APPENDIX A
NATIONAL MARINE FISHERIES SERVICE
INCIDENTAL HARASSMENT AUTHORIZATION

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

Incidental Harassment Authorization

Apache Alaska Corporation (Apache), 200 Post Oak Boulevard, Suite 100, Houston, Texas 77056, is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1371(a)(5)(D)), to harass small numbers of marine mammals incidental to a marine geophysical (seismic) survey conducted by Apache in Cook Inlet, Alaska between April 2012 and April 2013:

1. This Authorization is valid from April 30, 2012 through April 30, 2013.

2. This Authorization is valid only for Apache's activities associated with seismic survey operations that shall occur in the following specified geographic area:

   Area 1 encompasses approximately 3,554 km^2 and includes a 6.41 km buffer around intertidal and offshore areas, as specified in Apache's Incidental Harassment Authorization application, Biological Assessment, and associated Environmental Assessment. On the western side of Cook Inlet, Area 1 extends from the Beluga River to approximately 4.5 km sound of the Big River. On the eastern side, Area 1 extends from the town of Salamantof on the Kenai Peninsula to approximately 7 km north of the Swanson River.

3. <u>Species Authorized and Level of Takes</u>

   (a) The incidental taking of marine mammals, by Level B harassment only, is limited to the following species in the waters of Cook Inlet:

   (i) Odontocetes – see Table 2 (attached) for authorized species and take numbers.

   (ii) Pinnipeds – see Table 2 (attached) for authorized species and take numbers.

   (iii) If any marine mammal species are encountered during seismic activities that are not listed in Table 2 (attached) for authorized taking and are likely to be exposed to sound pressure levels (SPLs) greater than or equal to 160 dB re 1 μPa (rms), then the Holder of this Authorization must alter speed or course, power-down or shut-down the sound source to avoid take.

   (b) The taking by injury (Level A harassment) serious injury, or death of any of the species listed in Table 2 or the taking of any kind of any other species of marine mammal is prohibited and may result in the modification, suspension or revocation of this Authorization.

4. The methods authorized for taking by Level B harassment are limited to the following acoustic sources without an amendment to this Authorization:

(i) Two air gun arrays, each with a capacity of 2,400 in^3;
(ii) A 440 in^3 air gun array;
(iii) A 10 in^3 air gun;
(iv) A Scout Ultra-Short Baseline (USBL) transceiver; and
(v) A Lightweight Release USBL transponder.

5. The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Office of Protected Resources, National Marine Fisheries Service (NMFS), at 301-427-8401.

6. The Holder of this Authorization is required to cooperate with NMFS and any other Federal, state, or local agency monitoring the impacts of the activity on marine mammals.

7. Mitigation and Monitoring Requirements

The Holder of this Authorization is required to implement the following mitigation and monitoring requirements when conducting the specified activities to achieve the least practicable adverse impact on affected marine mammal species or stocks:

(a) Utilize a sufficient number of NMFS-qualified, vessel-based Protected Species Visual Observers (PSVOs) (except during meal times and restroom breaks, when at least one PSVO shall be on watch) to visually watch for and monitor marine mammals near the seismic source vessels during daytime operations (from nautical twilight-dawn to nautical twilight-dusk) and before and during start-ups of sound sources day or night. Two PSVOs will be on the source vessels and two PSVOs will be on the support vessel to observe the safety and disturbance zones. PSVOs shall have access to reticle binoculars (7x50 Fujinon), big-eye binoculars (25x150), and night vision devices. PSVO shifts shall last no longer than 4 hours at a time. PSVOs shall also make observations during daytime periods when the sound sources are not operating for comparison of animal abundance and behavior, when feasible. When practicable, as an additional means of visual observation, Apache's vessel crew may also assist in detecting marine mammals.

(b) In addition to the vessel-based PSVOs, utilize a shore-based station to visually monitor for marine mammals. The shore-based station will follow all safety procedures, including bear safety. The location of the shore-based station will need to be sufficiently high to observe marine mammals; the PSOs would be equipped with pedestal mounted "big eye" (20x110) binoculars. The shore-based PSOs would scan the area prior to, during, and after the survey operations involving the use of sound sources, and would be in contact with the vessel-based PSOs via radio to communicate sightings of marine mammals approaching or within the project area.

(c) When survey operations occur near a river mouth, utilize the crew helicopter to conduct aerial surveys near river mouths prior to the commencement of air gun operations in order to identify locations where beluga whales congregate. The helicopter may also be used to look for marine mammals during other times, when practicable. The types of helicopters currently planned for use by Apache include a Bell 407, Bell UH1B, and ASB3. Weather and scheduling permitting, aerial surveys will fly at an altitude of 305 m (1,000 ft). 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 mammal(s).

(d) PSVOs shall conduct monitoring while the airgun array and nodes are being deployed or recovered from the water.

(e) Record the following information when a marine mammal is sighted:

(i) Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc., and including responses to ramp-up), and behavioral pace; and

(ii) Time, location, heading, speed, activity of the vessel (including number of airguns operating and whether in state of ramp-up or power-down), Beaufort sea state and wind force, visibility, and sun glare; and

(iii) The data listed under Condition 7(c)(ii) shall also be recorded at the start and end of each observation watch and during a watch whenever there is a change in one or more of the variables.

(f) Utilize the passive acoustic monitoring (PAM) system to detect and allow some localization of marine mammals around the source vessels during all seismic survey operations and during most periods when sound sources are not operating. One NMFS-qualified Protected Species Observer (PSO) and/or expert bioacoustician (i.e., Protected Species Acoustic Observer [PSAO]) shall monitor the PAM at all times in shifts no longer than 6 hours. An expert bioacoustician shall design and set up the PAM system and be present to operate or oversee PAM, and available when technical issues occur during the survey.

(g) Do and record the following when an animal is detected by the PAM:

(i) Notify the on-duty PSVO(s) immediately of a vocalizing marine mammal so a power-down or shut-down can be initiated, if marine mammals are detected (visually or acoustically) approaching or within the relevant EZ (as defined in Table 1, attached);

(ii) Enter the information regarding the vocalization into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position, and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information.

(h) Visually observe the entire extent of the exclusion zone (EZ) (180 dB re 1 μPa [rms] for cetaceans and 190 dB re 1 μPa [rms] for pinnipeds; see Table 1 [attached] for distances) using NMFS-qualified PSVOs, for at least 30 minutes (min) prior to starting the airgun array (day or night). If the PSVO finds a marine mammal within the EZ, Apache must delay the seismic survey until the marine mammal(s) has left the area. If the PSVO sees a marine mammal that surfaces, then dives below the surface, the PSVO shall wait 30 min. If the PSVO sees no marine mammals during that time, they should assume that the animal has moved beyond the EZ. If for any reason the entire radius cannot be seen for the entire 30 min (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the EZ, the airguns may not be ramped-up.

(i) Establish a 180 dB re 1 μPa (rms) and 190 dB re 1 μPa (rms) EZ for marine mammals before the full array (2400 in^3) is in operation; and a 180 dB re 1 μPa (rms) and 190 dB re 1 μPa (rms) EZ before a single airgun (10 in^3) is in operation, respectively. See Table 1 (attached) for distances and EZs.

(j) Implement a "ramp-up" procedure when starting up at the beginning of seismic operations or anytime after the entire array has been shutdown for more than 10 min, which means start the smallest sound source first and add sound sources in a sequence such that the source level of the array shall increase in steps not exceeding approximately 6 dB per 5-min period. During ramp-up, the PSVOs shall monitor the EZ, and if marine mammals are sighted, a power-down, or shut-down shall be implemented as though the full array were operational. Therefore, initiation of ramp-up procedures from shut-down requires that the PSVOs be able to visually observe the full EZ as described in Condition 7(h) (above).

(k) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the relevant EZ. If speed or course alteration is not safe or practicable, or if after alteration the marine mammal still appears likely to enter the EZ, further mitigation measures, such as a power-down or shut-down, shall be taken.

(l) Power-down or shut-down the sound source(s) if a marine mammal is detected within, approaches, or enters the relevant EZ (as defined in Table 1, attached). A shut-down means all operating sound sources are shut-down (i.e., turned off). A power-down means reducing the number of operating sound sources to a single operating 10 in^3 airgun, which reduces the EZ to the degree that the animal(s) is no longer in or about to enter it.

(m) Following a power-down, if the marine mammal approaches the smaller designated EZ, the sound sources must then be completely shut-down. Seismic survey activity shall not resume until the PSVO has visually observed the marine mammal(s) exiting the EZ and is not likely to return, or has not been seen within the EZ for 15 min for species with shorter dive durations (small odontocetes and pinnipeds) or 30 min for species with longer dive durations (large odontocetes, including killer whales and beluga whales).

(n) Following a power-down or shut-down and subsequent animal departure, survey operations may resume following ramp-up procedures described in Condition 7(h).

(o) Marine geophysical surveys may continue into night and low-light hours if such segment(s) of the survey is initiated when the entire relevant EZs can be effectively monitored visually or acoustically (i.e., PSVO(s) or PSAO(s) must be able to see the extent of or hear sounds within the entire relevant EZ).

(p) No initiation of survey operations involving the use of sound sources is permitted from a shut-down position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant EZ cannot be effectively monitored (visually or acoustically) by the PSVO(s) or PSAO on duty.

(q) If a beluga whale (*Delphinapterus leucas*) cow/calf pair is visually sighted approaching or within the 160-dB disturbance zone, survey activity will not commence or the sound source(s) shall be shut-down until the animals are no longer present within the 160-dB zone.

(r) Whenever aggregations or groups of beluga whales (*Delphinapterus leucas*) and/or killer whales (*Orcinus orca*) are detected approaching or within the 160-dB disturbance zone, survey activity will not commence or the sound source(s) shall be shut-down until the animals are no longer present within the 160-dB zone. An aggregation or group of whales shall consist of when five or more individuals of any age/sex class are visually sighted that do not appear to be traveling (e.g., feeding, socializing, etc.).

8. <u>Reporting Requirements</u>

The Holder of this Authorization is required to:

(a) Submit a weekly field report, no later than close of business (Alaska time) each Thursday during the weeks when in-water seismic survey activities take place. The field reports will contain and summarize the information required under Condition 8(b).

(b) Submit a monthly report, no later than the 15th of each month, to NMFS' Permits and Conservation Division for all months during which in-water seismic survey activities take place. These reports must contain and summarize the following information:

(i) 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;

(ii) 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.

(iii) 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.

(iv) 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 Incidental Harassment Authorization. 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 Endangered Species Act-listed marine mammals.

(c) Submit a draft Technical Report on all activities and monitoring results to NMFS' Permits and Conservation Division within 90 days of the completion of the Apache survey. The Technical Report will include:

(i) 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);

(ii) analyses of the effects of various factors influencing detectability of marine mammals (e.g., sea state, number of observers, and fog/glare);

(iii) 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;

(iv) 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.

(d) Submit a final report to the Chief, Permits and Conservation Division, Office of Protected Resources, NMFS, within 30 days after receiving comments from NMFS on the draft report. If NMFS decides that the draft report needs no comments, the draft report shall be considered to be the final report.

9. In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a manner prohibited by this Authorization, such as an injury (Level A harassment), serious injury or mortality (e.g., ship-strike, gear interaction, and/or entanglement), Apache shall immediately cease the specified activities and immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401 and/or by email to Jolie.Harrison@noaa.gov and Brian.D.Hopper@noaa.gov, and the Alaska Regional Stranding Coordinators (Aleria.Jensen@noaa.gov and Barabara.Mahoney@noaa.gov). The report must include the following information:

(a) time, date, and location (latitude/longitude) of the incident;
(b) the name and type of vessel involved;
(c) the vessel's speed during and leading up to the incident;
(d) description of the incident;
(e) status of all sound source use in the 24 hours preceding the incident;
(f) water depth;
(g) environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility);
(h) description of marine mammal observations in the 24 hours preceding the incident;
(i) species identification or description of the animal(s) involved;
(j) the fate of the animal(s); and
(k) photographs or video footage of the animal (if equipment is available).

Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS shall work with Apache to determine what is necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. Apache may not resume their activities until notified by NMFS via letter or email, or telephone.

In the event that Apache discovers an injured or dead marine mammal, and the lead PSO determines that the cause of the injury or death is unknown and the death is relatively recent (i.e., in less than a moderate state of decomposition as described in the next paragraph), Apache will immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401, and the NMFS Alaska Stranding Hotline (1-877-925-7773) and/or by email to the Alaska Regional Stranding Coordinators (Aleria.Jensen@noaa.gov and Barabara.Mahoney@noaa.gov). The report must include the same information identified in the Condition 9(a) above. Activities may continue while NMFS reviews the circumstances of the incident. NMFS will work with Apache to determine whether modifications in the activities are appropriate.

In the event that Apache discovers an injured or dead marine mammal, and the lead PSO determines that the injury or death is not associated with or related to the activities authorized in Condition 2 of this Authorization (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), Apache shall report the incident to the Acting Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, at 301-427-8401, and the NMFS Alaska Stranding Hotline (1-877-925-7773) and/or by email to the Alaska Regional Stranding Coordinators (Aleria.Jensen@noaa.gov and Barbara.Mahoney@noaa.gov), within 24 hours of the discovery. Apache shall provide photographs or video footage (if available) or other documentation of the stranded animal sighting to NMFS and the Marine Mammal Stranding Network.

10. Apache is required to comply with the Terms and Conditions of the ITS corresponding to NMFS's Biological Opinion issued to both U.S. Army Corps of Engineers and NMFS's Office of Protected Resources.

11. A copy of this Authorization and the ITS must be in the possession of all contractors and PSOs operating under the authority of this Incidental Harassment Authorization.

APR 30 2012

Helen M. Golde
Acting Director
Office of Protected Resources
National Marine Fisheries Service

Date

Attachment

Attachment

Table 1: Estimated Distances to Sound Thresholds (Apache will conduct a sound source verification study to determine the actual distances to these threshold zones)

Source	190 dB	180 dB	160 dB
Pinger	1 m	3 m	25 m
10 cui Air gun	10 m	33 m	330 m
440 cui Air gun	NA	NA	NA
2,400 cui air gun (nearshore)	0.51 km	1.42 km	6.41 km
2,400 cui air gun (offshore)	1.18 km	0.98 km	4.89 km

Table 2. Authorized Take Numbers for Each Marine Mammal Species in Cook Inlet.

Species	Authorized Take in the Cook Inlet Action Area
Odontocetes	
Beluga whale (*Delphinapterus leucas*)	30
Killer whale (*Orcinus orca*)	10
Harbor porpoise (*Phocoena phocoena*)	20
Pinnipeds	
Steller sea lion (*Eumetopias jubatus*)	20
Harbor seal (*Phoca vitulina richardsi*)	50

APPENDIX B
APACHE MARINE MAMMAL MONITORING PLAN

Marine Mammal Monitoring Plan

for
Alaska Apache Corporation
3D Seimic Program
Cook Inlet, Alaska

Prepared for
Alaska ApacheCorporation
2000 Post Oak Boulevard
Suite 100
Houston, TX 77056-4400

Prepared by

SAExploration, Inc.
8240 Sandlewood Place
Anchorage Alaska

AUGUST 2011

TABLE OF CONTENTS

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AMAR	Advanced Multichannel Acoustic Recorders
APACHE	APACHE Alaska Corporation
PAM	Passive Acoustic Monitoring
PSO	Protected Species Observer

1.0 MONITORING

APACHE Alaska Corporation's (APACHE) 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.

1.1 Visual Monitoring

1.1.1 Visual Boat-Based Monitoring

Three vessels will employ PSOs to identify marine mammals during all daytime hours of air gun 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. When marine mammals are about to enter or are sighted within designated safety zones, air gun 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 air gun 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).

With NMFS consultation, PSOs will be hired by APACHE. 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 4 hours with 2 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 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 reticle 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.

All observations 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 (air gun 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.

1.1.2 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 on scaffolding with big-eye binoculars. The PSO would scan the area prior to, during, and after the air gun 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.

1.1.3 Aerial-Based Monitoring

When practicable, APACHE proposes to utilize the crew helicopter to conduct aerial surveys near river mouths prior to the commencement of operations in order to identify locations of congregations of beluga whales. The helicopter will not be used every day, but will be used when operating near a river mouth. The types of helicopters currently planned to be used by APACHE include a Bell 407, Bell UH1B, and ASB3. Aerial surveys will fly at an altitude of 305 m (1,000 ft) when practical and weather conditions permit. 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; Blackwell et al. 2002).

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

- The basis for real-time mitigation (air gun power down, shut 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. When practicable, APACHE proposes to utilize the crew helicopter to conduct aerial surveys of areas near river mouths prior to the commencement of operations. These surveys will assist in the identification of congregations of beluga whales.

1.2 Acoustic Monitoring

In order to further enhance detection of cetaceans, APACHE proposes to utilize passive acoustic monitoring (PAM). The actual PAM system has not yet been identified, but APACHE anticipates utilizing the same system as used in the 2D test program in March, 2011 in Cook Inlet.

APACHE assumes that because a detailed sound source verification (SSV) was conducted as part of the 2D technology test in March 2011 that further SSV will not be required. APACHE will work with NMFS if an SSV is deemed necessary.

1.2.1 Fixed PAM Stations

The fixed system may include two JASCO Advanced Multichannel Acoustic Recorders (AMAR) systems deployed in surface buoys on anchored moorings. The AMARs will send real-time acoustic data via digital UHF radio-broadcast systems to the PAM operators aboard the *M/V Dreamcatcher* (one on each vessel). The PAM operators will use specialized real-time detection software and audio playback to detect marine mammal sounds. If the PAM operators detect marine mammals, APACHE will initiate a temporary shut-down of air gun systems to avoid takes. Restarting of the air gun systems would occur as defined in Incidental Harassment Authorization.

Proposed Locations

Based on results of the test program, these buoys are not deployable when there is ice present. However, the buoys were operational when anchored on the crew boat (*M/V Dreamcatcher)* and signals of beluga whales were detectable up to 8 km. Therefore, if ice conditions allow, the PAM systems will be located inside the exclusion zone boundary in both the up-inlet and down-inlet directions. The boundaries are predicted to occur at between 4,400 m and 5,700 m from the sources, depending on airgun array configuration. Detection ranges for beluga whales are nominally a maximum of 2 km for whistles and 500 m for clicks, although much greater ranges for whistle detections have been achieved with AMARs (>8 km in the Cook Inlet in the spring test program). We propose to locate the PAM moorings in the middle of the inlet at 1 km inside the exclusion zone boundaries both east and west of the survey sites. This approach will be able to detect whistles from animals just entering the exclusion zone and well into the zone. It has the added benefit of providing coverage closer to the air gun sources to identify animals that may have eluded visual observers near the boundary. Prior to the start of the test program, APACHE and JASCO will work to identify the best location for the fixed PAMs to allow for monitoring of the safety zone.

If there is ice present, the PAM system will be deployed from the *M/V Dreamcatcher*.

Acoustic Systems and Frequencies

We will deploy JASCO's AMAR-G2 digital acoustic recording/streaming systems (Figure 1). The AMARs will be set to digitally sample at 100 kHz (depending on quality of radio link at the site) with 24-bit samples, in order to capture both whistles and clicks. These sample rates capture acoustic frequencies up to 16 and 32 kHz respectively. Killer whale calls occur primarily between 400 Hz and 15 kHz. Beluga whistles occur primarily between 3 kHz and 11 kHz. Clicks for both species occur primarily in the 10 kHz to 50 kHz band. Both sample rates will effectively capture the full range of call and whistle frequencies but the higher 64 kHz sample rate is required to capture the significant bandwidth of clicks. Calls and whistles are detectable to larger ranges so are the more important signal of interest here. However, only clicks may be present while the animals are feeding. Belugas may not vocalize when killer whales are present to avoid detection.

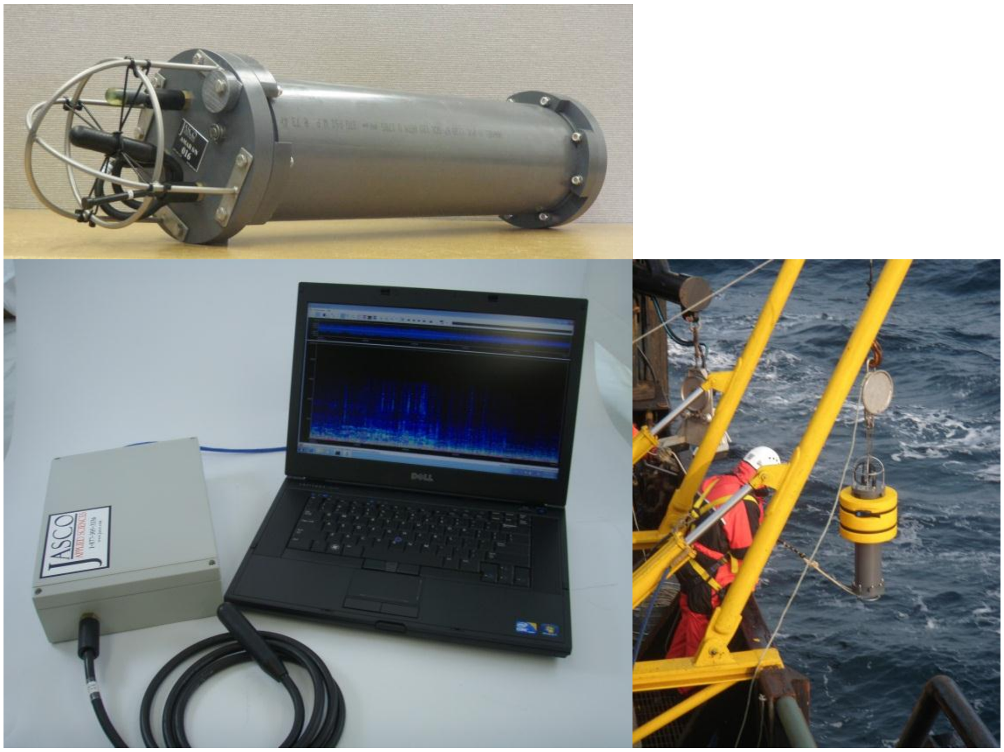


Figure 1: AMAR Recorders. In pressure case (top and right) and in deck box (left-bottom)

Radio Telemetry Acoustic Buoys

The AMAR deck box units (Figure 1, bottom left) with batteries will be mounted in surface-buoys that also support the radio telemetry systems. The buoys gave 12-ft masts on which the telemetry antennas are mounted. These buoys are highly visible so will reduce the risk of collision by support vessels working nearby.

The radio telemetry system provides high-bandwidth TCP-IP connectivity direct to the AMAR recorder from a base station located on nearby vessels. The AMAR has built in ability to stream data through the radio's TCP-IP channels. The buoy's radio system will be a 5 GHz 1000 mW 802.11b/g/N extended range outdoor TCP/IP link. The radio telemetry system includes LS5 transmitting radios (Figure 2, left) with whip-style antennas on the buoys. AirMax base stations (Figure 2, right) will be mounted on the work boats where the PAM operators will work. The LS5 radio is designed for multi-kilometer marine telemetry links. The present application will use shorter distances so very good performance is expected even in poor weather conditions.

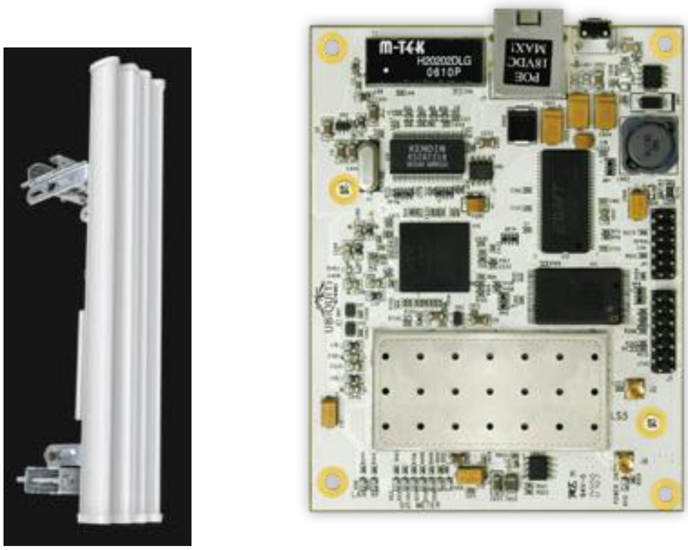


Figure 2: Radio system base station (built into antenna at left) and buoy radio transmitter at right. A co-linear array whip antenna will be mounted on a standard seismic streamer tail-buoy and connected to the transmitter which will be housed in a small pressure case at the buoy.

Real-Time Data Display and Logging

Acoustic data received at the buoys will be streamed back to the work boats over the radio. These data will be directly displayed in a scrolling spectrogram format and audio played out to a speaker and headphone system using JASCO's standard SpectroPlotter software (Figure 3). The software also logs data to acoustic files in PCM WAV format. We will log all recorded data for possible post-processing (not included in this application).

SpectroPlotter will run on ruggedized field laptop computers connected directly to the radio-link system. The PAM operators will utilize the displays to assist in detections of beluga and killer whale sounds.

