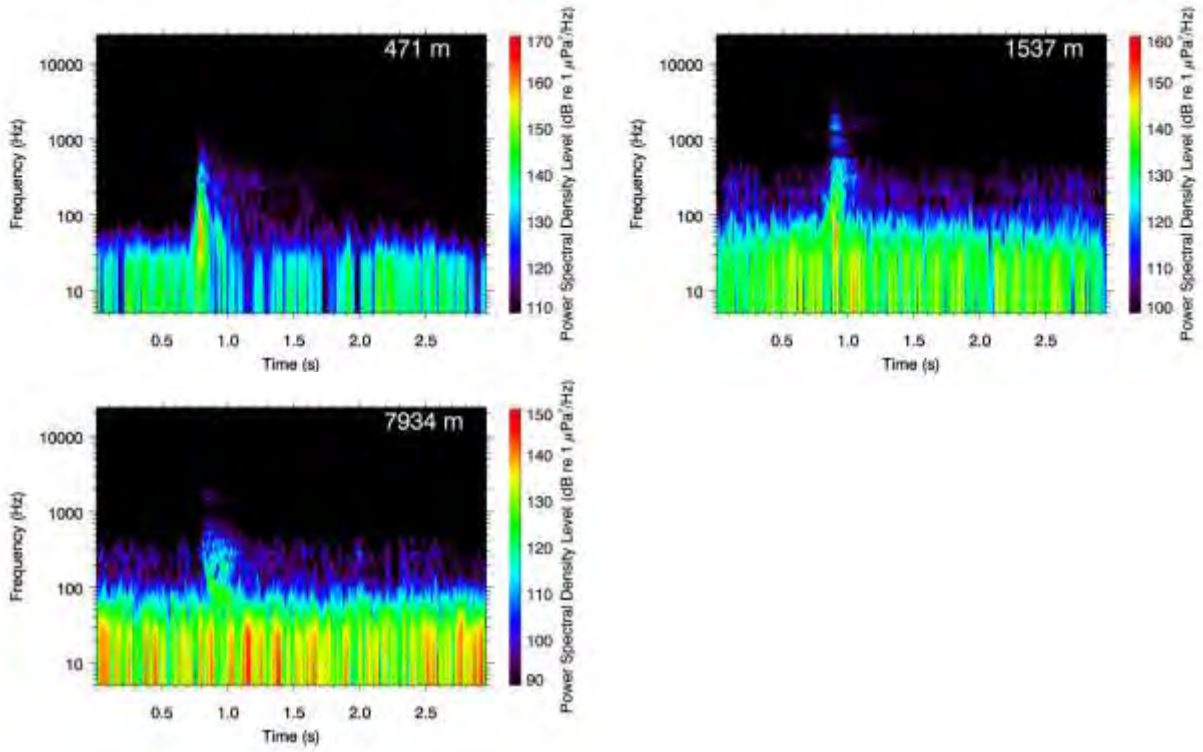


Figure 20. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

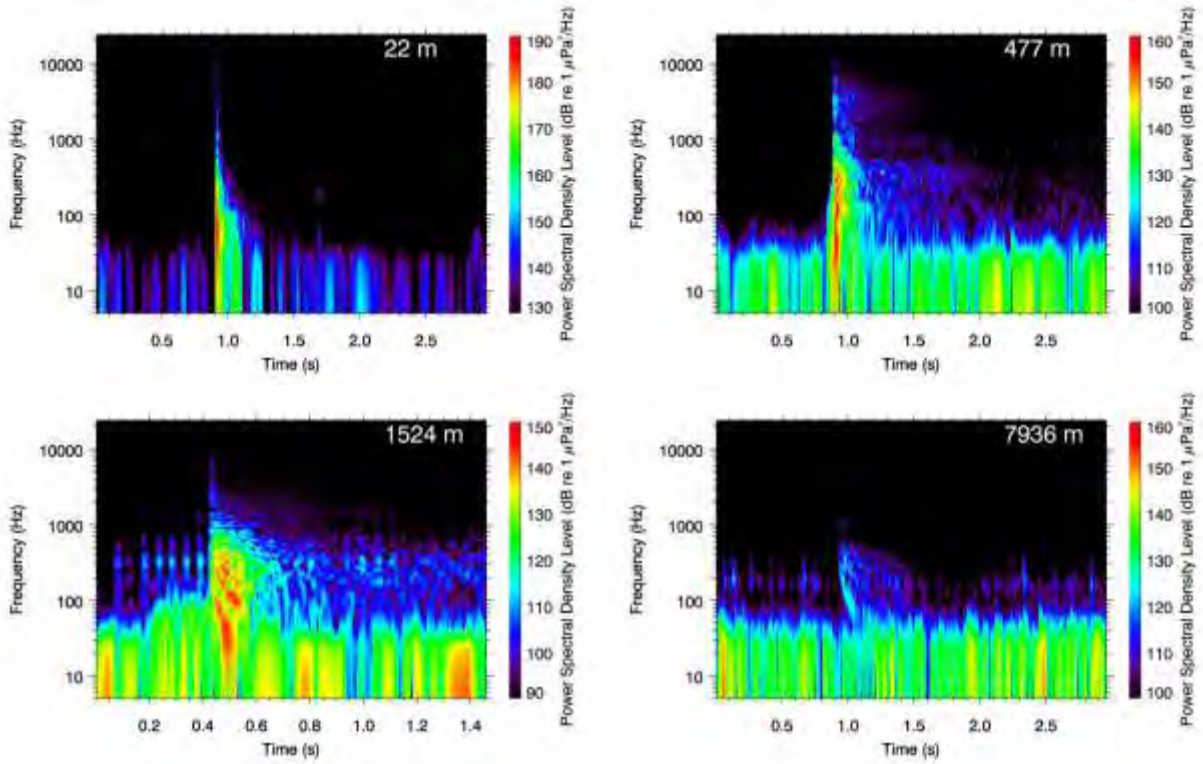


Figure 21. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

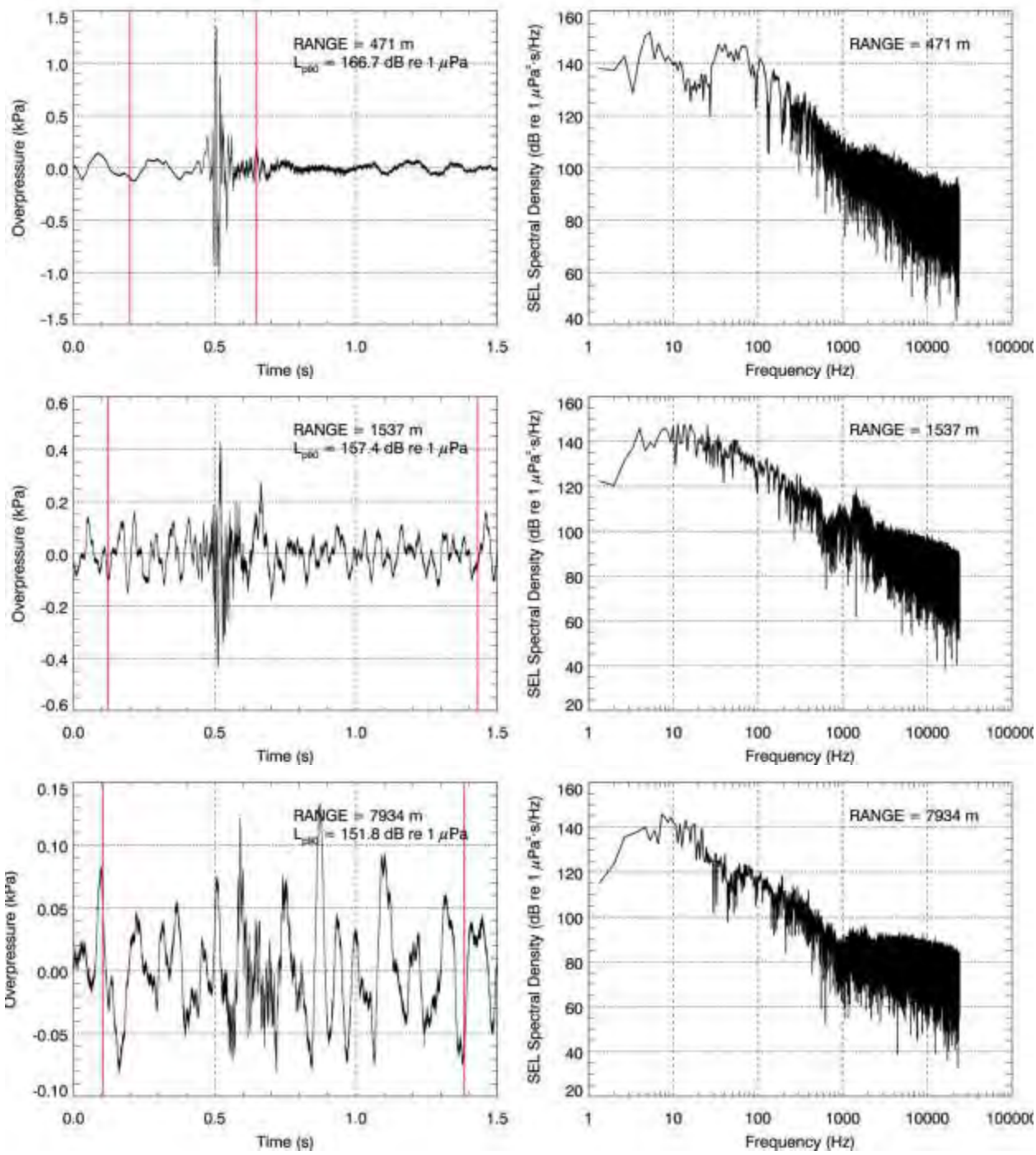
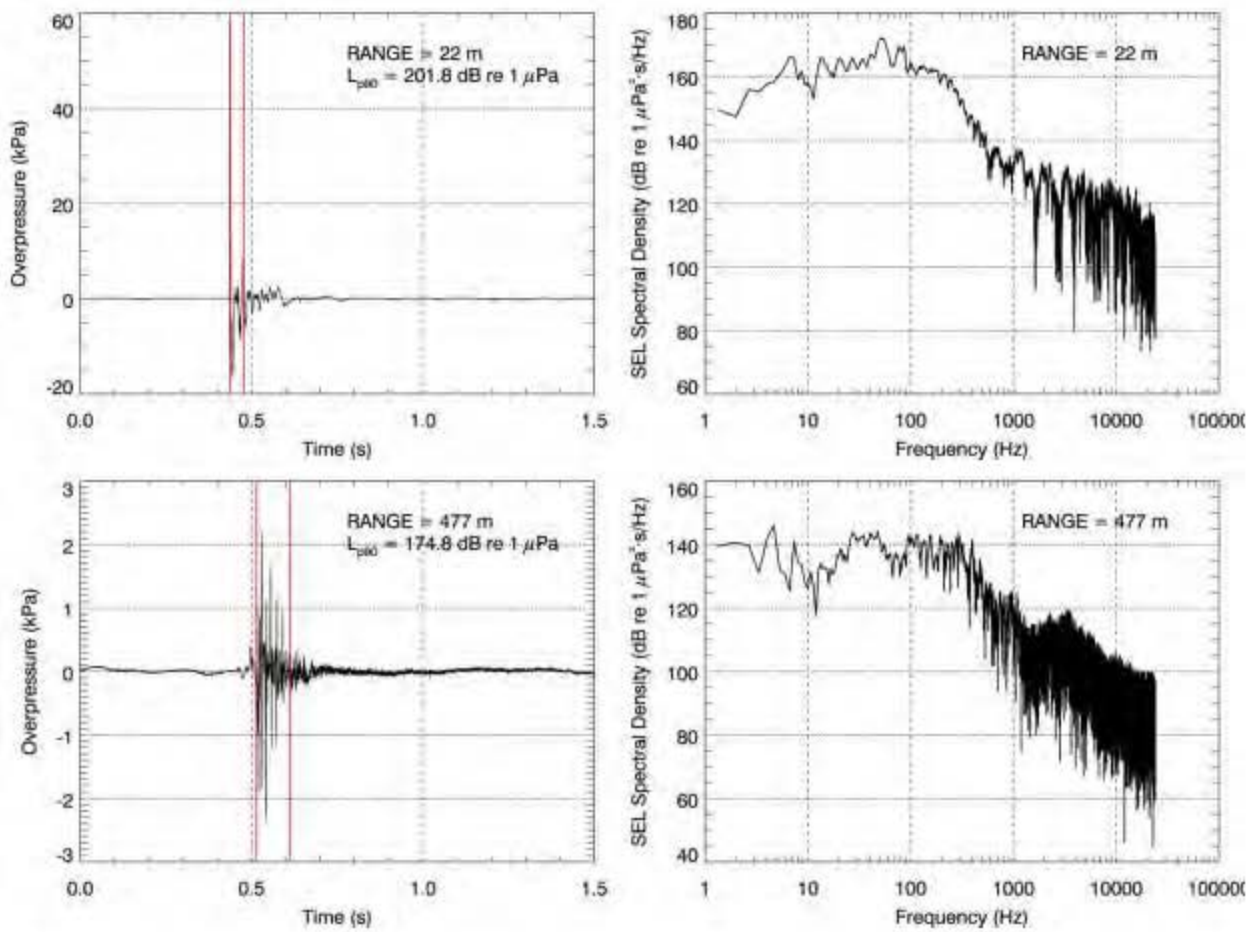


Figure 22. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 22 m
L_pk0 = 201.8 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 22 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 477 m
L_pk0 = 174.8 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 477 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

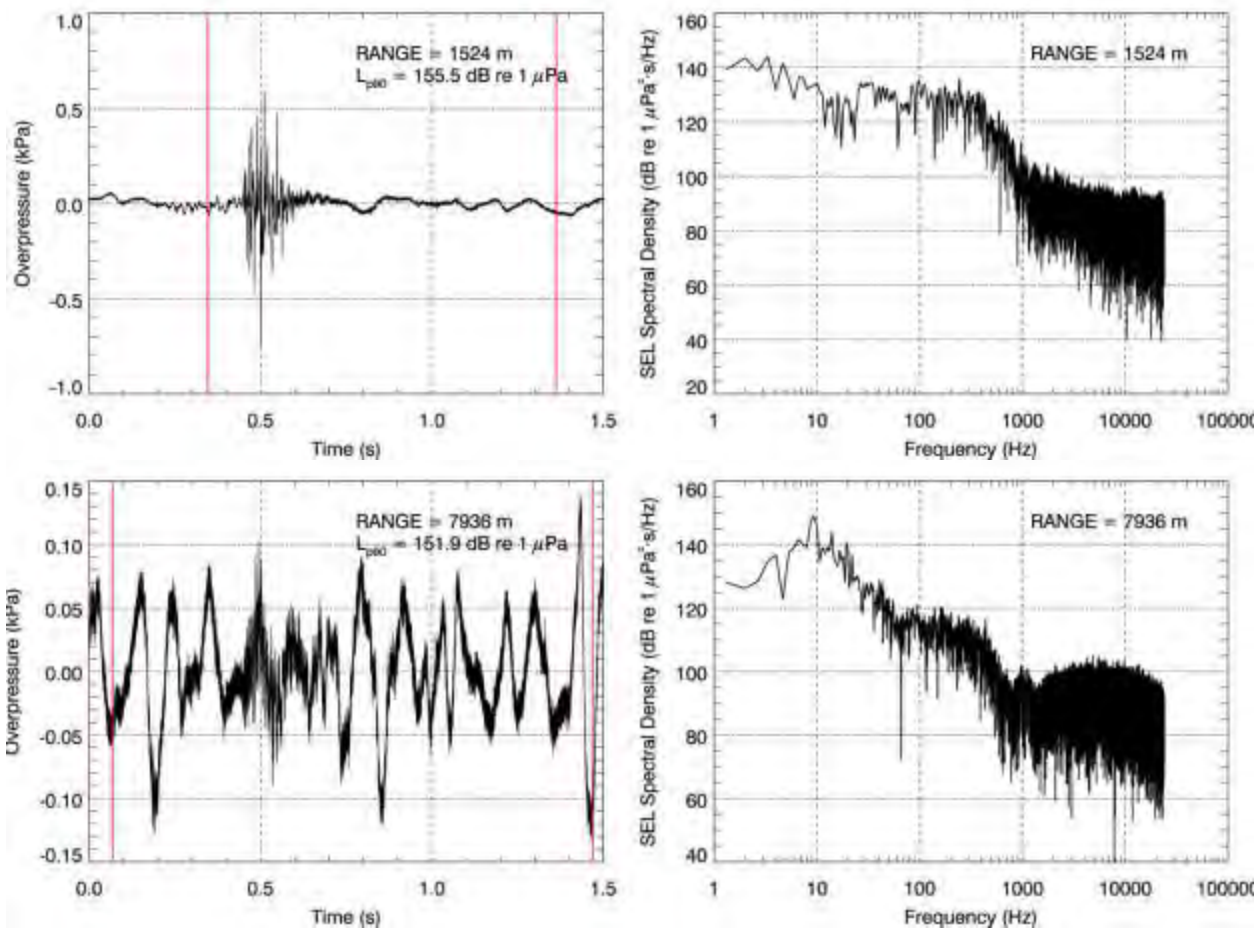


Figure 23. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

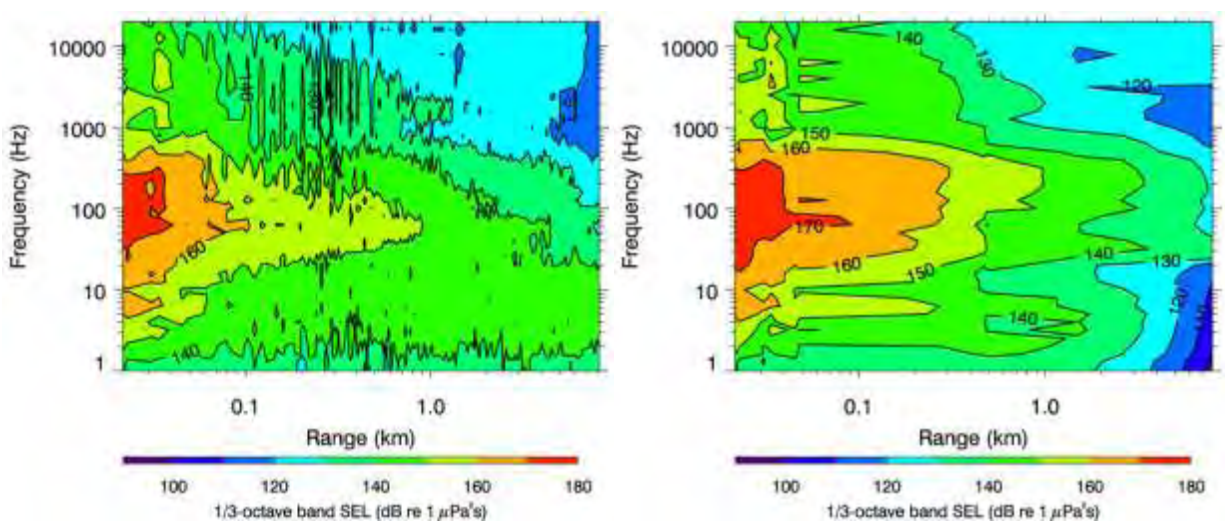


Figure 24. 1/3 octave band SEL levels as a function of range and frequency for the 440 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

4.2.2. Track 2

Peak SPL, 90% rms SPL and SEL for each shot along the offshore line (Track 2) were computed from acoustic data recorded on OBHs E-H. Figure 25 shows sound levels from the 440 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 7 lists ranges to several rms SPL thresholds for each of the fits in Figure 25. Figures Figure 26 and Figure 27 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 28 presents spectrograms of 440 in³ airgun array pulses in the endfire direction at 546 m, 1583 m, 5477 m, and 8459 m. Pulses in the broadside direction near CPA at 80 m, 546 m, 1552 m, and 5505 m are shown in Figure 29. Figures Figure 30 and Figure 31 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 32. Sound levels near the source were highest between 30 and 200 Hz in the endfire direction and between 20 and 300 Hz in the broadside direction.

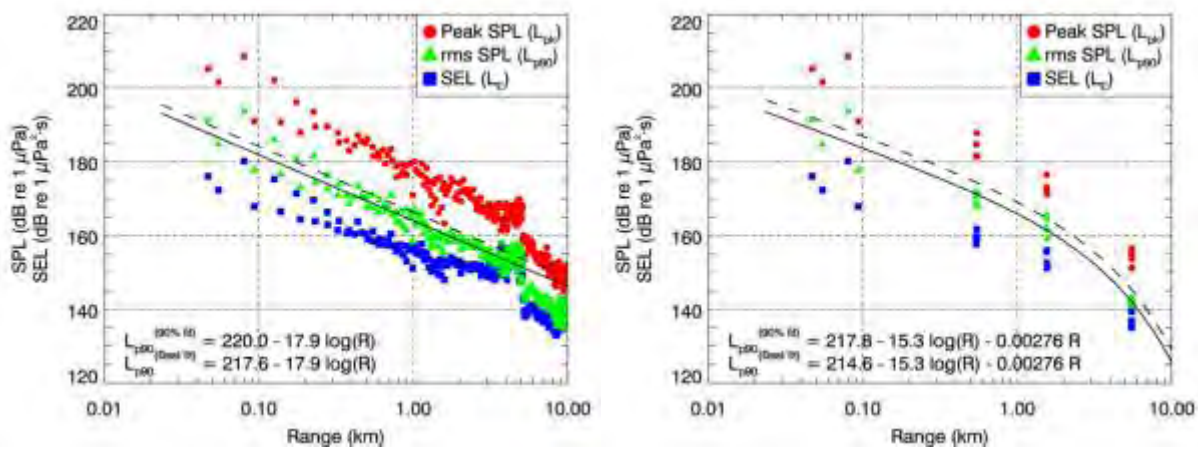


Figure 25: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 440 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore line (Track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values. The endfire empirical fit was restricted to measurements at ranges less than 5 km to provide accurate distances to thresholds above 150 dB; data at ranges beyond 5 km are shown for completeness.

Table 7: Threshold radii for the 440 in^3 airgun array at the offshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 25.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	35	47	40	64
180	130	170	170	260
170	460	630	630	910
160	1700	2300	1800	2300