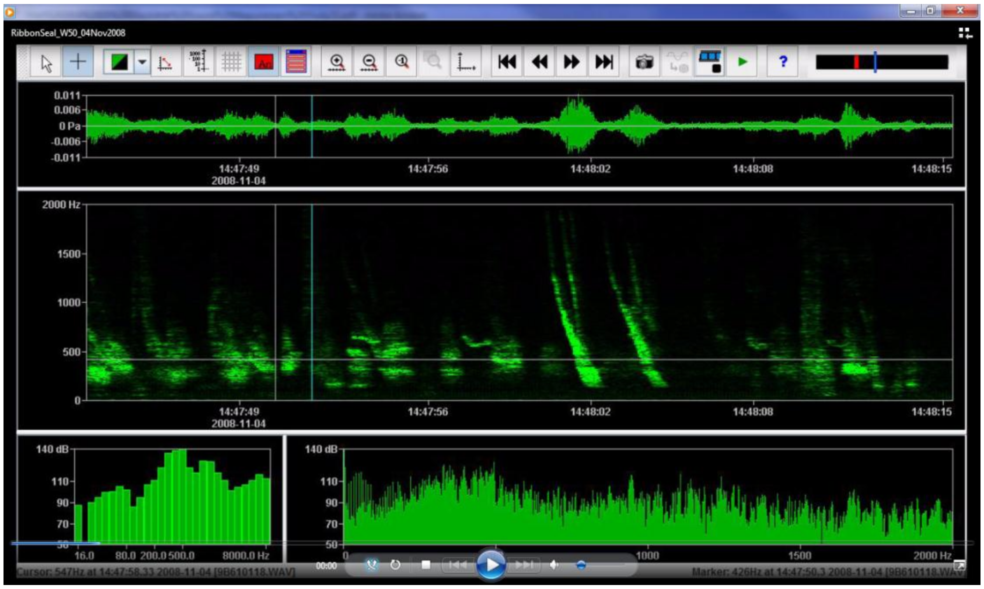


Figure 3: SpectroPlotter display window. Spectrogram scrolls as sound is received and played back through audio system. This software also logs data to files for possible post-processing.

Data Analysis

Only real-time analysis is proposed here, but all data will be recorded for possible post-processing. Post processing is not included in this proposal but can be discussed as an add-on. The real-time analysis will consist of:

a. Audio playback of real-time acoustic data on the work boats.
b. Real-time display of spectrogram and current sound levels.
c. PAM operator to log anthropogenic (man-made) noise events other than seismic survey sounds.
d. PAM operator to log start and stop times for air gun activity (only start and stop times for shot sequences).
e. PAM operator to log all marine mammal sound detections. All detections occurring during seismic shooting will be red-flagged and immediate notifications sent to the survey operators to initiate shut-downs.
f. Logging acoustic data to files containing 30 minutes of data.

Limitations

Acoustic monitoring for detecting marine mammals has limitations. First, it requires that the animals produce sounds, and second it requires those sounds to be of sufficient amplitude to be detected at the monitoring location. Sounds produced by marine mammals will decrease in amplitude with distance from the animal. Detection of sounds at the monitoring stations requires that the received levels of the biological sounds exceed background noise and other measurement noise. Background noise originates from waves, rain and from other vessels operating in the inlet. Measurement noise will include water flow noise at the hydrophone and low level electronic noise. Flow noise could be significant for this study due to high tidal currents in Cook Inlet. Flow noise is a significant issue for masking low frequency sounds from mysticetes. It will be less of a problem for detecting beluga and killer whale calls that occur at higher frequencies (most above 1 kHz). We also understand that seismic survey activity will be limited to times close to tide changes, when currents are small. Still flow noise likely will be the dominant measurement noise source. We estimate that the maximum detection range for belugas and killer whales will be 2-3 km for this study.

2.0 MITIGATION MEASURES

2.1 Proposed Safety Radii

In order to avoid any takes by injury (Level A), APACHE proposes to shut down air guns 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 (5 or greater) approach. APACHE proposes to shut down if a group of more than five beluga whales 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.

The methods discussed in Section 2.4.3 of the Biological Assessment for positioning the receivers includes introduction of sound into the water. JASCO has also calculated the distances to the 190, 180, and 160 dB received sound levels for these sources. The distances for the single 10 cui air gun were estimated using the results of a field validation test performed for a shallow hazard program for Shell's 2007 Beechy Point program in the Alaskan Beaufort Sea (Funk et al. 2008). This site is unusually conducive to sound propagation and consequently the measurements presented in Table 1 below are likely conservative for use in the Cook Inlet.

As described in Section 2.4.3, 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 160 dB isopleth would be 25 m (see Table 1). 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).

Received sound levels for determining safety zones were obtained from the results of a field validation test conducted by JASCO for a seismic program in Cook Inlet for ConocoPhillips in 2007 for the larger airgun configurations. JASCO carried out acoustic measurements of an 810 cui airgun array as a function of distance from the source for ConocoPhillips's 2007 Beluga 3D Seismic Shoot survey program, as well as for the 2010 APACHE test program.

Distances to the 190, 180, and 160 dB with the various airgun configurations and pingers were estimated. These estimates are provided in Table 1.

Table 1. Summary of Distance to NMFS Sound Level Thresholds.

Source	190 dB	180 dB	160 dB
Pinger	1 m	3 m	25 m
10 cui airgun	10 m	33 m	330 m
2,400 cui airgun (nearshore)	0.51k m	1.42 km	6.41 km
2,400 cui airgun (offshore)	1.18 km	0.98 km	4.89 km

APACHE proposes to monitor these zones for beluga whales before, during, and after the operation of the offshore airguns and pingers. Monitoring will be conducted using qualified PSOs on three vessels and a boat-based and fixed real-time passive acoustic monitoring (PAM).

2.2 Power Down Procedure

A power down procedure involves reducing the number of air guns in use such that the radius of the 180 dB (or 190 dB) zone is decreased to the extent that marine mammals are not in the safety zone. In contrast, a shut down procedure occurs when all air gun activity is suspended. During a power down, a mitigation air gun, typically the 10 cui is operated. Operation of the mitigation gun allows the safety radii to decrease to 10 m, 33 m, and 330 m 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 air guns 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 safety zone when first detected, the air guns 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 safety zone when first detected, the air guns will be shut down immediately.

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

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

2.3 Shut-Down Procedure

As noted previously, a shut-down occurs when all air gun activity is suspended. The operating air gun (s) and/or pinger will be shut down completely if a marine mammal approaches the applicable injury safety zone. The shutdown 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 safety zone.

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

- Is visually observed to have left the safety zone;
- Has not been seen within the zone for 15 min in the case of pinnipeds or harbor porpoise;
- Has not been seen within the zone for 30 min in the case of cetaceans.

2.4 Ramp Up Procedure

A “ramp up” procedure gradually increases air gun volume at a specified rate. Ramp up is used at the start of air gun operations, including a power down, shut down, and after any period greater than 10 minutes in duration without air gun operations. the air gun array begins operating after a specified-duration period without air gun 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 air gun array configurations. During the ramp up, the safety zone for the full air gun 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 air guns will not be initiated if a marine mammal is sighted within or near the applicable safety radii at any time.

2.5 Speed or Course Alteration

If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, 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 air gun(s).

3.0 REPORTING

A report will be submitted to NMFS within 90 days after the end of the project. The report will describe the operations that were conducted and the marine mammals that were observed. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report will summarize the dates and locations of seismic operations, and all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities, marine mammal behavior and any observed behavioral changes).

APPENDIX C
JASCO ACOUSTIC REPORTS

APPENDIX C-1
LAND-BASED EXPLOSIVES SOUND SOURCE VERIFICATION REPORT

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.

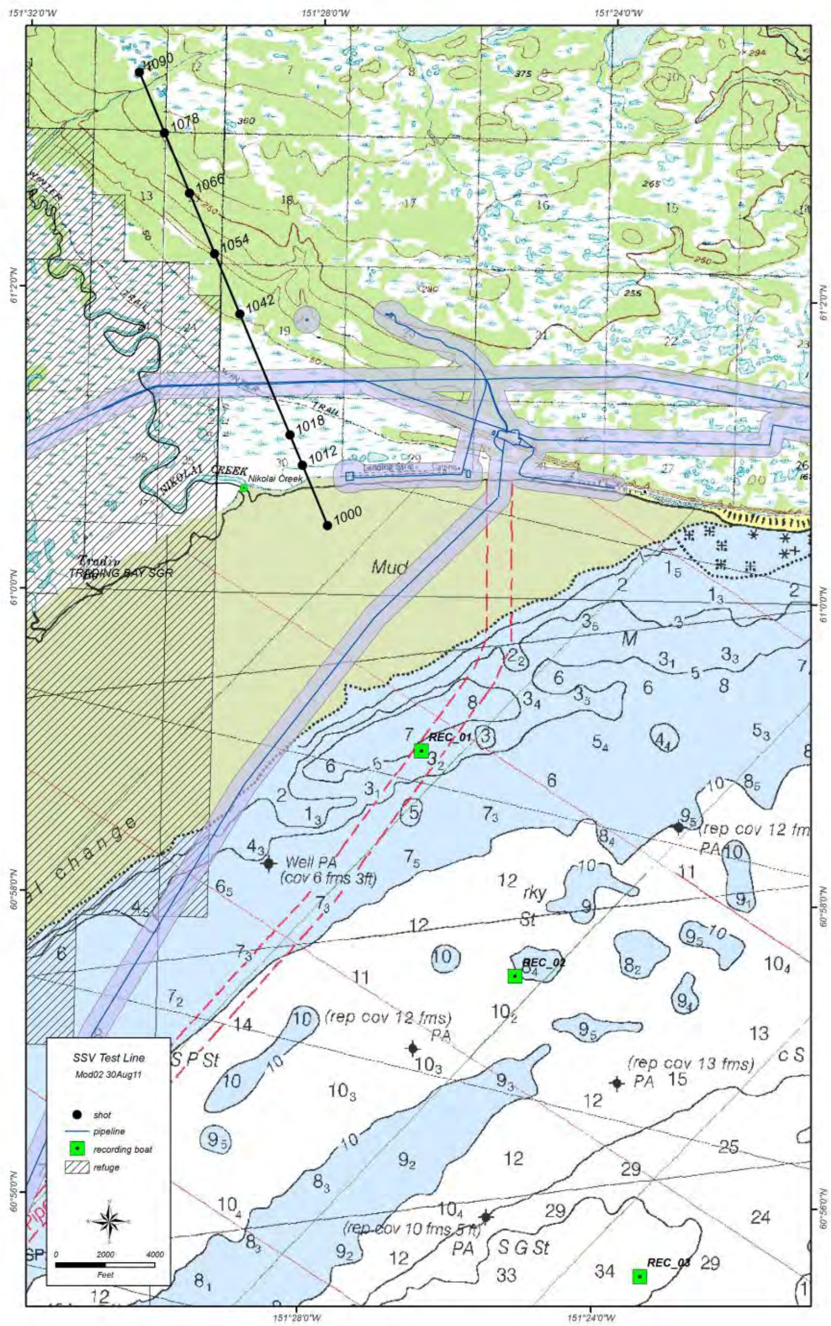


Figure 1. SSV test shothole location and OBH locations.

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).

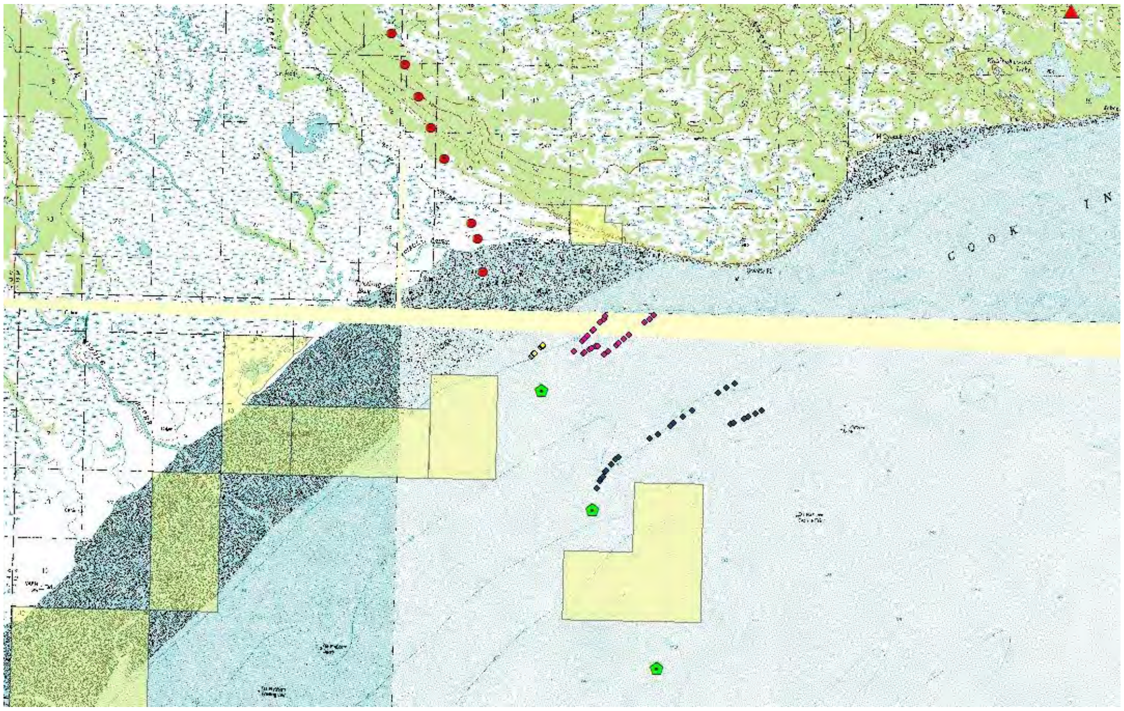


Figure 3. Locations of vessels during shothole detonations.
Yellow is zodiac with particle sensor, pink is *M/V Peregrine Falcon*, and gray is *M/V Maxime*.

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.

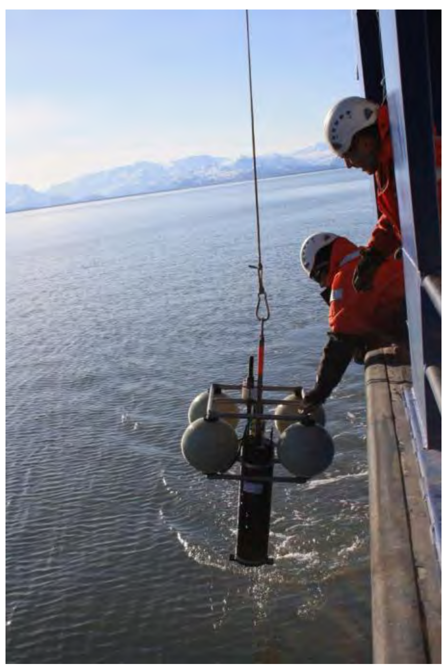


Figure 5. Deployment of OBH in Cook Inlet.

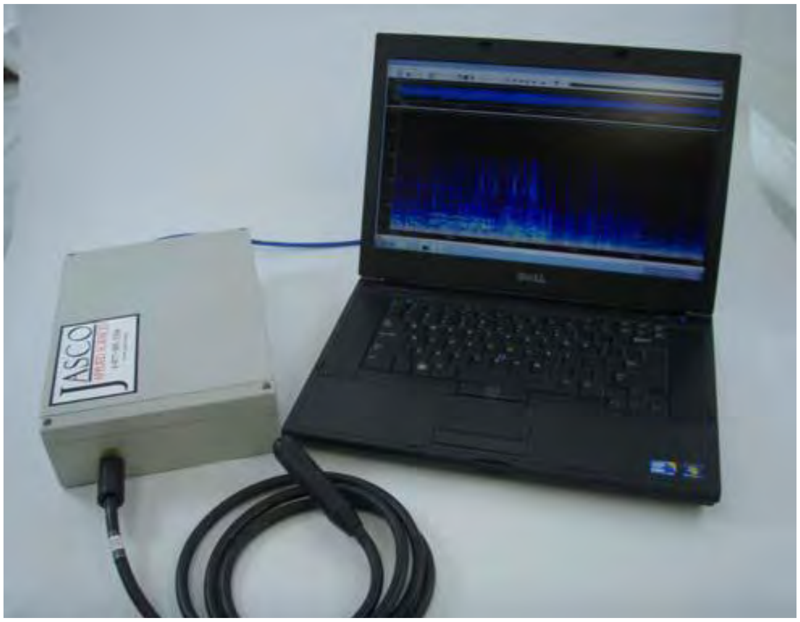


Figure 6. JASCO ADAMs digital acoustic monitoring system and SpectroPlotter real-time monitoring/logging software

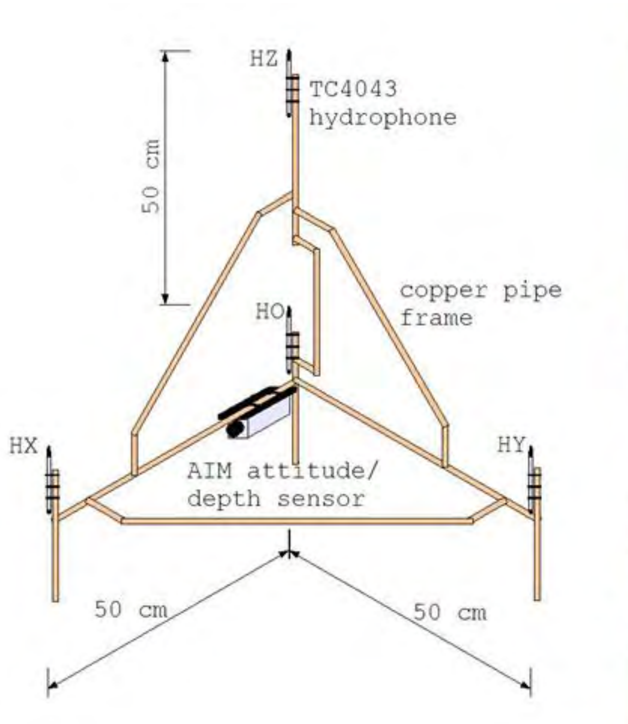


Figure 7. Four-hydrophone arrangement for particle velocity measurements using pressure gradient method.

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

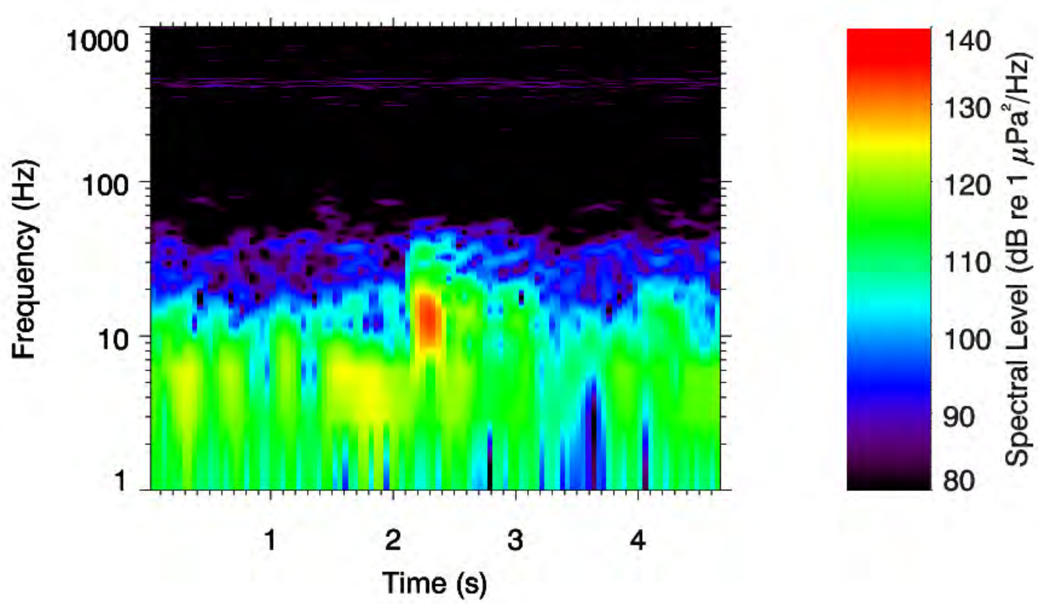


Figure 9. Spectrogram plot of land explosion shot ID number 9 on OBH at 3022 m receiver range

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)

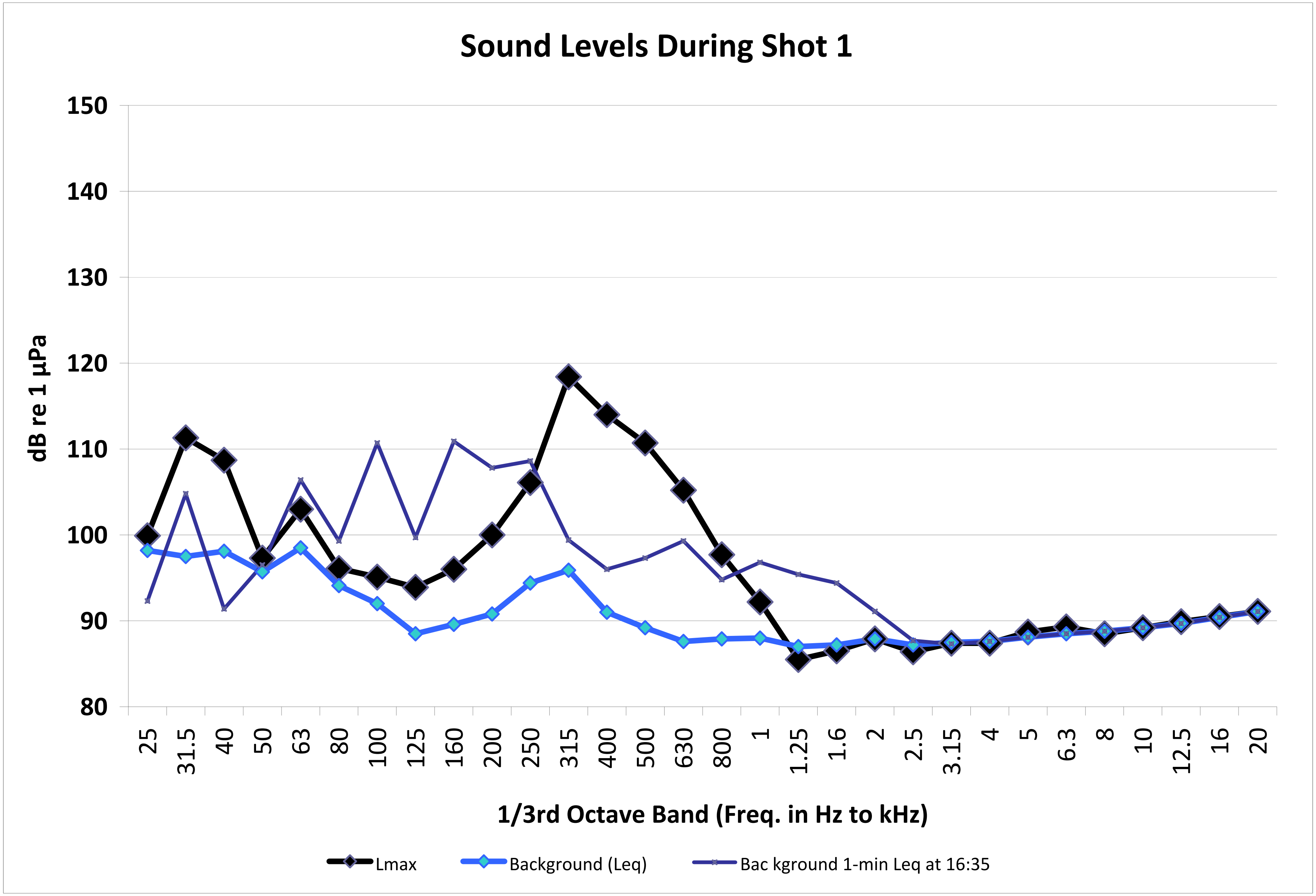
Type	SP	Lat (WGS-84)	Long (WGS-84)	Month#	Day#	Year	Hour	Min	Sec	Comment	Symbol#	SymbolColor	SymbolDisplay	Altitude (Meters)	Depth (Meters)	Temp Deg C	Ref Dist	Ref units
T	1000, 2 kg, 25'	60.99128891	-151.4275184	9	18	2011	0	54	25	-9.47583	1.00E+25	1.00E+25	M	4.3694	115.311	33279454.9	0.873877	5
T	1012, 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

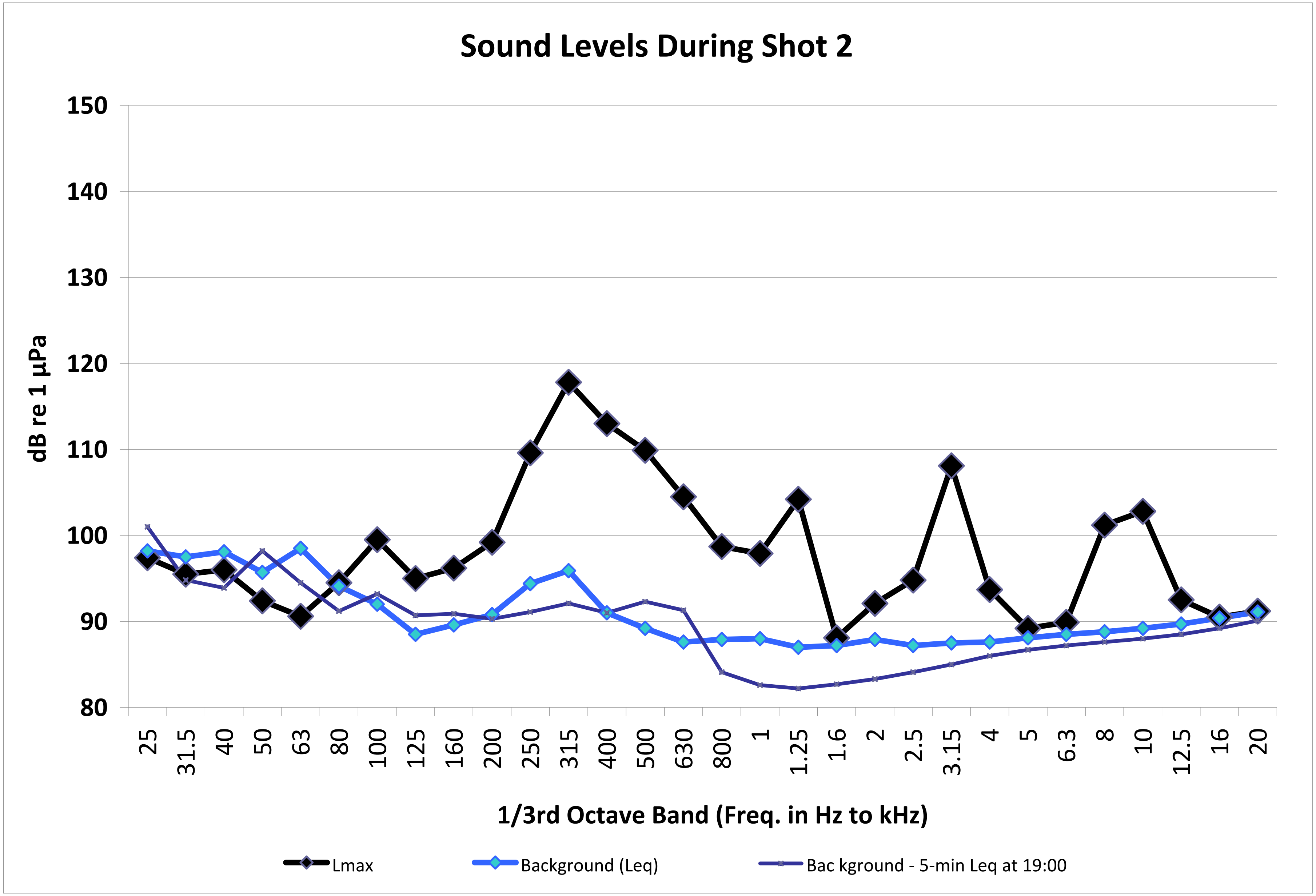
Appendix A
Apache Alaska Corporation
Land-Based Explosives SSV
Sept 17, 2011
M/V Maxime Measurements (6 km)

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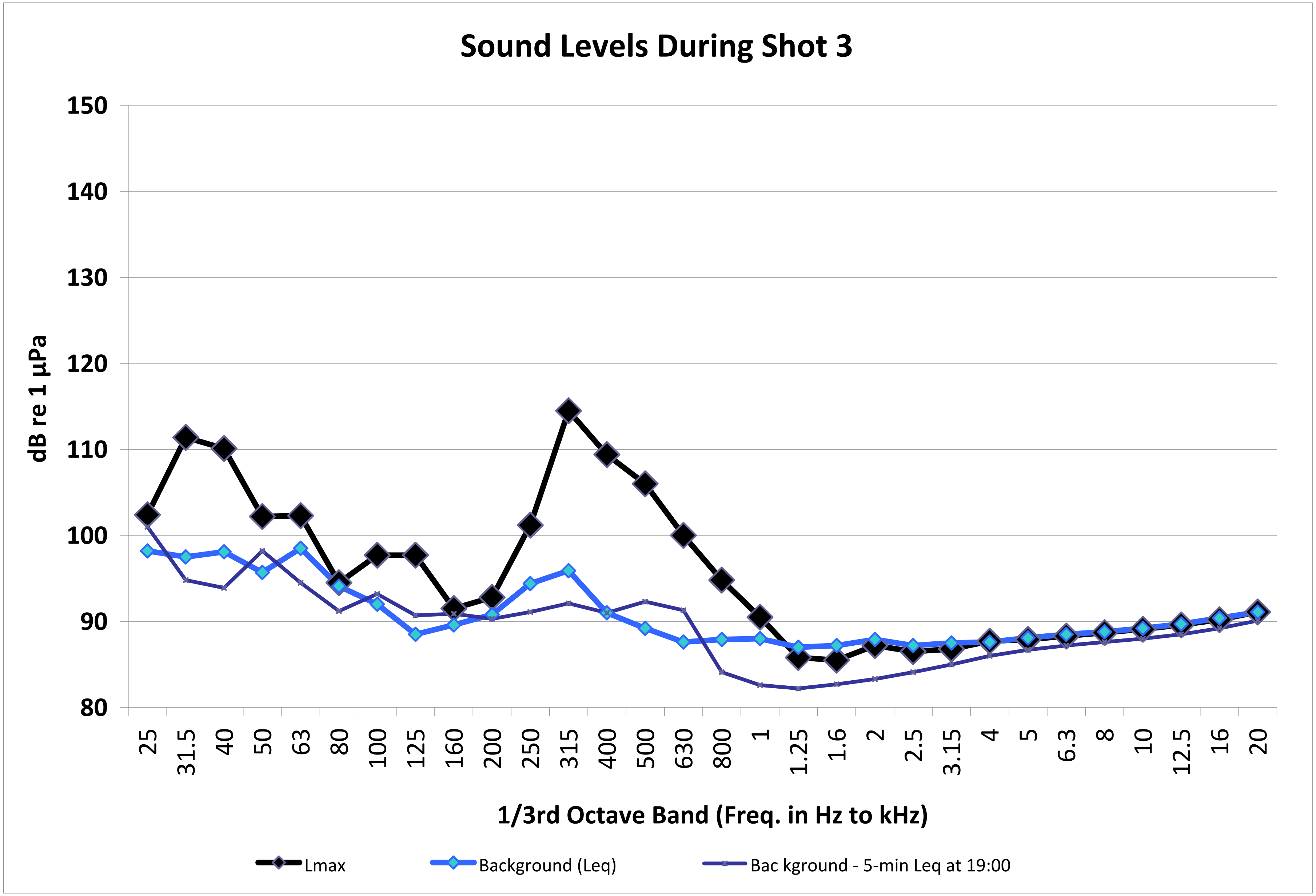
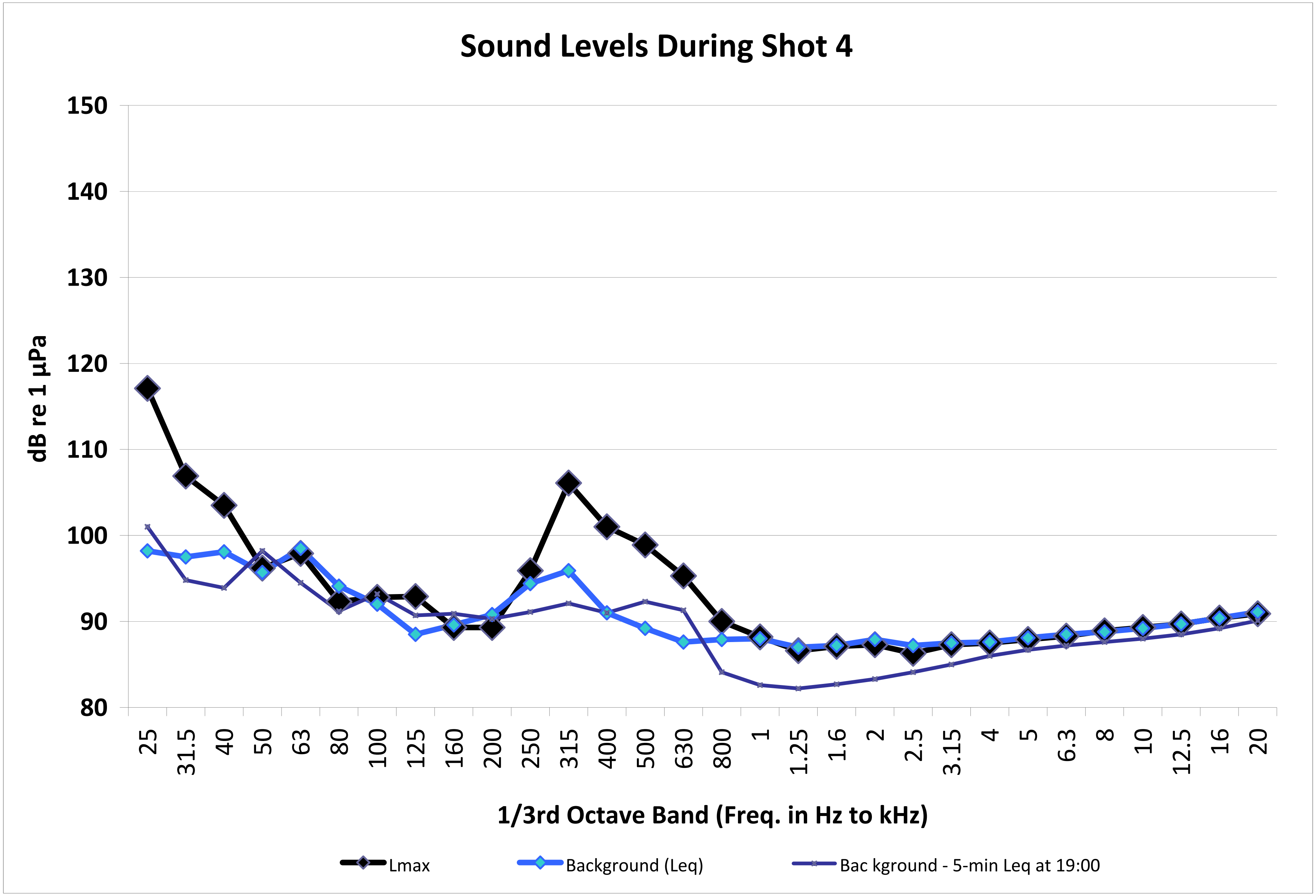
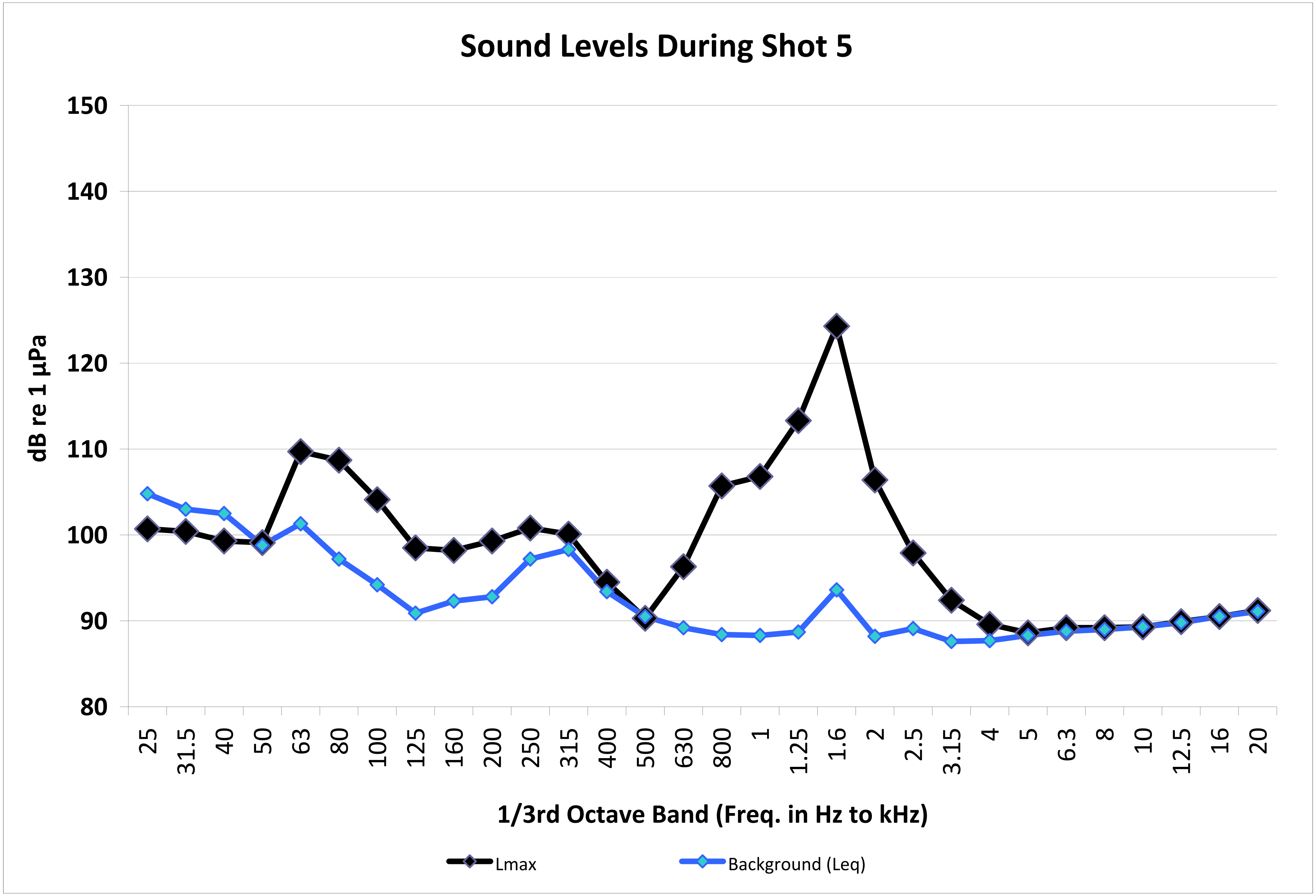
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00



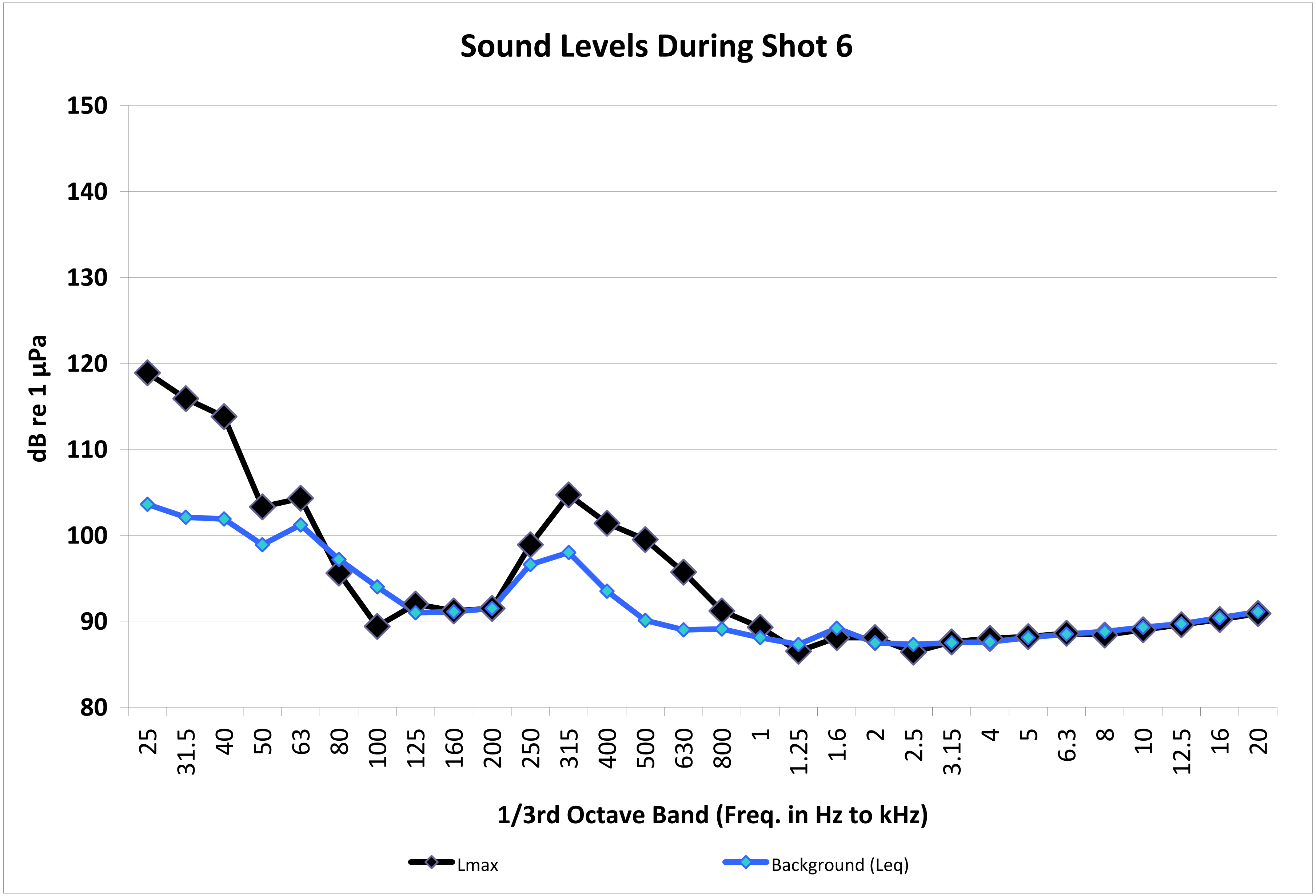
Sound Levels During Shot 3
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00

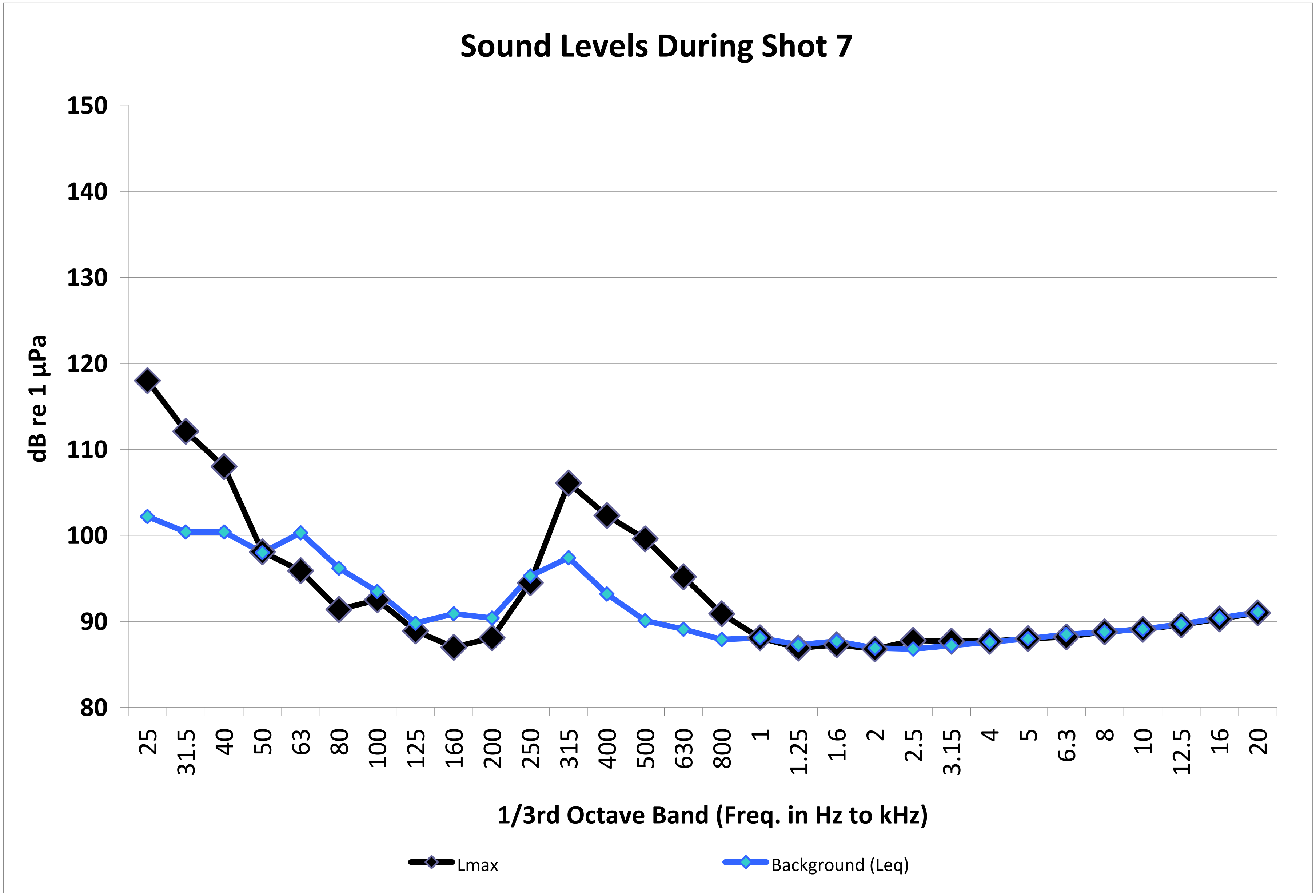


Sound Levels During Shot 4
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)
Bac kground - 5-min Leq at 19:00

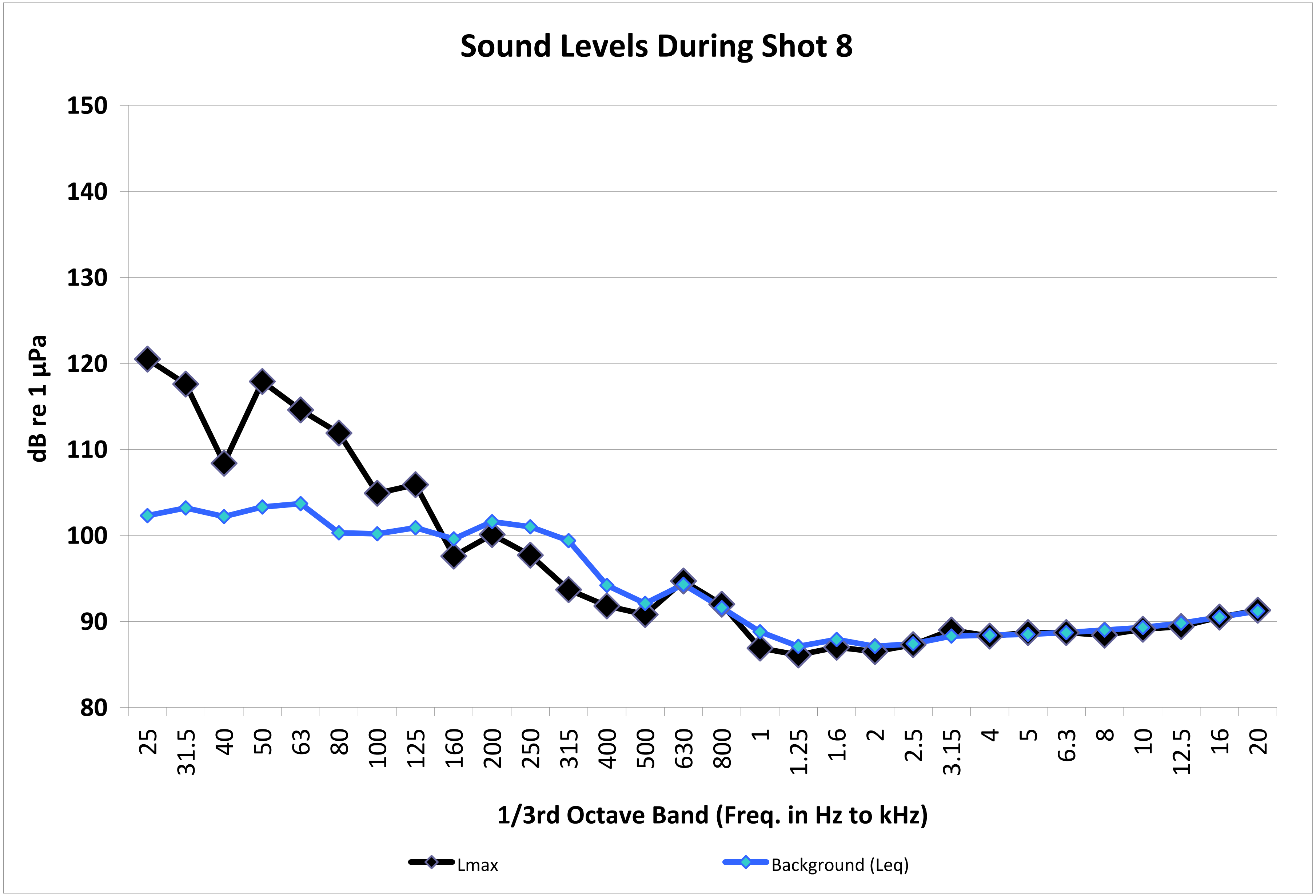


Sound Levels During Shot 5
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)