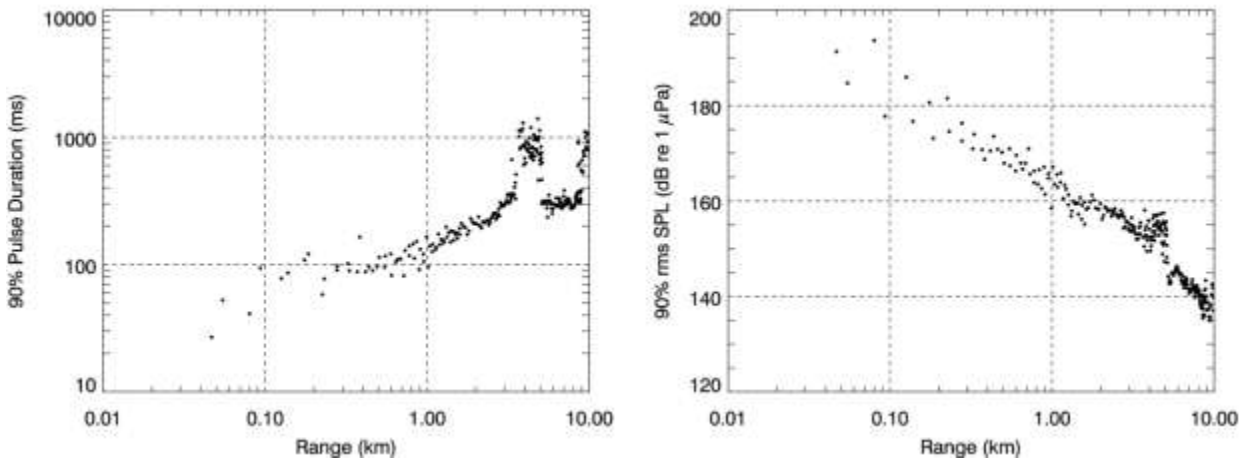


Figure 26. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

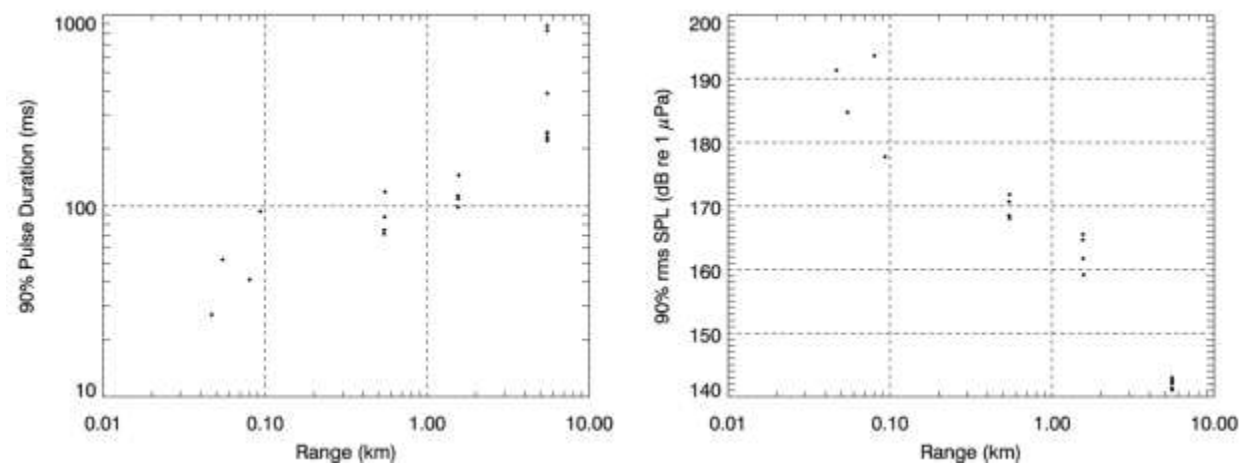


Figure 27. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

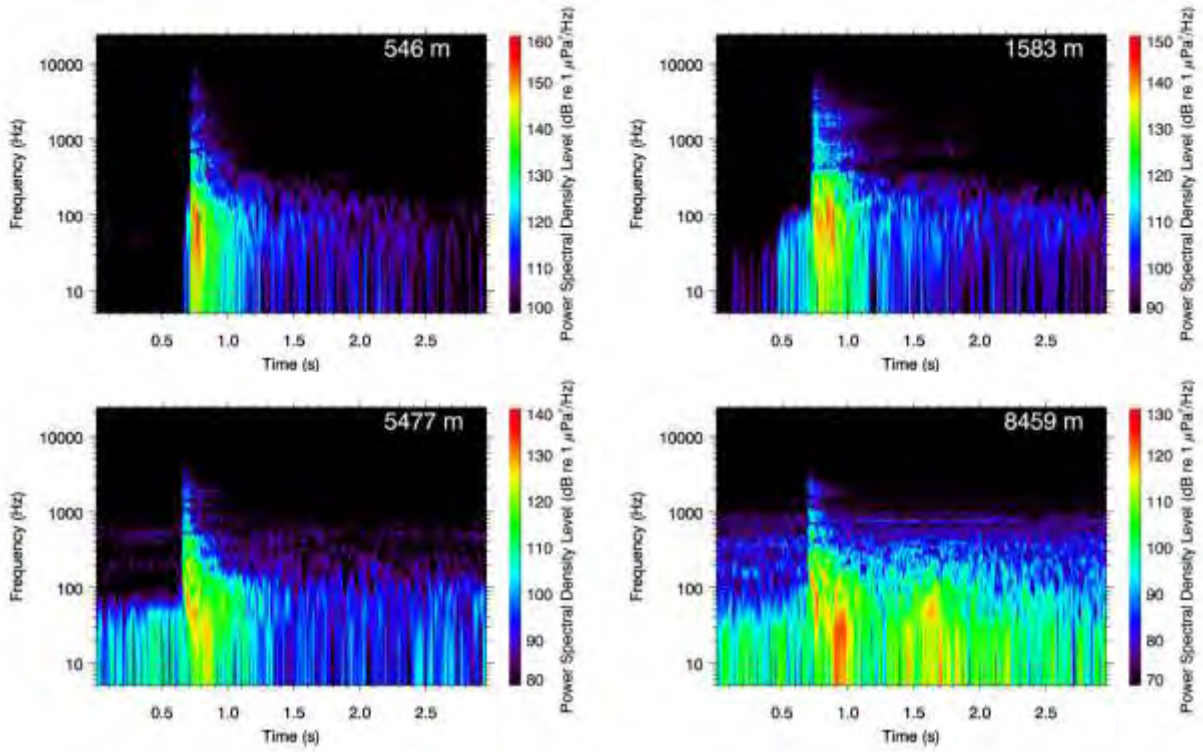


Figure 28. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

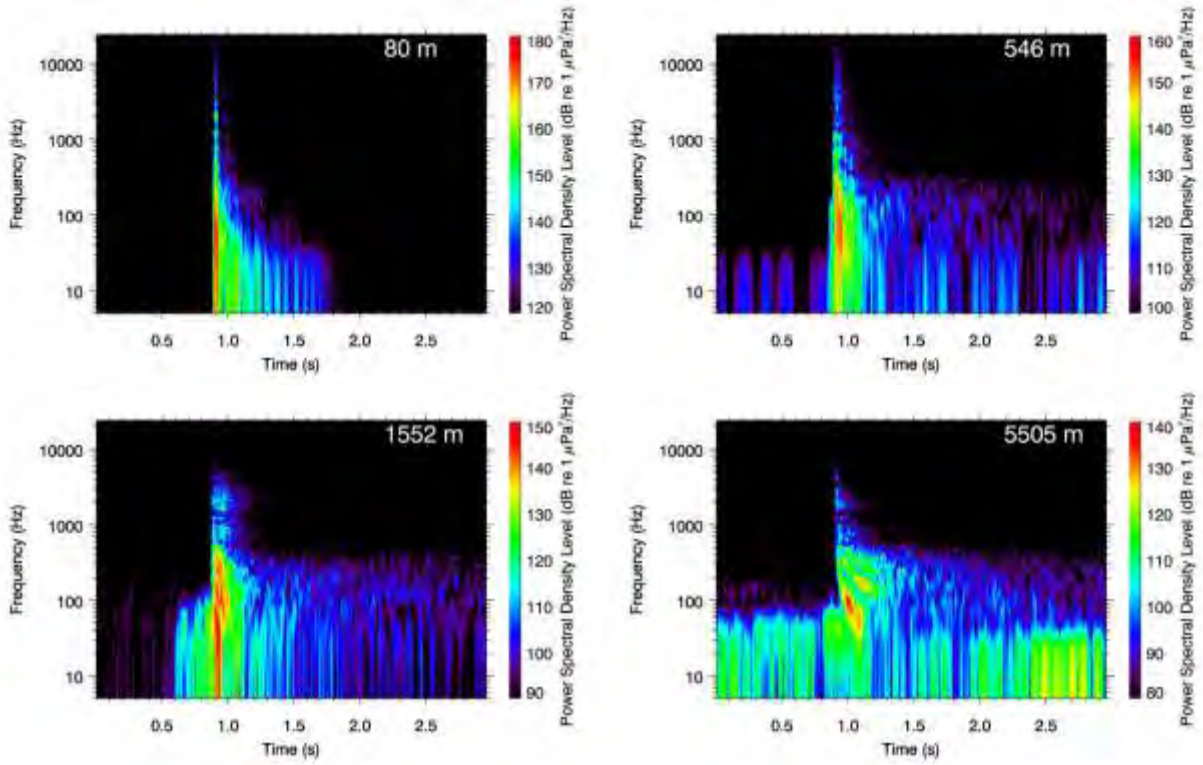
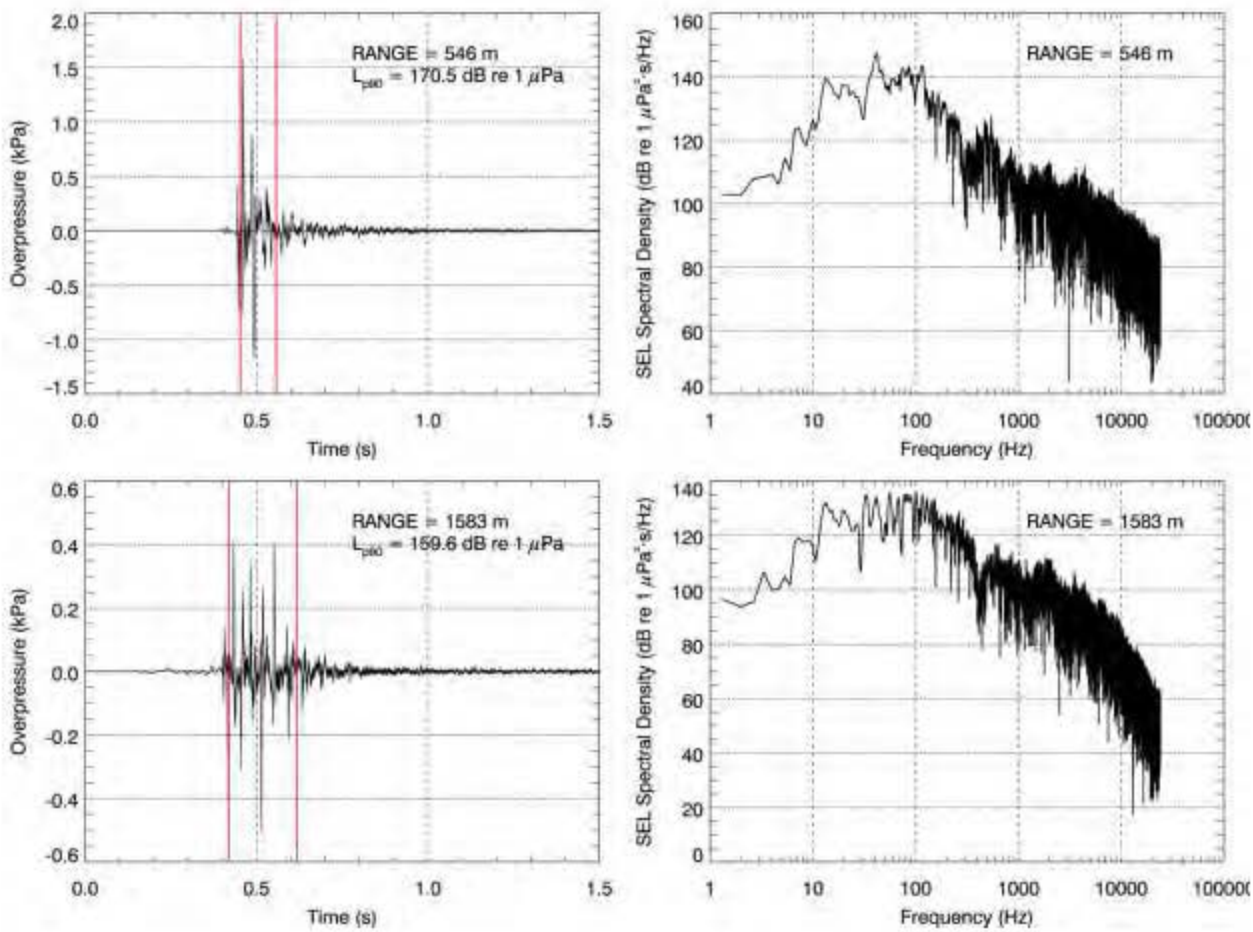


Figure 29. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5505 m spectrogram is 2048-pt FFT, 48 kHz sample rate).


RANGE = 546 m
L_{pk0} = 170.5 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 546 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 1583 m
L_{pk0} = 159.6 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 1583 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

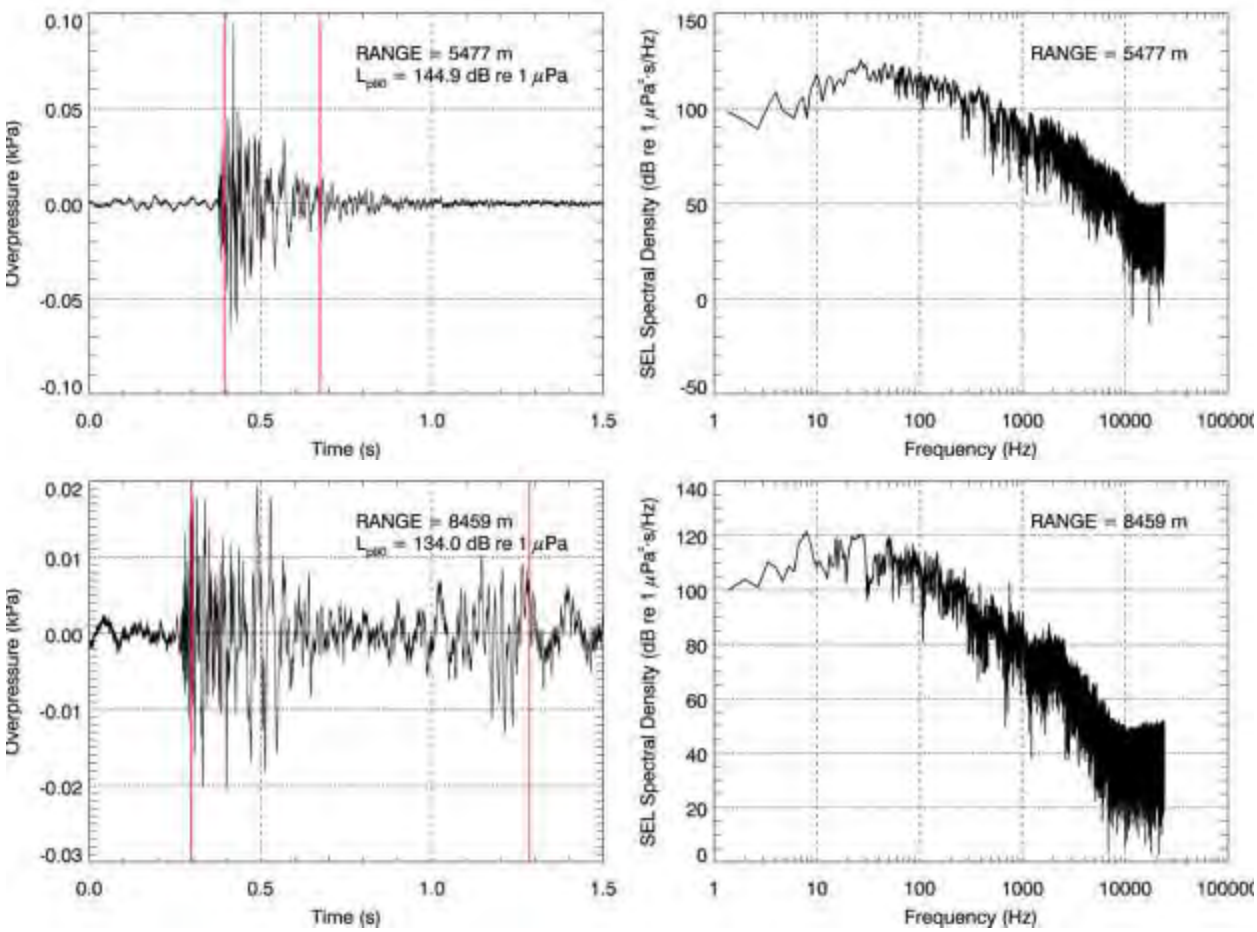
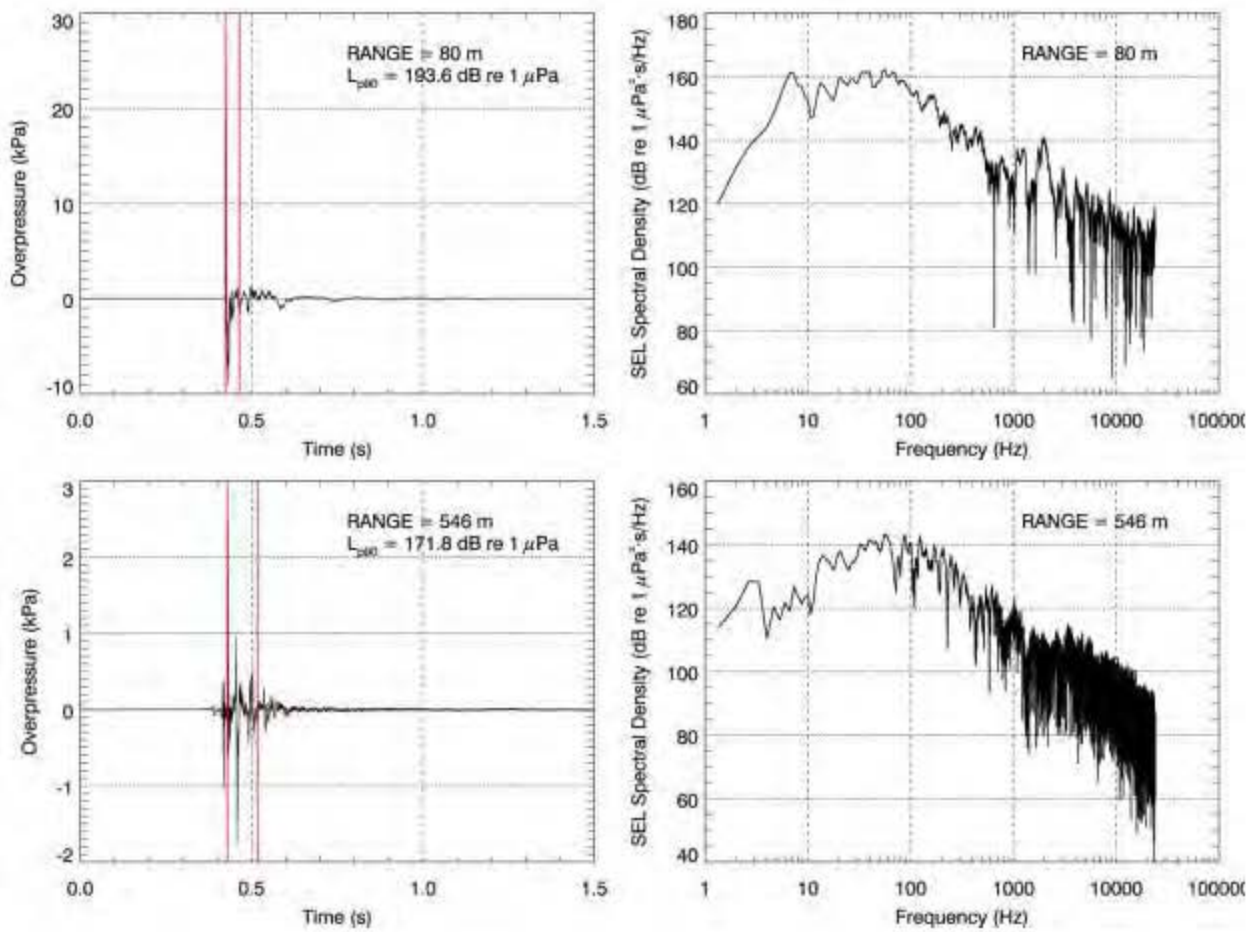


Figure 30. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 80 m
L_{pk0} = 193.6 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 80 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 546 m
L_{pk0} = 171.8 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 546 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

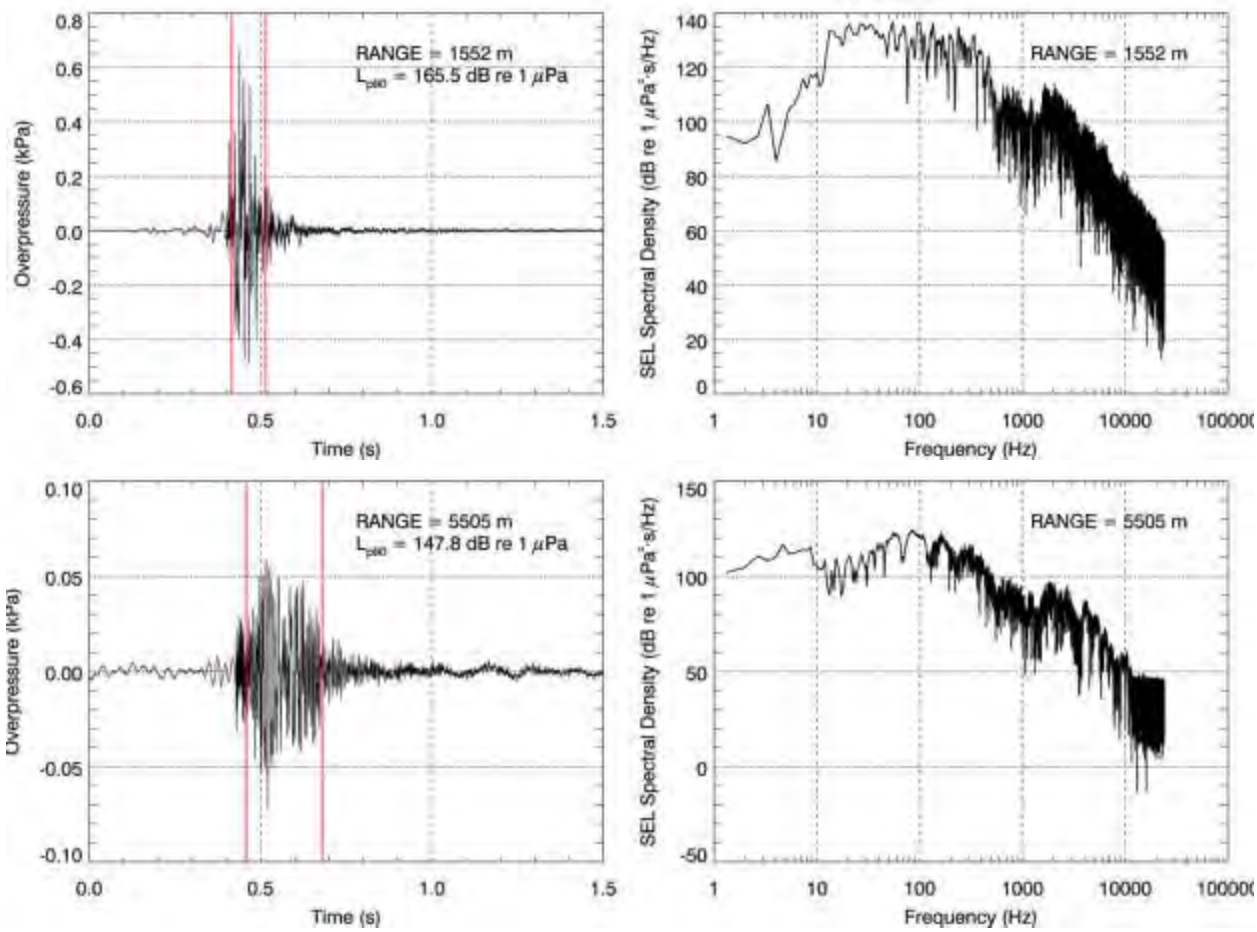


Figure 31. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

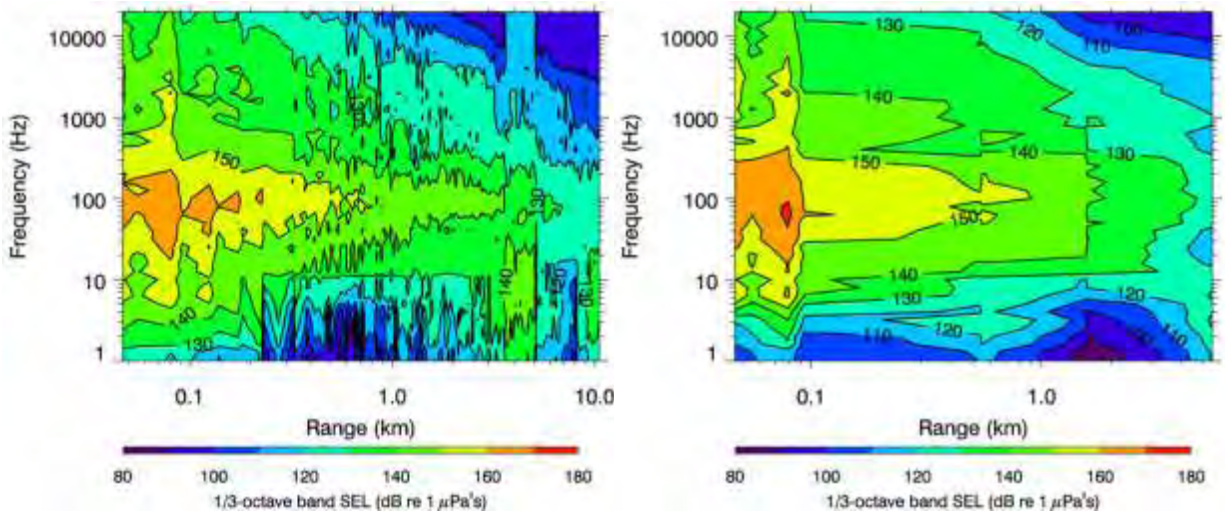


Figure 32. 1/3 octave band SEL levels as a function of range and frequency for the 440 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

4.3. 1200 in³ Airgun Array

4.3.1. Track 1

Peak SPL, 90% rms SPL and SEL for each shot on the nearshore line (Track 1) were computed from acoustic data recorded on OBHs A-D. Figure 33 shows sound levels from the 1200 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 8 lists ranges to several rms SPL thresholds for each of the fits in Figure 33. Figures Figure 34 and Figure 35 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 36 presents spectrograms of 1200 in³ airgun array pulses in the endfire direction at 393 m, 1416 m, and 6271 m. Pulses in the broadside direction near CPA at 107 m, 380 m, 1429 m, and 7840 m are shown in Figure 37. Figures Figure 38 and Figure 39 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 40. Sound levels near the source were highest between 80 and 300 Hz in both the endfire and broadside directions.

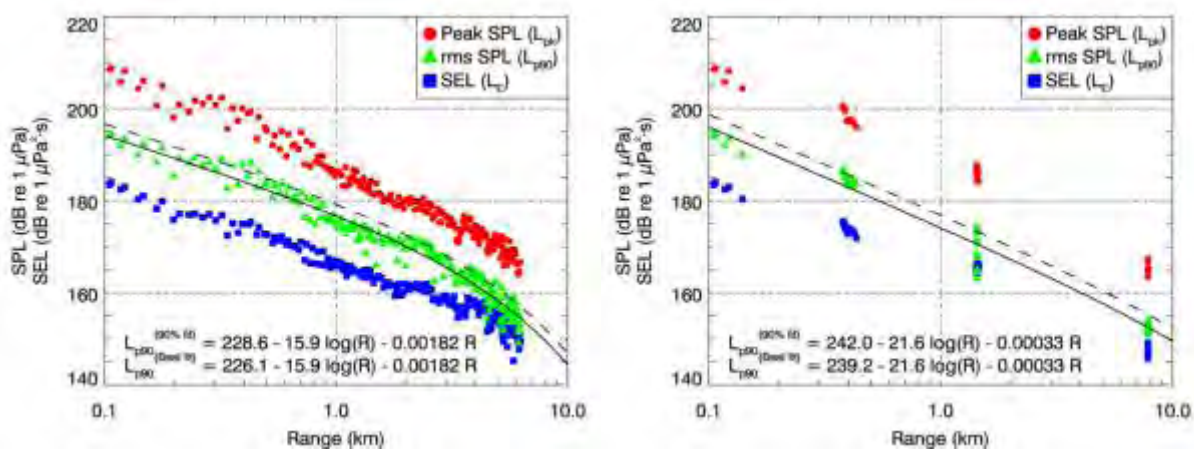


Figure 33: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 1200 in³ airgun array pulses in the endfire (left) and broadside (right) directions measured at the nearshore site (Track 1). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Table 8: Threshold radii for the 1200 in^3 airgun array at the nearshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 33.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	180	250	190	250
180	670	910	540	720
170	2000	2500	1500	2000
160	4500	5300	4000	5200