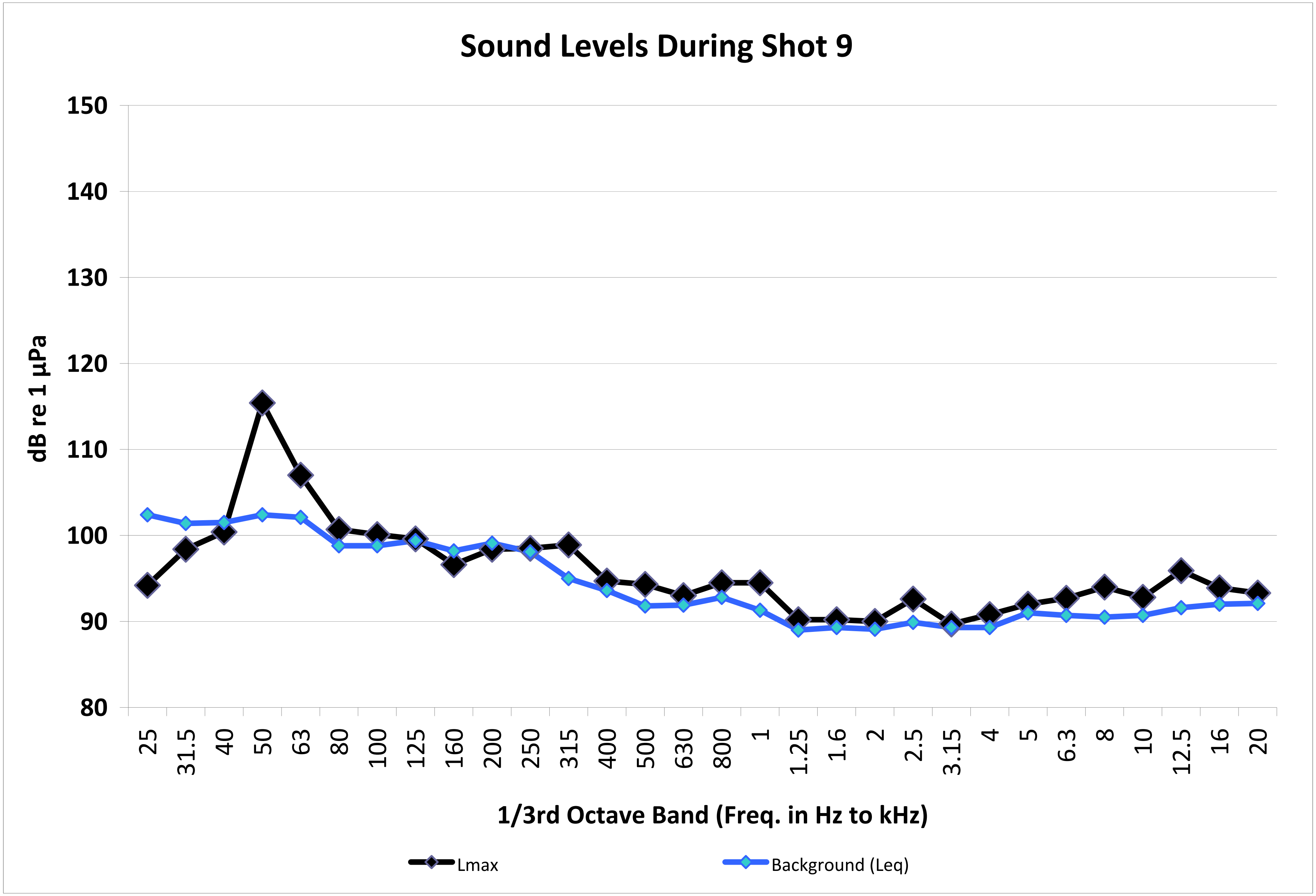

Sound Levels During Shot 6
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



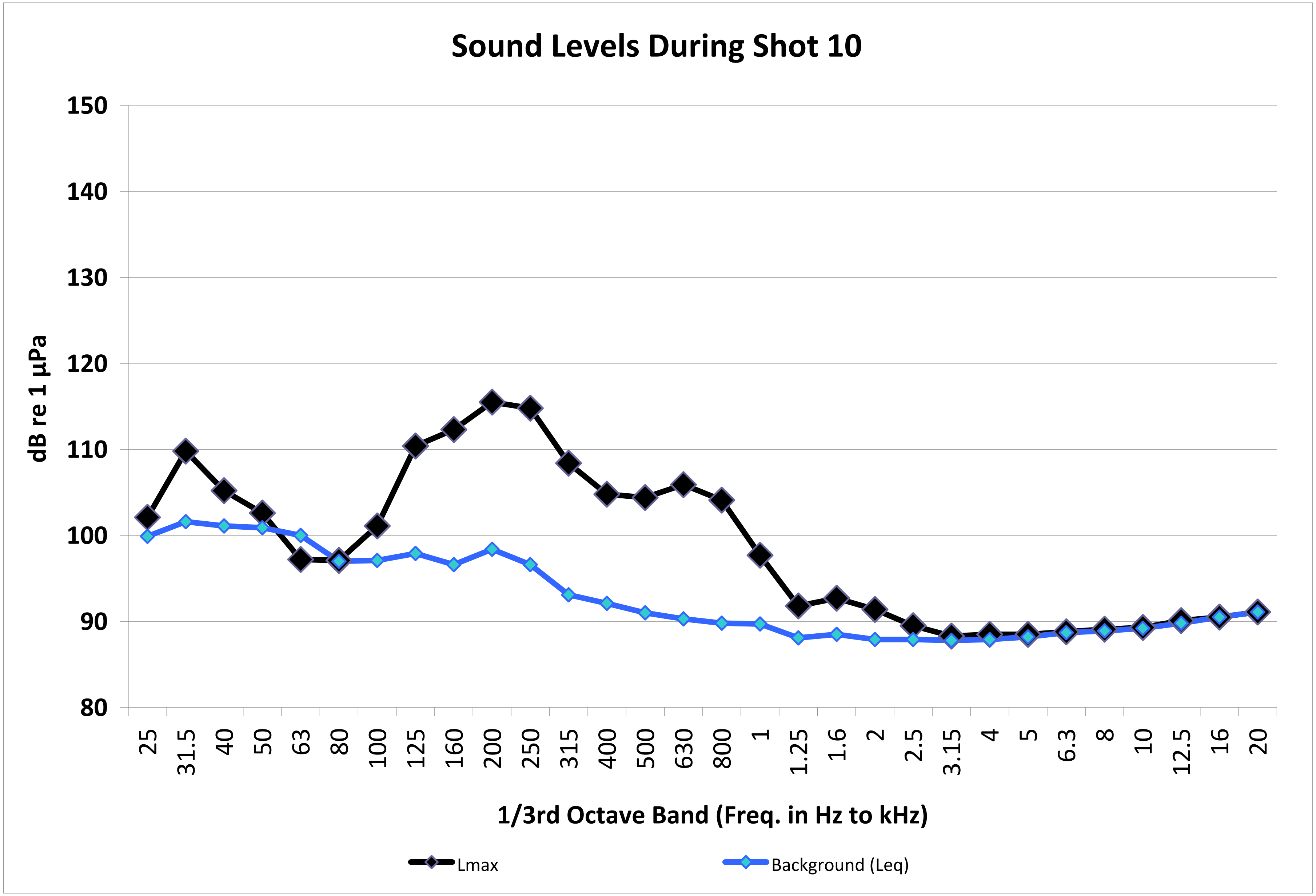
Sound Levels During Shot 7
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



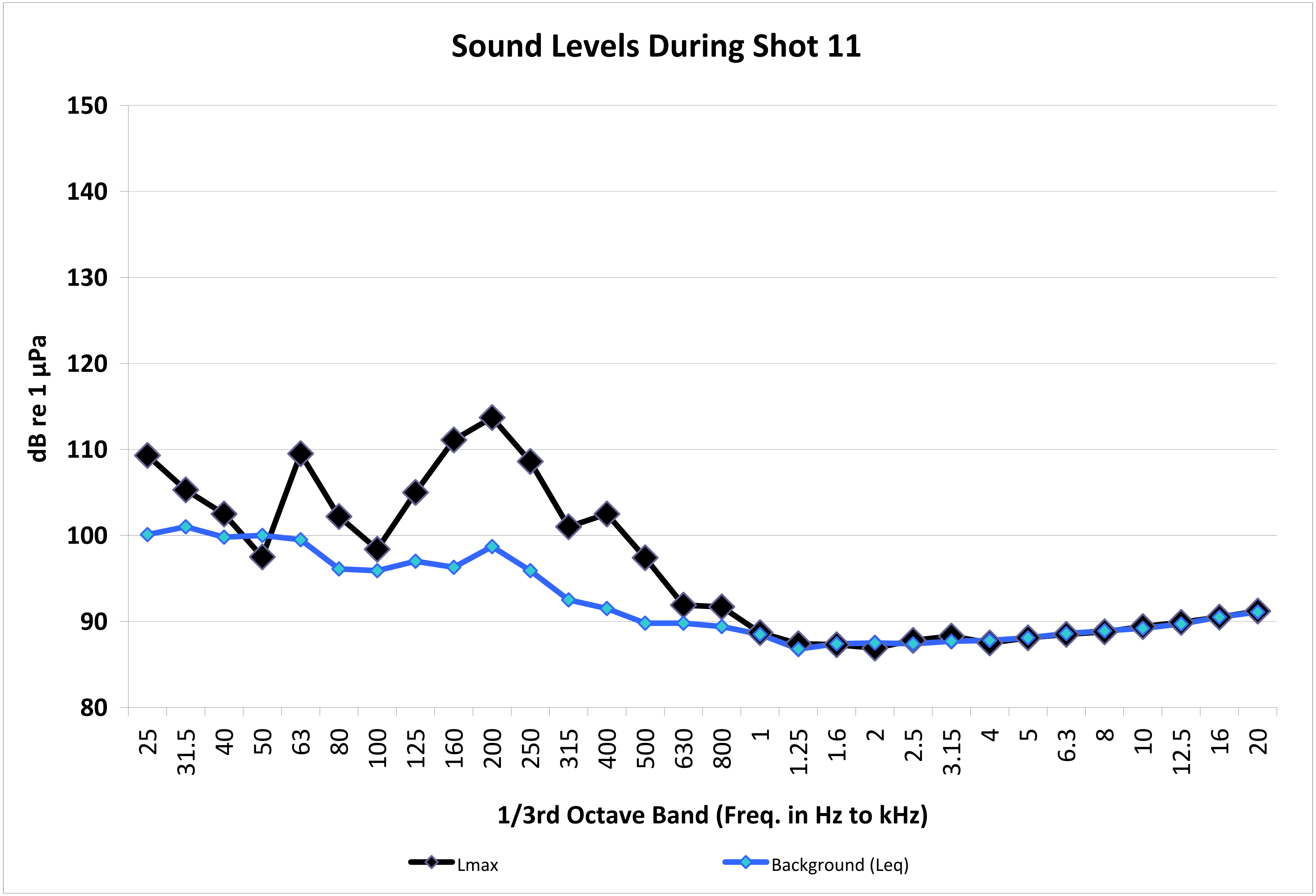
Sound Levels During Shot 8
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



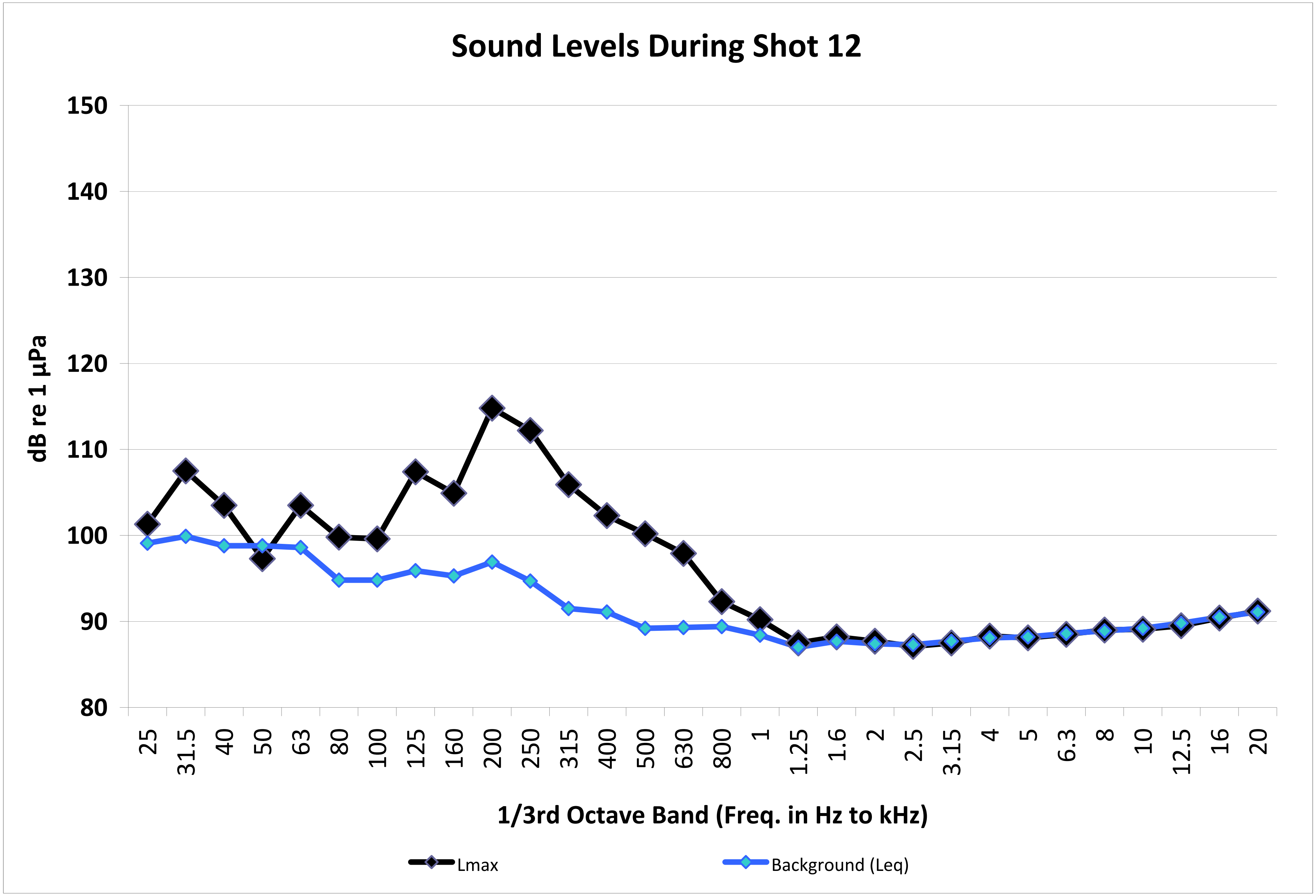
Sound Levels During Shot 9
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



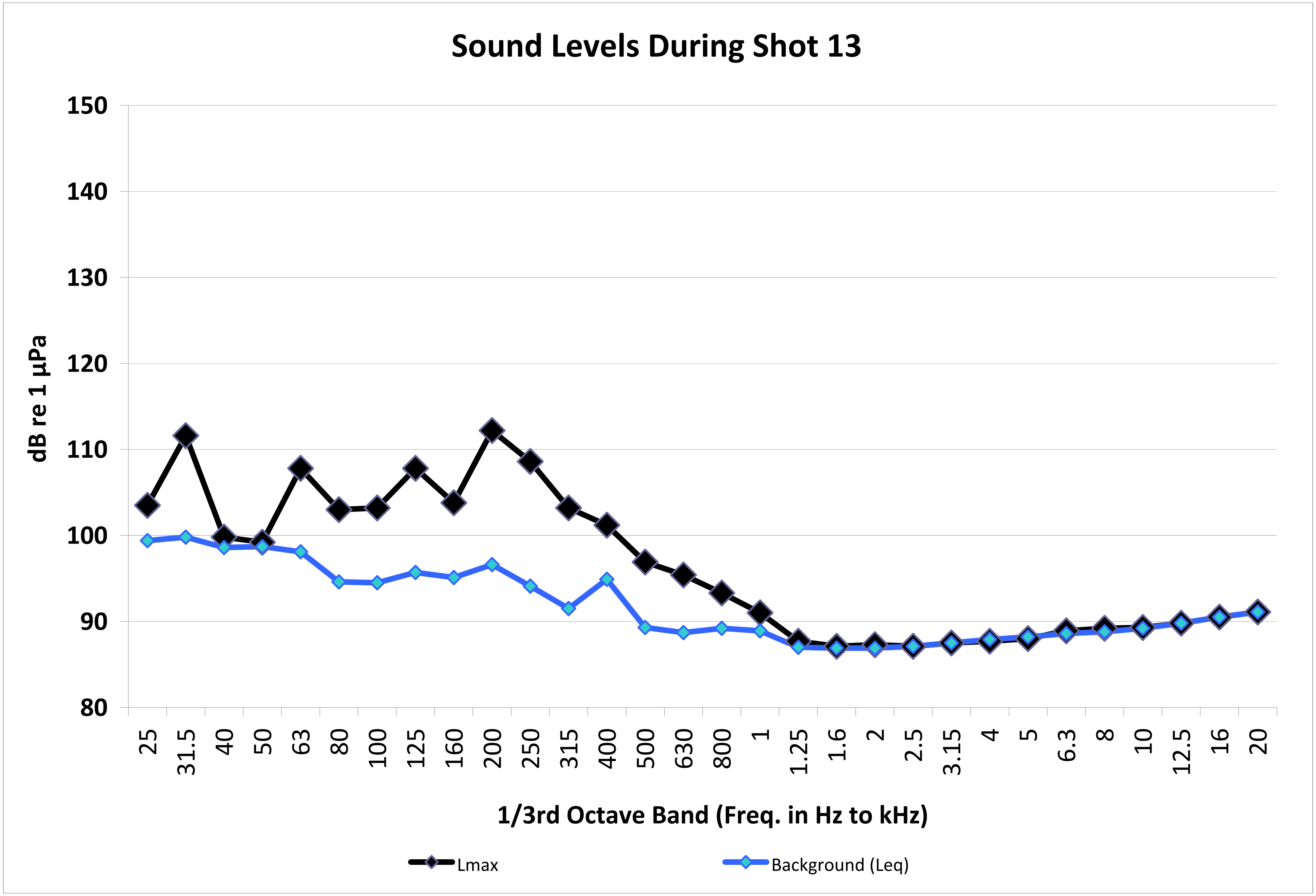
Sound Levels During Shot 10
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



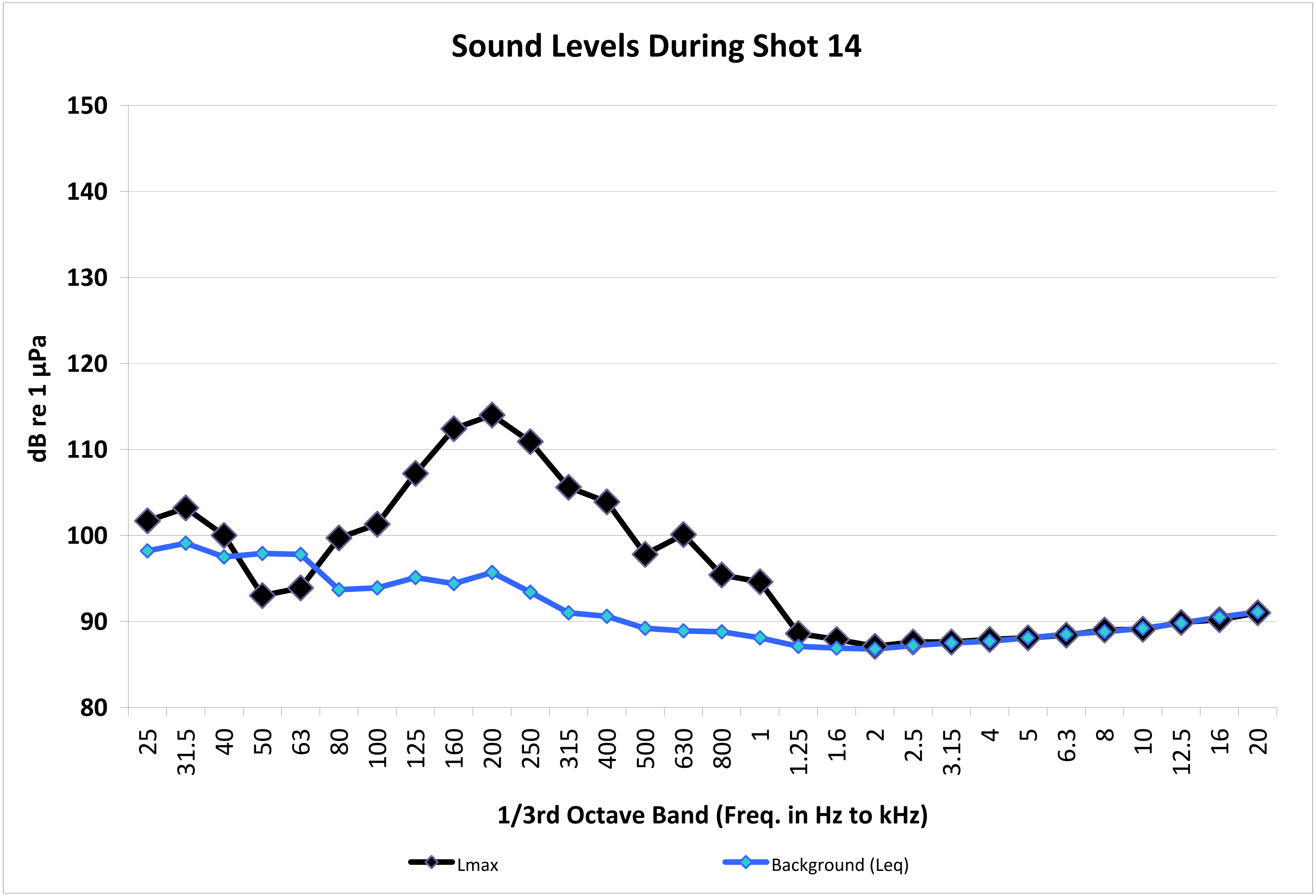
Sound Levels During Shot 11
150
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



Sound Levels During Shot 12
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 13
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 14
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120
110
100
90
80
dB re 1 µPa
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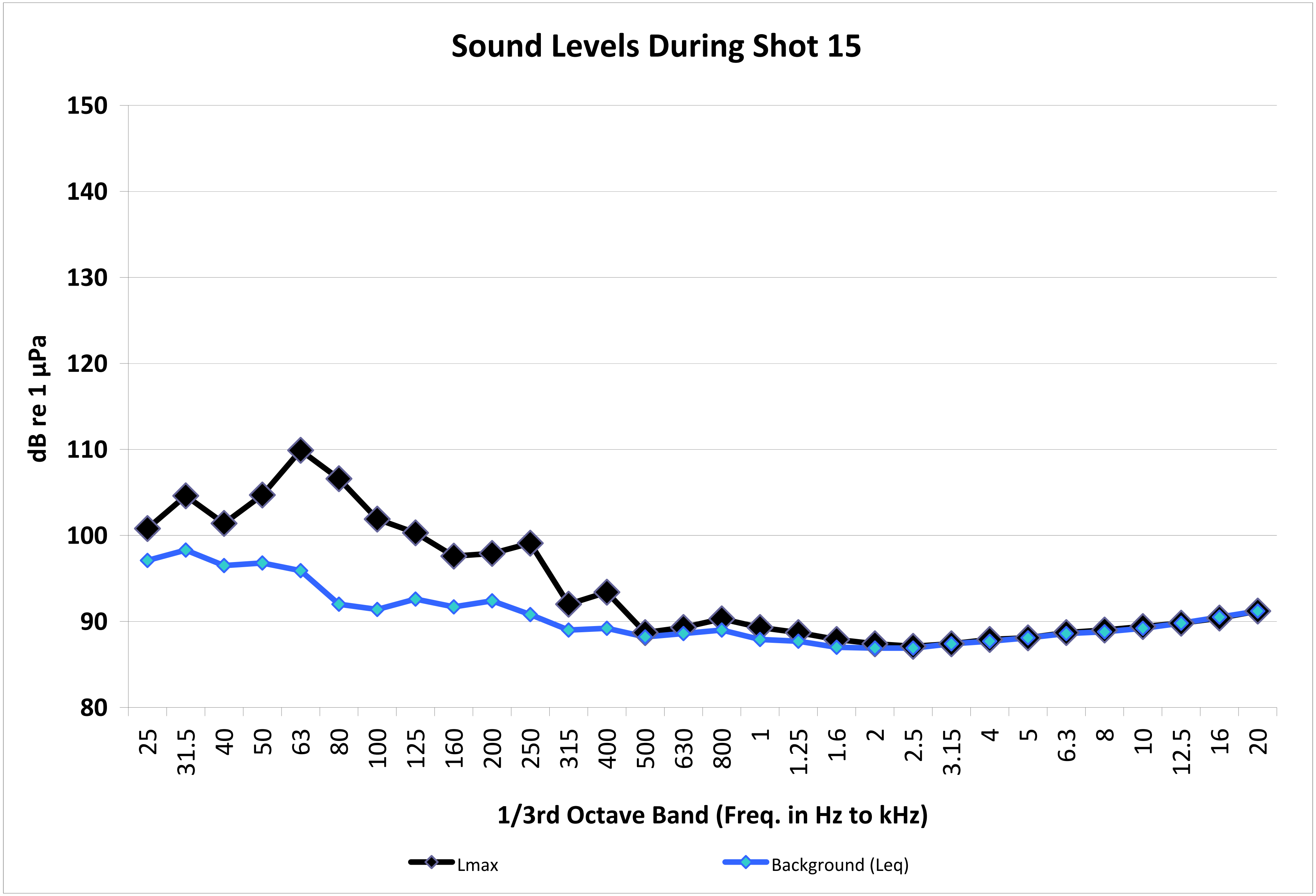
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 15
dB re 1 µPa
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140
130
120
110
100
90
80
25
31.5
40
50
63
80
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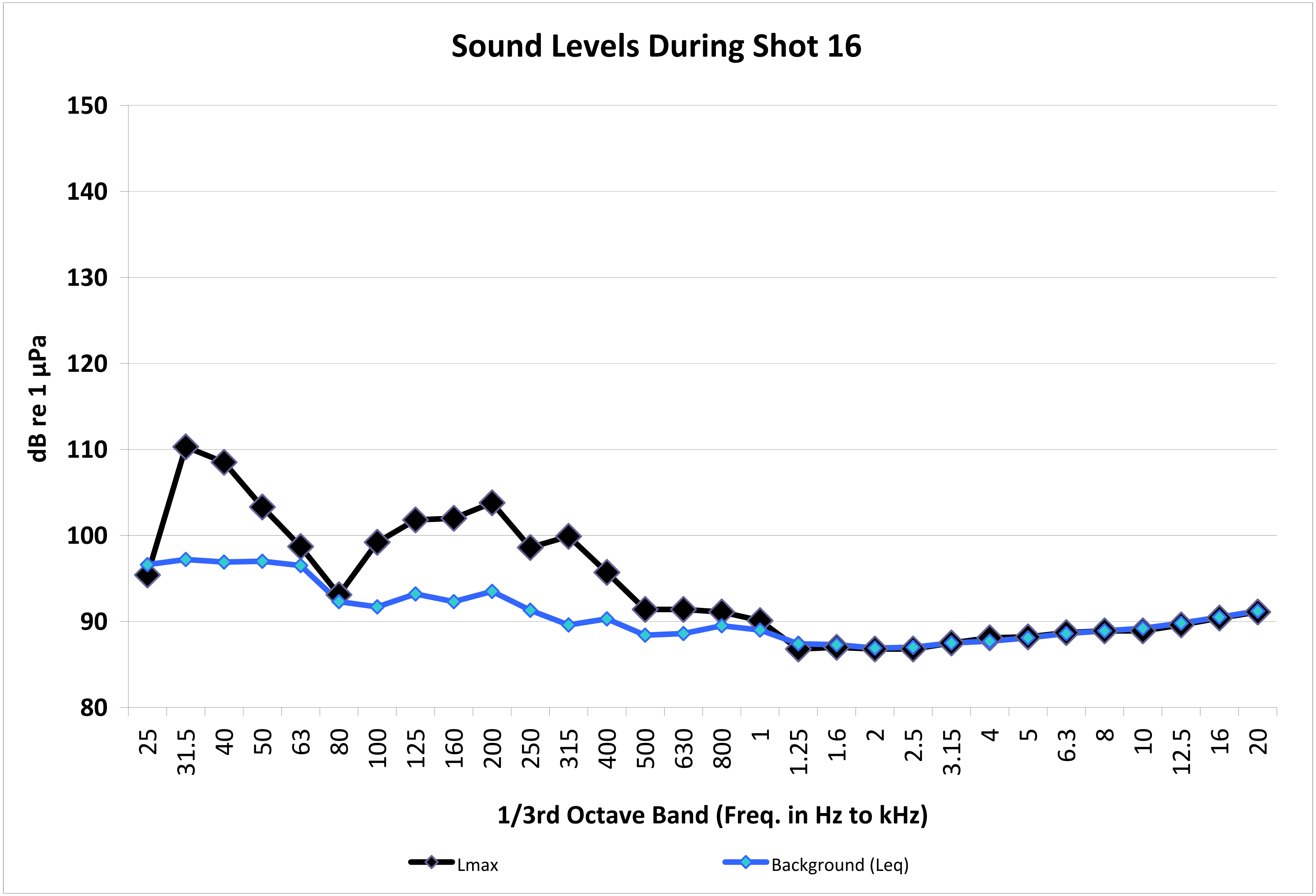
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