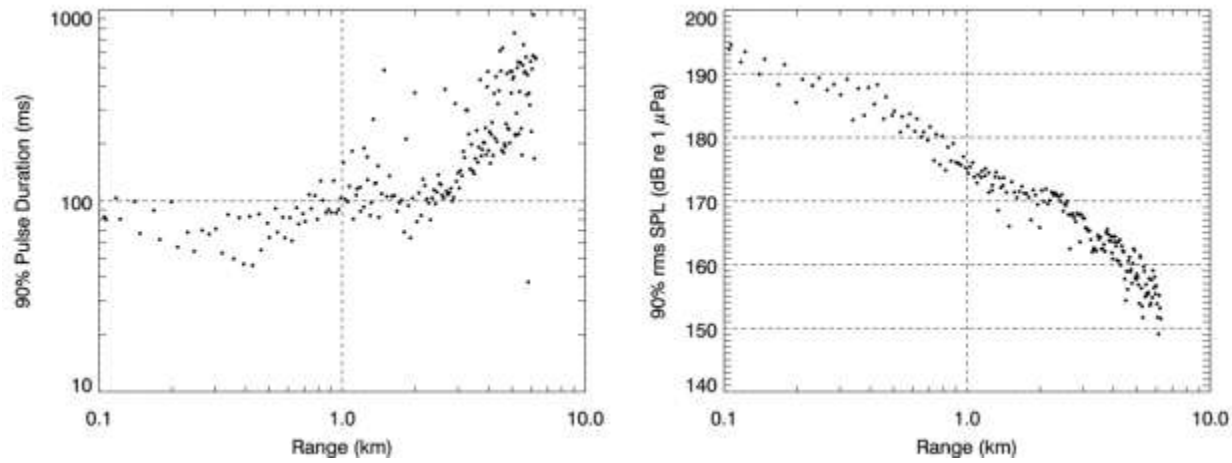


Figure 34. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

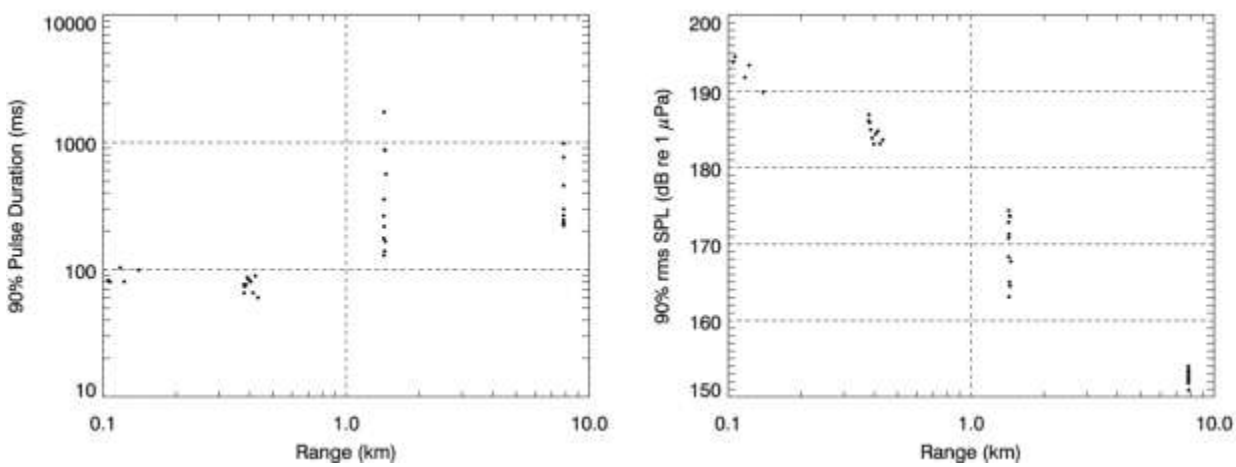


Figure 35. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

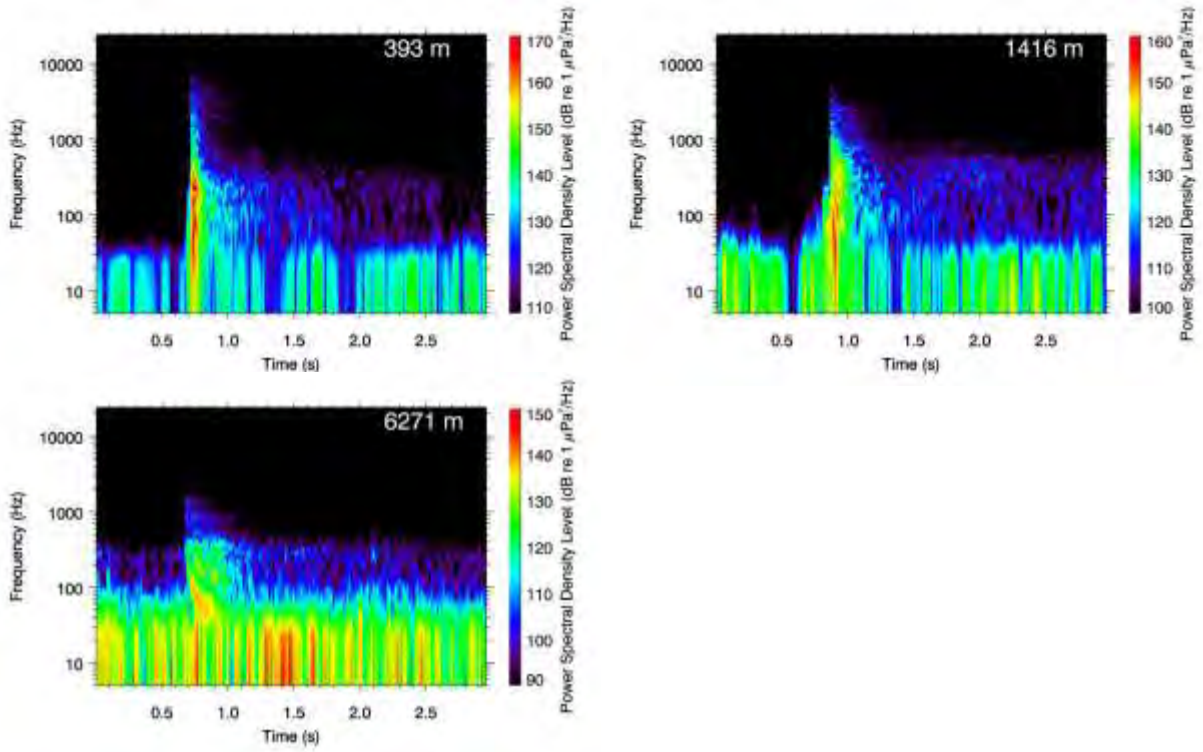


Figure 36. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

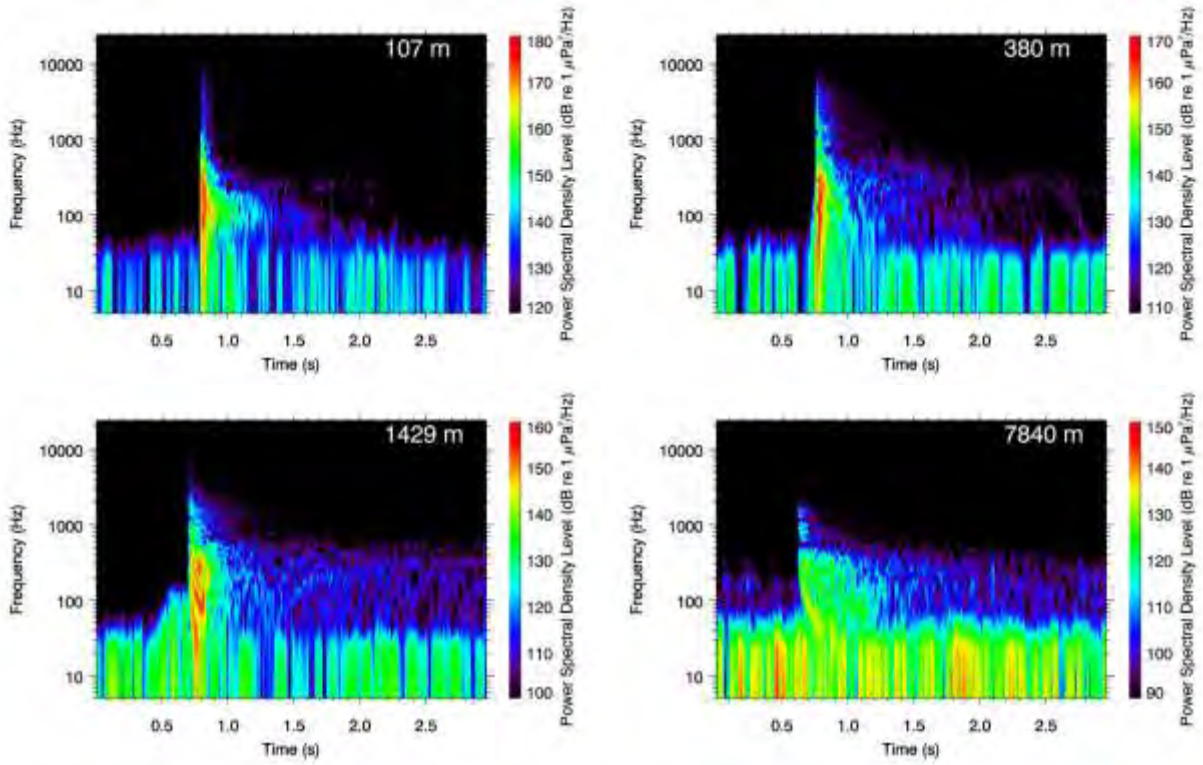


Figure 37. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

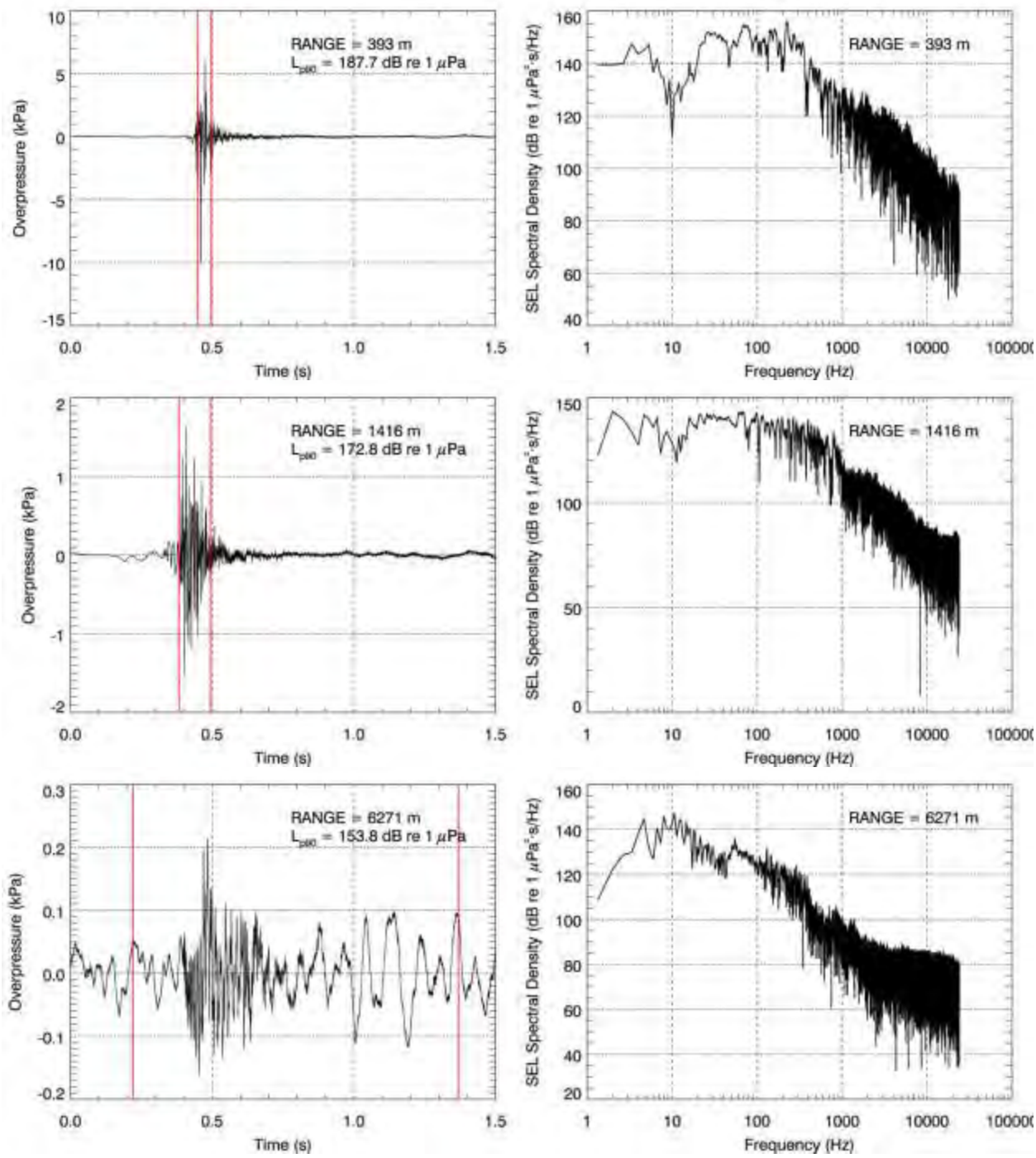
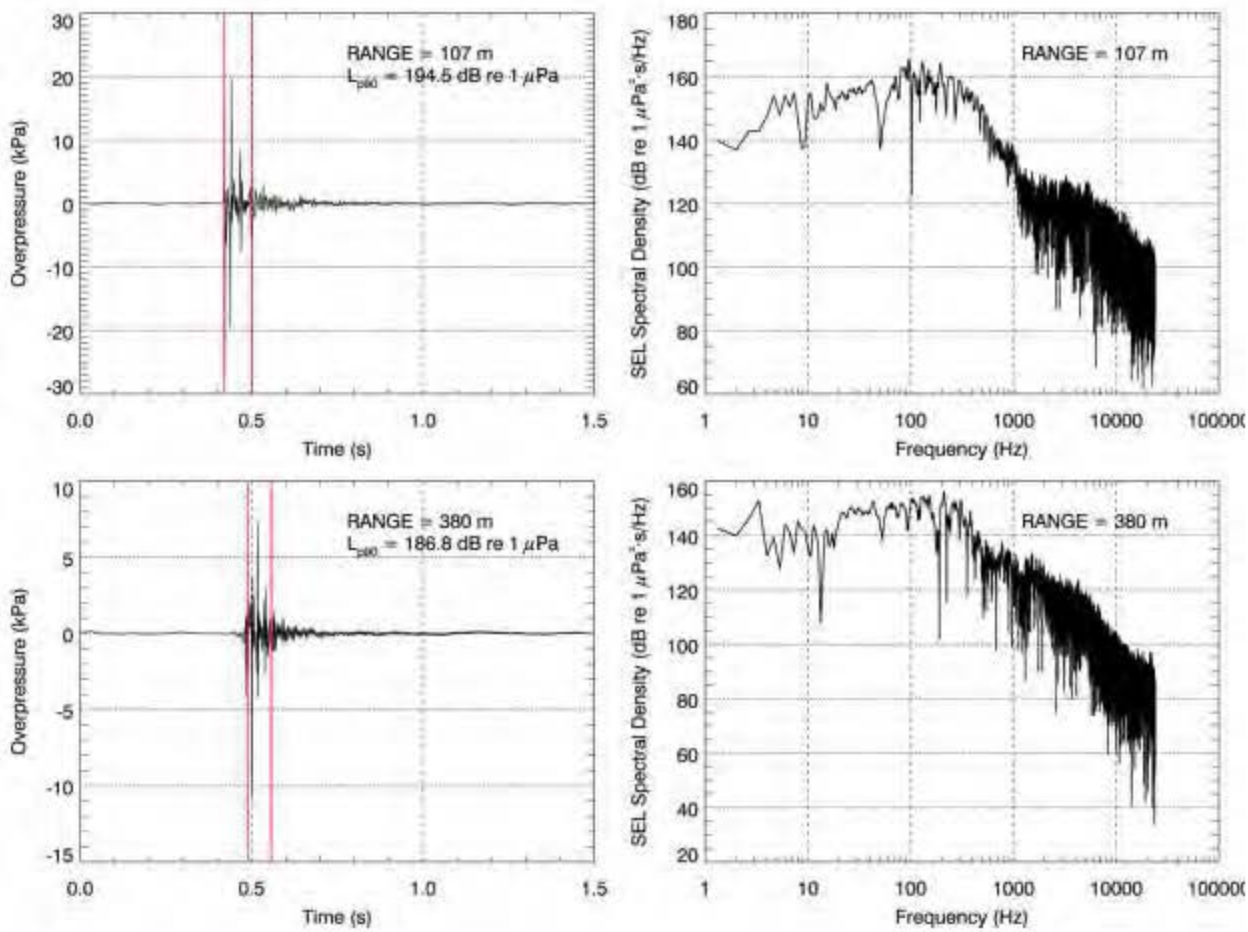


Figure 38. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 107 m
L_{pk0} = 194.5 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 107 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 380 m
L_{pk0} = 186.8 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 380 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

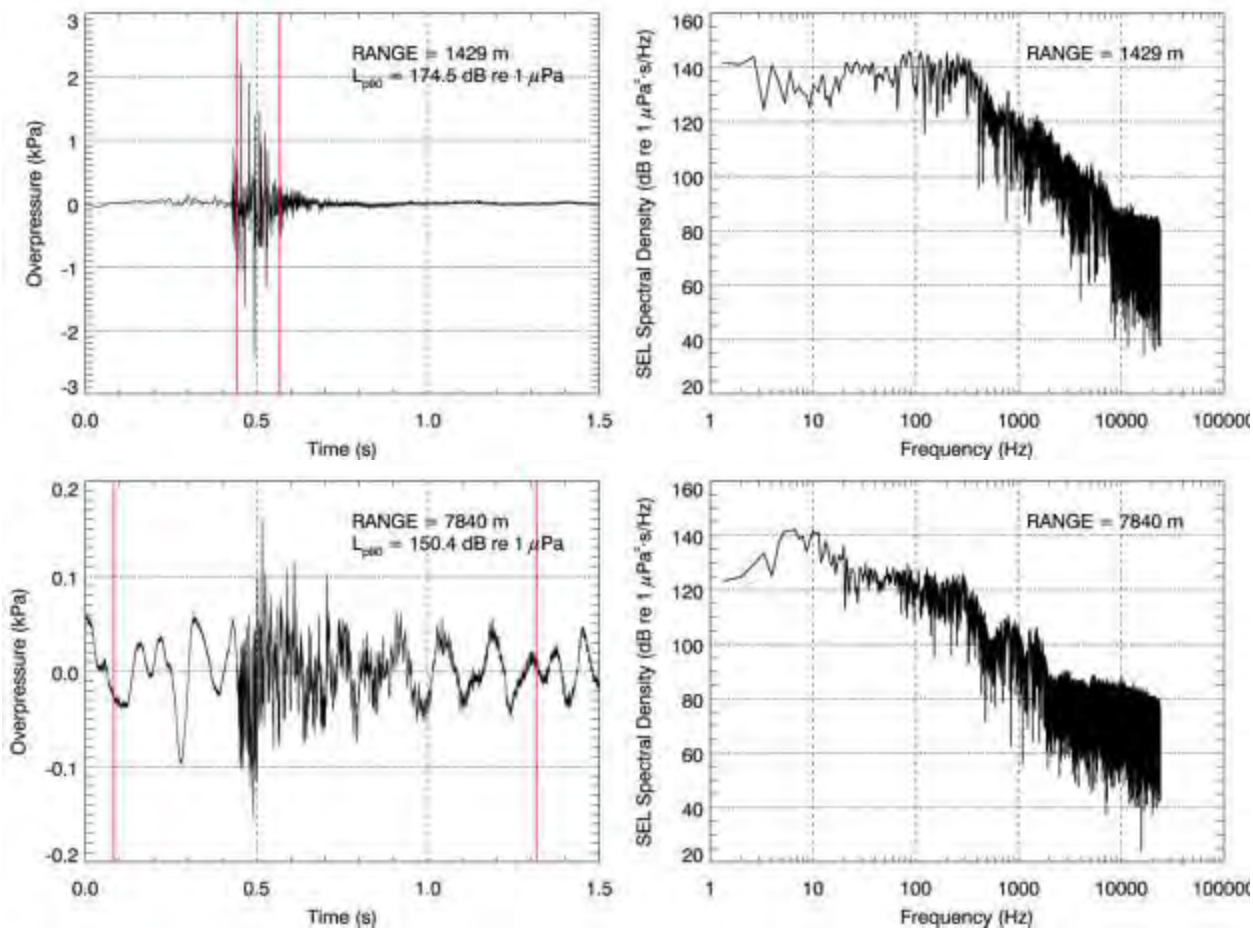


Figure 39. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

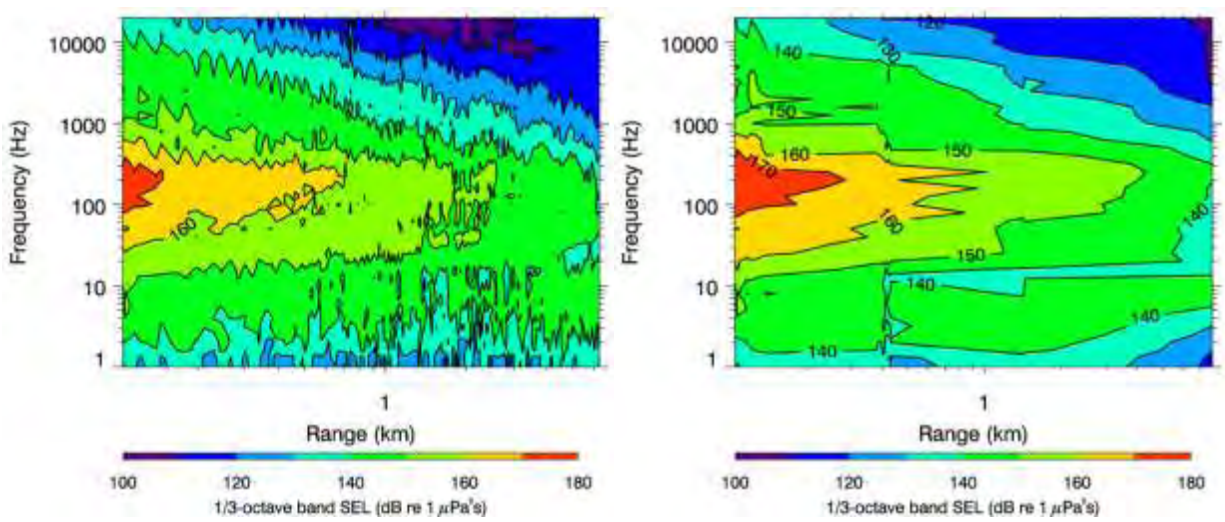


Figure 40. 1/3 octave band SEL levels as a function of range and frequency for the 1200 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

4.3.2. Track 2

Peak SPL, 90% rms SPL and SEL for each shot on the offshore line were computed from acoustic data recorded on OBHs E-H. Figure 41 shows sound levels from the 1200 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 9 lists ranges to several rms SPL thresholds for each of the fits in Figure 41. The radius to the 160 dB threshold is derived from a linear fit to the data at ranges less than 5 km (see Section 3.3). This radius is expected to exceed that which would be derived from longer range measurements with absorptive loss effects and likely overestimates the true radius to the 160 dB threshold. Figures Figure 42 and Figure 43 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 44 presents spectrograms of 1200 in³ airgun array pulses in the endfire direction at 574 m, 1553 m, 5480 m, and 6418 m. Pulses in the broadside direction near CPA at 75 m, 570 m, 1558 m, and 5509 m are shown in Figure 45. Figures Figure 46 and Figure 47 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 48. Sound levels near the source were highest between 30 and 200 Hz in the endfire direction and between 20 and 200 Hz in the broadside direction.

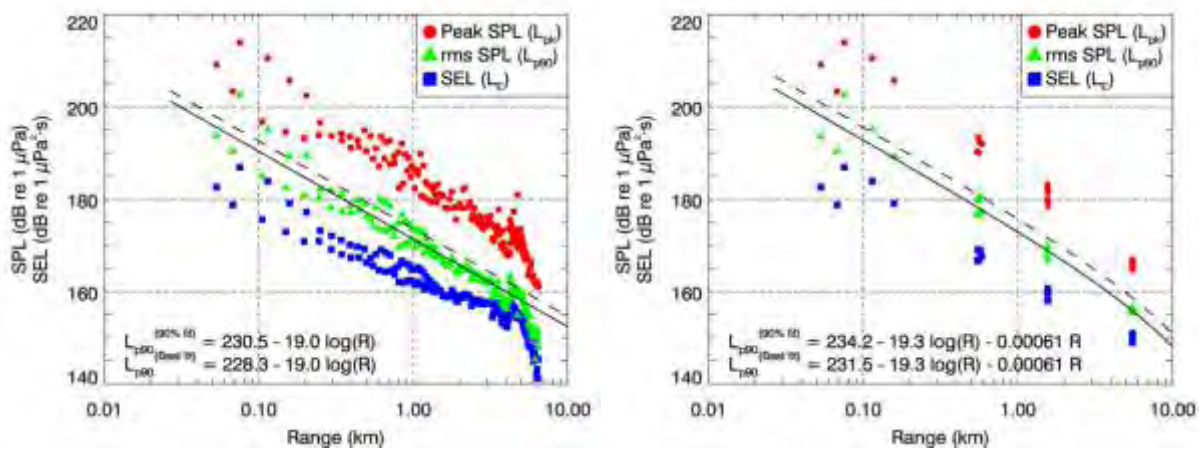


Figure 41: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 1200 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore sites (Track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values. The endfire empirical fit was restricted to measurements at ranges less than 5 km to provide accurate distances to thresholds above 160 dB; data at ranges beyond 5 km are shown for completeness.

Table 9: Threshold radii for the 1200 in^3 airgun array at the offshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 41.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	100	140	140	190
180	350	460	450	610
170	1200	1500	1400	1800
160	4000	5200	3800	4900