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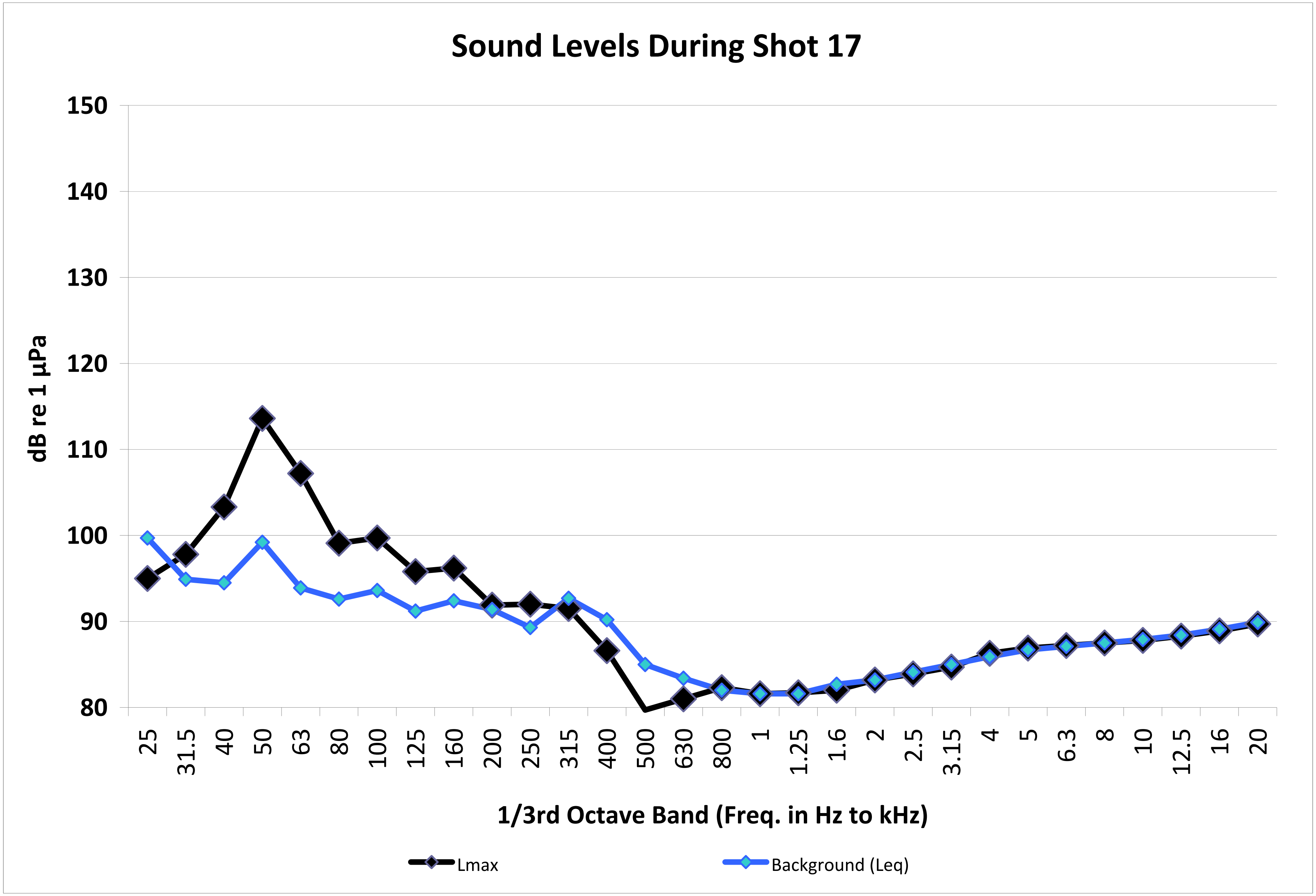
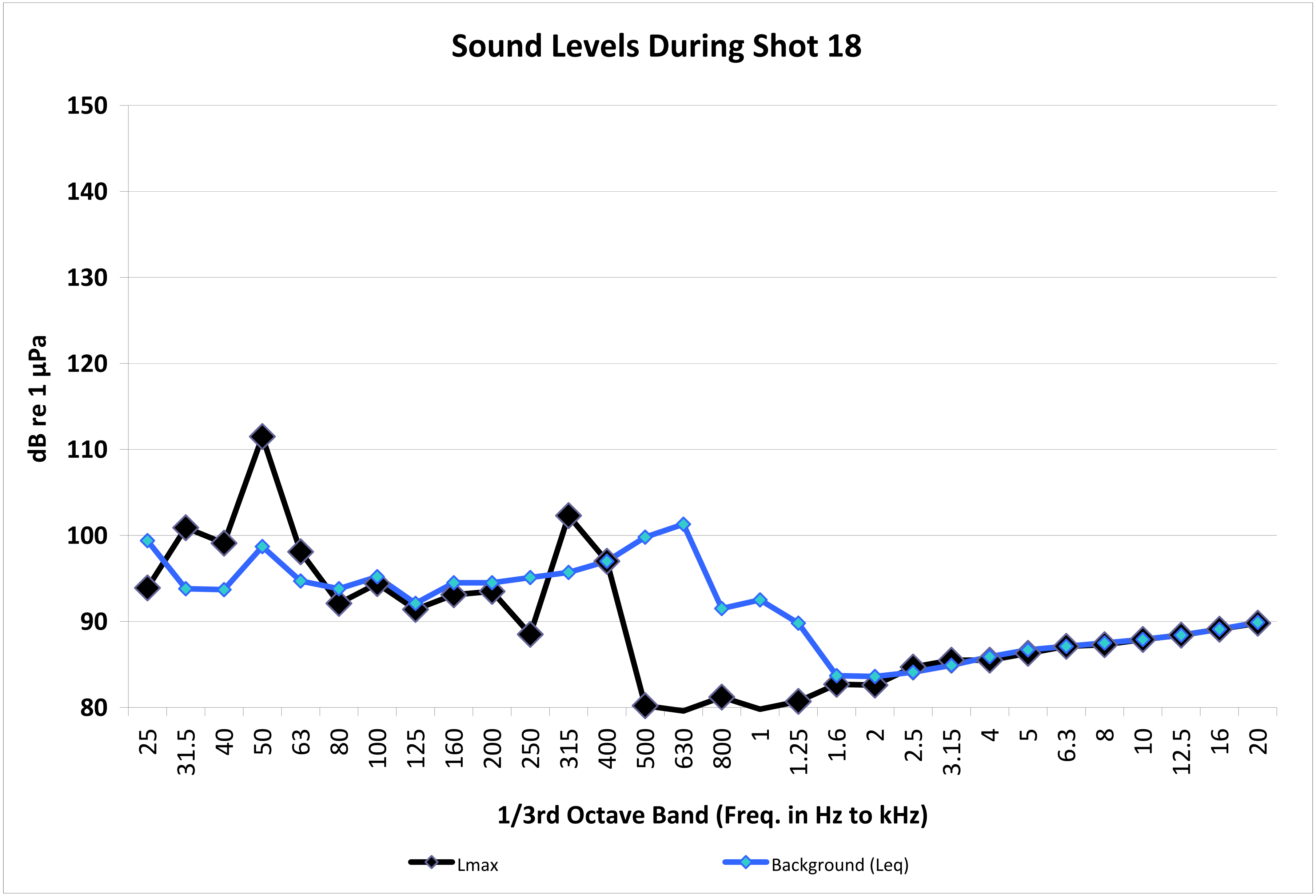
140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 17
dB re 1 µPa
150
140
130
120
110
100
90
80
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 18
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140
130
120
110
100
90
80
dB re 1 µPa
25
31.5
40
50
63
80
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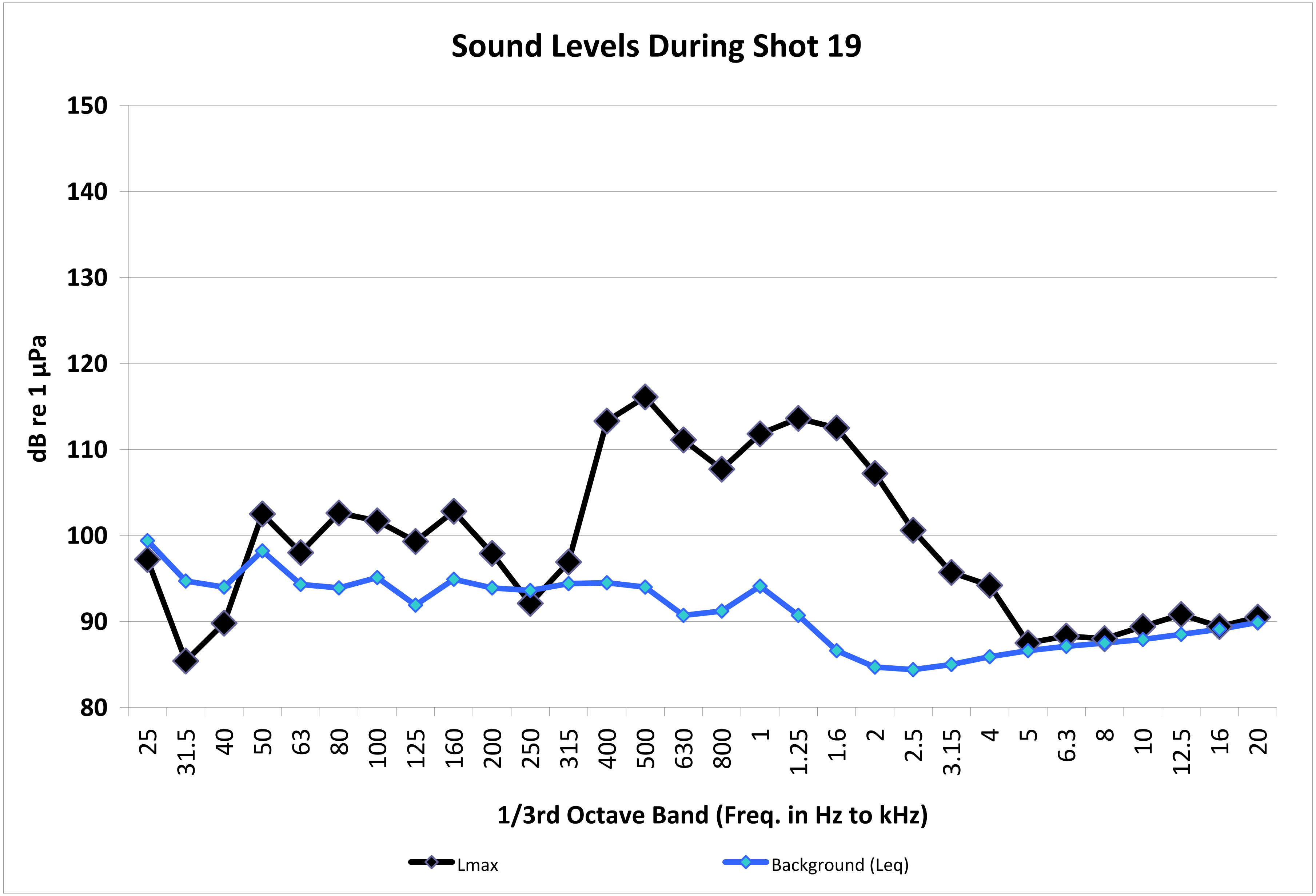
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


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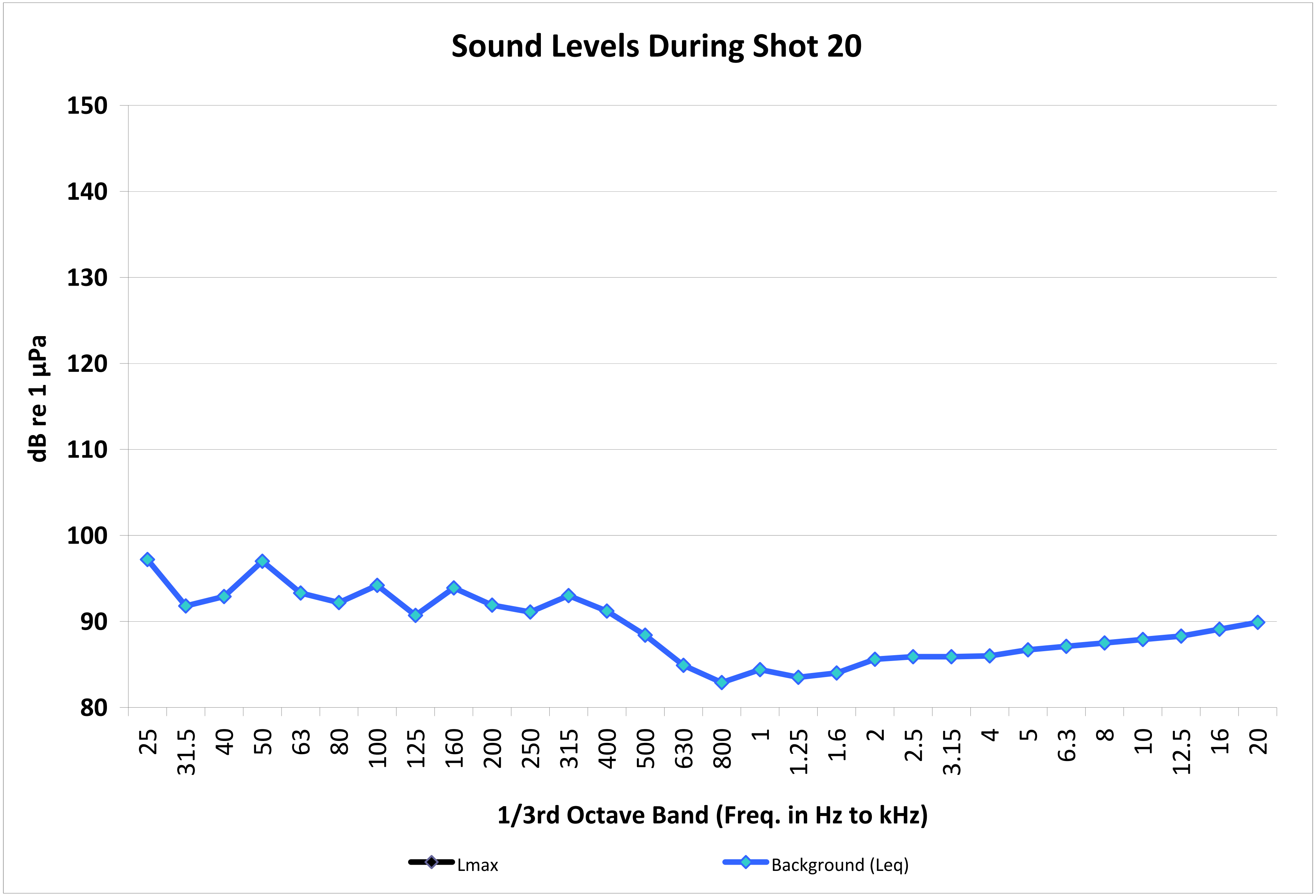
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)



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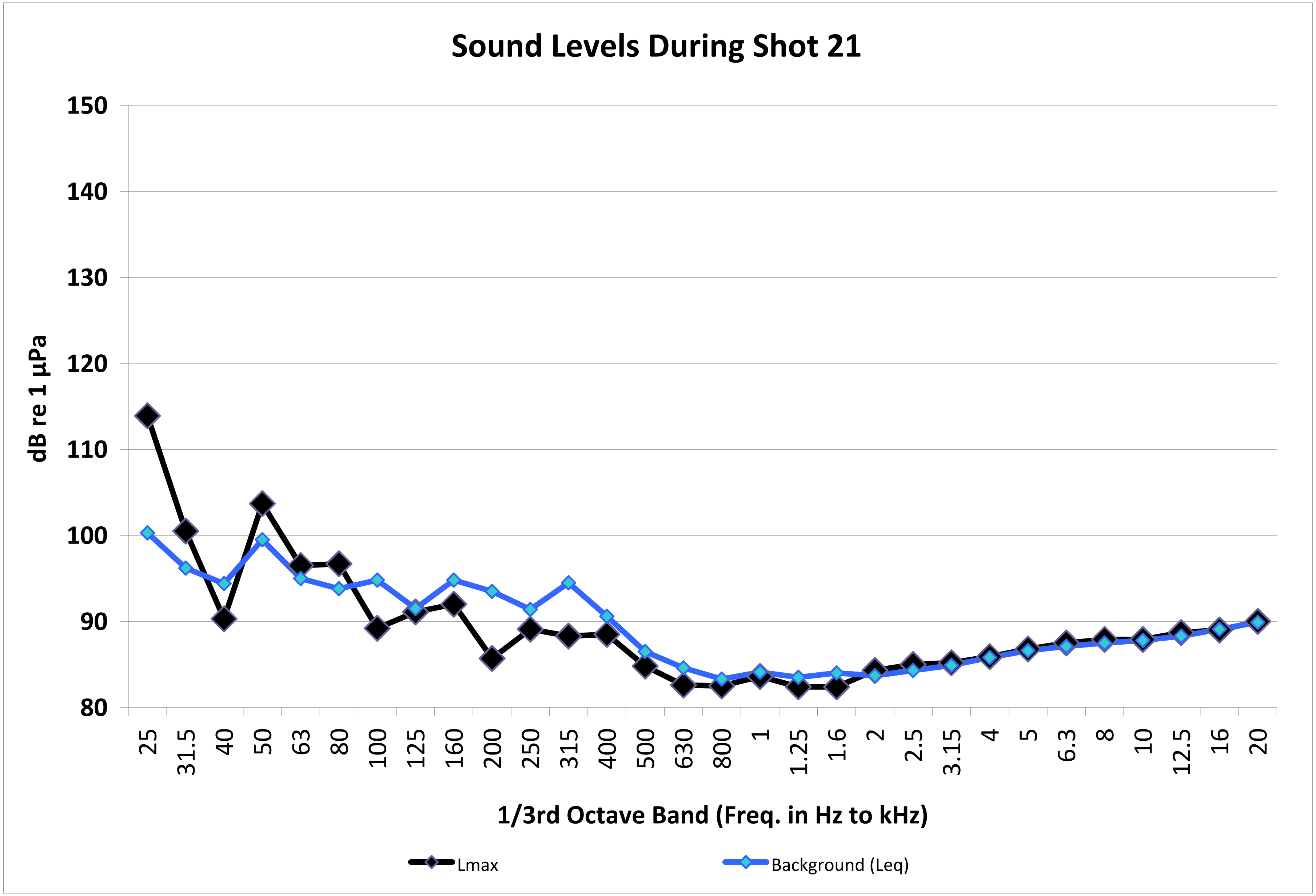
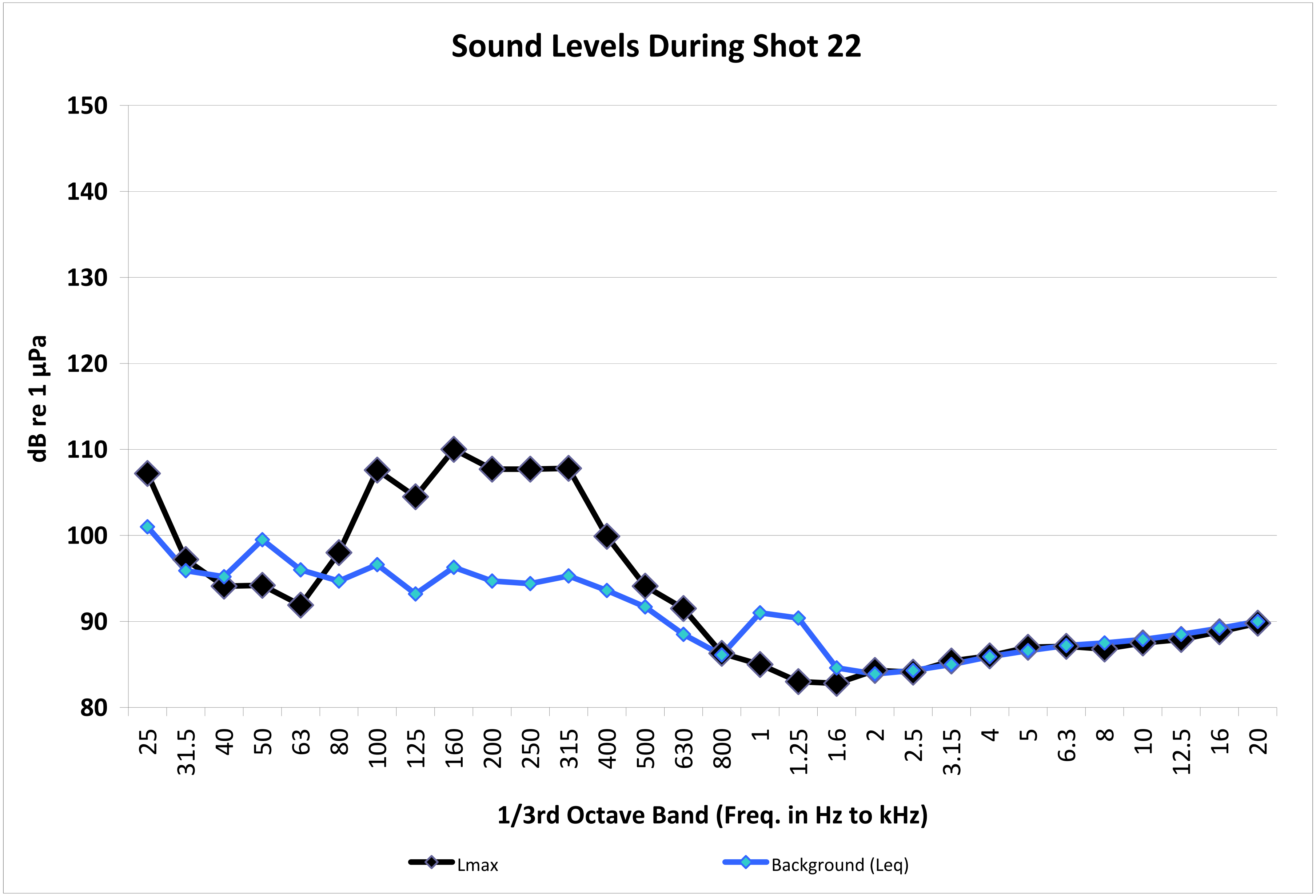
125
160
200
250
315
400
500
630
800
1
1.25
1.6
2
2.5
3.15
4
5
6.3
8
10
12.5
16
20
1/3rd Octave Band (Freq. in Hz to kHz)
Lmax
Background (Leq)


Sound Levels During Shot 21
dB re 1 µPa
150
140
130
120
110
100
90
80
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 22
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)

APPENDIX C-2
AIRGUN SOUND SOURCE VERIFICATION REPORT

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

Submitted to:
Fairweather LLC for
Apache Corporation

Authors:
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2013 January 4

P001134-006
Version 2.0

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Contents

Tables

Figures

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.

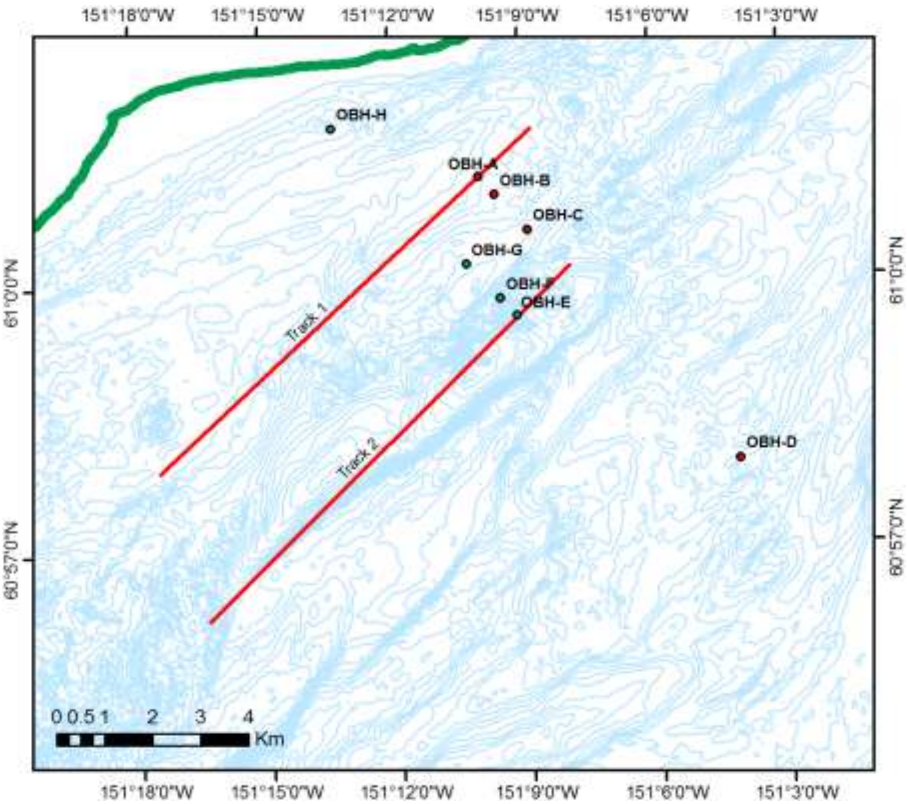


Figure 1. Map of the two acoustic survey lines and OBH locations.

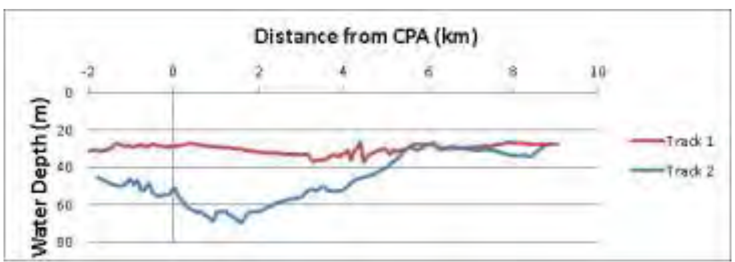


Figure 2: Water depth values along Track 2 measured during a single transit of the source vessel.

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.

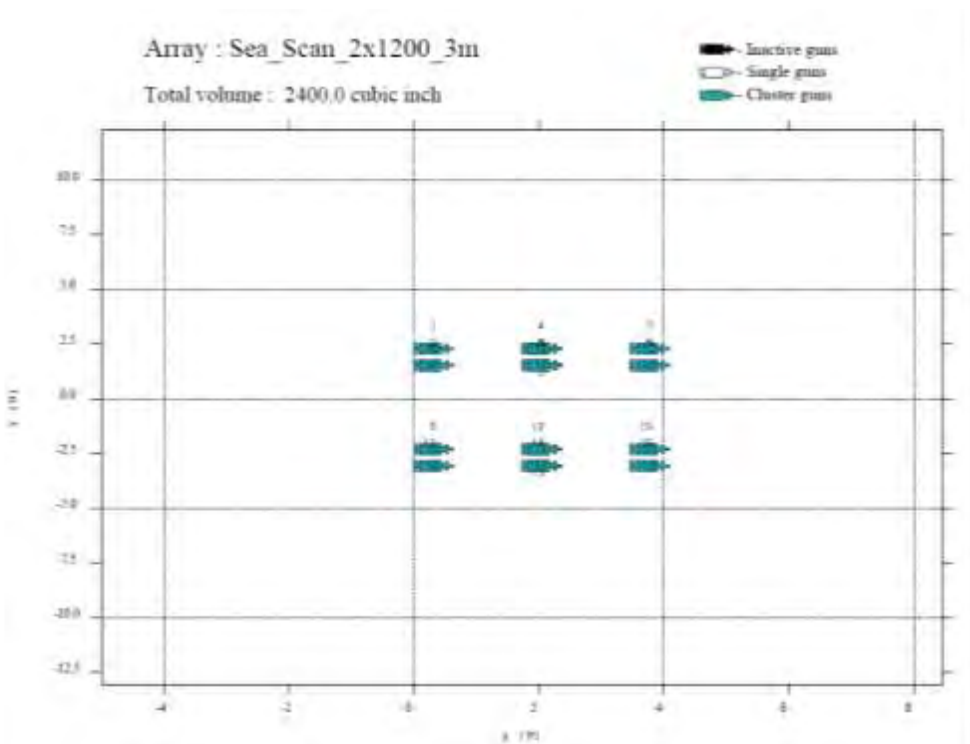


Figure 4. Geometry layout of 2400 in^3 array. Tow depth is 3.0 m; the volume of each airgun is indicated in cubic inches. This array consists of two 1200 in^3 sub-arrays separated horizontally by 4.6 m.

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 in^3 airgun array, the 2440 in^3 airgun array, and 10 in^3 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:

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

$$RL = SL - A\log_{10} R \qquad (2)$$

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 in^3 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 in^3 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.

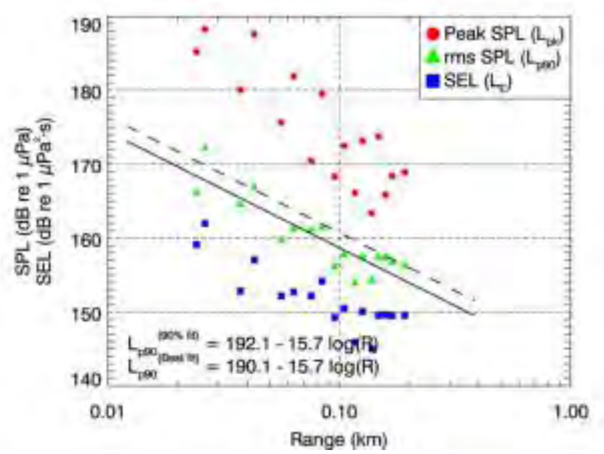


Figure 7: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 10 in^3 mitigation airgun pulses in the endfire direction for the nearshore track. Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90}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

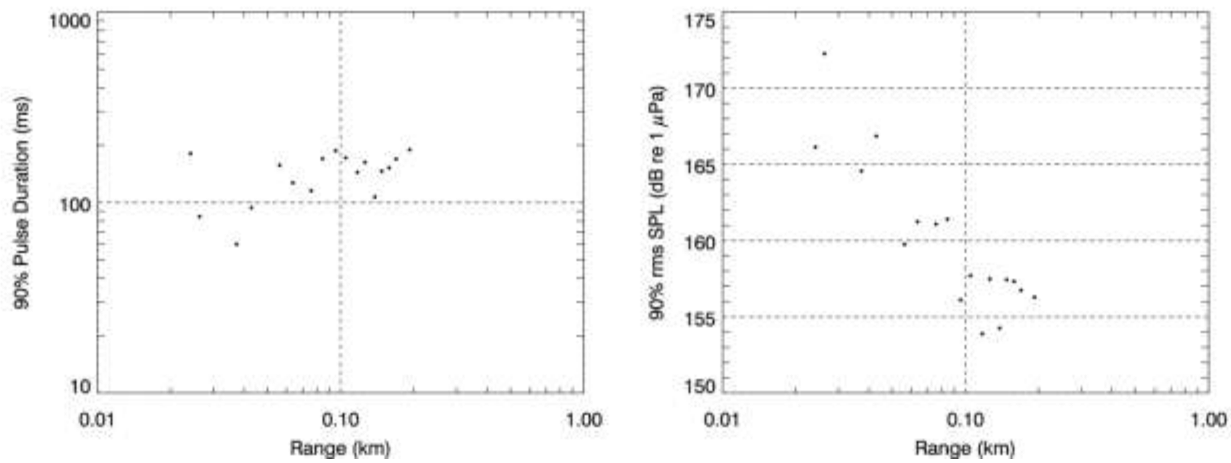


Figure 8. 10 in³ airgun array 90% pulse duration (left) and rms SPL (right) as a function of range at the nearshore site.

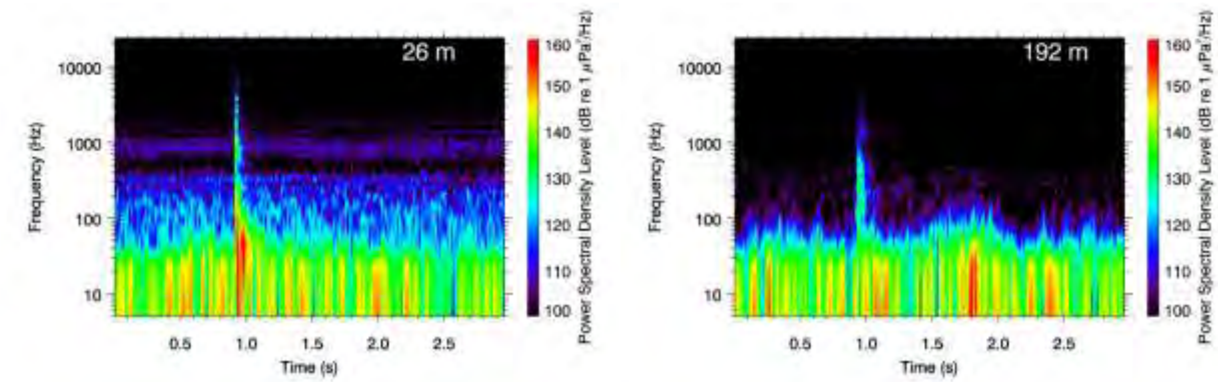


Figure 9. Spectrograms of airgun pulses from the 10 in³ airgun array at two distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

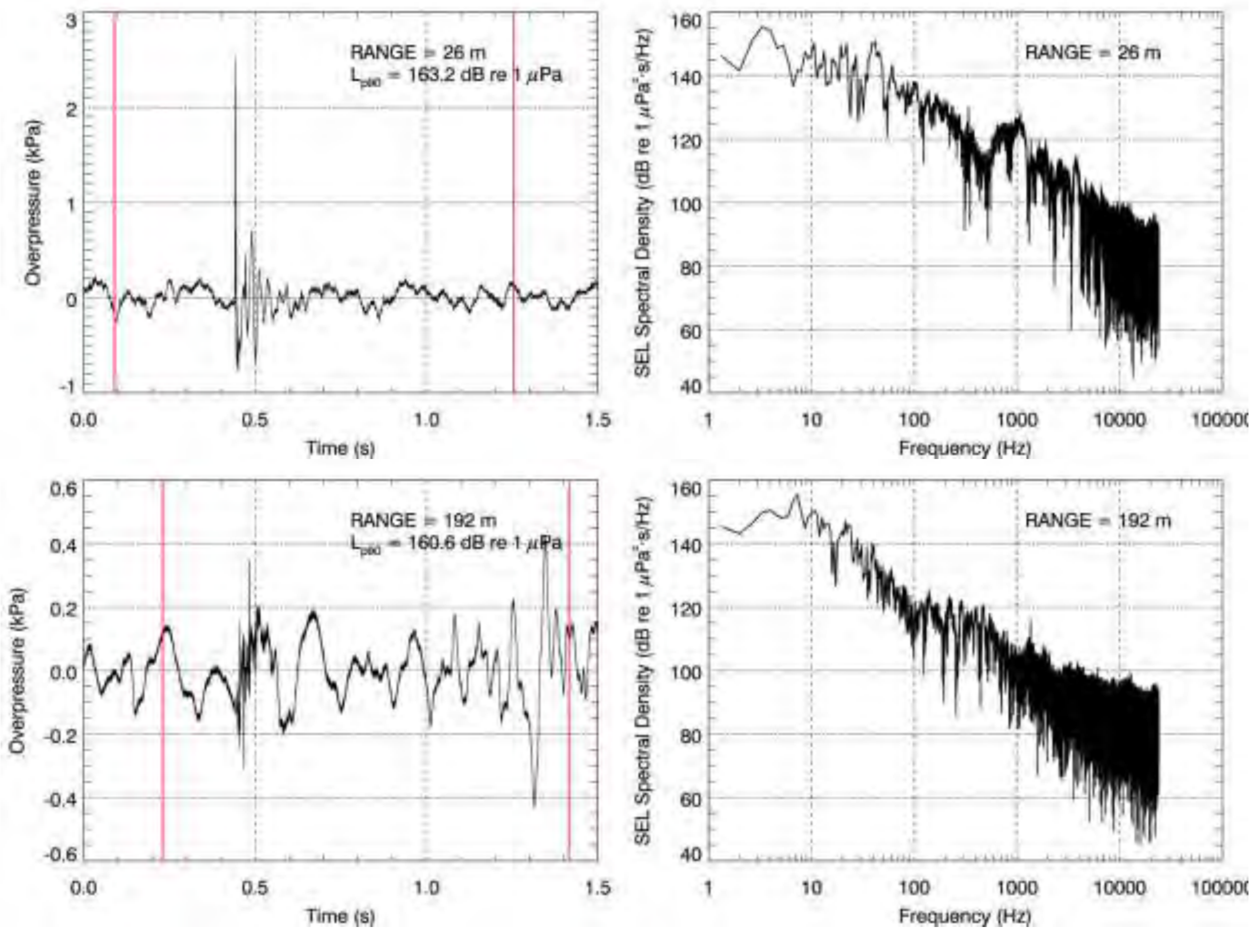


Figure 10. Waveform (left) and corresponding SEL spectral density (right) plots of 10 in³ airgun array pulses at two distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

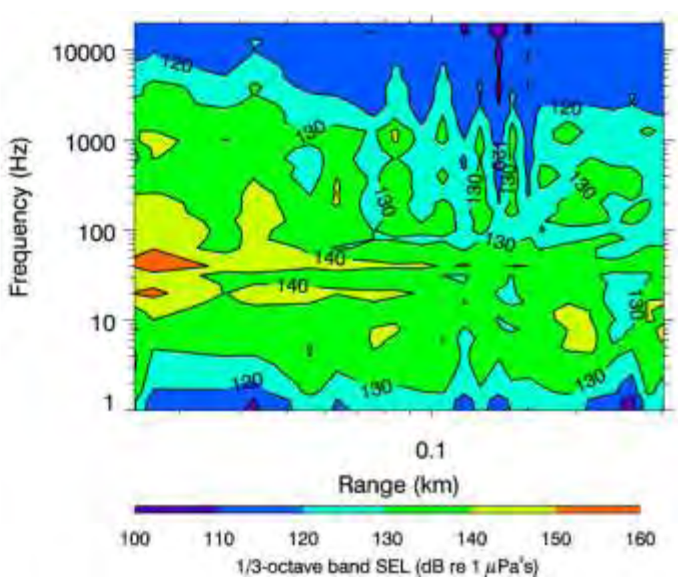


Figure 11. 1/3 octave band SEL levels as a function of range and frequency for the 10 in³ airgun array in the endfire direction at the nearshore site.

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.

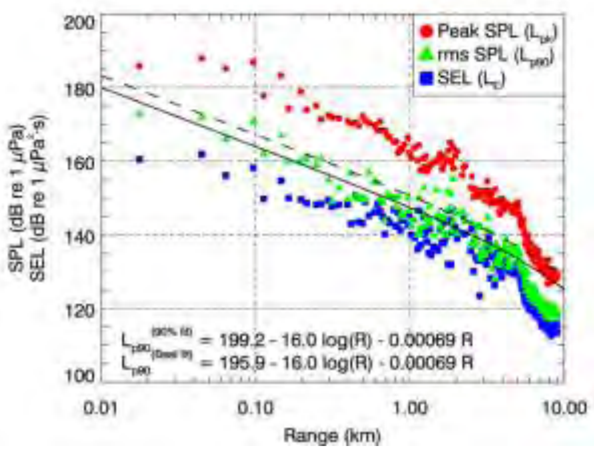


Figure 12: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 10 in^3 mitigation airgun pulses in the endfire direction for the offshore track. Solid line is best fit of the empirical function to SPL$_{rms90}$ values. Dashed line is the best-fit adjusted to exceed 90% of the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

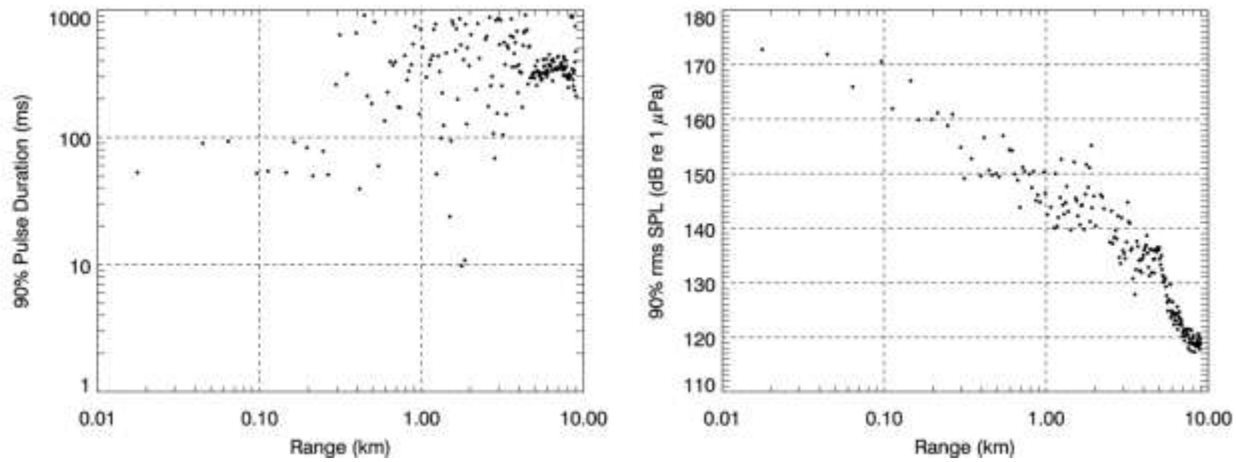


Figure 13. 10 in³ airgun array 90% pulse duration (left) and rms SPL (right) as a function of range at the offshore site.

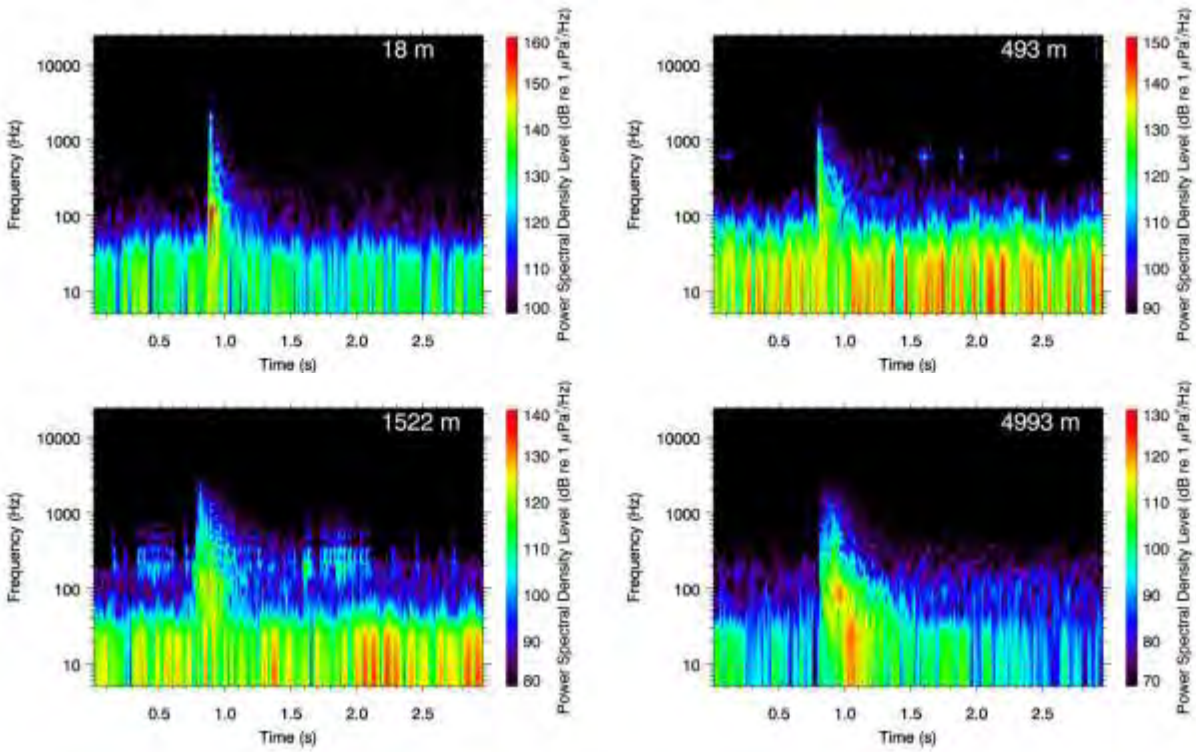
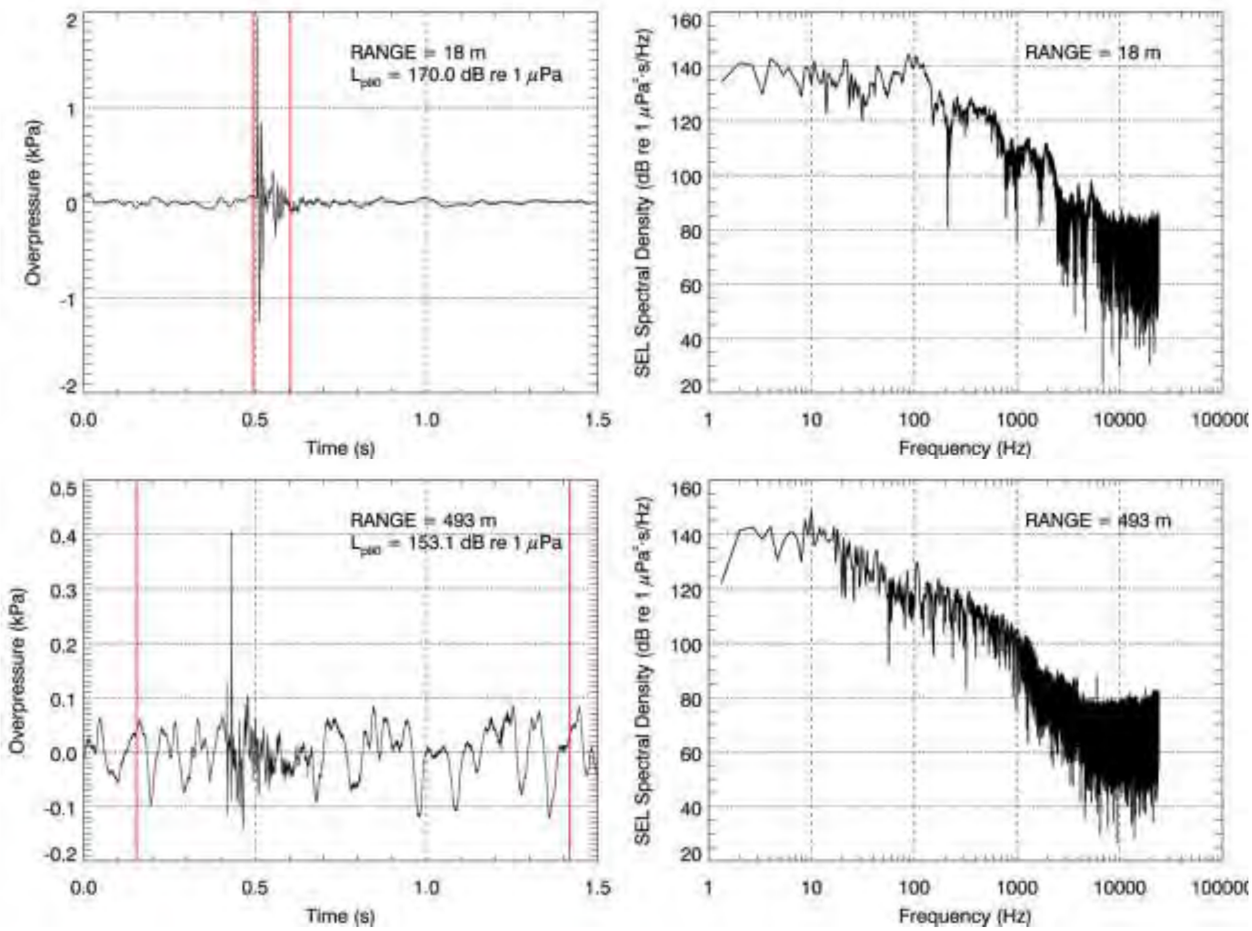


Figure 14. Spectrograms of airgun pulses from the 10 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.