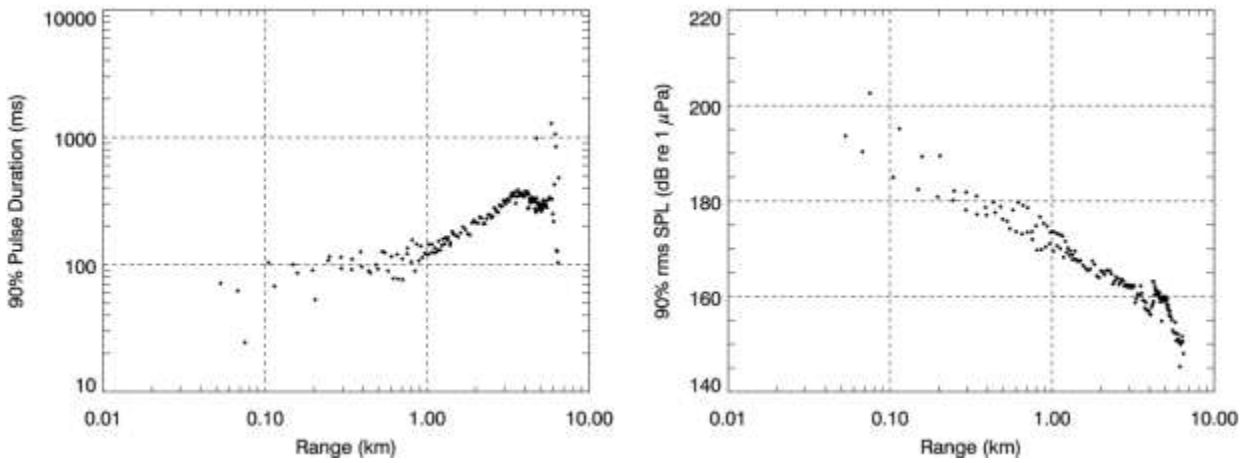


Figure 42. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

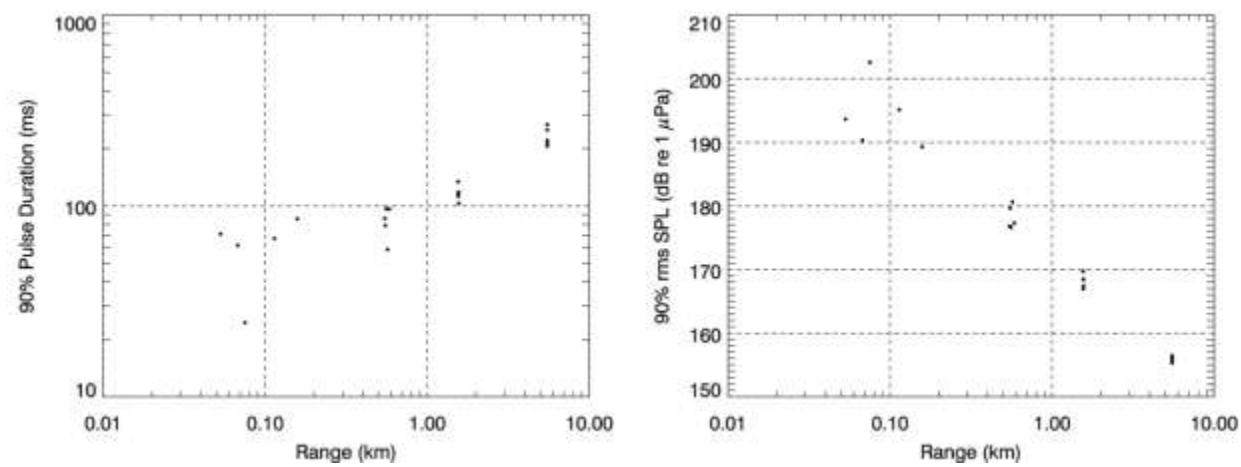


Figure 43. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

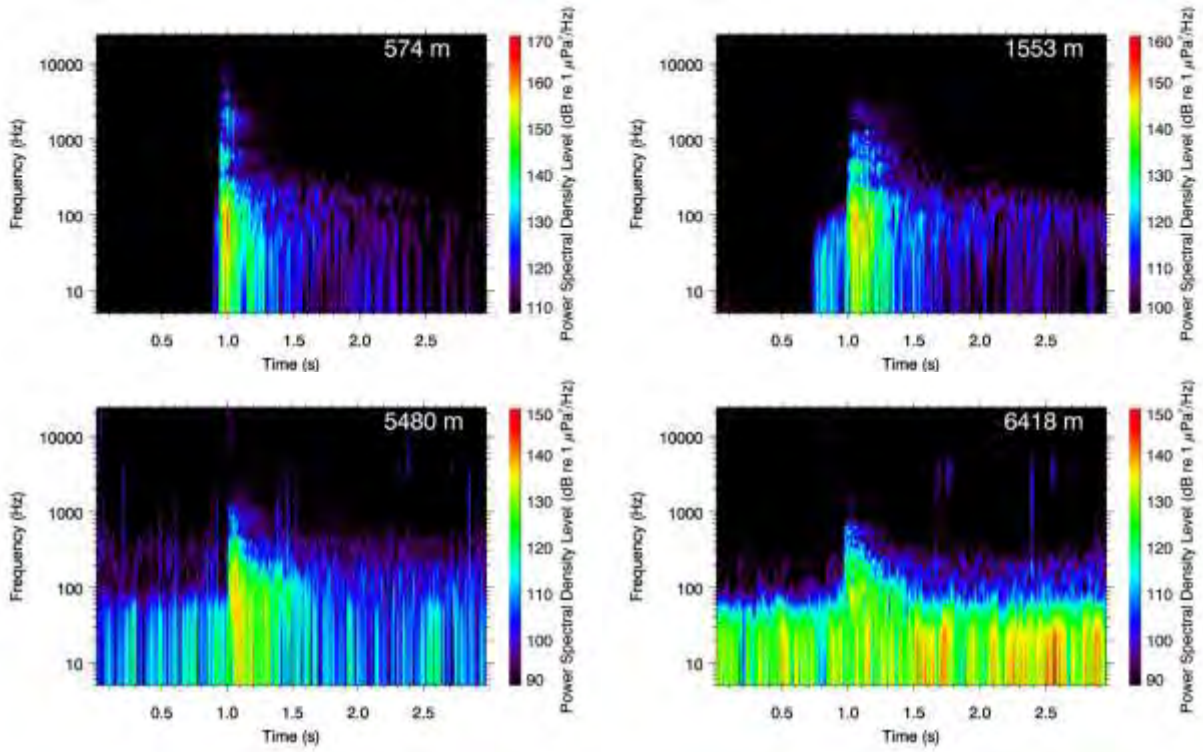


Figure 44. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

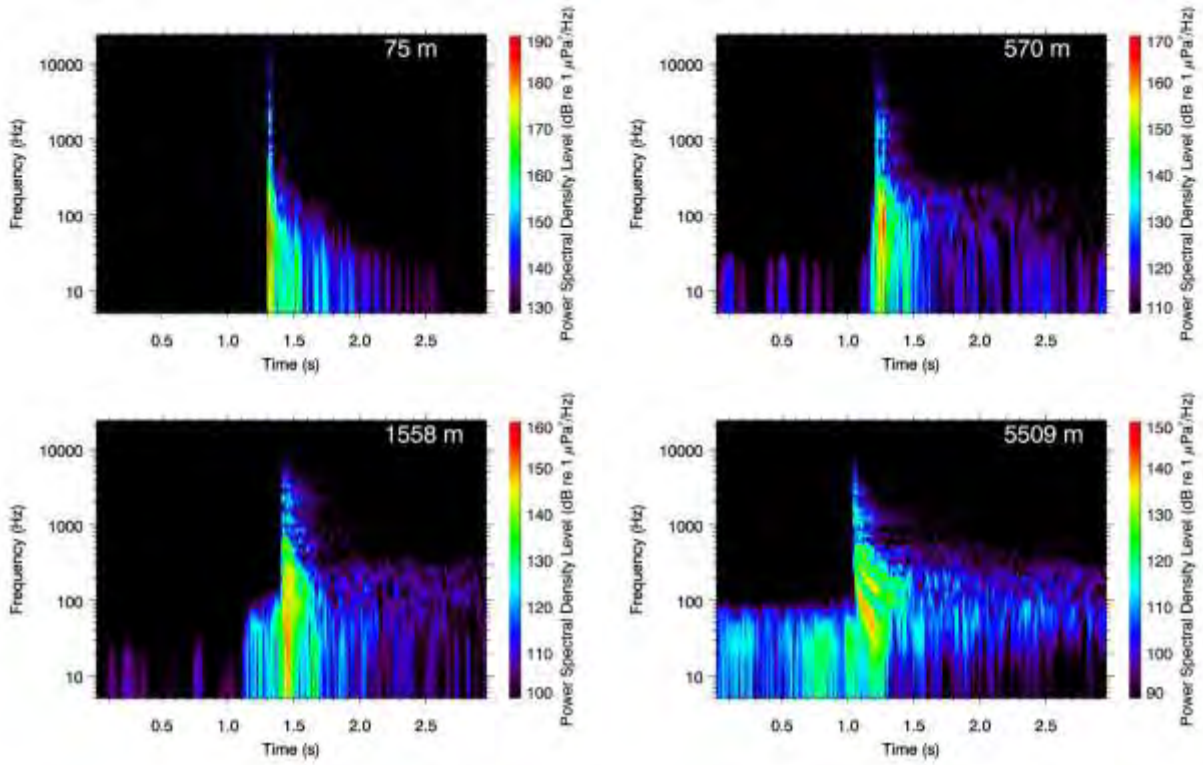
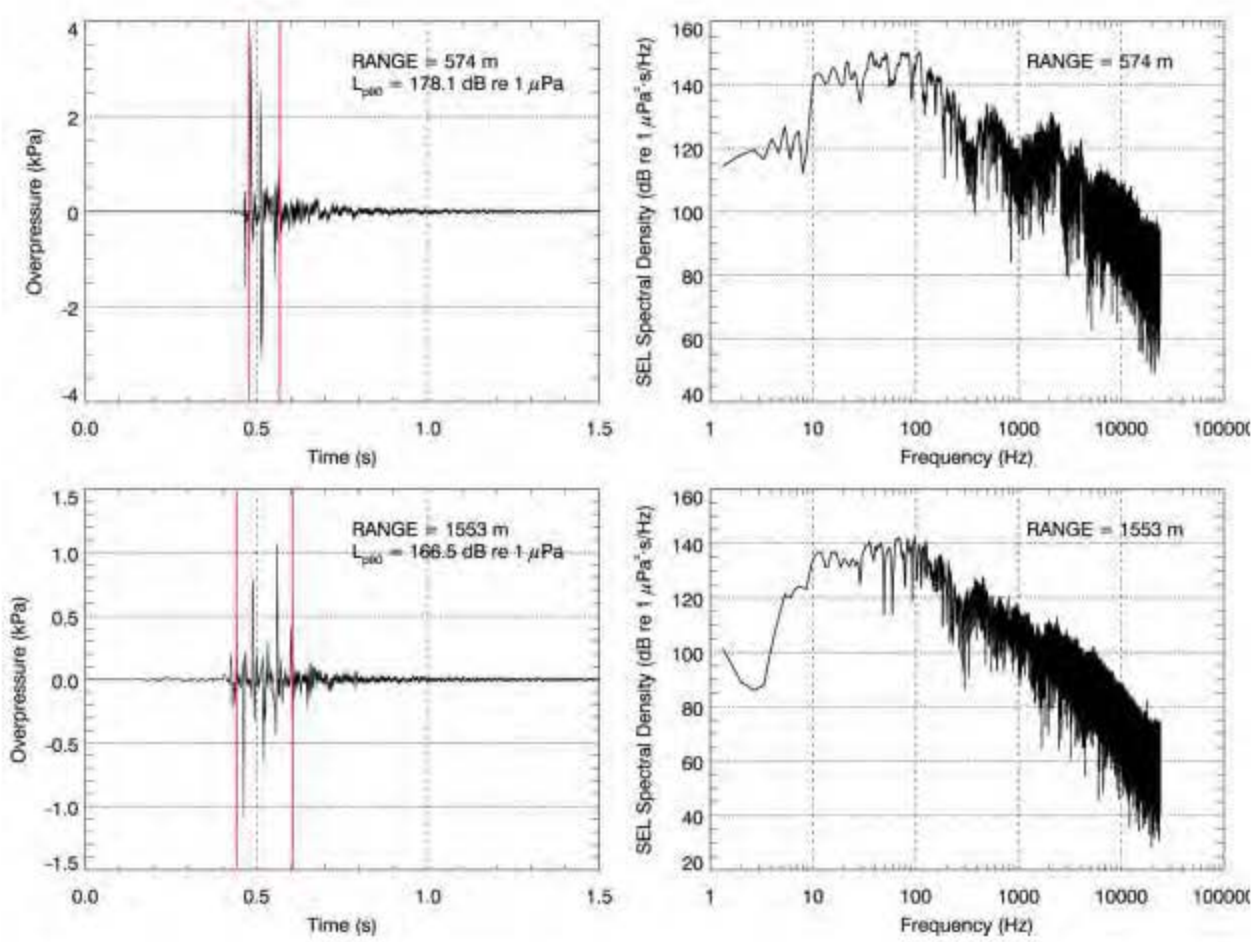


Figure 45. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5509 m spectrogram is 2048-pt FFT, 48 kHz sample rate).


RANGE = 574 m
L_{pk0} = 178.1 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 574 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 1553 m
L_{pk0} = 166.5 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 1553 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

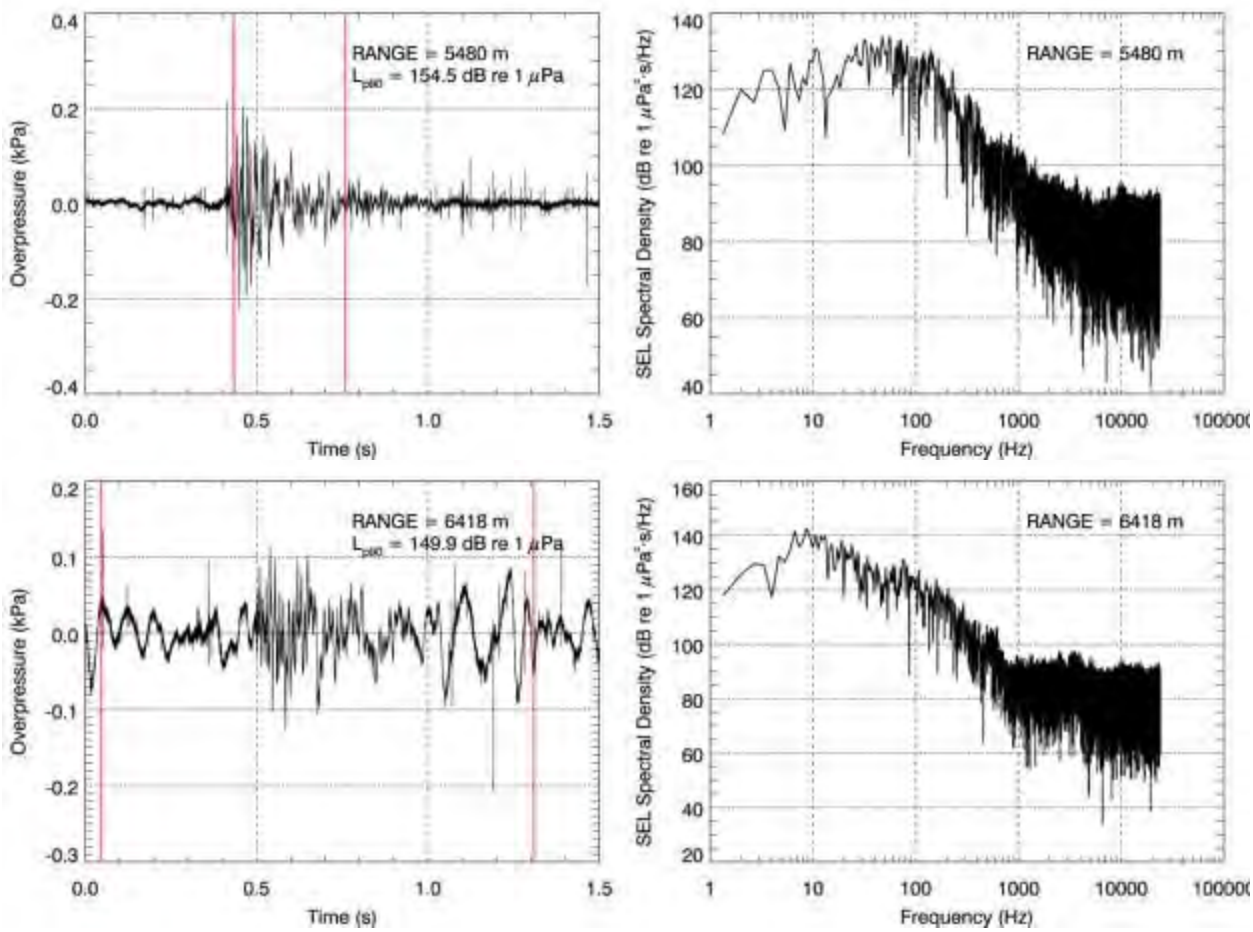
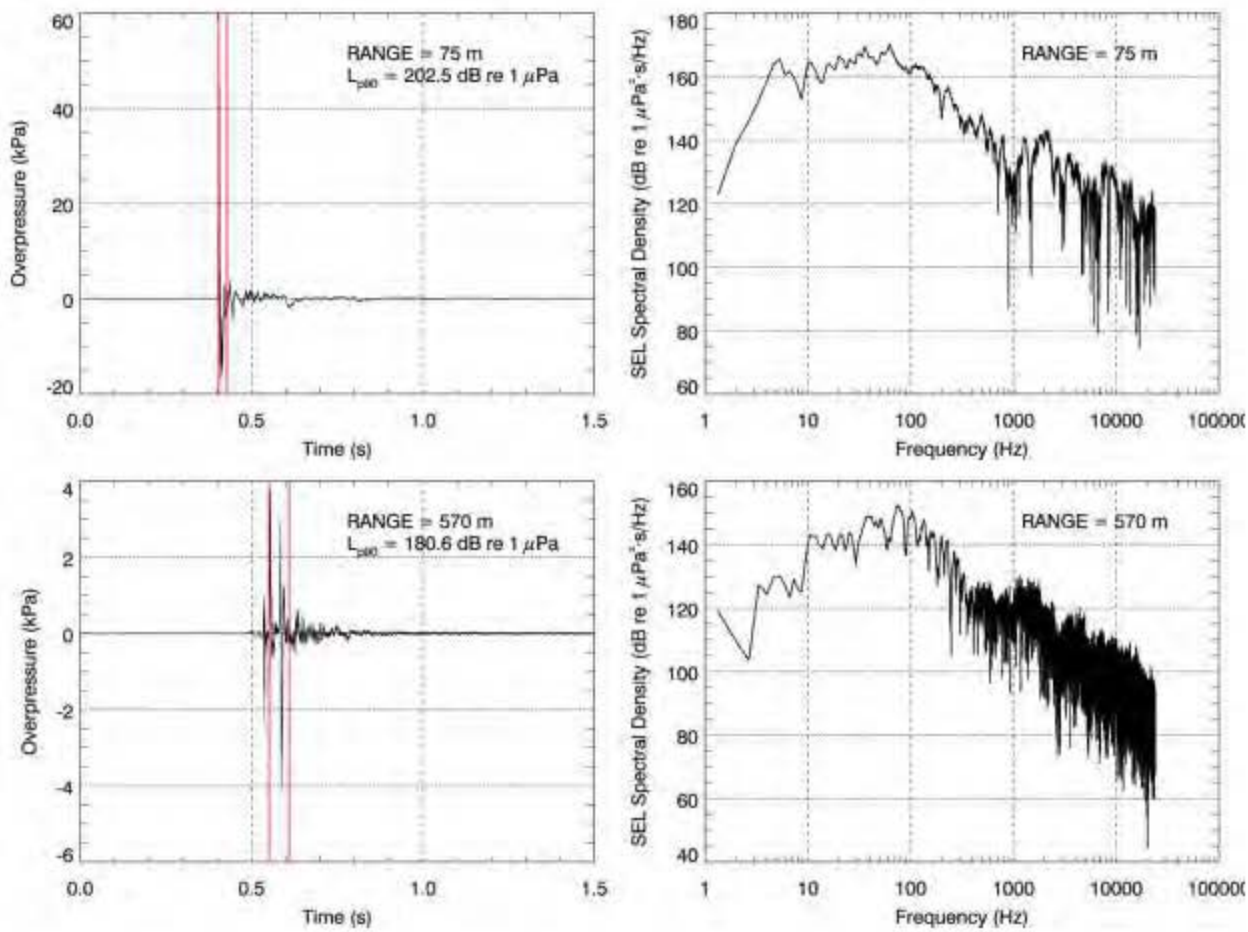


Figure 46. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 75 m
L_{pk0} = 202.5 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 75 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 570 m
L_{pk0} = 180.6 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 570 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

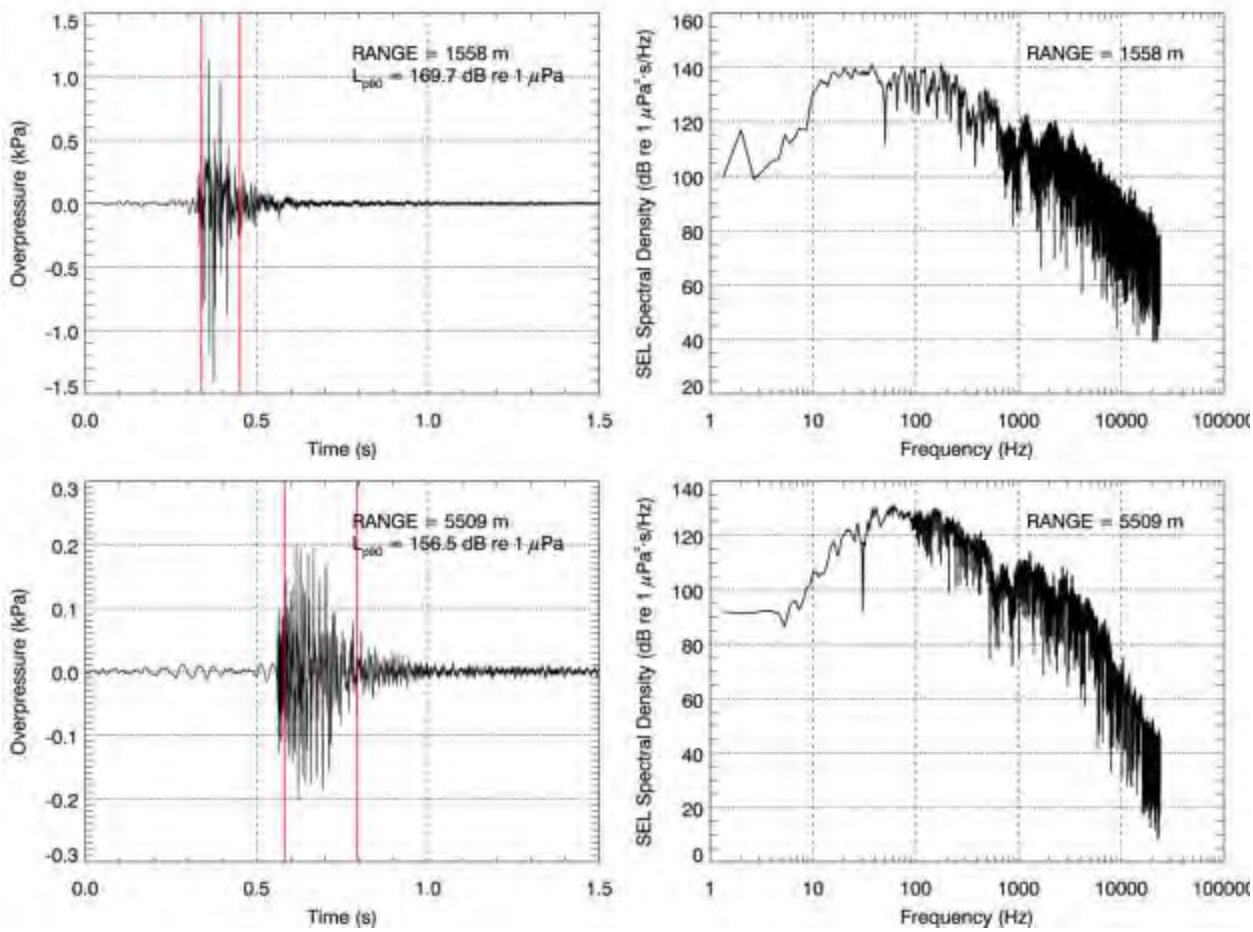


Figure 47. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

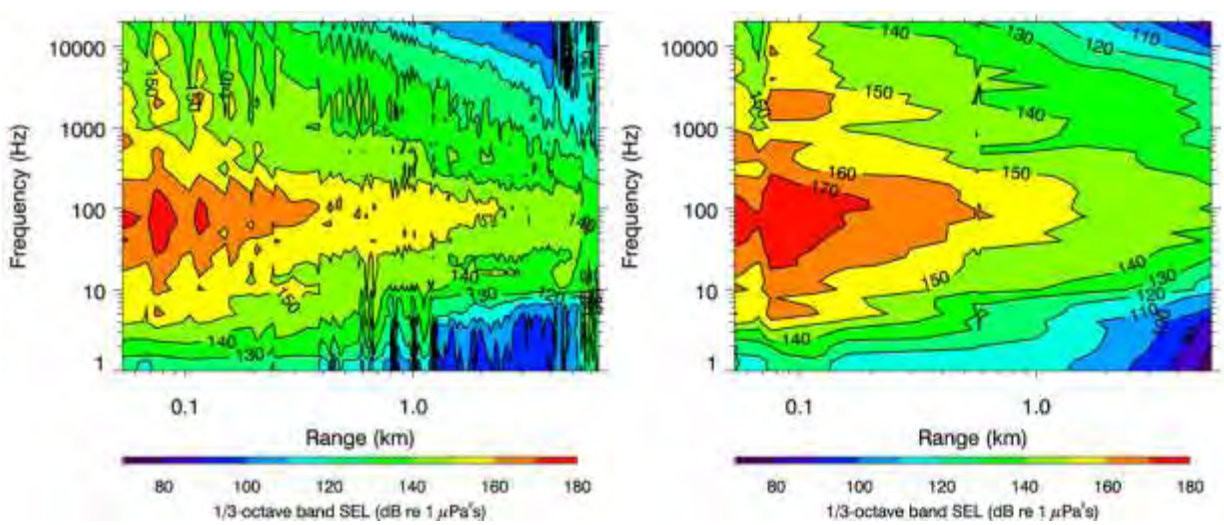


Figure 48. 1/3 octave band SEL levels as a function of range and frequency for the 1200 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

4.4. 2400 in³ Airgun Array

4.4.1. Track 1

Peak SPL, 90% rms SPL and SEL for each shot on the nearshore line were computed from acoustic data recorded on OBHs A-D. Figure 49 shows sound levels from the 2400 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 10 lists ranges to several rms SPL thresholds for each of the fits in Figure 49. The measured levels are consistent with acoustic measurements of the 2400 in³ array that were collected in Cook Inlet by JASCO in 2011 (McCrodan et al, 2011). Figures Figure 50 and Figure 51 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 52 presents spectrograms of 2400 in³ airgun array pulses in the endfire direction at 484 m, 1510 m, 7922 m, and 8993 m. Pulses in the broadside direction near CPA at 42 m, 477 m, 1524 m, and 7949 m are shown in Figure 53. Figures Figure 54 and Figure 55 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 56. Sound levels near the source were highest between 30 and 150 Hz in the endfire direction and between 50 and 200 Hz in the broadside direction.

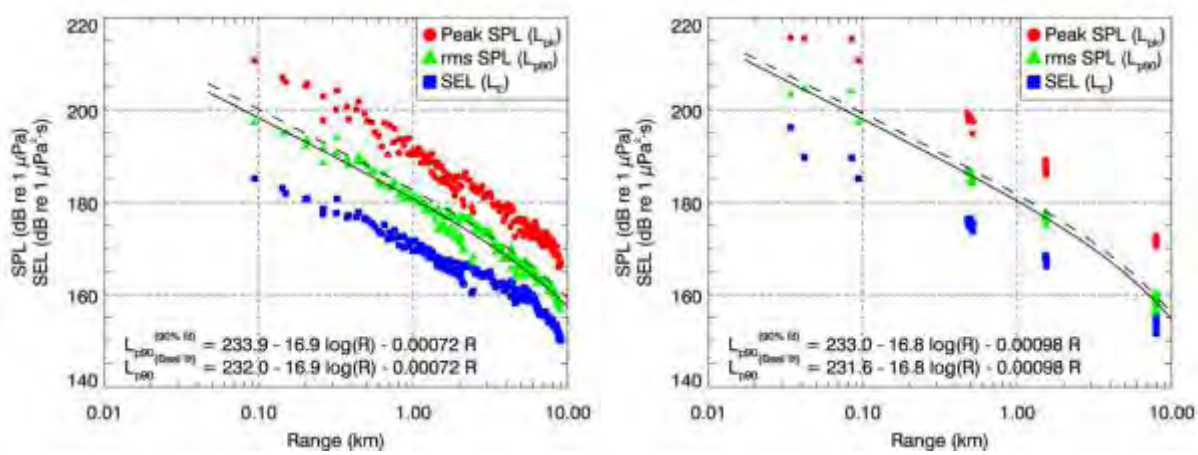


Figure 49: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 2400 in³ airgun array pulses in the endfire (left) and broadside (right) directions measured at the nearshore sites (track 1). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Table 10: Threshold radii for the 2400 in^3 airgun array at the nearshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 49.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	300	380	290	350
180	1100	1400	1030	1210
170	3400	4100	3080	3500
160	8200	9500	7070	7770