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)

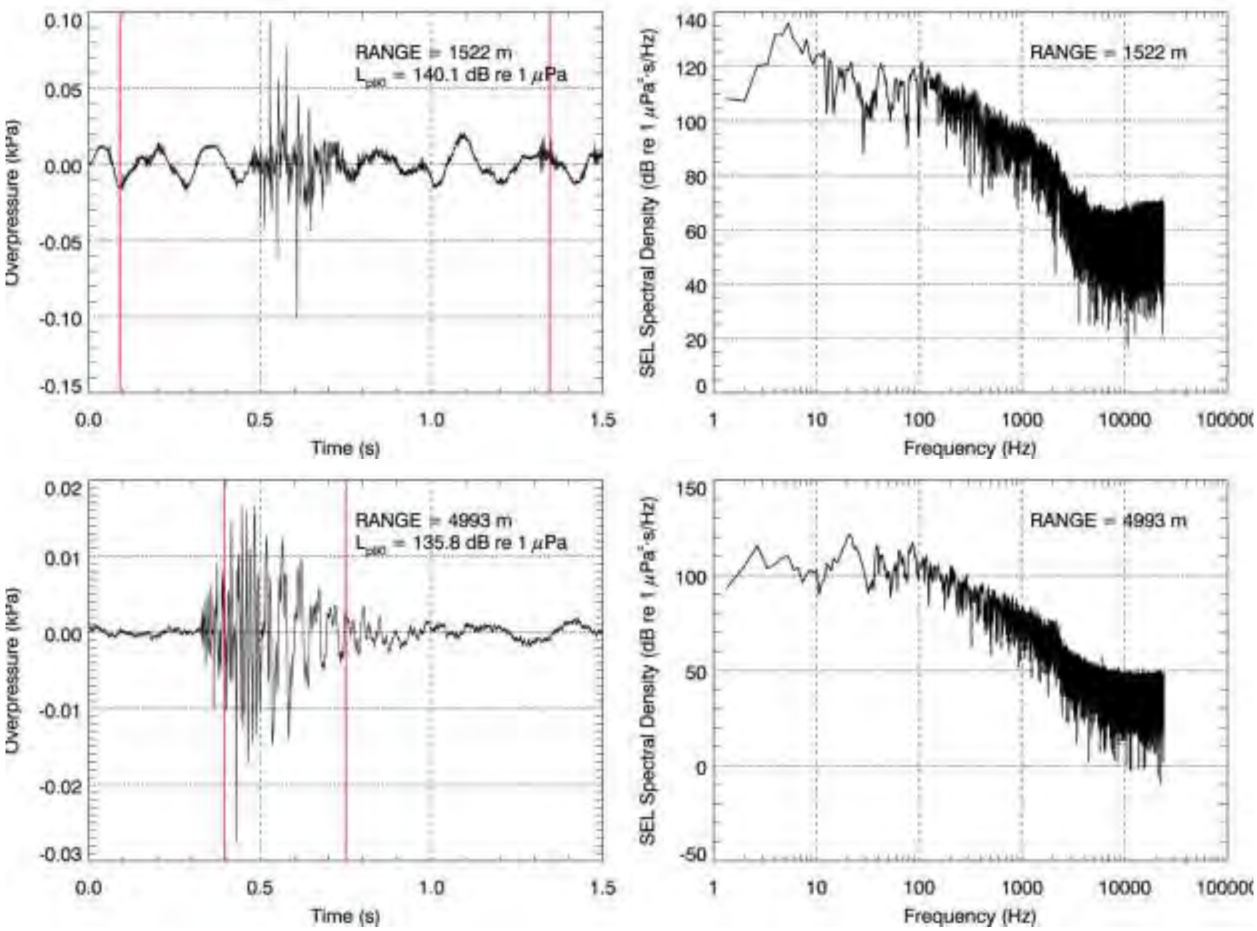


Figure 15. Waveform (left) and corresponding SEL spectral density (right) plots of 10 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

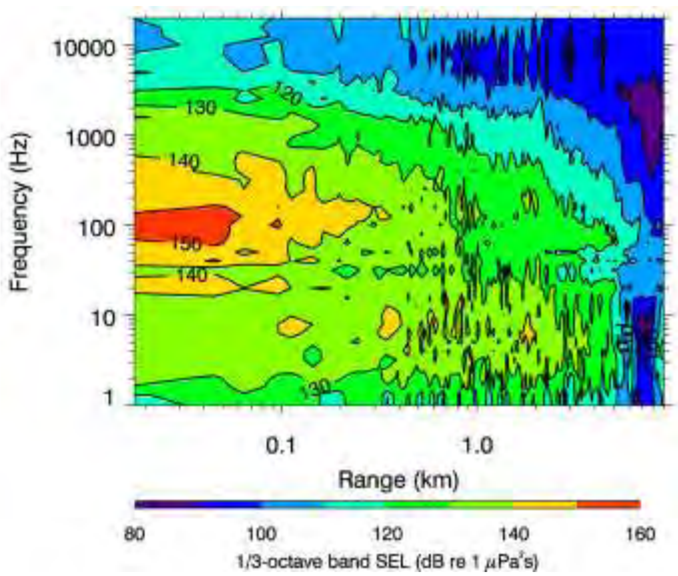


Figure 16. 1/3 octave band SEL levels as a function of range and frequency for the 10 in³ airgun array in the endfire direction at the offshore site.

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.

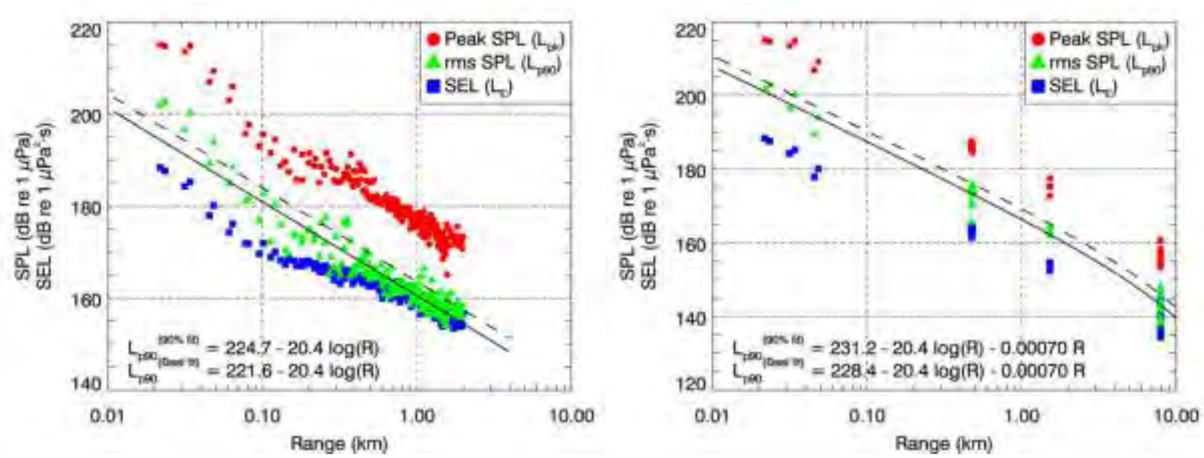


Figure 17: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 440 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured for the nearshore line (Track 1). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is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

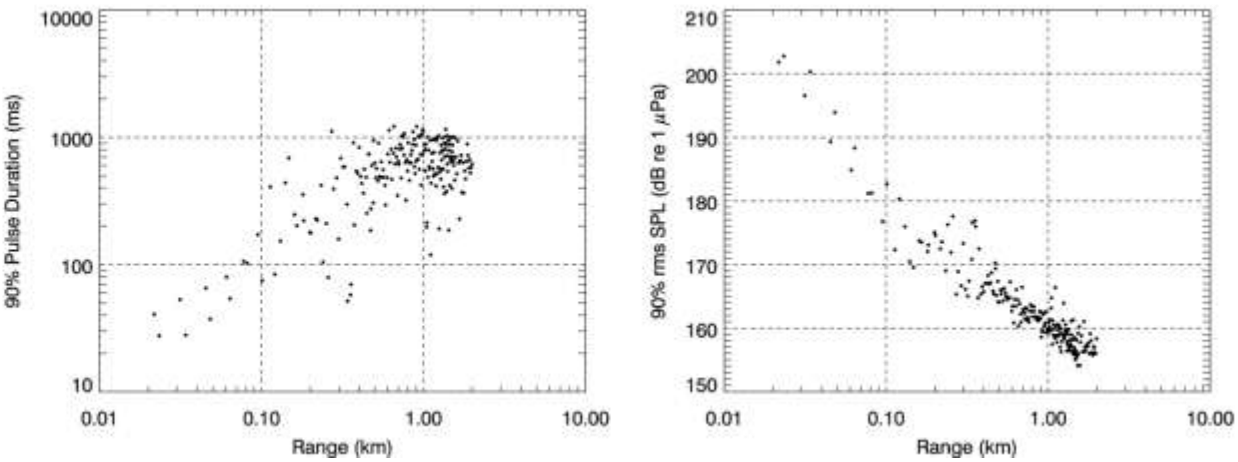


Figure 18. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

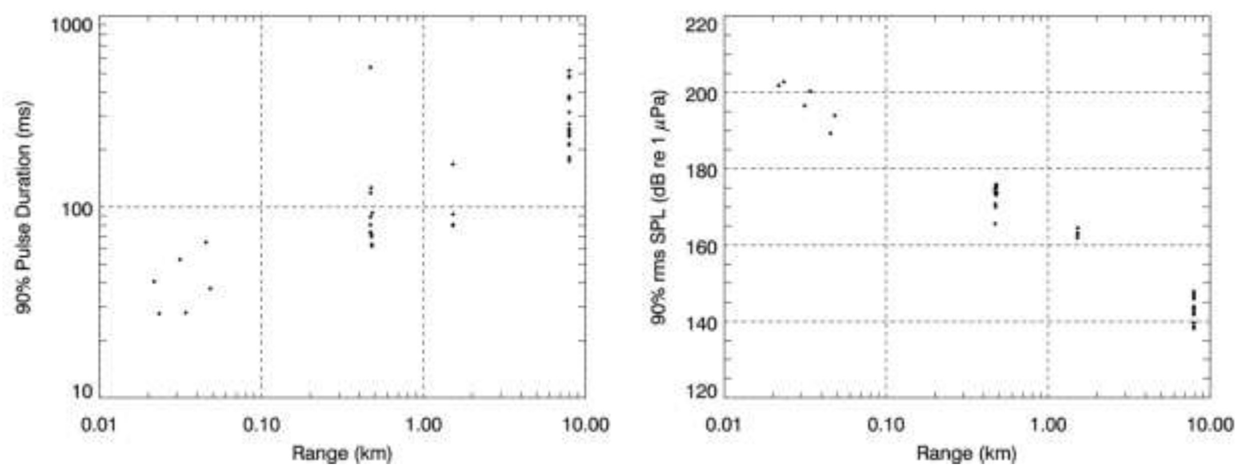


Figure 19. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

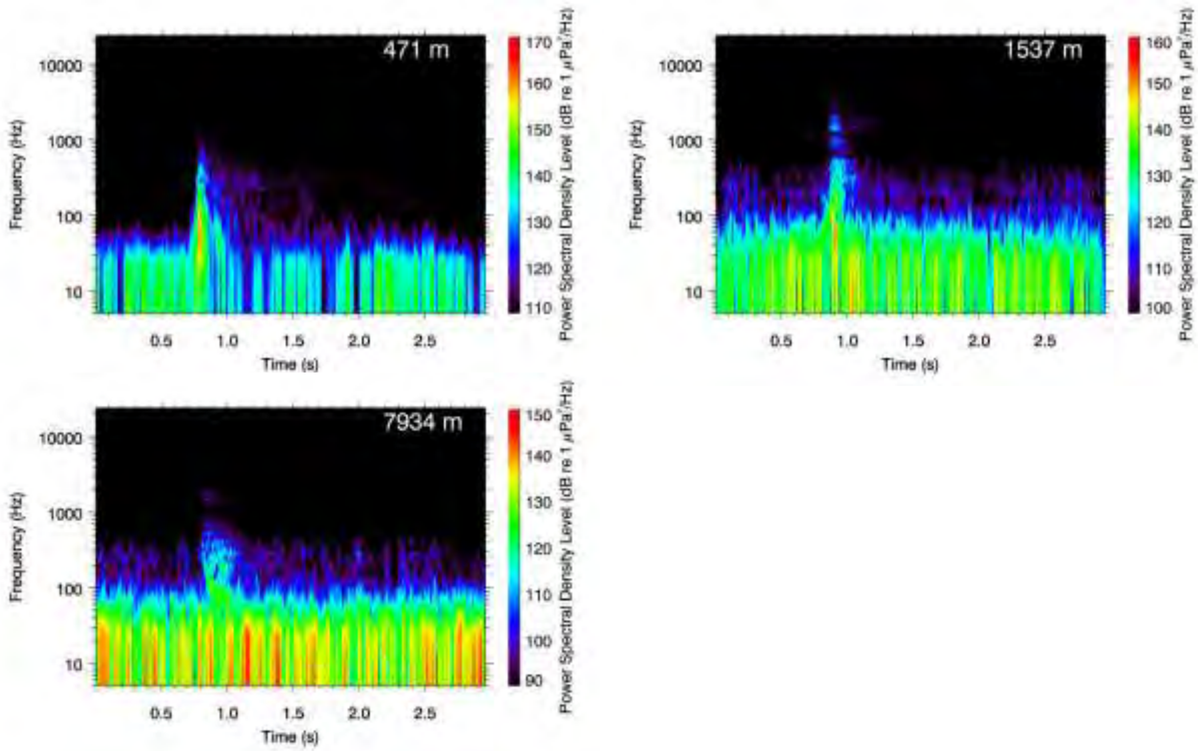


Figure 20. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

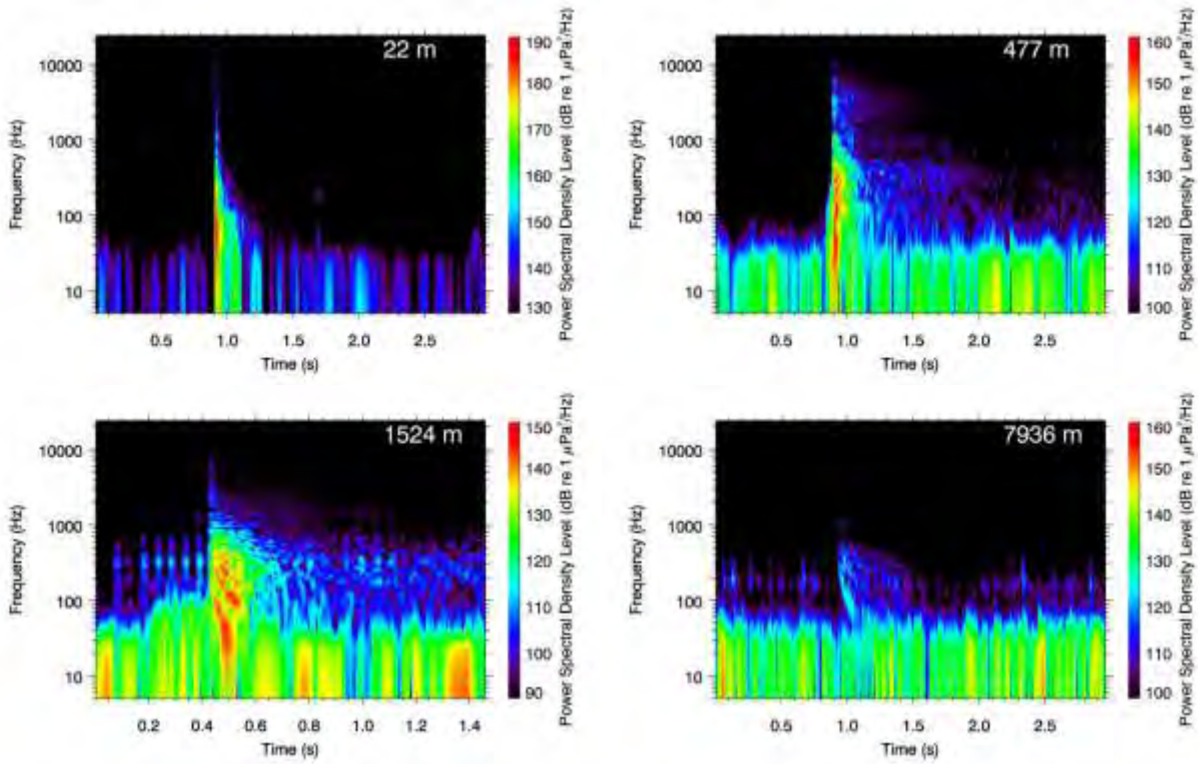


Figure 21. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

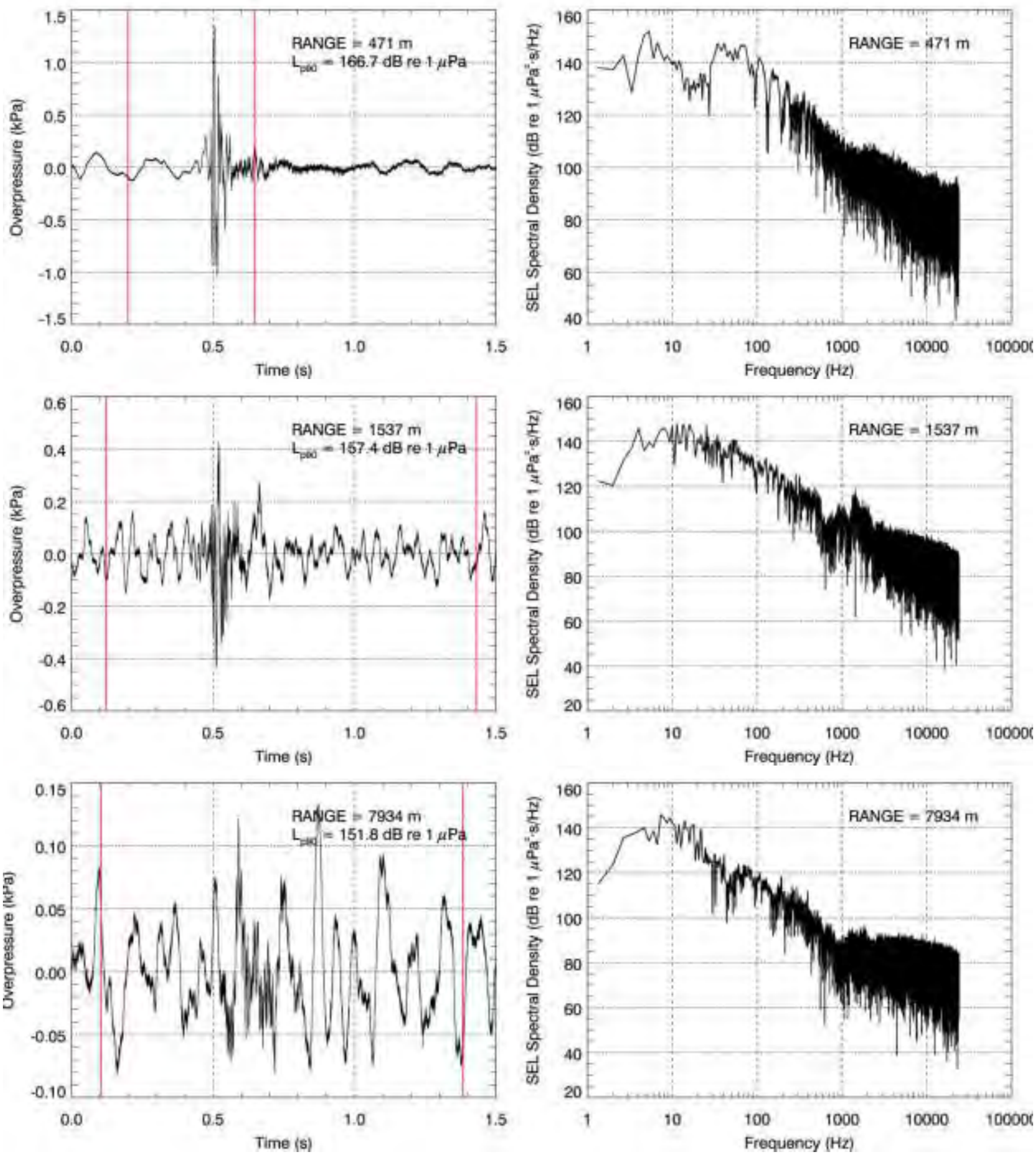
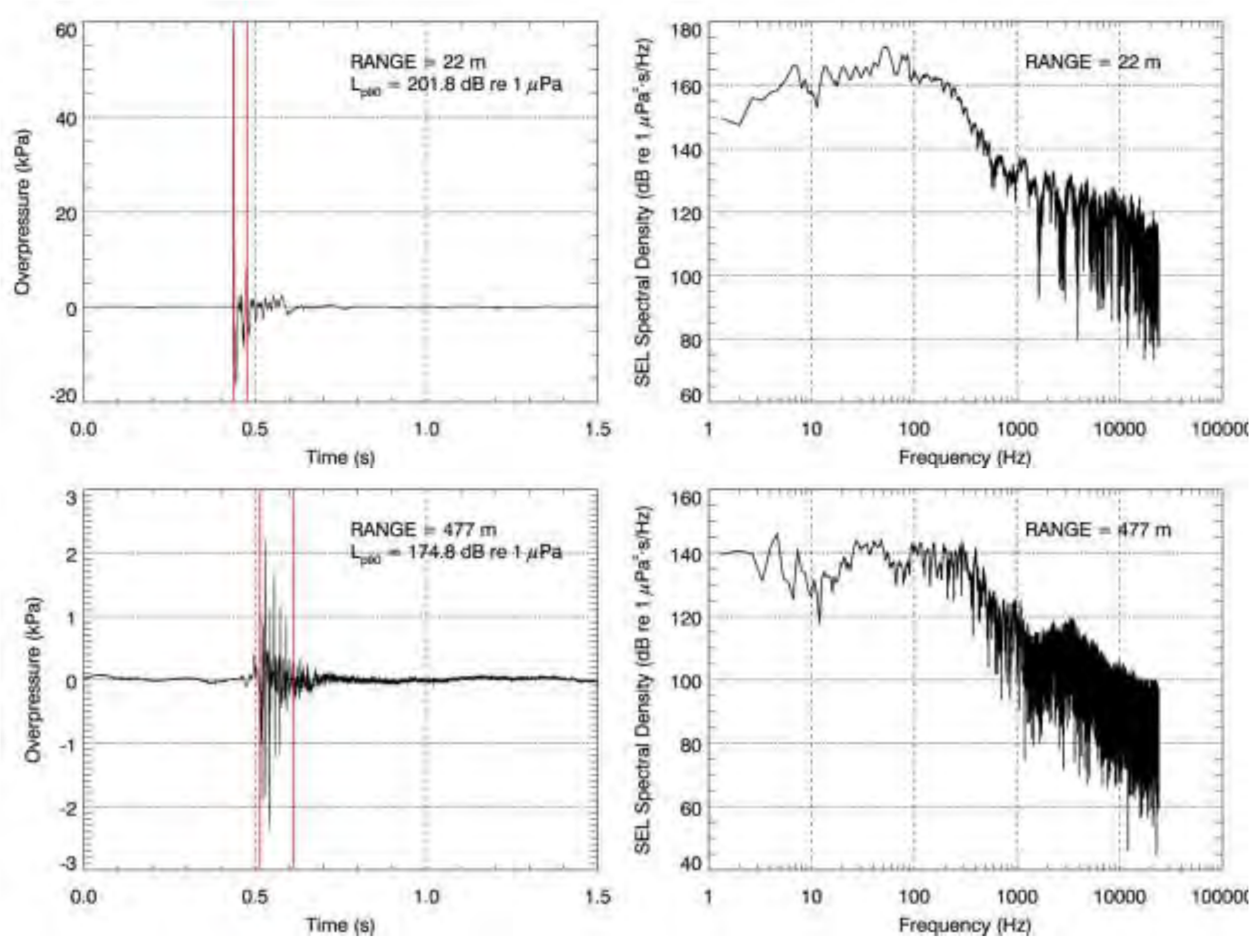


Figure 22. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


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)

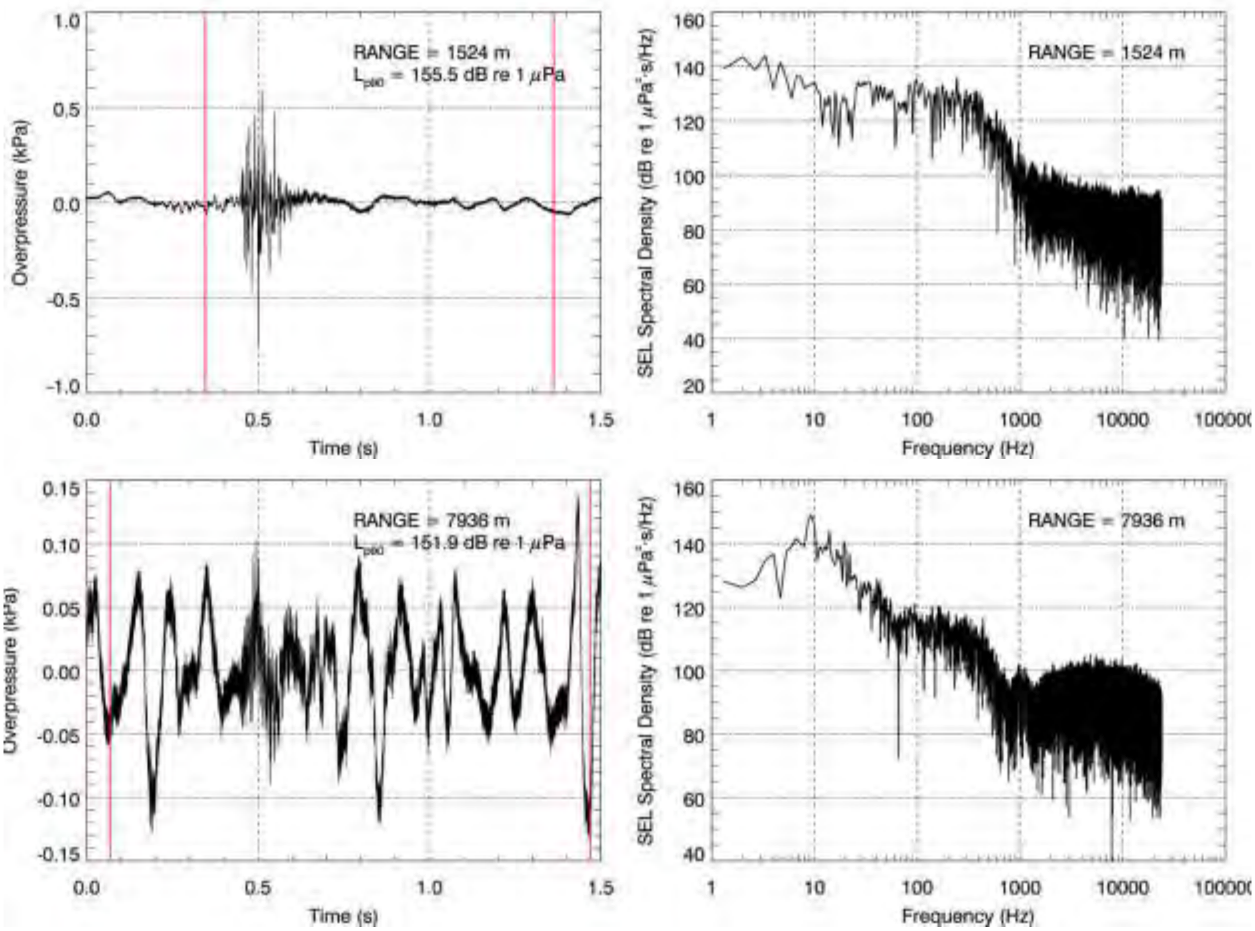


Figure 23. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

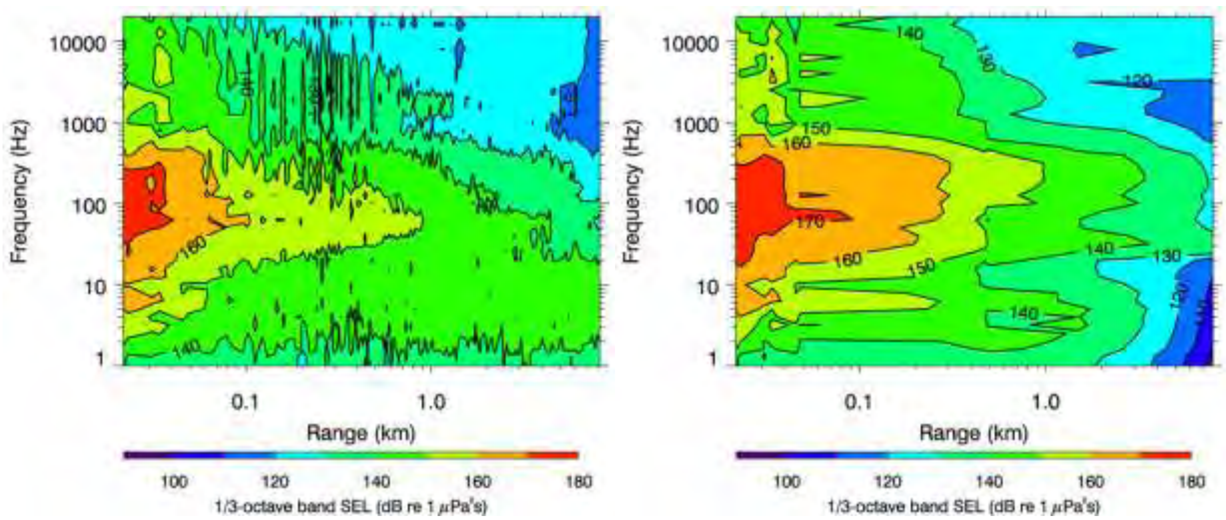


Figure 24. 1/3 octave band SEL levels as a function of range and frequency for the 440 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

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.