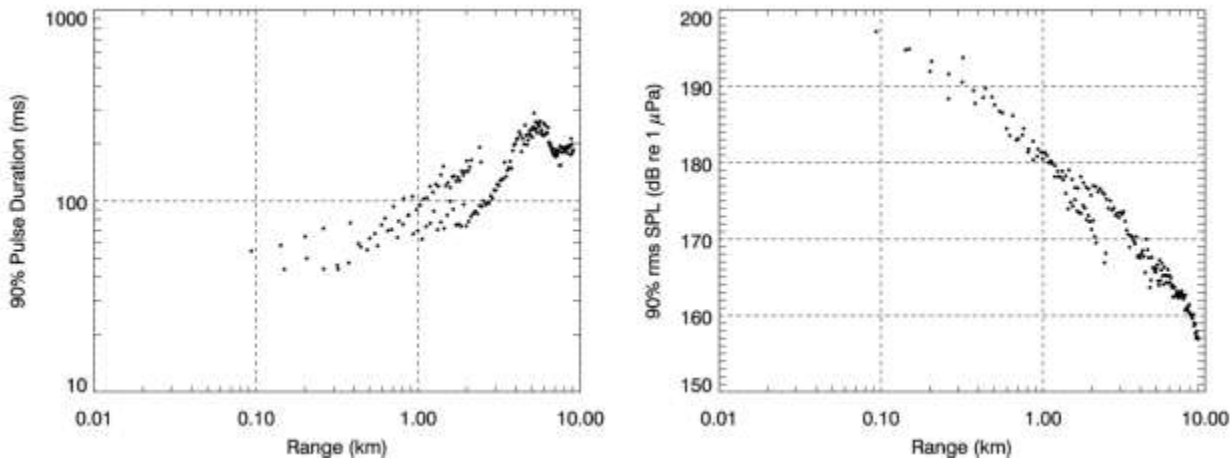


Figure 50. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

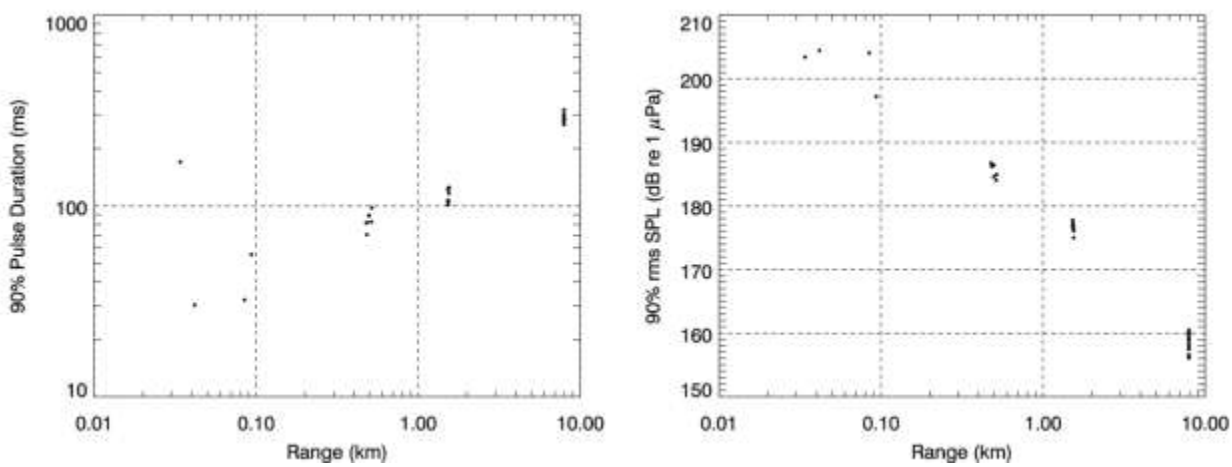


Figure 51. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

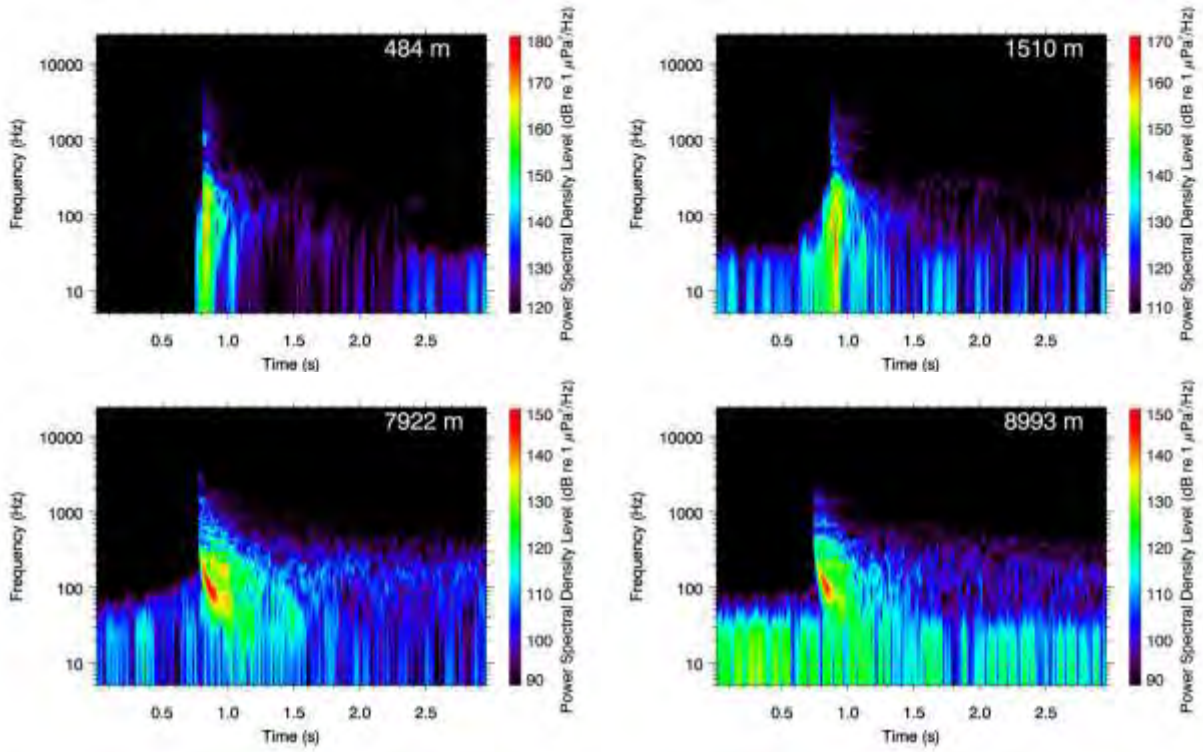


Figure 52. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

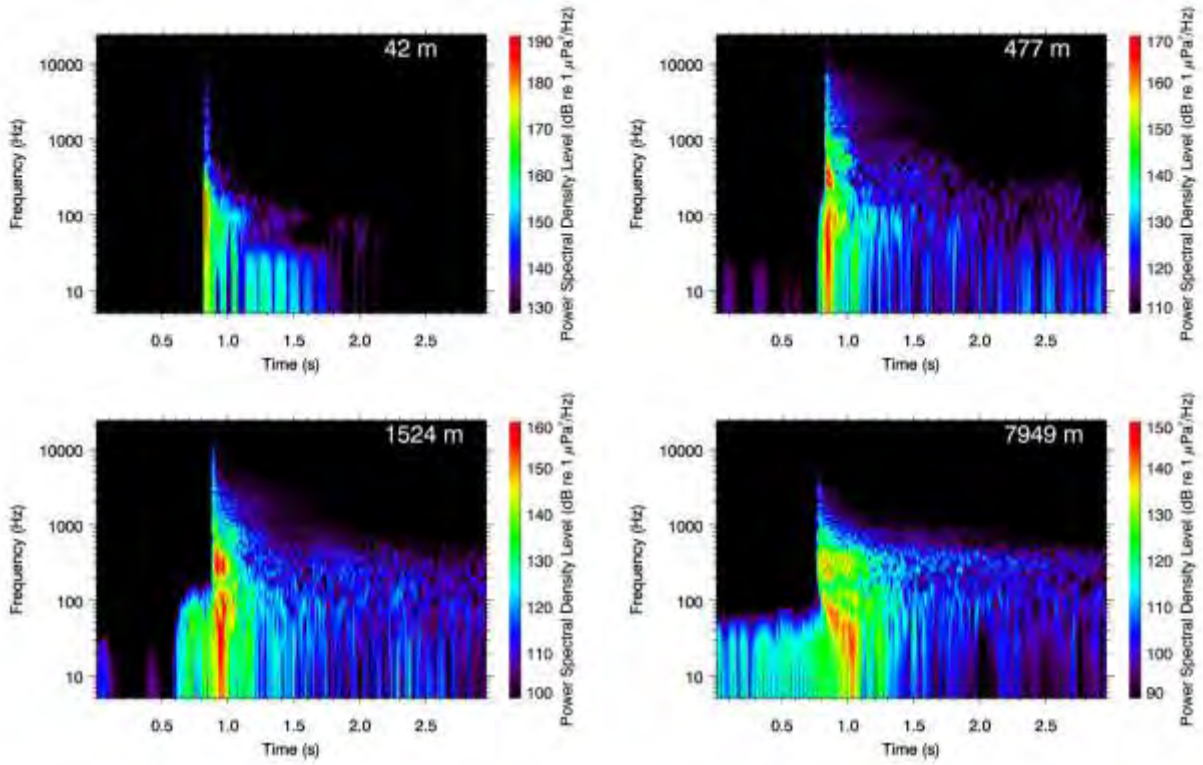
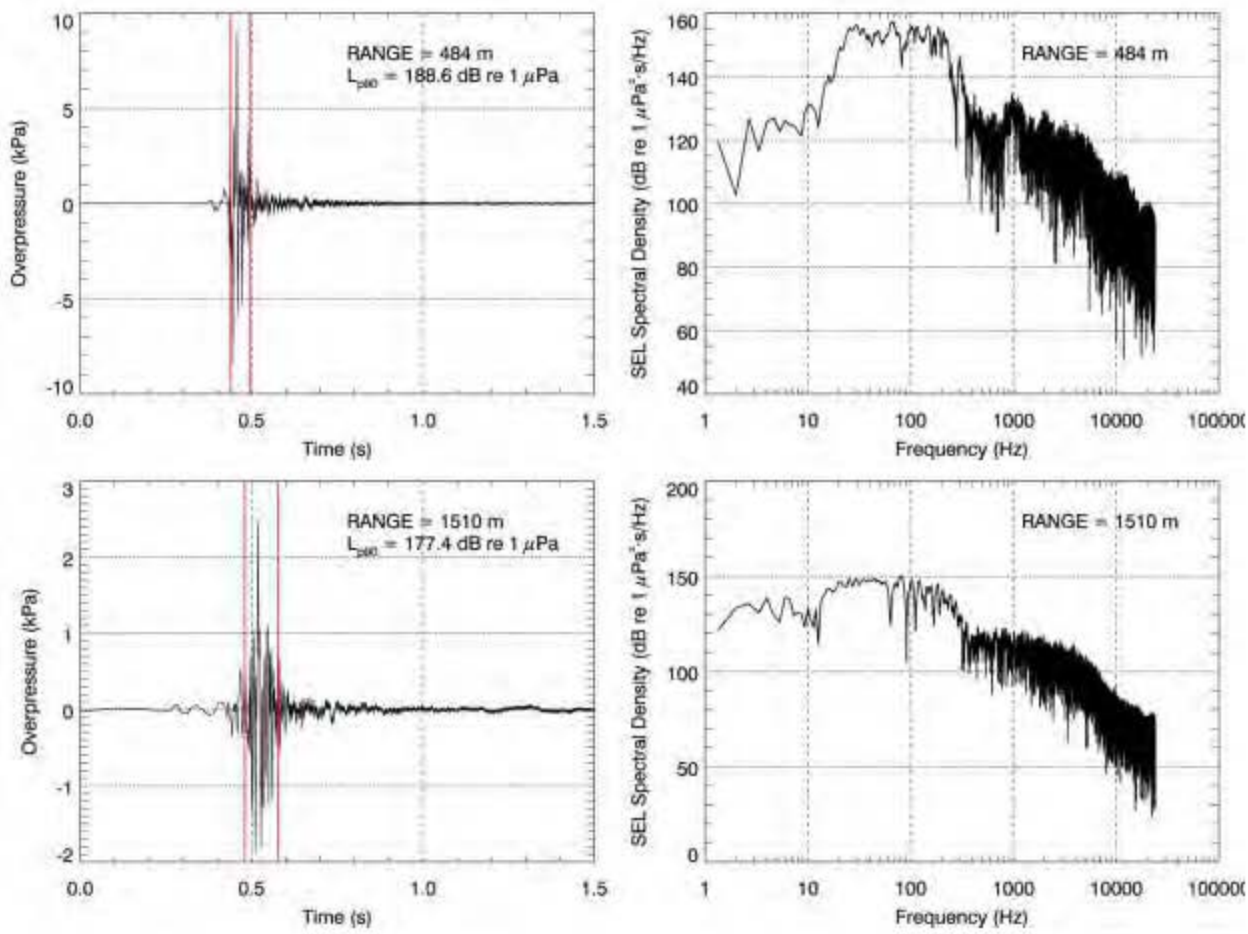


Figure 53. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.


RANGE = 484 m
L_{pk0} = 188.6 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 484 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 1510 m
L_{pk0} = 177.4 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 1510 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

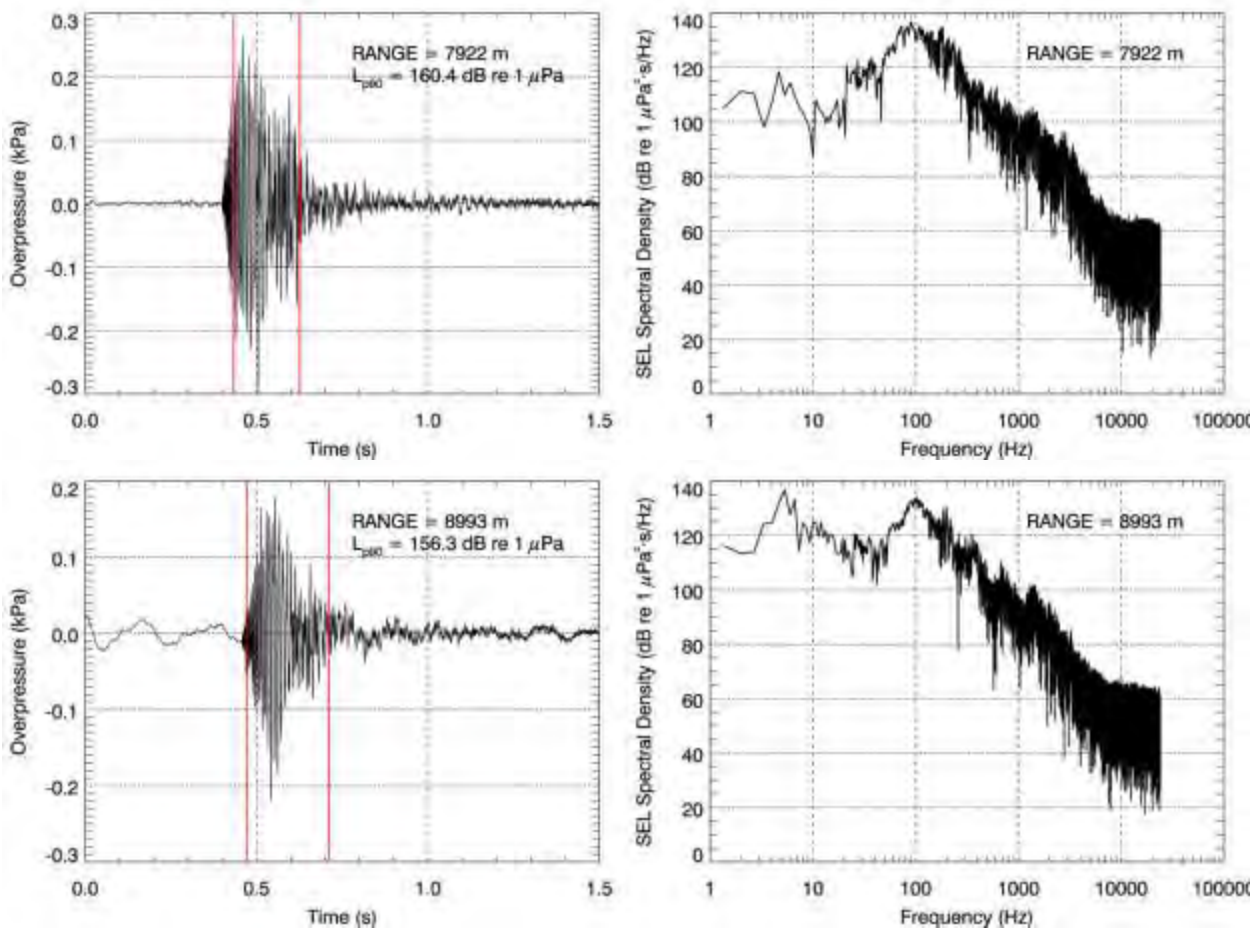
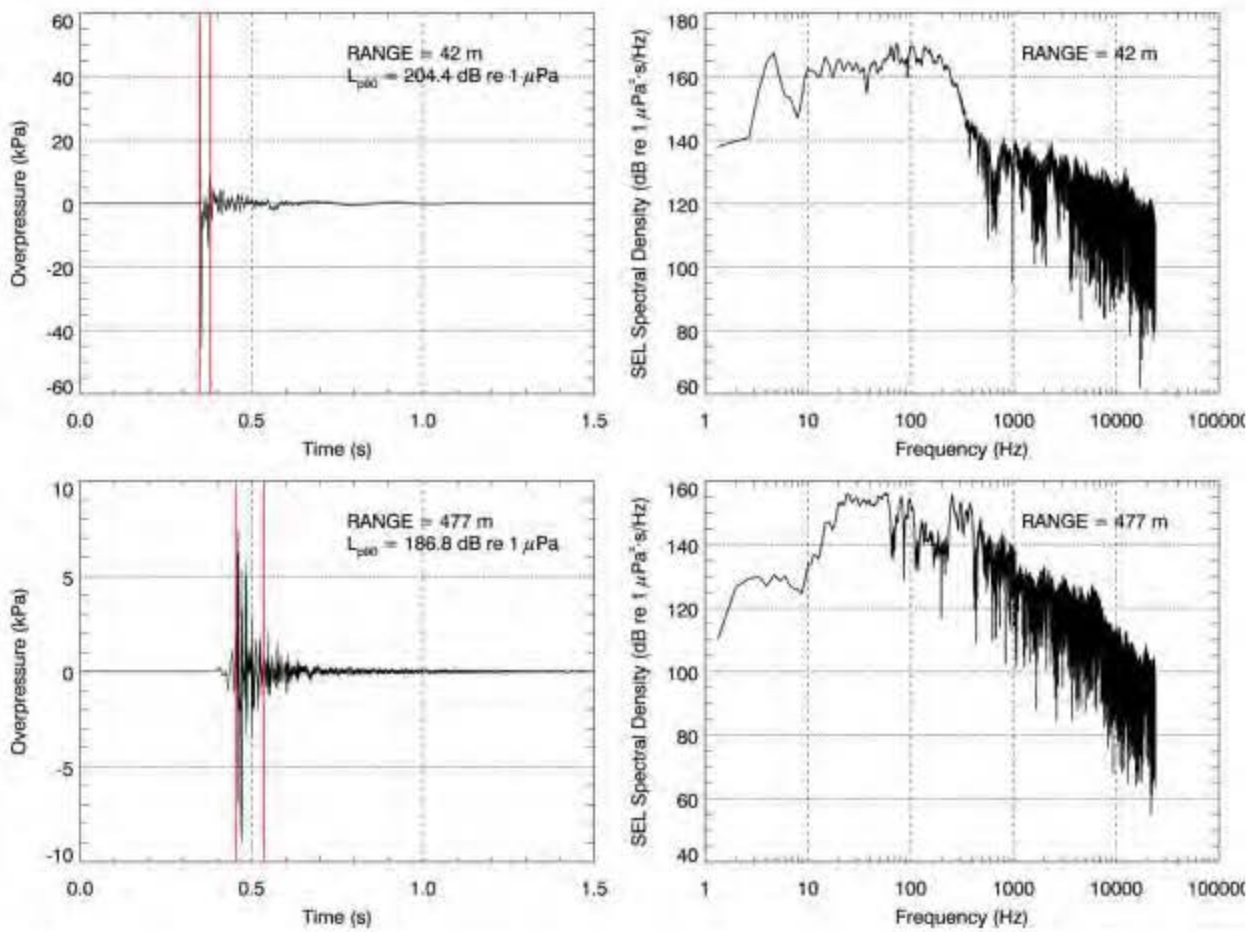


Figure 54. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 42 m
L_{pk0} = 204.4 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 42 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 477 m
L_{pk0} = 186.8 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 477 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

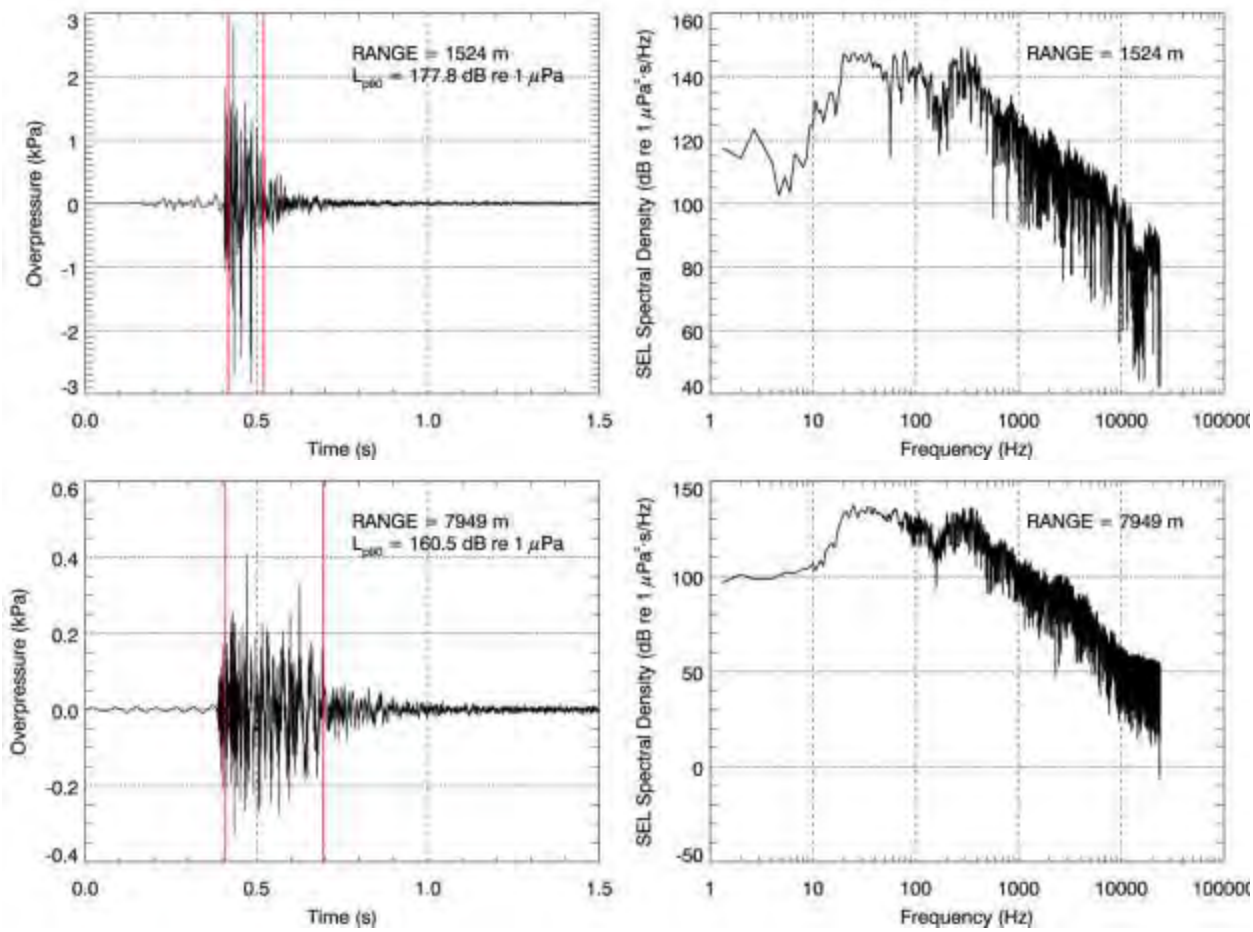


Figure 55. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

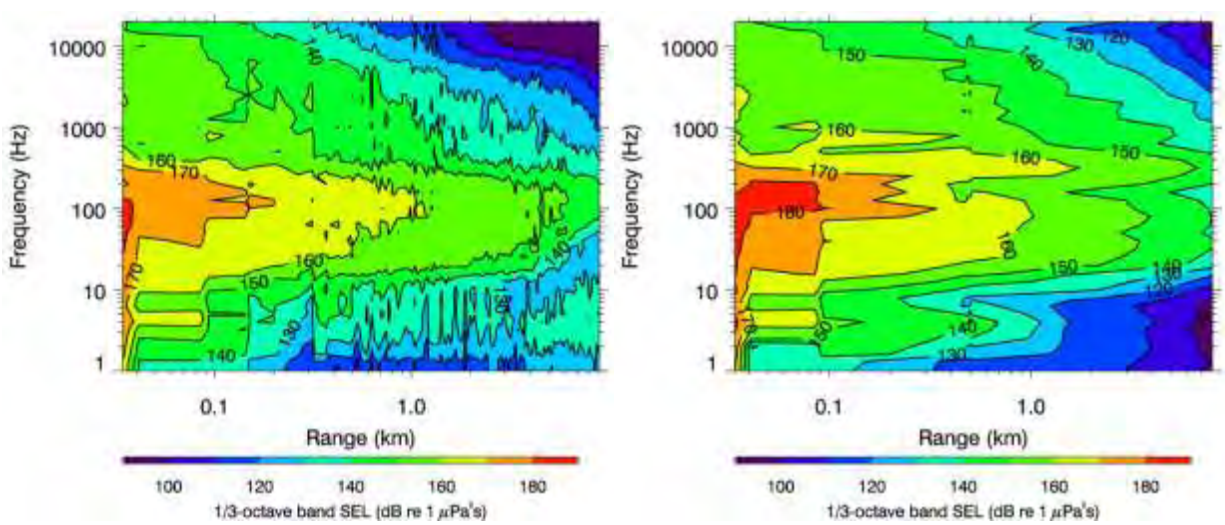


Figure 56. 1/3 octave band SEL levels as a function of range and frequency for the 2400 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

4.4.2. Track 2

Peak SPL, 90% rms SPL and SEL for each shot on the offshore line were computed from acoustic data recorded on OBHs E-H. Figure 57 shows sound levels from the 2400 in³ airgun array versus slant range measured in the endfire and broadside directions. Sound levels are from the more sensitive TC4032 hydrophones unless clipping or non-linear effects near saturation were observed. For those pulses, sound levels are from the less sensitive TC4043 hydrophone. Table 11 lists ranges to several rms SPL thresholds for each of the fits in Figure 57. The measured levels are consistent with acoustic measurements of the 2400 in^3 array that were collected in Cook Inlet by JASCO in 2011 (McCrodan et al, 2011). The radius to the 160 dB threshold in the endfire direction is derived from a linear fit to the data at ranges less than 5 km (see Section 3.3). This radius is expected to exceed that which would be derived from longer range measurements with absorptive loss effects and likely overestimates the true radius to the 160 dB threshold. Figures Figure 58 and Figure 59 illustrate how rms pulse duration varied with range in the endfire and broadside directions, with the rms SPL for comparison. Figure 60 presents spectrograms of 2400 in³ airgun array pulses in the endfire direction at 613 m, 1554 m, 5525 m, and 8699 m. Pulses in the broadside direction near CPA at 43 m, 592 m, 1584 m, and 5528 m are shown in Figure 61. Figures Figure 62 and Figure 63 show waveforms and SEL spectral density plots of these same endfire and broadside pulses, respectively. Contour plots of 1/3-octave band levels versus range and frequency are shown in Figure 64. Sound levels near the source were highest between 30 and 300 Hz in the endfire direction and between 20 and 300 Hz in the broadside direction.

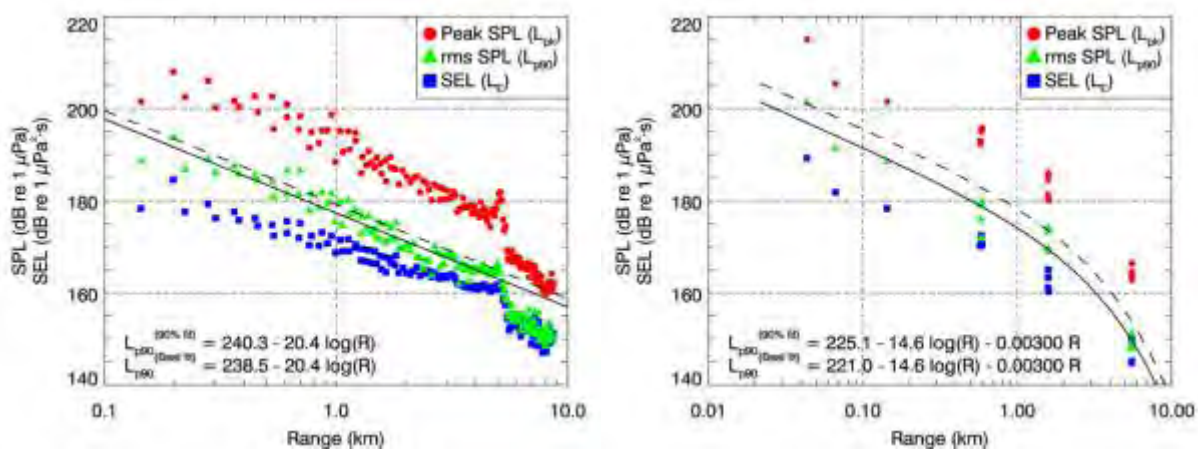


Figure 57: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 2400 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore site (Track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values. The endfire empirical fit was restricted to measurements at ranges less than 5 km to provide accurate distances to thresholds above 150 dB; data at ranges beyond 5 km are shown for completeness.

Table 11: Threshold radii for the 2400 in^3 airgun array at the offshore site as determined from empirical fits to SPL_{rms90} versus distance data in Figure 57.

SPL_{rms90} Threshold (dB re 1 µPa)	Range (m) in endfire direction		Range (m) in broadside direction	
	Best fit	90th percentile fit	Best fit	90th percentile fit
190	240	290	120	220
180	740	910	500	820
170	2300	2800	1500	2130
160	<7100* (> 5295)	<8700* (> 5295)	3220	4080

*Extrapolated based on a linear fit to the data at <5km range, excluding absorptive loss effects

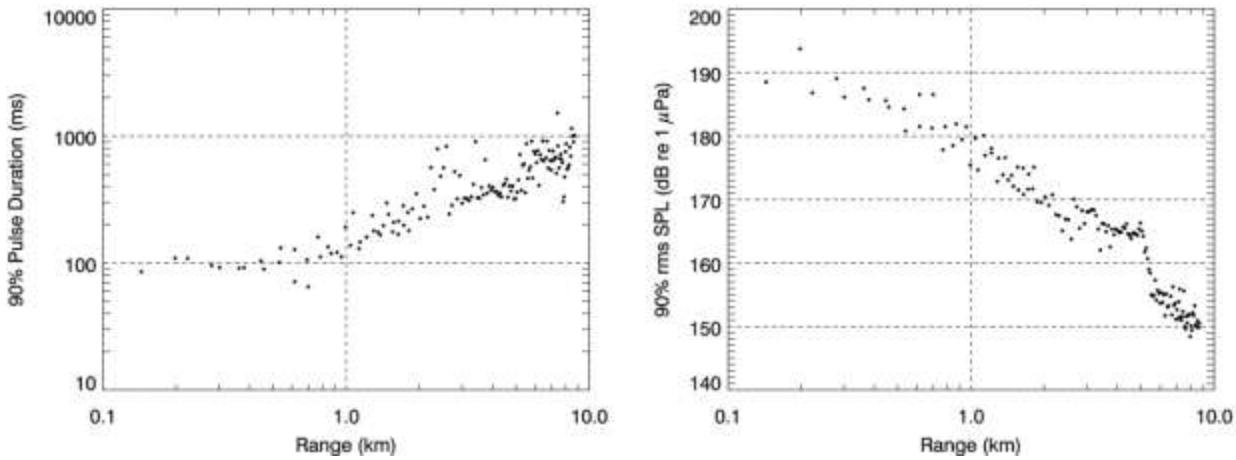


Figure 58. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

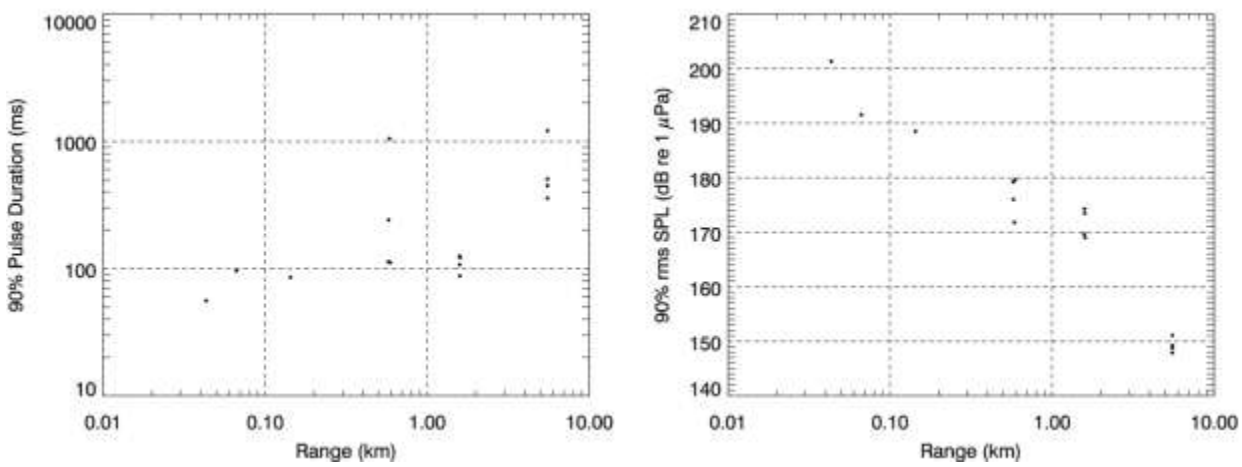


Figure 59. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

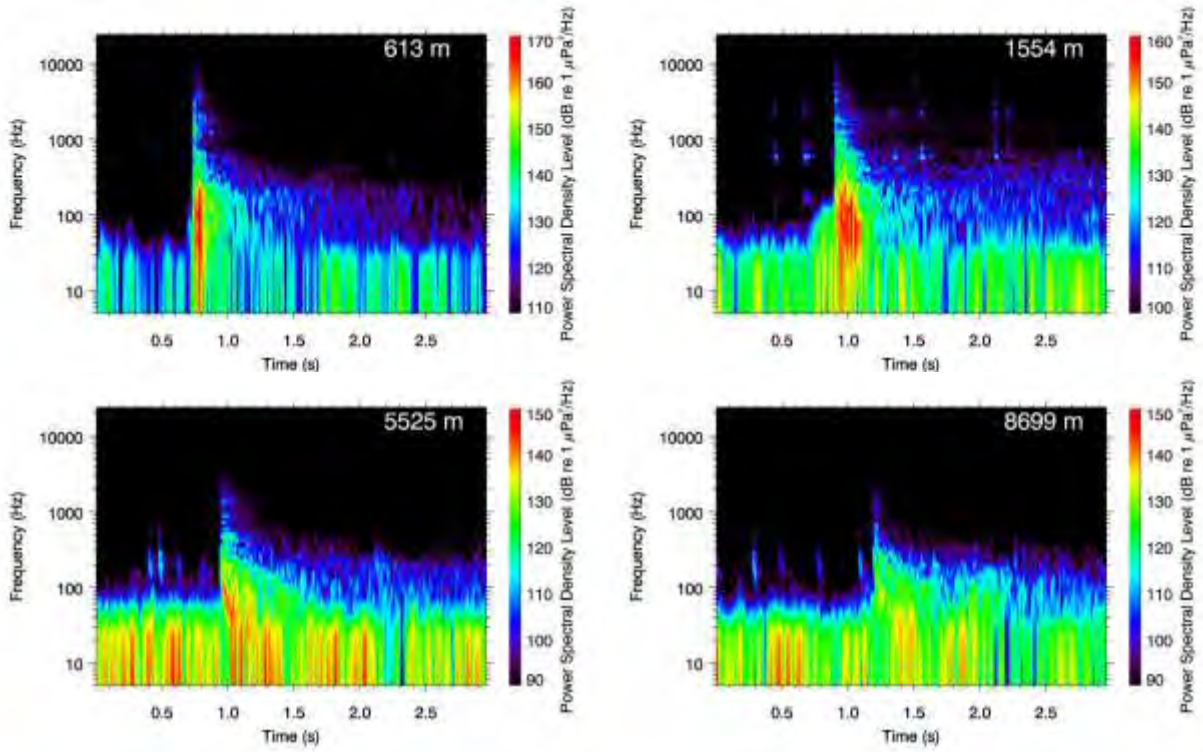


Figure 60. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

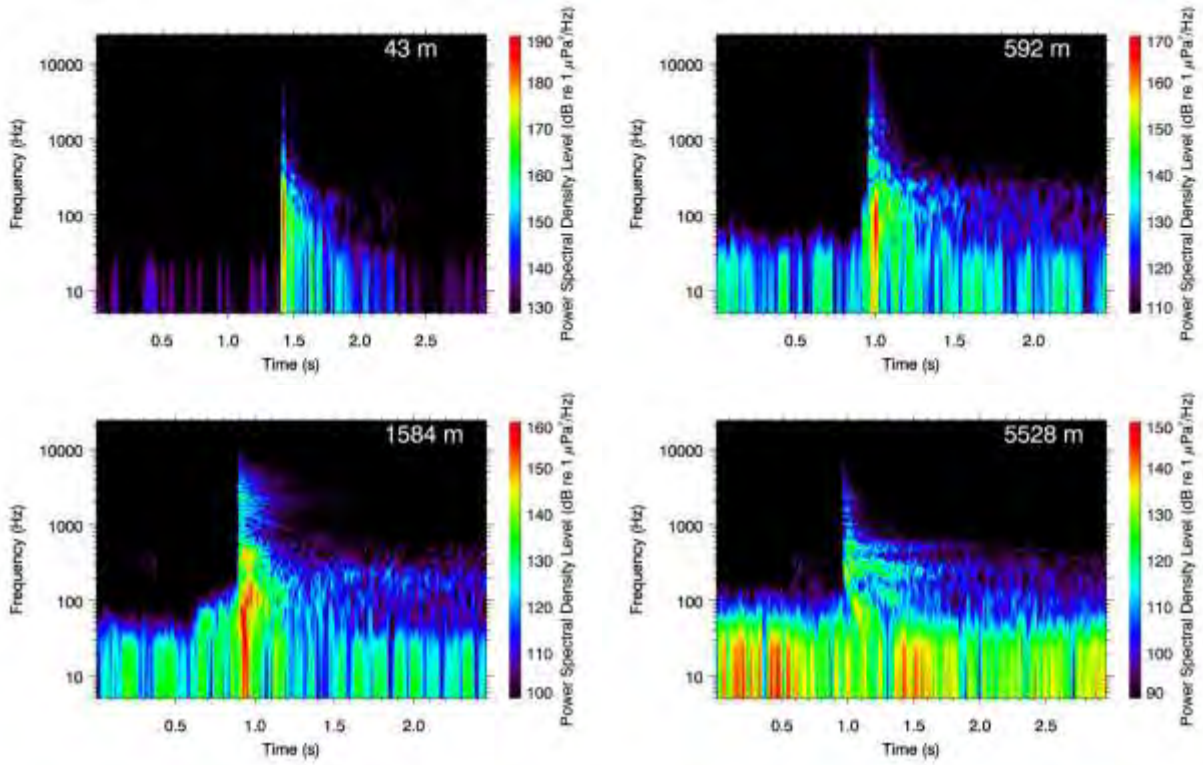
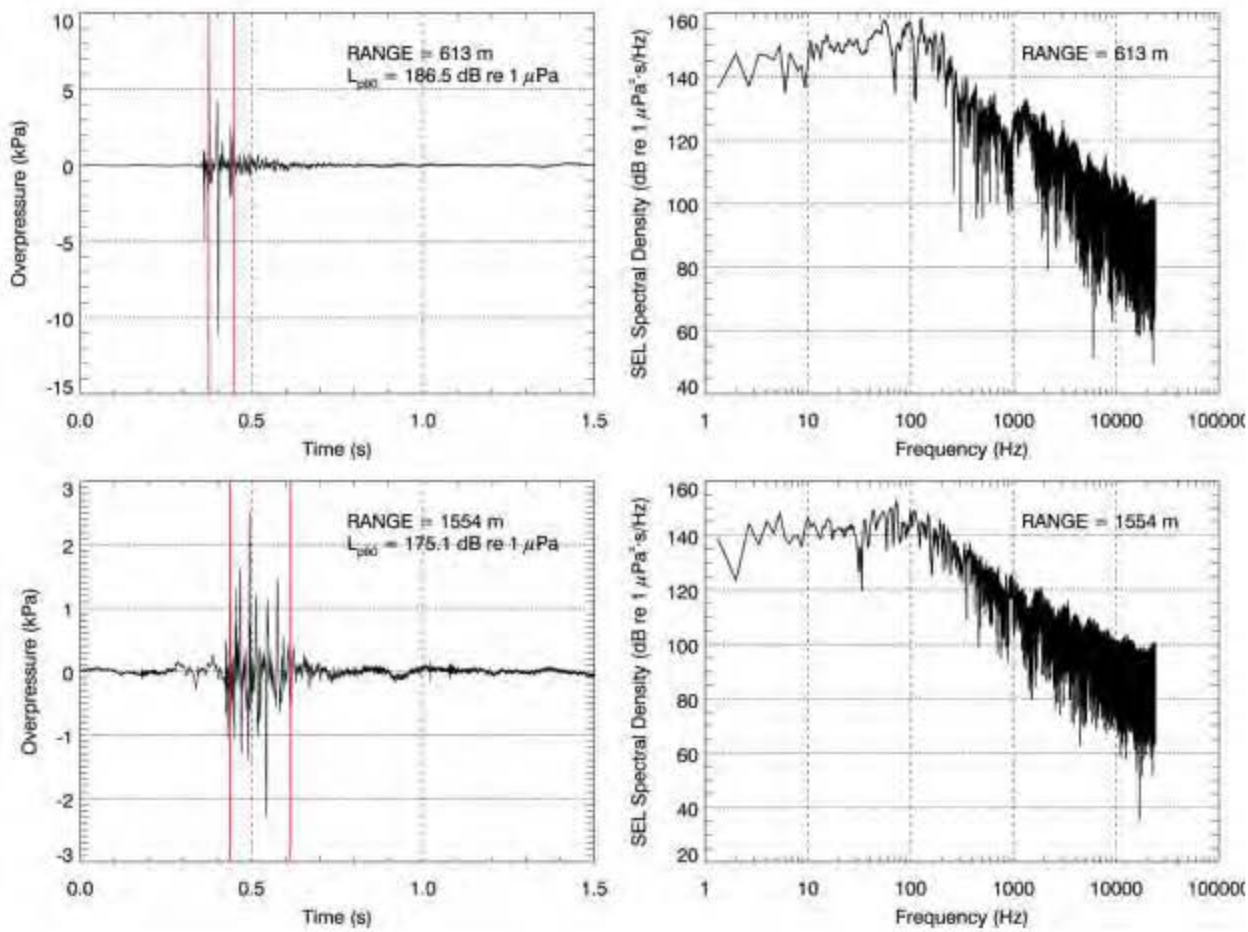


Figure 61. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5528 m spectrogram is 2048-pt FFT, 48 kHz sample rate).


RANGE = 613 m
L_{pk0} = 186.5 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 613 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 1554 m
L_{pk0} = 175.1 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 1554 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

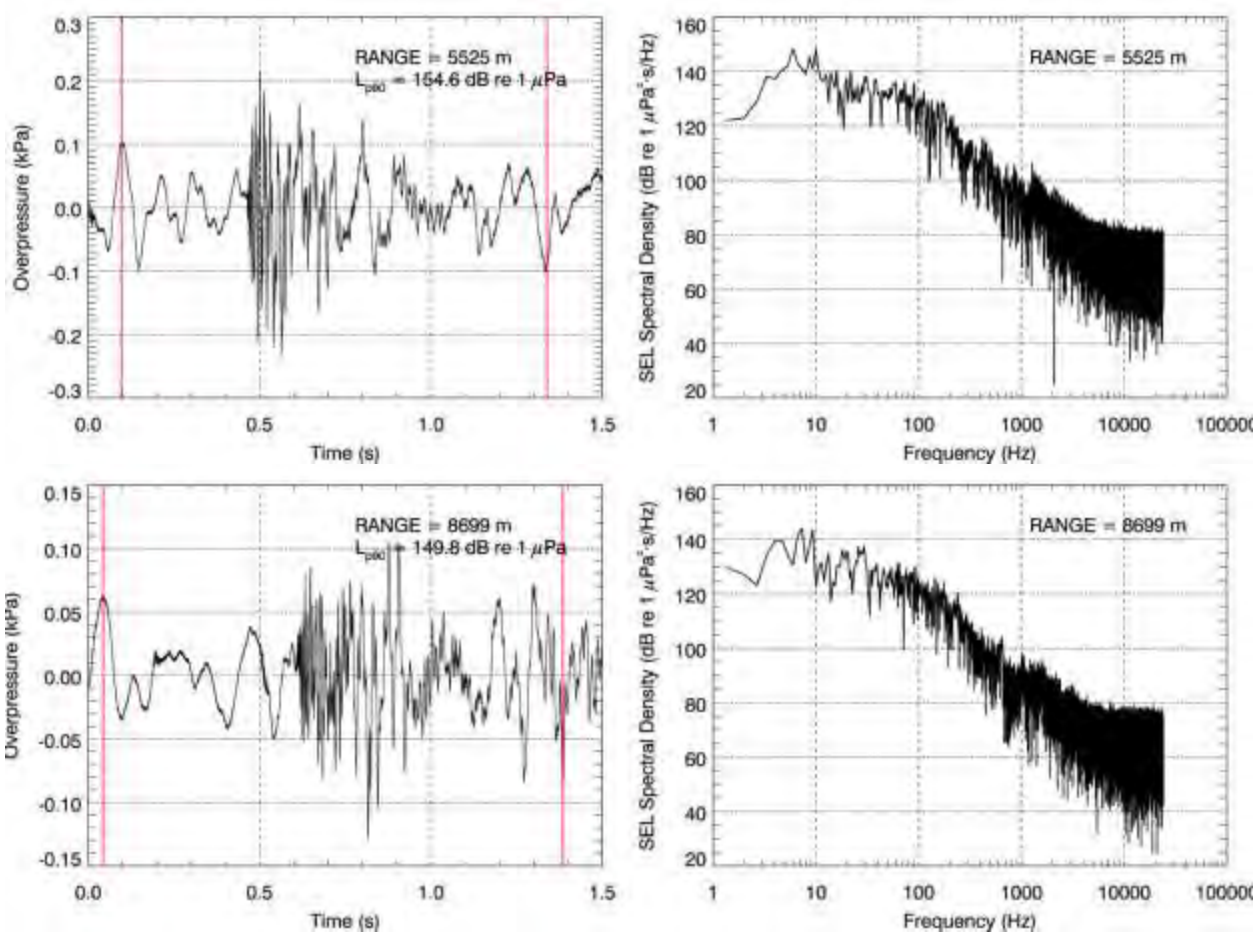
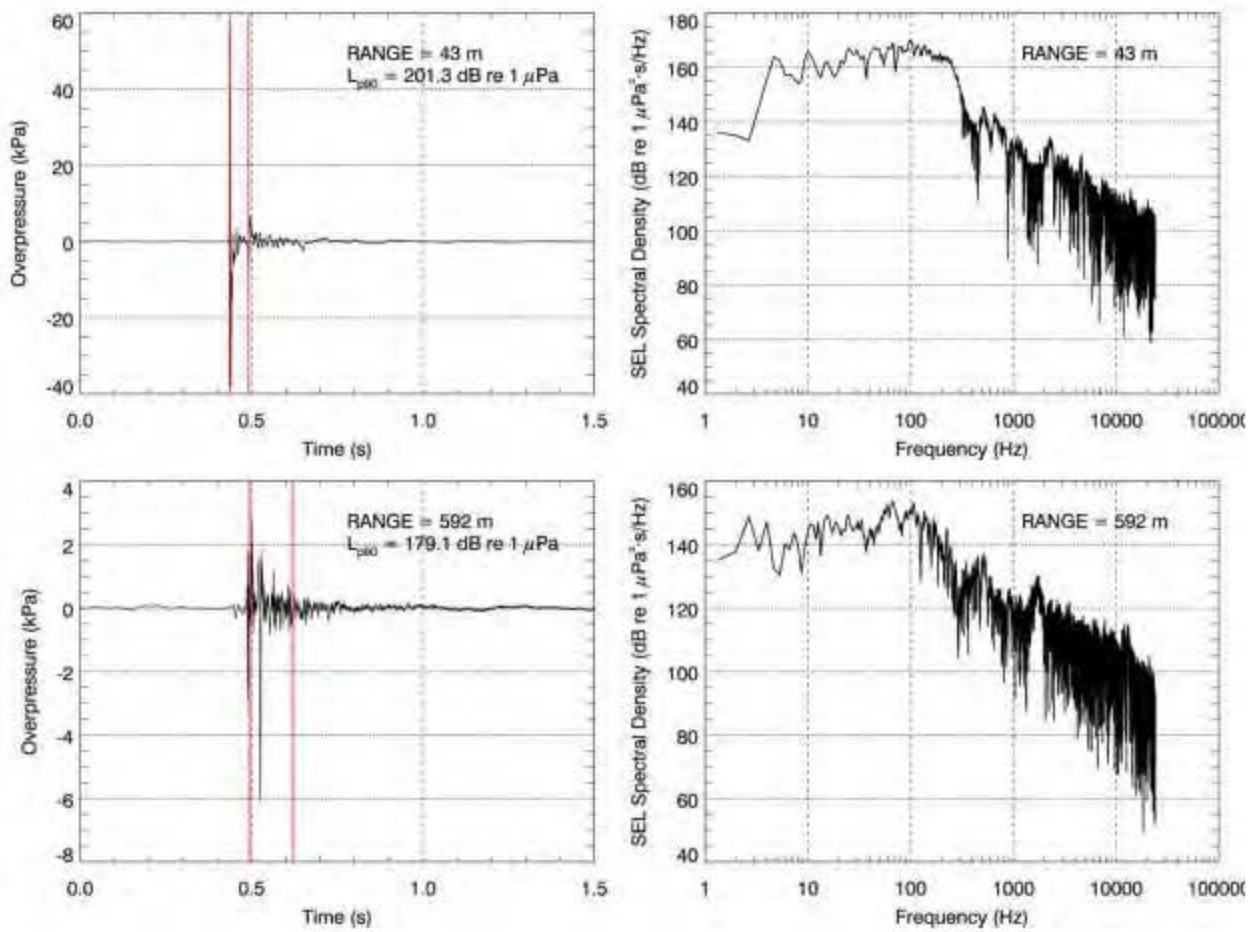


Figure 62. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


RANGE = 43 m
L_{pk0} = 201.3 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 43 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)
RANGE = 592 m
L_{pk0} = 179.1 dB re 1 μPa
Overpressure (kPa)
Time (s)
RANGE = 592 m
SEL Spectral Density (dB re 1 μPa²·s/Hz)
Frequency (Hz)

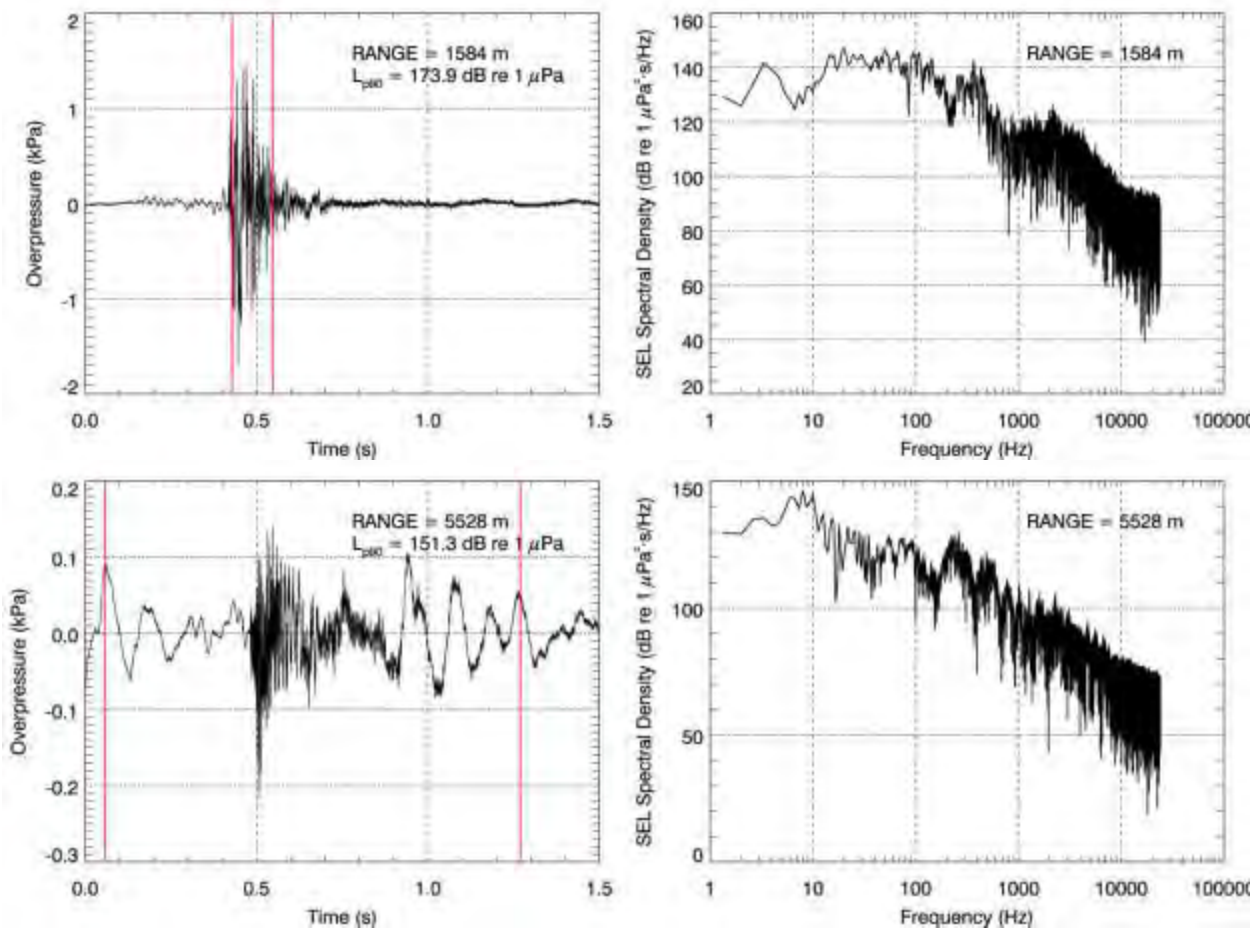


Figure 63. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

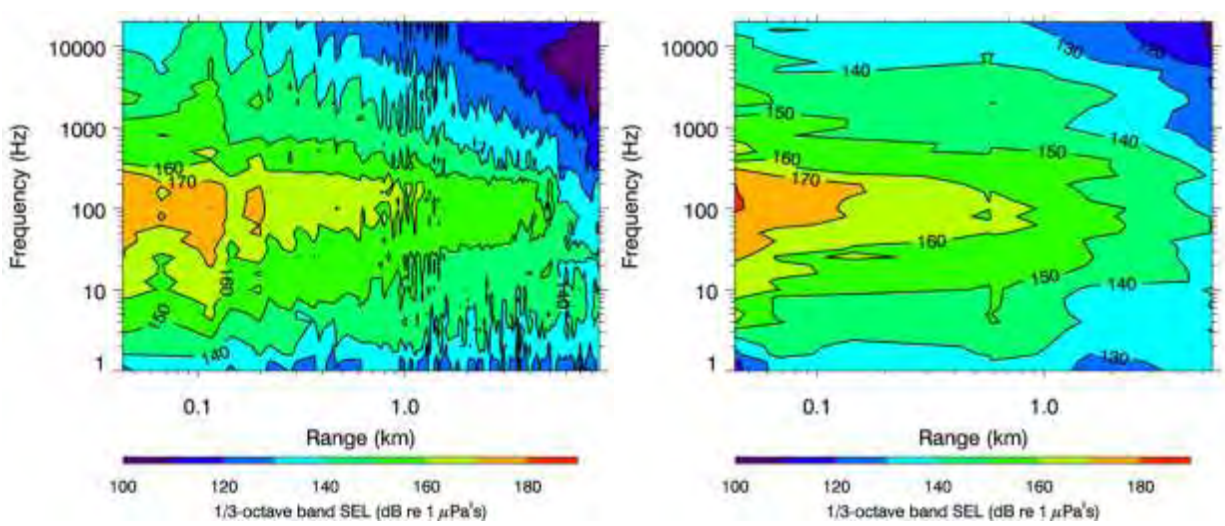


Figure 64. 1/3 octave band SEL levels as a function of range and frequency for the 2400 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

5. Comparison with Pre-Season Estimates

Pre-season safety radii estimates are included in the IHA for the 10 in^3 mitigation airgun and for the 2400 in^3 airgun array in inshore and offshore environments. The values for the 2400 in^3 array were derived from an acoustic modelling study conducted by JASCO in 2011 for generic model sites (Warner et al, 2011) and those for the 10 in^3 were estimated from previous measurements. Tables 12-14 list the pre-season radii predictions and the maximum corresponding measured 90th percentile fit distances for the two airgun systems. The ratio of measured to predicted levels is also shown.

The threshold distances for the 10 in^3 airgun were consistently less than, or equal to, the pre-season estimates. The measured threshold distance to 160 dB 1 μPa for the 2400 in^3 array exceeded the pre-season estimates for both the nearshore and offshore lines.

Table 12. 10 in³ mitigation airgun: Comparison of measurements with pre-season estimated marine mammal safety radii.

	Safety Radii (m)				
SPL_{rms90} Threshold (dB re 1 µPa)	Pre-season Estimated	90th Percentile Measured Nearshore	90th Percentile Measured Offshore	Nearshore Ratio (%)	Offshore Ratio (%)
190	10	10	10	100	100
180	33	10	10	30	30
160	330	110	280	33	85

Table 13. 2400 in³ airgun array: Comparison of measurements with pre-season estimated **nearshore** marine mammal safety radii. Measured distances are maximized over the endfire and broadside directions.

	Safety Radii		
SPL_{rms90} Threshold (dB re 1 µPa)	Pre-season Estimated (from IHA)	90th Percentile Measured	Ratio (%)
190	510	380	75
180	1420	1400	99
160	6410	9500	148

Table 14. 2400 in³ airgun array: Comparison of measurements with pre-season estimated **offshore** marine mammal safety radii. Measured distances are maximized over the endfire and broadside directions.

	Safety Radii		
SPL_{rms90} Threshold (dB re 1 µPa)	Pre-season Estimated (from IHA)	90th Percentile Measured	Ratio (%)
190	180	290	161
180	980	910	93
160	4890	8700	178

6. Summary and Conclusions

Table 15 presents the maximum distances to 190, 180 and 160 dB re 1 µPa threshold levels for each of the four airgun array source configuration. These distances are based on the 90th percentile fits as described in Section 3.3.1. They are the maxima over direction (broadside and endfire) and environment (nearshore and offshore sites). The radius to the 160 dB re 1 µPa threshold for the 2400 in^3 array is the largest threshold distance and exceeds the pre-season estimate by as much as 48%, although it is substantially less for receivers in shallower (<10 m) water depths.

The maximum threshold radii were measured in the endfire direction from the 2400 in^3 array as it transited on the nearshore track in water depths that varied between approximately 25 m and 35 m. The range to the 160 dB re 1 µPa threshold is highly dependent on the water depth in which the source is operating; the endfire-radii (~8700 m) along the offshore track, with depths

from 35-65 m, were smaller than those for the inshore track due to increased spreading loss in deeper water.

Measured sound levels decreased as sound propagated from deeper water into shallower water. Examples of this effect include the sharp drop-off of sound levels beyond 5 km range along the offshore track (discussed in Section 3.3.1) and also the reduced levels that were observed on the broadside recorders for the offshore track. These broadside recorders were located in shallower water to approximately 10 m depth on the shoreward side of the survey track. In this case the 160 dB radius was measured at a broadside range of 4080 m, which is less than half the range measured in the endfire direction in deep water and also less than the pre-season estimate.

The lower levels received in shallower water should be considered particularly for effects assessments on belugas, which tend to spend a high proportion of time close to shore and in shallow waters.

Table 15: Maximum threshold distances for the mitigation airgun and three airgun arrays. Distances are maximized over direction and environment and are based on the 90th percentile fits.

SPL_{rms90} Threshold (dB re 1 µPa)	90th Percentile Distance (m)			
	10 in^3	440 in^3	1200 in^3	2400 in^3
190	10	100	250	380
180	10	310	910	1400
160	280	2500	5300	9500*

*This radius applies to receivers in water depths of approximately 25 m. The radius is substantially reduced for receivers in 10 m water depth, and it slightly reduced for receivers in water depths from 35-65m.

6.1. Monitoring Recommendations

Based on the results summarized above, we recommend that the extent of the exclusion zone for protected species monitoring be dependent on water depth within the zone. Through this definition, the monitoring zone may not be circular about the source. Due to shorter distances to sound thresholds measured in shallow (<10 m) waters, we suggest that the 160 dB re 1 µPa zone be reduced from the values in Table 15 when the zone extends into shallow waters. Table 16 lists the recommended distances based on water depth of the region being observed.

Table 16 Recommended monitoring distances based on water depth.

Water depth at receiver	Suggested Monitoring Distance
Shallow water depths (≤ 10 m)	5 km
Intermediate water depths (10 – 50 m)	9.5 km
Deep water depths (> 50 m)	8.7 km

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APPENDIX C

JASCO Hydroacoustic Modeling of Airgun Noise for Apache's Cook Inlet Seismic Program

Hydroacoustic Modeling of Airgun Noise for Apache's Cook Inlet Seismic Program

24-Hour Harassment Area Calculations

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1. Introduction

This acoustic modeling study has been performed to estimate underwater sound levels produced by airgun array systems of Apache's planned Cook Inlet seismic surveys. Sound from airgun arrays has the potential to harass nearby marine mammals. The National Marine Fisheries Service (NMFS) presently considers exposures of marine mammals to impulsive airgun sound levels above 160 dB re 1 μPa (rms) to cause harassment. Exposures above this threshold are considered level-B takes by NMFS (in contrast to level-A takes which refer to injury). Level-B takes generally need to be permitted under Incidental Harassment Authorizations (IHA). Apache will apply for an IHA for their seismic programs and consequently needs to estimate the number of takes for several species. The number of acoustic takes for each species is calculated by multiplying the area ensonified above 160 dB re 1 μPa (rms), by the spatial density of that species. The modeling work performed here estimates the areas needed to calculate the take numbers to be requested in the IHA application.

This report describes the methods and computer models used to predict noise levels. It provides distances to several SPL thresholds and reports the areas ensonified above 160 dB re 1 μPa per 24-hour period of surveying in Cook Inlet for several depth environments. The predictions will be used to estimate the number of takes over the duration of Apache's seismic program.

2. Acoustic Metrics

2.1. Impulsive Noise Metrics

Impulsive or transient noise is characterized by brief acoustic events characterized by rapid pressure change at the onset of the event followed by pressure decay back to pre-existing levels within a few seconds or less. Impulsive sound levels are commonly characterized using three acoustic metrics: peak pressure, rms pressure or sound pressure level (SPL), and sound exposure level (SEL). The peak pressure (symbol L_{Pk}) is the maximum instantaneous absolute sound pressure level measured over the impulse duration:

$$L_{Pk} = 20\log_{10}\left(\max\left|p(t)\right| / P_{ref}\right) \tag{1}$$

In this formula, $p(t)$ is the instantaneous sound pressure as a function of time t, measured over the impulse duration $0 \le t \le T$. This metric is very commonly quoted for impulsive sounds but does not take into account the duration or bandwidth of the noise.

The rms sound pressure level may be measured over the impulse duration according to the following equation:

$$L_P = 10\log_{10}\left(\frac{1}{T}\int_T p(t)^2\,dt / P_{ref}^2\right) \tag{2}$$

In practice the beginning and end times of an impulse can be difficult to identify precisely. In studies of underwater impulsive noise, T is often taken to be the interval over which the cumulative per-pulse SEL (see following discussion) rises from 5% to 95% of the total pulse SEL. This interval, (T_{90}), contains 90% of the total SEL and the SPL computed over this interval

is therefore referred to as the 90% rms SPL (L_{P90}). Figure 1 shows an example of an impulsive noise pressure waveform, with the corresponding peak pressure, rms pressure, and 90% time interval.

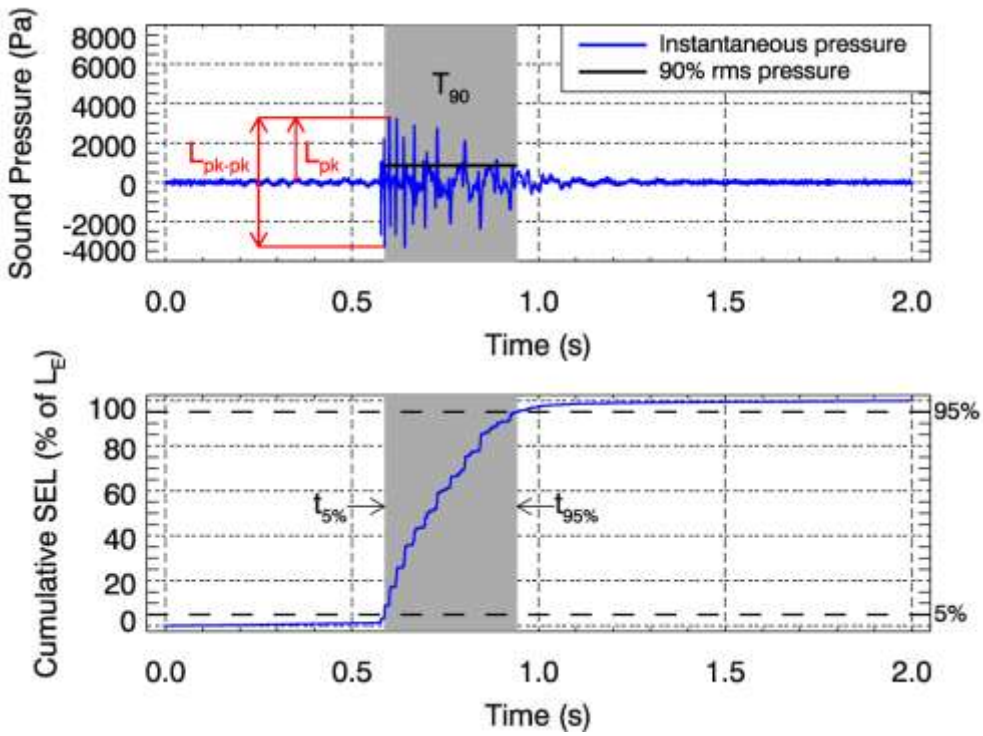


Figure 1. Example waveform (top) and cumulative SEL (bottom) for an impulsive noise measurement. The peak and peak-to-peak levels are annotated on the waveform plot and the 90% rms SPL is indicated with a black line. The gray area indicates the 90% time interval (T_{90}) over which the rms pressure is computed.

The sound exposure level or SEL (symbol L_E) is a measure related to the sound energy flux density of one or more impulses, but it does not account for impedance of the propagating medium and it is not measured in energy density units. The SEL for a single impulse is computed from the time-integral of the squared pressure over the impulse duration:

$$L_E = 10\log_{10}\left(\int_{T_{100}} p(t)^2\,dt / P_{ref}^2\right) \tag{3}$$

Sound exposure levels for impulsive noise sources (i.e. airgun impulses) presented in this report refer to single pulse SELs.

Because the 90% rms SPL and SEL for a single impulse are both computed from the integral of square pressure, these metrics are related by a simple expression that depends only on the duration of the 90% time window T_{90}:

$$L_E = L_{P90} + 10\log_{10}(T_{90}) + 0.458 \tag{4}$$

In this formula, the 0.458 dB factor accounts for the remaining 10% of the impulse SEL that is excluded from the 90% time window. In the following sections of this report, all references to rms levels refer to the 90% rms SPL metric.

Finally, the SPL and SEL metrics are sometimes calculated from a pressure signal that has been first passed through frequency filters. The filters are designed to account for frequency-dependent hearing sensitivity of the species exposed to the sound. If filtering is applied then the SPL and SEL levels are described as frequency-weighted. Several standard filters are used, including filters designed for marine mammal hearing, but these are not currently considered by NMFS for Cook Inlet effects assessment. A good discussion of filtering approaches for marine mammals is given in a recent report that describes methods for noise effects assessments based on frequency-weighted SEL (Southall *et. al*., 2007).

3. Methods

3.1. Sound Propagation Model

The acoustic propagation model used for this study was JASCO's Marine Operations Noise Model. MONM computes the received sound pressure level from noise sources such as airguns and vessels. 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 shear wave losses due to reflections from elastic seabeds. The PE method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins, 1993).

MONM 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 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 traverses.

Full waveform pressure-time series predictions were computed using MONM in full wave mode. In this mode, MONM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands between 10 and 2048 Hz. This frequency range includes the important bandwidth of noise emissions for the airgun array considered here. Range-dependent impulse-response functions were modeled between these frequencies in 1 Hz steps and convolved with the far-field source signature of the airgun array to generate synthetic pressure waveforms along each transect. These waveforms were then analyzed to determine the rms SPL as a function of range from the source. MONM's sound level predictions have been validated against other models and experimental data (Hannay & Racca, 2005).

3.2. Acoustic Source Levels of the Airgun Array

The acoustic source level of the 2400 in^3 airgun array was predicted using JASCO'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.

The array geometry is shown in Figure 2. The array consists of 16 individual guns with individual volumes of 150 in^3 arranged in clustered pairs. The overall layout is comprised of two sub-arrays of 8 guns each. Only 12 airguns are shown in the figure below because each sub-array contains a pair of airguns suspended below the middle pairs (and hence not visible in this plan view).

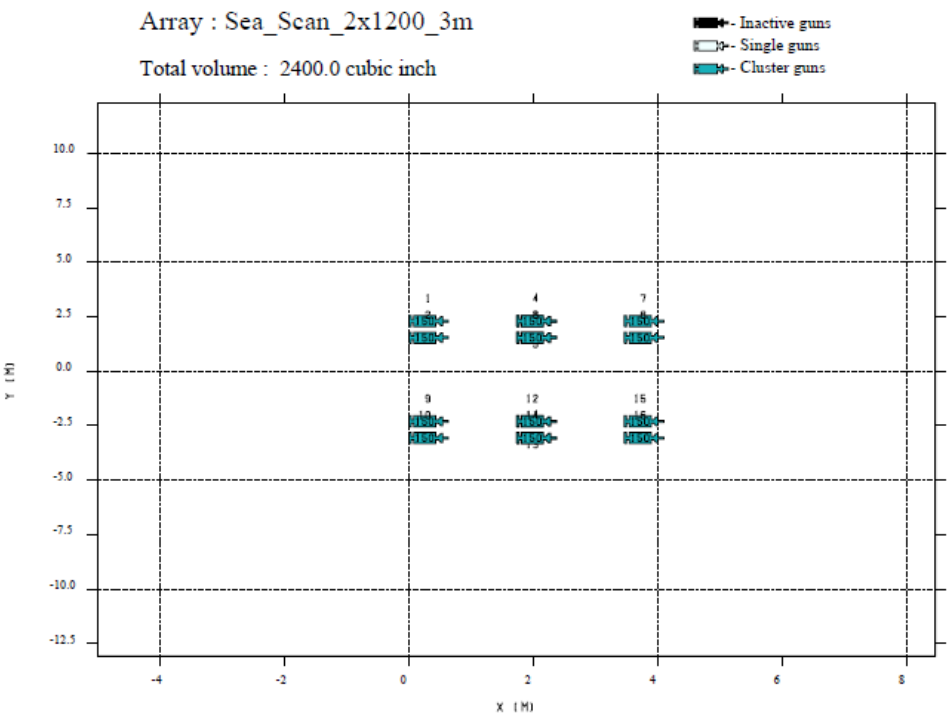


Figure 2: Geometry layout of 2400 in^3 array. Tow direction is to the right; tow depth is 3.0 m; the volume of each airgun is indicated in cubic inches.

The airgun array is expected to be operated at a constant depth of 3 m during the course of the survey. The modeling of the airgun array signature was carried out for a towing depth of 3 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.

The general trend is for spectral levels to decrease with increasing frequency, and most of the airgun energy is contained in frequencies below 500 Hz. To calculate the source directivity, the far-field array signature was filtered into 1/3-octave pass bands. Source directivity is insignificant below 100 Hz but it becomes prominent at higher frequencies. The horizontal directivity of the array as a function of frequency is presented in Figure 4. In these plots, the arrow indicates the tow direction of the array and the solid black curves indicate sound exposure level in dB re 1 $\mu Pa^2 s$ at 1 m as a function of angle in the horizontal plane. These levels are not directly used by MONM in full waveform mode; they are included here only to illustrate the horizontal directivity pattern of the array. MONM inherently treats vertical and horizontal directivity in full-wave mode.

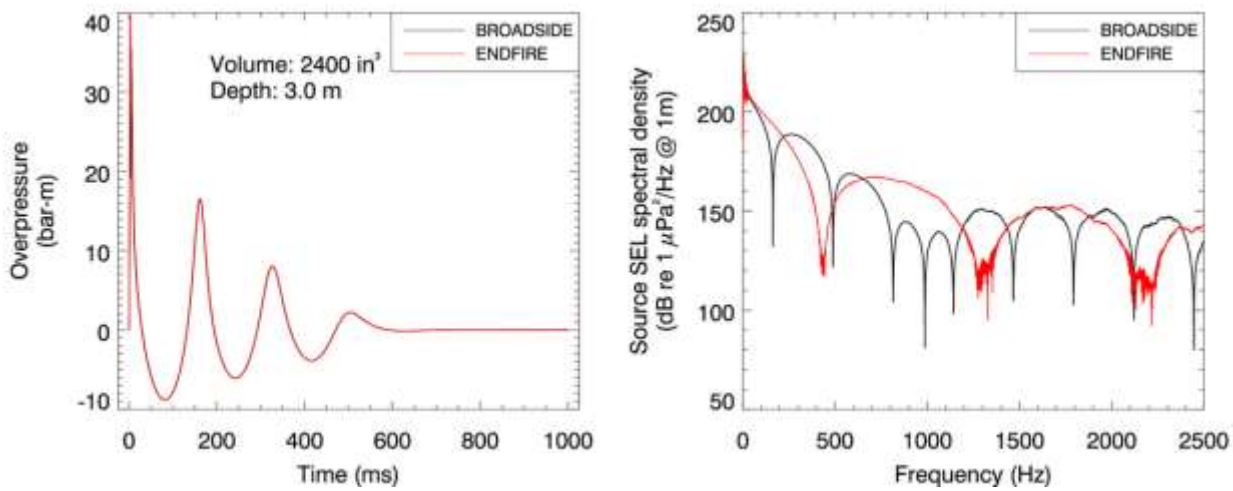


Figure 3: Overpressure signature and power spectrum for the 2400 in^3 array in the broadside and endfire directions. Surface ghosts are not included in these signatures.

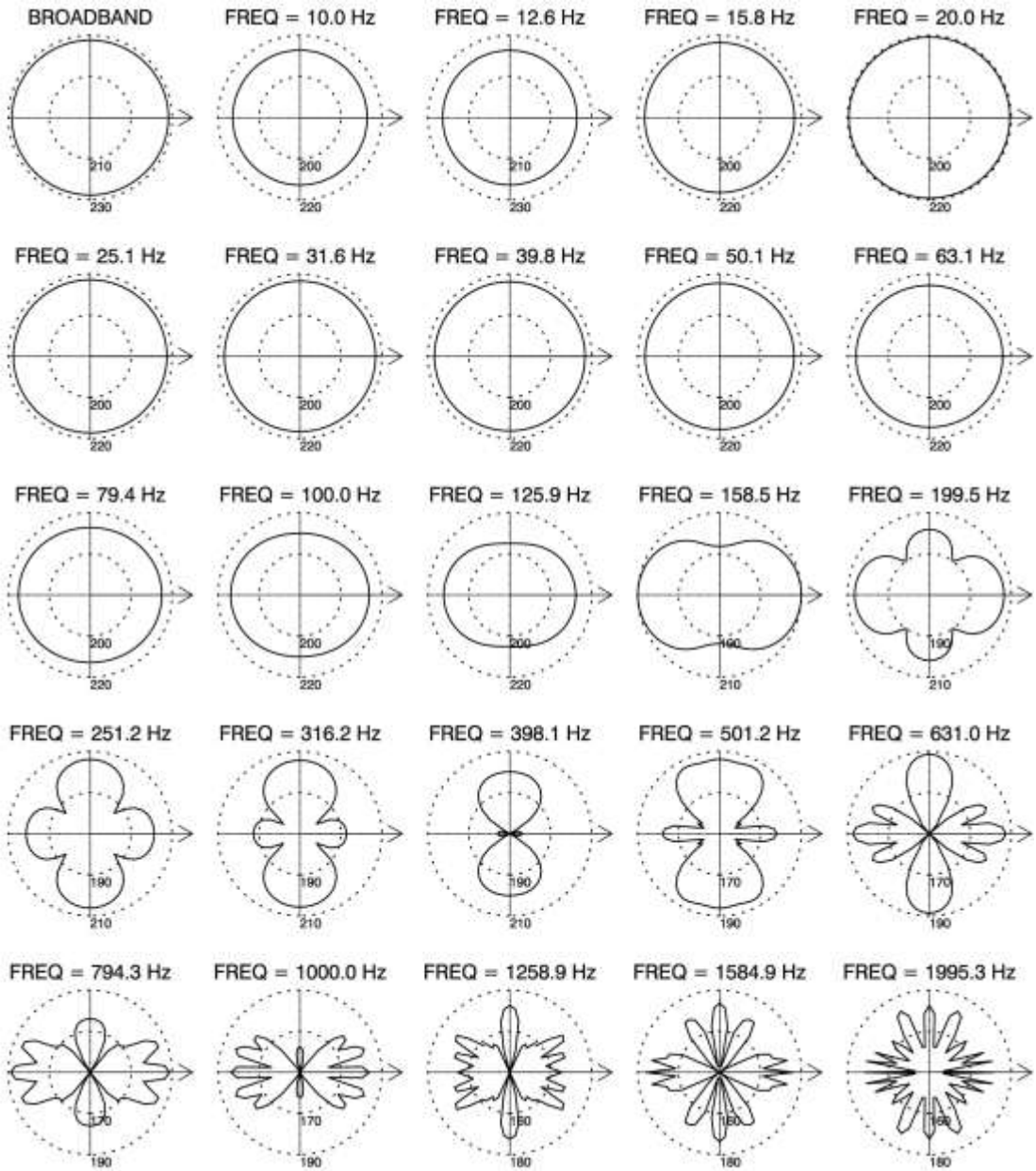


Figure 4: Azimuthal directivity patterns of the seismic array source levels (dB re 1 μPa^2 s at 1 m) for the 2400 in^3 array towed at 3 m depth, in 1/3-octave bands, by center frequency.

3.3. Acoustic Environment

3.3.1. Bathymetry

The acoustic models use high-resolution grids of bathymetry to define water depths inside a region of interest. Apache plans to survey many prospects in Cook Inlet over the duration of their surveys and the precise locations and sequence of prospects to be surveyed are presently unknown. However, the general bathymetry along the inlet is relatively uniform and consequently representative environments can be defined that are relevant for multiple survey locations.

Two general survey environment scenarios were considered for this modeling study: a nearshore survey scenario (from shore out to 18 km offshore) and a channel survey scenario (more than 18 km from each shore). The nearshore scenario was further divided into 3 distance intervals of 6 km each from shore, with this interval defined by the zone that can be surveyed in a 24 hour period based on an anticipated survey line length and line spacings that are discussed later.

Water depths for the nearshore scenario increase by 25 m per 10 km distance away from shore. The depth of the channel scenario has constant depth of 80 m, which is the approximate median depth along the center of the Cook Inlet's channel.

3.3.2. Underwater sound speed

The sound velocity profile (SVP) used in the acoustic model was derived from conductivity-temperature-depth (CTD) surveys conducted within the project test area in Cook Inlet between 25 March and 1 April 2011. The CTD data reveal a fairly uniform sound speed with depth for all fourteen casts conducted (typically < 2 m/s variation) (see Figure 5), with a mean value of 1436 m/s across all depths.

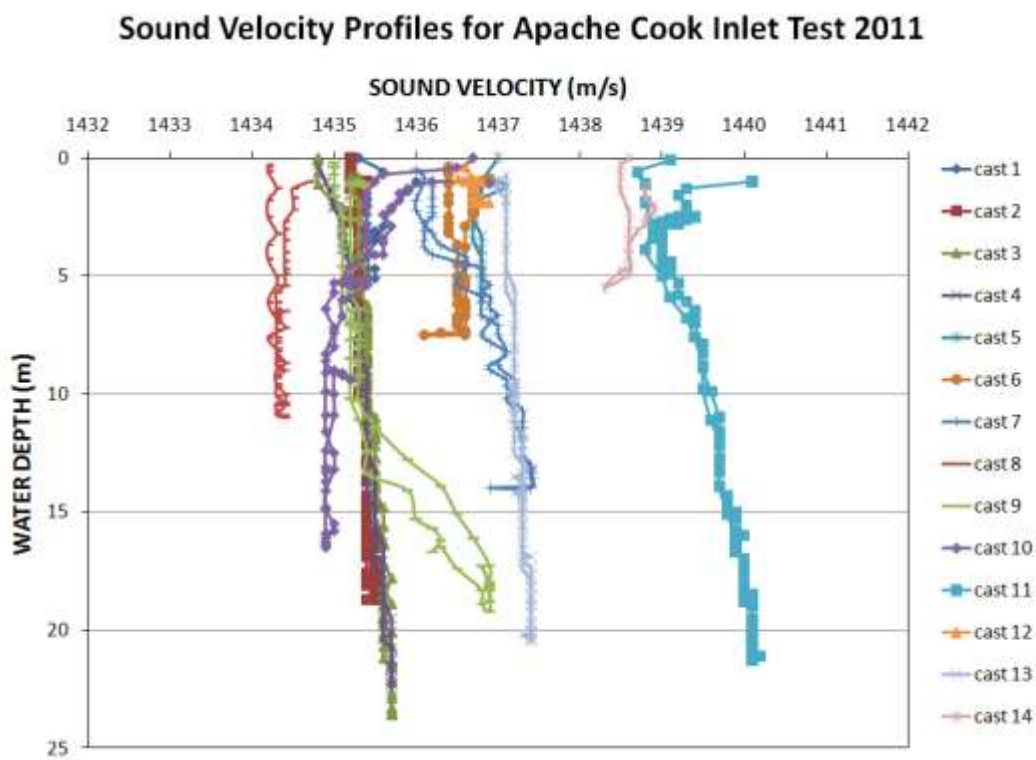


Figure 5: Sound velocity profiles as derived from CTD cast measurements obtained between 25 March and 1 April 2011 in Cook Inlet, Alaska.

Variability in sound velocity profile shape can exist with time of year due to seasonal temperature and salinity cycles. Therefore, a review of two other sources of SVP data for Cook Inlet was done to confirm the validity of this observed iso-velocity SVP shape and mean value.

Sound velocity profiles were examined for each month of the year using the US Naval Oceanographic Office's Generalized Digital Environmental Model (Teague *et al.*1990) database

for a location in the middle of Cook Inlet. The other source of SVP is from field work conducted in April 2007 (JASCO). The data from these two sources concurs with the SVP from the 2011 measurements, and thus a constant sound velocity of 1436 m/s was used in the acoustic model.

3.3.3. Seabed geoacoustics

The geoacoustic profile for Cook Inlet, describing the elasto-acoustic properties of the seabed sediments, was first estimated from a geological profile at the Port of Anchorage (Hashash, 2008). The engineered fill and Bootlegger Cove formation layers were disregarded as they would not be present in the majority of Cook Inlet. The resulting profile consisted of a surface layer of sand, silt, and clay, overlaying glacial-fluvial sands, gravels, and glacial till. Descriptions of soil composition for these layers were used to estimate geoacoustic properties, using the methods described by Hamilton (1980).

The five geoacoustic layer properties considered by the sound propagation model for sub-bottom sediments are as follows:

1. Relative density: The density of the bottom materials relative to the density of water.
2. Compressional-wave sound speed: The phase speed of longitudinal body waves (P-waves) in the bottom materials (units of m/s).
3. Compressional attenuation: The rate of attenuation (units of dB per wavelength) of longitudinal body waves in the bottom materials.
4. Shear-wave sound speed: The phase speed of transverse body waves (S-waves) in the bottom materials (units of m/s).
5. Shear attenuation: The rate of attenuation (units of dB per wavelength) of transverse body waves in the bottom materials.

MONM accepts profiles of density, compressional-wave speed, and compressional attenuation defined to arbitrary depth in the bottom. Reflection losses at the seabed, caused by partial conversion of compressional waves to shear waves at each layer interface, are accounted for in MONM using a complex-density approximation.

In order to ensure that the derived geoacoustic parameters were appropriate for Cook Inlet, MONM was run to model sound levels from the 880 in^3 array used in the ConocoPhillips 2007 survey (JASCO, 2007). The modeled peak, rms, and SEL values were compared to measured data and the compressional sound speed at the seabed was adjusted until an optimal fit between the modeled and measured levels was obtained. The resulting geoacoustic profile, intended to represent mean sediment properties over Cook Inlet, is presented in the table below.

Table 1: Seabed geoacoustic profile for Cook Inlet. Geoacoustic parameters are based on the soils containing a mixture of sands, silts, and clays transitioning to glacial-fluvial sands, gravels, and glacial till with depth.

Depth (mbsf)	Density (g/cm^3)	Compressional Sound Speed (m/s)	Compressional Attenuation (dB/λ)	Shear Sound Speed (m/s)	Shear Attenuation (dB/λ)
0	1.58	1480	0.17	110	2.0
108	2.18	1844	0.50	-	-

3.4. Area of Harassment Calculation

The area ensonified to above 160 dB re 1 μPa over 24 hours of seismic surveying is dependent on the seismic survey line geometry because the zones from multiple survey lines often overlap. Apache plans to survey 12 to 14, 16.1 km long lines each day. The survey lines will be parallel to shore, separated nominally by 503 m, and immediately-adjacent lines will be surveyed sequentially. Based on this survey description, MONM was used to model sounds from the array in the two characteristic environments described in Section 3.3.1.

For the nearshore surveys, the source was modeled at three positions on the slope with water depths 5, 25, and 45 m. At each source position, three transects were modeled corresponding to the onshore, offshore, and parallel-to-shore directions. Since the airgun array will be towed parallel to shore, these directions correspond with the onshore-broadside, offshore-broadside, and endfire directions relative to the array. For the channel surveys, the source was modeled in 80 m deep water in the broadside and endfire directions.

The received levels vary with distance from the array and with receiver depth (that can be anywhere in the water column). The distances to 160 dB re 1 μPa were calculated in each direction by considering the maximum level over all possible receiver depths. We interpolated and extrapolated from the distance values modeled for the 3 different source location water depths of the nearshore scenario to obtain the 160 dB re 1 μPa distances for all source location water depths between 5 and 54 m.

The acoustic footprint for each survey line was calculated by defining encompassing rectangles formed by the distance of the 160 dB re 1 μPa threshold from the survey line, accounting for the differences in these distances for the different directions (Figure 6). The total area ensonified over the period of 24 hours was calculated from the union of 14 single survey line rectangles. Figure 7 illustrates the process for the union of just two survey line rectangles; this process was extended to all 14 lines of one day's anticipated survey production.

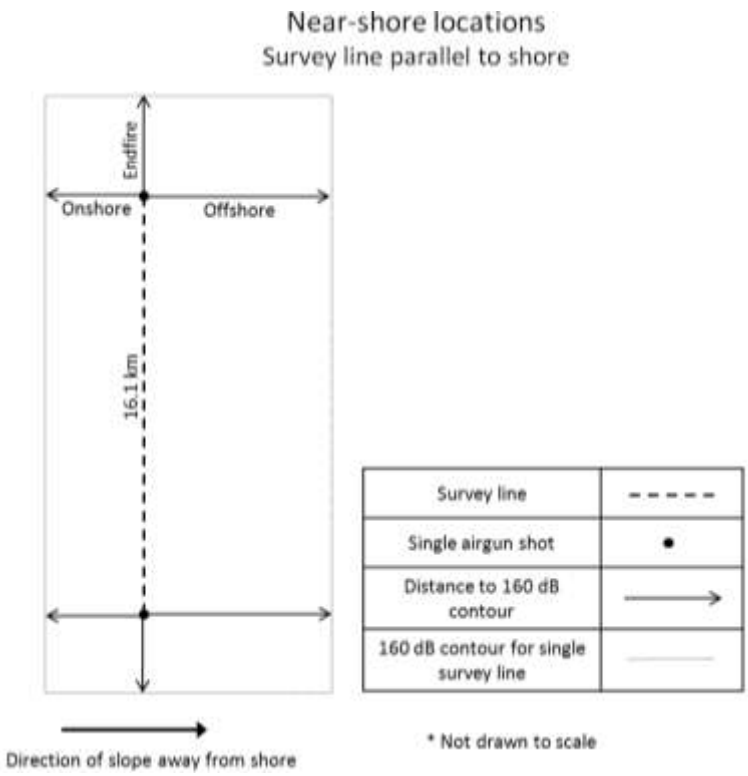


Figure 6: Diagram showing the creation of the 160 dB rectangular contour for a single survey line. In practice the corners are rounded but this has only a small reducing influence on the total areas.

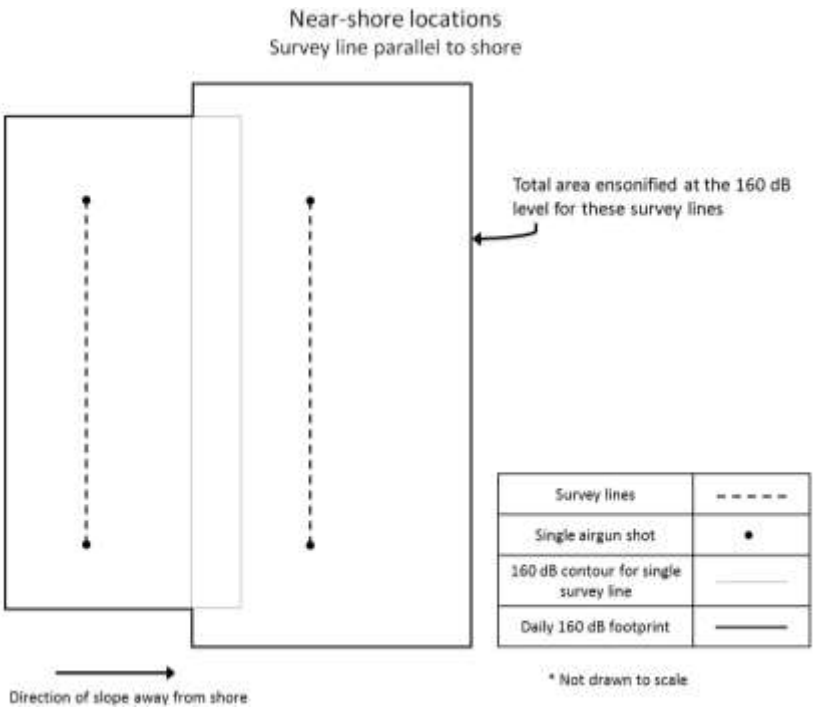


Figure 7: Diagram showing the union of two 160 dB rectangles (light grey lines) from two survey lines to get the combined 160 dB footprint (bold black line). The more offshore survey line (right) is in deeper water which supports better sound propagation. It consequently has a larger individual footprint size, hence its larger rectangle.

The daily area ensonified to 160 dB for nearshore surveys depends on the water depths of the lines surveyed. A daily survey of 14 parallel lines with 500 m spacing would span 6.5 km, corresponding to a water depth variation of about 16 m. Because the total daily footprint for nearshore surveying varies with depth, we divided the nearshore scenarios into three depth intervals, each of which could be surveyed in a single day: shallow (5-21 m), intermediate (21-38 m), and deep (38-54 m). The 24-hour ensonified areas were computed separately for each of the three nearshore survey depth intervals.

4. Model Scenarios and Results

4.1. Overview of Model Scenarios

The distances to 190, 180 and 160 dB re 1 μPa threshold for various source depths and in different directions from the source, and relative to shore, were calculated by the acoustic model. The 160 dB re 1 μPa threshold distances were calculated for the three nearshore survey depth intervals and single depth channel survey also in different directions from the source. The daily areas ensonified above the 160 dB re 1 μPa threshold were then calculated for each of the four survey depth intervals. The distance and area results are presented below.

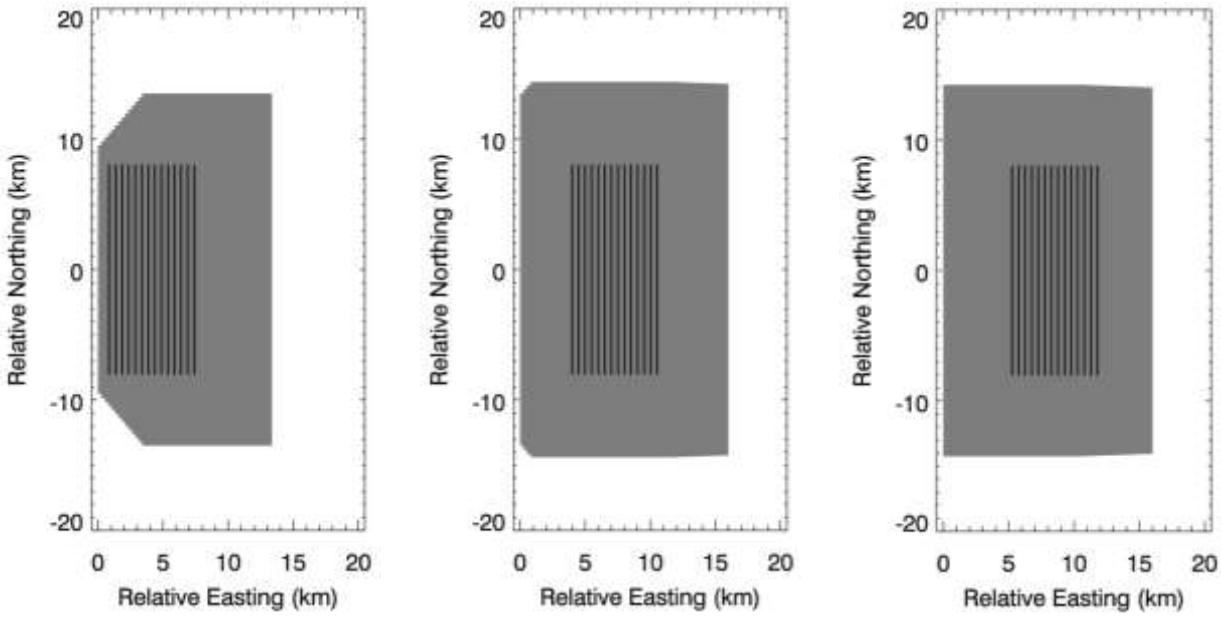
4.2. Nearshore Survey Results

The distances to the 160, 180, and 190 dB re 1 μPa sound level thresholds for the nearshore survey locations are given in Table 2. Distances correspond to the three transects modeled at each site in the onshore, offshore, and parallel to shore directions.

Table 2: Distances to sound level thresholds for the nearshore surveys.

Sound Level Threshold (dB re 1 μPa)	Water Depth at Source Location (m)	Distance in the Onshore Direction (km)	Distance in the Offshore Direction (km)	Distance in the Parallel to Shore Direction (km)
160	5	0.85	3.91	1.48
	25	4.70	6.41	6.34
	45	5.57	4.91	6.10
180	5	0.46	0.60	0.54
	25	1.06	1.07	1.42
	45	0.70	0.83	0.89
190	5	0.28	0.33	0.33
	25	0.35	0.36	0.44
	45	0.10	0.10	0.51

The 160 dB re 1 μPa footprints for one day of nearshore surveying in shallow, mid-depth, and deep water are shown in Figure 8; the corresponding areas of the footprints are listed in Table 3.



(a) (b) (c)

Figure 8: Daily footprints for (a) shallow, (b) mid-depth, and (c) deep water nearshore surveys. The ensonified areas are shown in gray and survey lines are shown in black.

Table 3: Areas ensonified to 160 dB re 1 µPa for nearshore surveys in 24 hours.

Nearshore Survey Depth Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 µPa (km^2)
Shallow	5-21	346
Mid-depth	21-38	458
Deep	38-54	455

4.3. Channel Survey Results

The distances to the 160, 180, and 190 dB re 1 µPa sound level thresholds for the channel surveys are shown below in Table 4. Distances correspond to the broadside and endfire directions.

Table 4: Distances to sound level thresholds for the channel surveys.

Sound Level Threshold (dB re 1 µPa)	Water Depth at Source Location (m)	Distance in the Broadside Direction (km)	Distance in the Endfire Direction (km)
160	80	4.24	4.89
180	80	0.91	0.98
190	80	0.15	0.18

The 160 dB re 1 µPa footprint for 24 hours of seismic survey in the inlet channel is shown in Figure 9; the corresponding area of the footprint is 389 km^2.

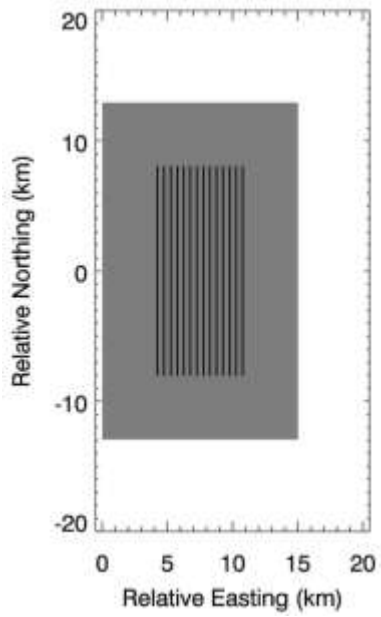


Figure 9: Daily footprint for channel surveys. The ensonified area is shown in gray and the survey lines are shown in black. Its area is 389 km^2.

5. Summary and Conclusion

This report presents results from a noise modeling study of Apache's planned seismic survey operations in Cook Inlet. The study characterized the acoustic environment in the Cook Inlet area by defining a generic nearshore sloped environment and a flat (constant depth) channel environment. Underwater noise was modeled from a 2400 in^3 airgun array and the distances that sound levels reached thresholds 160, 180, and 190 dB re 1 μPa (90% rms SPL) were computed. The areas ensonified above 160 dB re 1 μPa were calculated for 24 hour surveying periods in shallow, mid-depth, and deep water for the nearshore environment, and for 24 hours of surveying in the channel environment.

The signature of the 2400 in^3 airgun array was modeled using an airgun array source model (AASM) and was input to a range-dependent acoustic model in full waveform mode (MONM). Bathymetry has substantial influence on the distances that sound travels in the environments considered. Seismic sounds are predicted to propagate most strongly in the 21-55 m depth range, with greater attenuation (reduction of sound levels) for smaller and greater depths.

The maximum predicted distances for 90% rms SPL values to reach thresholds of 160, 180 and 190 dB re 1 μPa over all depths and azimuths modeled were 6.41 km, 1.42 km, 0.51 km, respectively. The areas ensonified above 160 dB re 1 μPa during 24 hours of surveying for the different environments considered is summarized in Table 5. These values can be used to estimate the number of takes expected over the course of a multi-day survey by simply multiplying by the corresponding animal spatial densities.

Table 5: Summary of ensonified areas to 160 dB re 1 μPa for one day of surveying.

Survey Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 μPa (km^2)
Nearshore - Shallow	5-21	346
Nearshore - Mid-depth	21-38	458
Nearshore - Deep	38-54	455
Channel	80	389

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APPENDIX D

JASCO REVISED AREAS TO 160dB re 1 µPA – 2400 in^3 ARRAY

Apache Cook Inlet Seismic Survey Sound Levels

Revised Areas to 160 dB re 1 µPa – 2400 in^3 array

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1. Introduction

This brief report contains revised estimates for areas of sound exposure associated with Apache Alaska Corporation's planned seismic surveys in Cook Inlet, Alaska. Sound from seismic survey airgun arrays has the potential to harass nearby marine mammals. The National Marine Fisheries Service (NMFS) presently considers impulsive airgun sound levels above 160 dB re 1 μPa (rms) as capable to cause harassment to marine mammals. Exposures above this threshold are considered level-B takes by NMFS (in contrast to level-A takes which refer to injury). Level-B takes generally need to be permitted under Incidental Harassment Authorizations (IHA).

JASCO Applied Sciences performed an acoustic modeling study in 2011 to estimate underwater sound levels produced by the airgun arrays of Apache's planned seismic surveys. A goal of the acoustic modeling work was to estimate areas of sound exposure using modeled distances to the 160 dB re 1 μPa (rms) threshold. These areas were used to calculate the marine mammal take numbers requested in Apache's IHA application.

A seismic survey took place in 2012, under the approved IHA, during which in-water sound level measurements were collected. The maximum measured distances from the airgun array to 160 dB re 1 μPa (rms) exceeded the model estimates by ratios of 1.21 to 1.50. This report describes the comparison of model predictions with measurements, and suggests adjustment factors based on the ratios of these threshold distances. Updates to the estimated areas over which the 160 dB re 1 μPa (rms) threshold will be exceeded were calculated by applying these adjustment factors to the original model results for all bathymetric scenarios considered. These results are suitable for use at calculating updated estimates of take for further surveys using the same type of survey equipment in these areas.

Full details of the underlying acoustic model and the techniques for calculating the areas of sound exposure can be found in the original modeling report from 2011 (Warner et al, 2011). Details and results from the 2012 measurement study can be found in the 5-day Sound Source Verification report from 2012 (Austin and Warner, 2012).

2. Methods

2.1. Calculation of areas of sound exposure

This section provides a brief review of the process used to calculate the areas of sound exposure, as detailed in the 2011 model report (Warner et al, 2011). This same process was used to obtain the areas in this current report, with the only difference being in the application of revised distances of the 160 dB re 1 µPa threshold from the survey line.

The original model study provided the area ensonified at levels above 160 dB re 1 µPa over 24 hours of seismic surveying. This area is dependent on the seismic survey line geometry because there is often overlap of the ensonified areas of multiple survey lines. Based on a general survey description, we computed the total area of sound exposure over 24 hours of seismic surveying assuming 12 to 14, 16.1 km survey lines would be acquired each day.

JASCO's sound propagation model MONM was used to model sounds from the array for several survey environments characteristic of Cook Inlet. The modeling study considered three nearshore environments with sloped seafloor and either shallow (5 m), mid-depth (25 m), or deep (45 m) water depth at the airgun position. A deep channel environment was modeled with a constant water depth of 80 m.

For the nearshore survey lines, the source was modeled at three positions on the slope with water depths of 5, 25, and 45 m. At each source position, three transects were modeled corresponding to the onshore, offshore, and parallel-to-shore directions. Since the airgun array will be towed parallel to shore, these directions correspond with the onshore-broadside, offshore-broadside, and endfire directions relative to the array. For the deep channel survey lines, the source was modeled in 80 m deep water in the broadside and endfire directions. The distances to 160 dB re 1 µPa were calculated in each direction using MONM, by considering the maximum level over all possible receiver depths.

The acoustic footprint for each survey line was calculated by defining encompassing rectangles formed by the distance of the 160 dB re 1 µPa threshold from the survey line, accounting for the differences in these distances for the different directions (Figure 1). The total area ensonified over the period of 24 hours was calculated from the union of 14 single survey line rectangles. Figure 2 illustrates the process for the union of just two survey line rectangles; this process was extended to all 14 lines of one day's anticipated survey production.

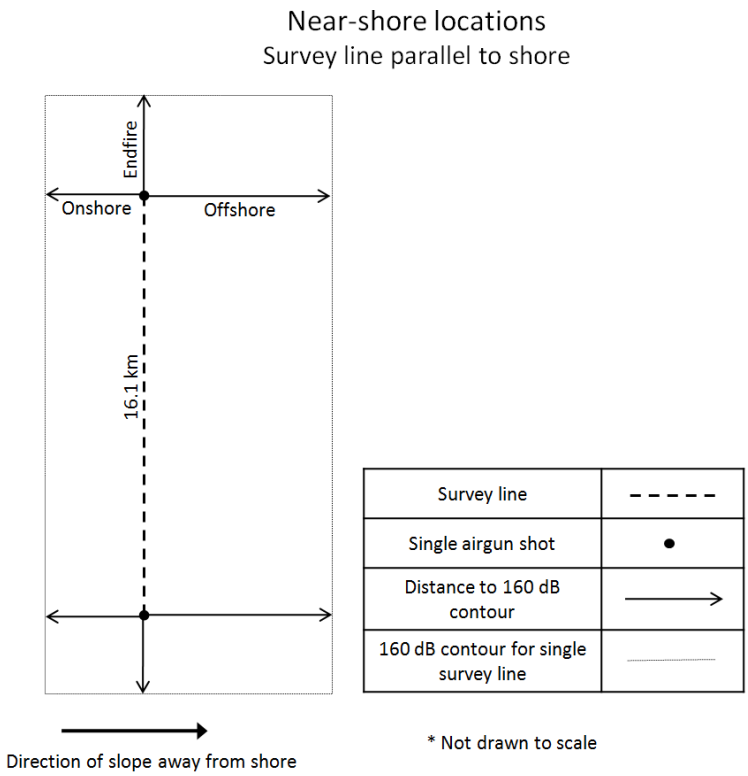

Figure 1: Diagram showing the creation of the 160 dB rectangular contour for a single survey line. In practice the corners are rounded but this has only a small influence on total area reduction.

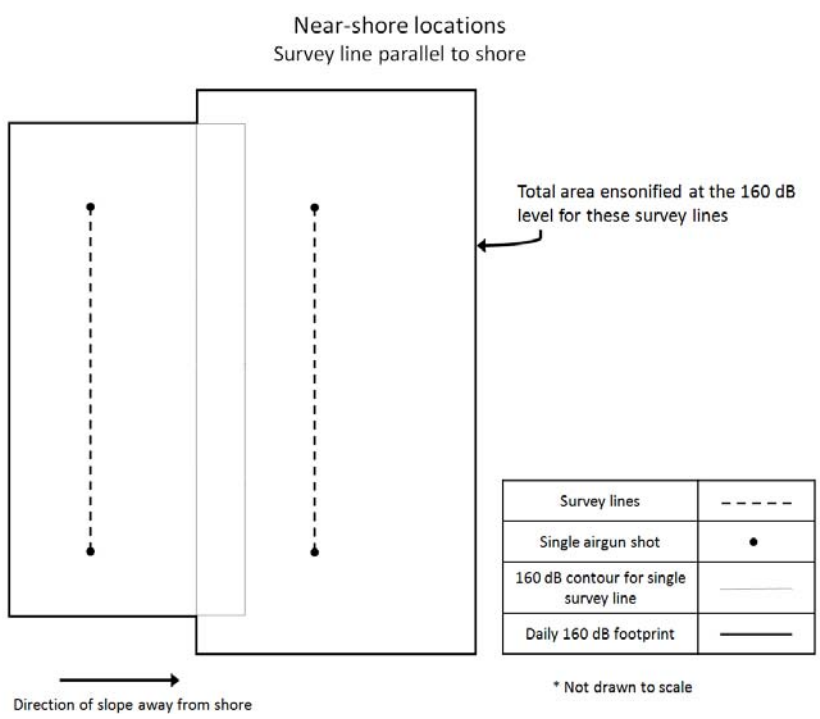

Figure 2: Diagram showing the union of two 160 dB rectangles (light grey lines) from two survey lines to get the combined 160 dB footprint (bold black line). The more offshore survey line (right) is in deeper water which supports better sound propagation. It consequently has a larger individual footprint size, hence its larger rectangle.

2.2. Threshold distance adjustments

Revised distances from the airgun array to 160 dB re 1 μPa were calculated by applying an offset to the 2011 model estimates. This offset was determined from the ratio of measured to modeled distances. This comparative analysis only considered measurements collected in conditions that were accurately reflected by one of the modeled environments (nearshore and offshore).

Measurements were collected for a nearshore survey line with water depths between 25 and 35 m (referred to as "Track 1" in the 2012 measurement report). These data were compared against the modeled distances for the nearshore, mid-depth survey classification. The data-to-model ratio was determined for the 160 dB re 1 μPa threshold distance in both the offshore-broadside and endfire directions (Table 1). This ratio formed the factor by which modeled distances to 160 dB re 1 μPa were increased. Measurements were not available for the onshore-broadside direction, but the offset was assumed to be the same as that for the offshore-broadside aspect. These broadside and endfire offsets were also applied to the modeled distances for the two other (shallow and deep water) nearshore environments.

Measurements were collected for a deep channel survey line (referred to as 'Track 2' in the 2012 measurement report) with water depths of 65 m and less. The bathymetry along the survey track was not constant and the source vessel was in relatively shallow water (<40 m) at ranges from the recorder beyond 5 km. These water depths differed significantly from the 80 m depth that was modeled. In addition, the distances in the measurement report were derived from an extrapolation using a data-fit that neglected long-range absorption effects and likely over-estimated the true range to 160 dB re 1 μPa (Austin and Warner, 2012). For these reasons, this was not considered to be a valid comparison and a data-to-model offset was not computed from these data. The offsets from the near-shore environment were, thus, also applied to the deep channel model estimates.

Table 1. Range to 160 dB re 1 μPa (rms) for the broadside and endfire aspects of a 2400 in^3 airgun array operating along a nearshore survey line.

	Broadside (km)	*Endfire* (km)
2011 Model Estimate (Mid-depth, offshore-broadside)	6.41	6.34
2012 Measurement (Track 1, offshore-broadside)	7.77	9.50
Ratio Data:Model	121%	150%

3. Results

The distances to the 160 dB re 1 μPa (rms) threshold from the 2011 model results were each adjusted using the data:model ratios defined above (Table 2). These adjusted threshold radii were used to re-compute the areas of ensonification. The revised areas are listed in Table 3.

Table 2 Ranges to 160 dB re 1 μPa (rms) for three different aspects of a 2400 in^3 airgun array.

	Water Depth at Source Location (m)	Distance in the Onshore Direction (km)	Distance in the Offshore Direction (km)	Distance in the Parallel to Shore Direction (km)
Original Model Estimates from 2011				
	5	0.85	3.91	1.48
	25	4.70	6.41	6.34
	45	5.57	4.91	6.10
	80	4.24	4.24	4.89
Adjusted Model Estimates Based on Offset from 2012 Measurements				
	5	1.03	4.73	2.22
	25	5.69	7.77	9.50
	45	6.75	5.95	9.15
	80	5.14	5.14	7.33

Table 3 Ensonified areas to 160 dB re 1 μPa for one day of surveying.

Survey Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 μPa (km^2) 2011 Estimate	Revised Estimate
Nearshore - Shallow	5-21	346	462
Nearshore - Mid-depth	21-38	458	629
Nearshore - Deep	38-54	455	623
Channel	80	389	517

4. Conclusion

Measurements collected in 2012 yielded distances to 160 dB re 1 µPa (rms) that exceeded model estimates from 2011 by a ratio of 121% in the offshore-broadside direction and 150% in the endfire direction. The modeled distances have been increased by the offset between the measured and modeled values. Areas of ensonification to 160 dB re 1 µPa (rms) have also been revised and are summarized below.

Survey Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 µPa (km^2)
Nearshore - Shallow	5-21	462
Nearshore - Mid-depth	21-38	629
Nearshore - Deep	38-54	623
Channel	80	517

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