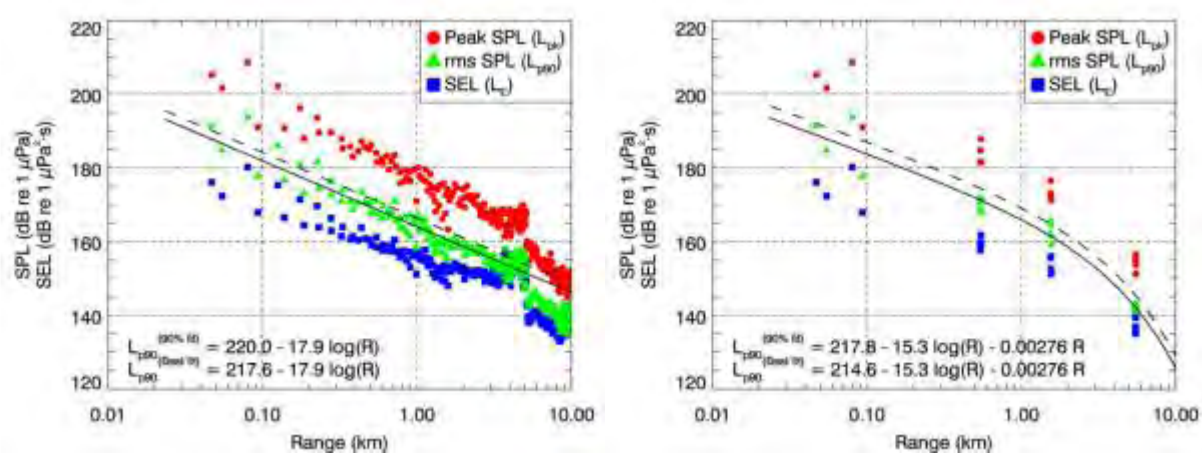


Figure 25: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 440 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore line (Track 2). Solid line is best fit of the empirical function to SPL$_{rms90}$ values. Dashed line is 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 Best fit	90th percentile fit	Range (m) in broadside direction 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

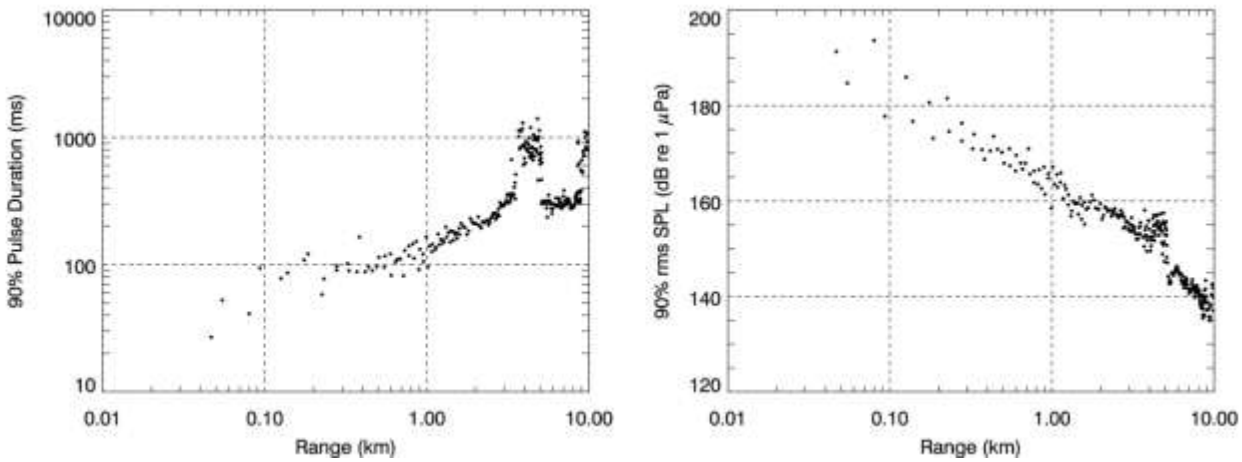


Figure 26. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

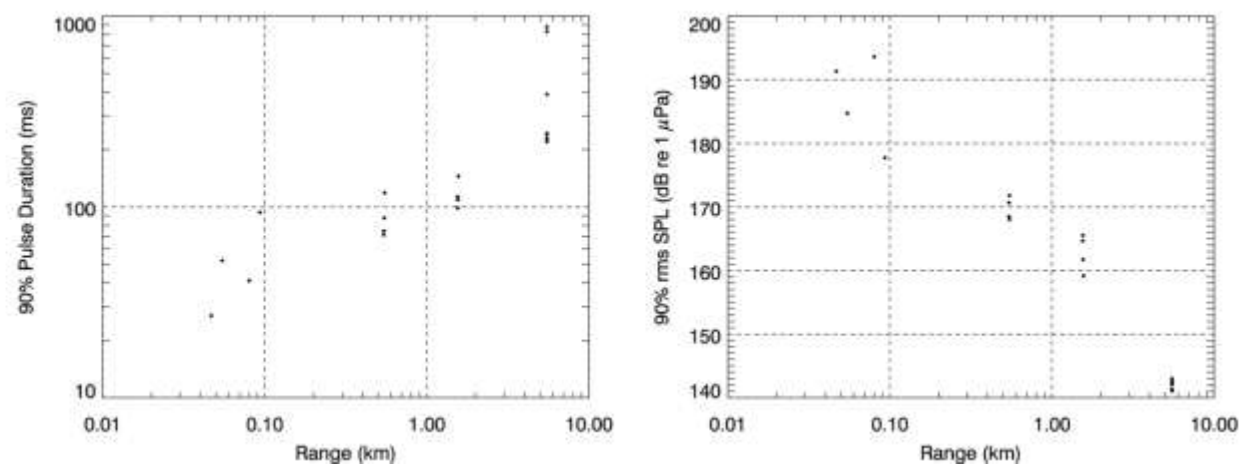


Figure 27. 440 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

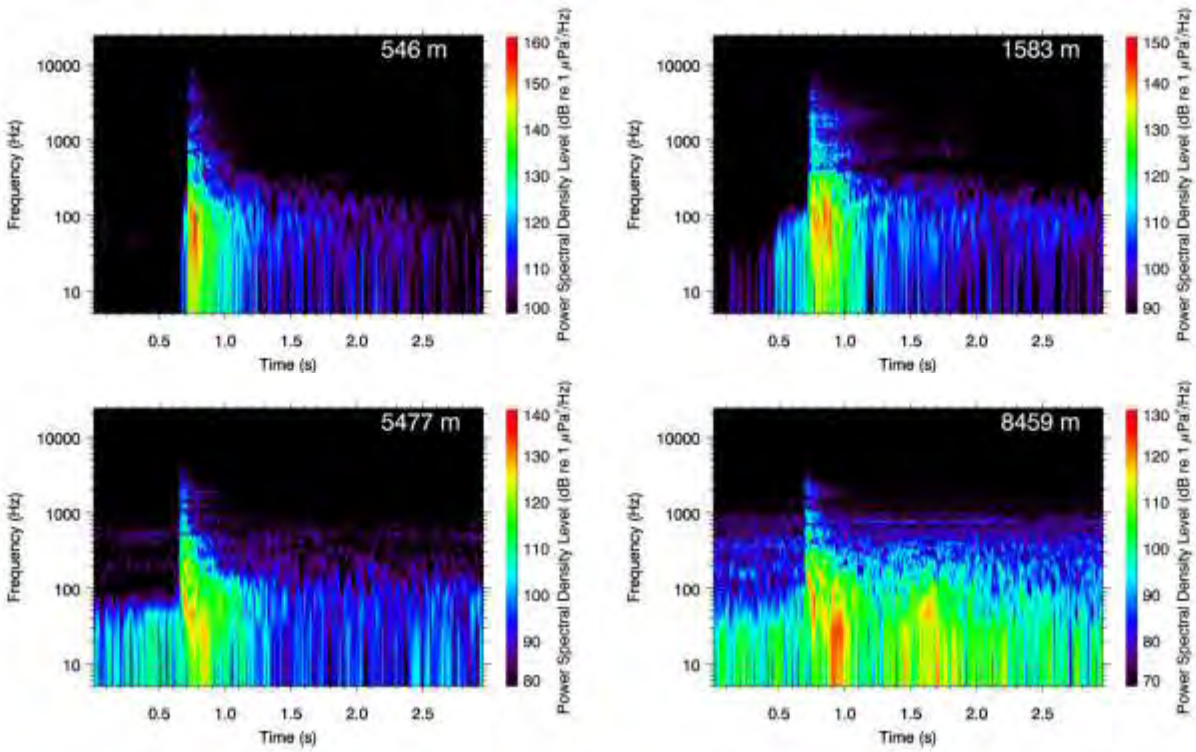


Figure 28. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

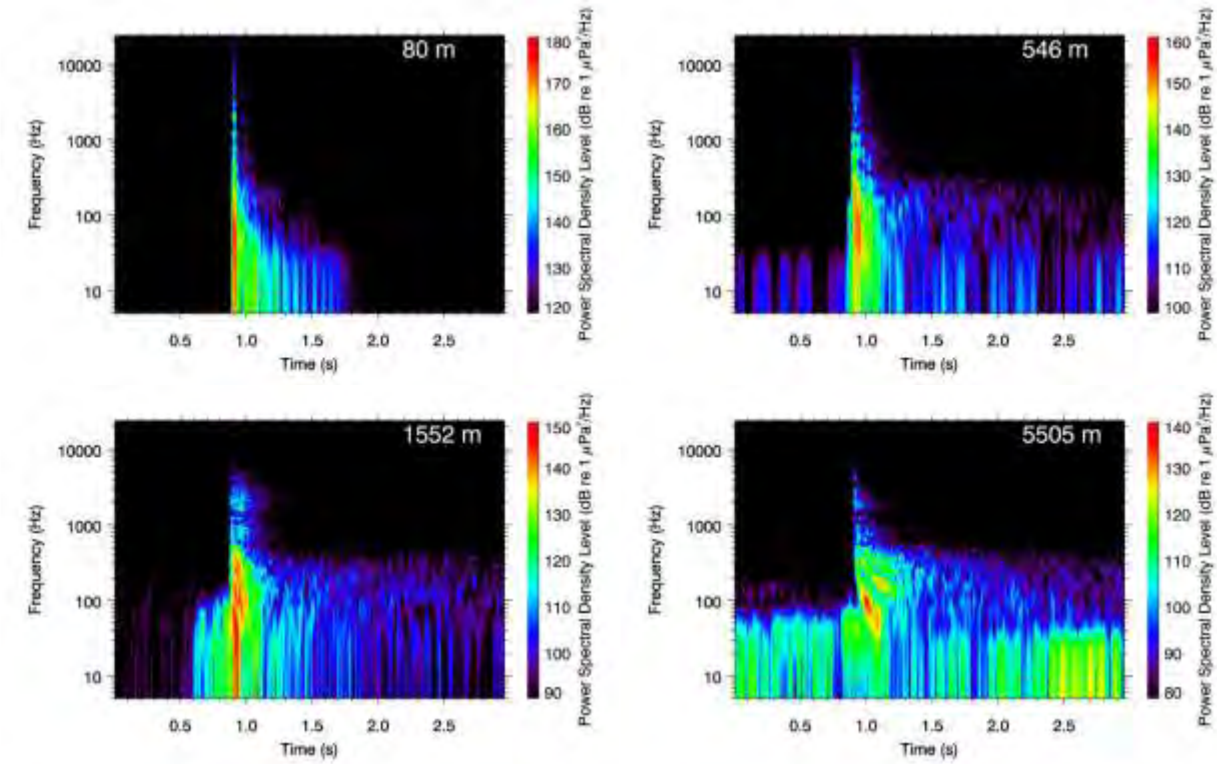
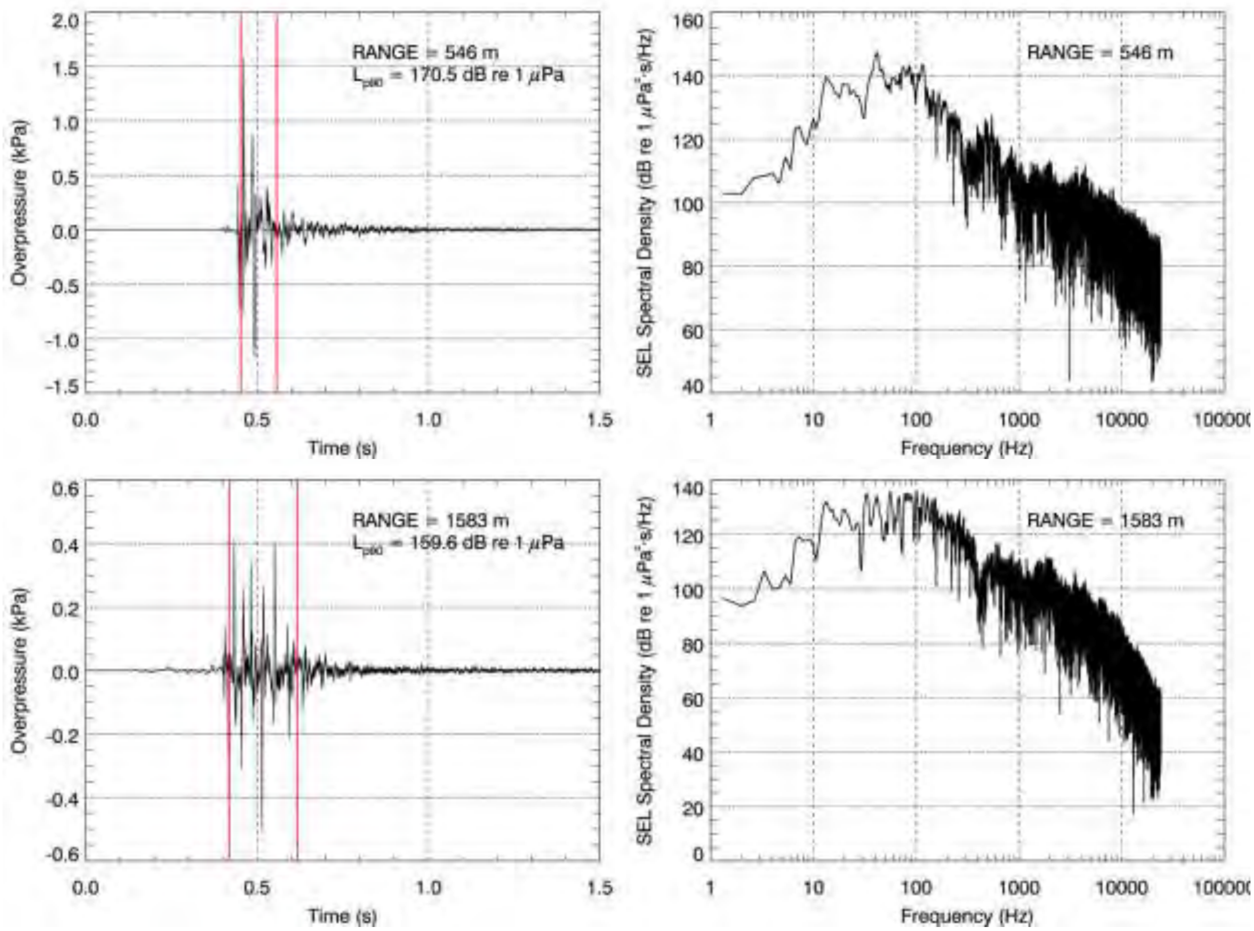


Figure 29. Spectrograms of airgun pulses from the 440 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5505 m spectrogram is 2048-pt FFT, 48 kHz sample rate).


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

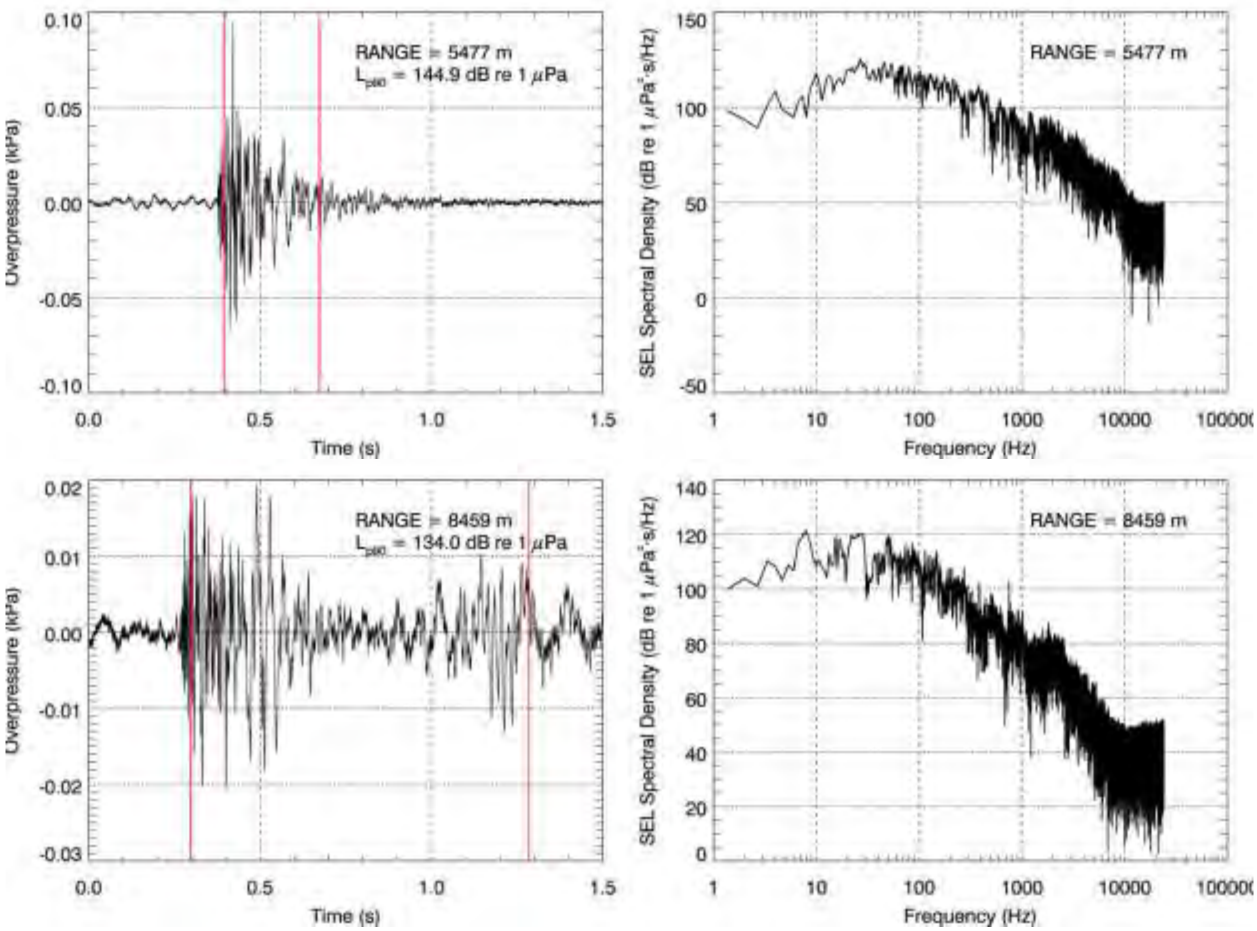
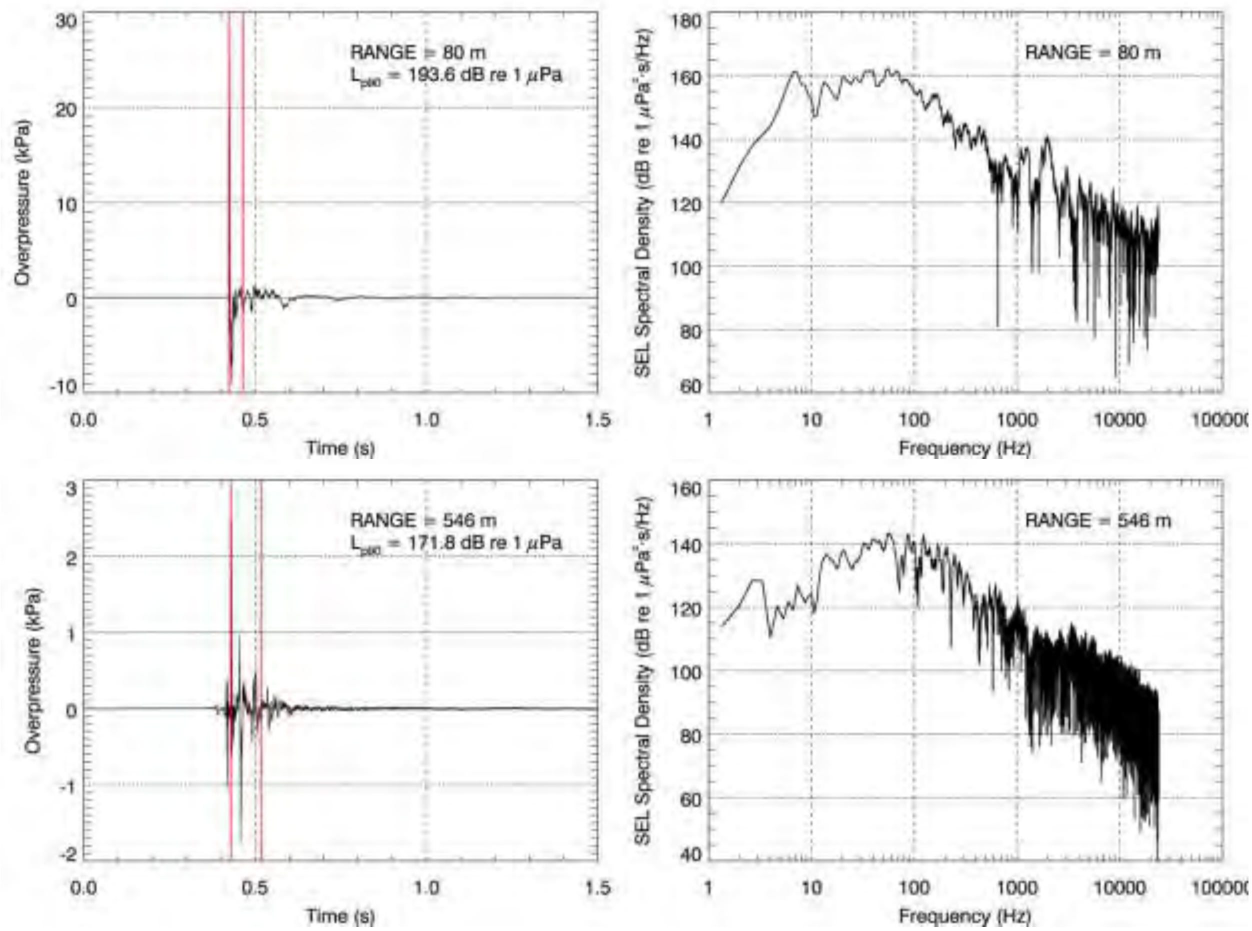


Figure 30. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


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)

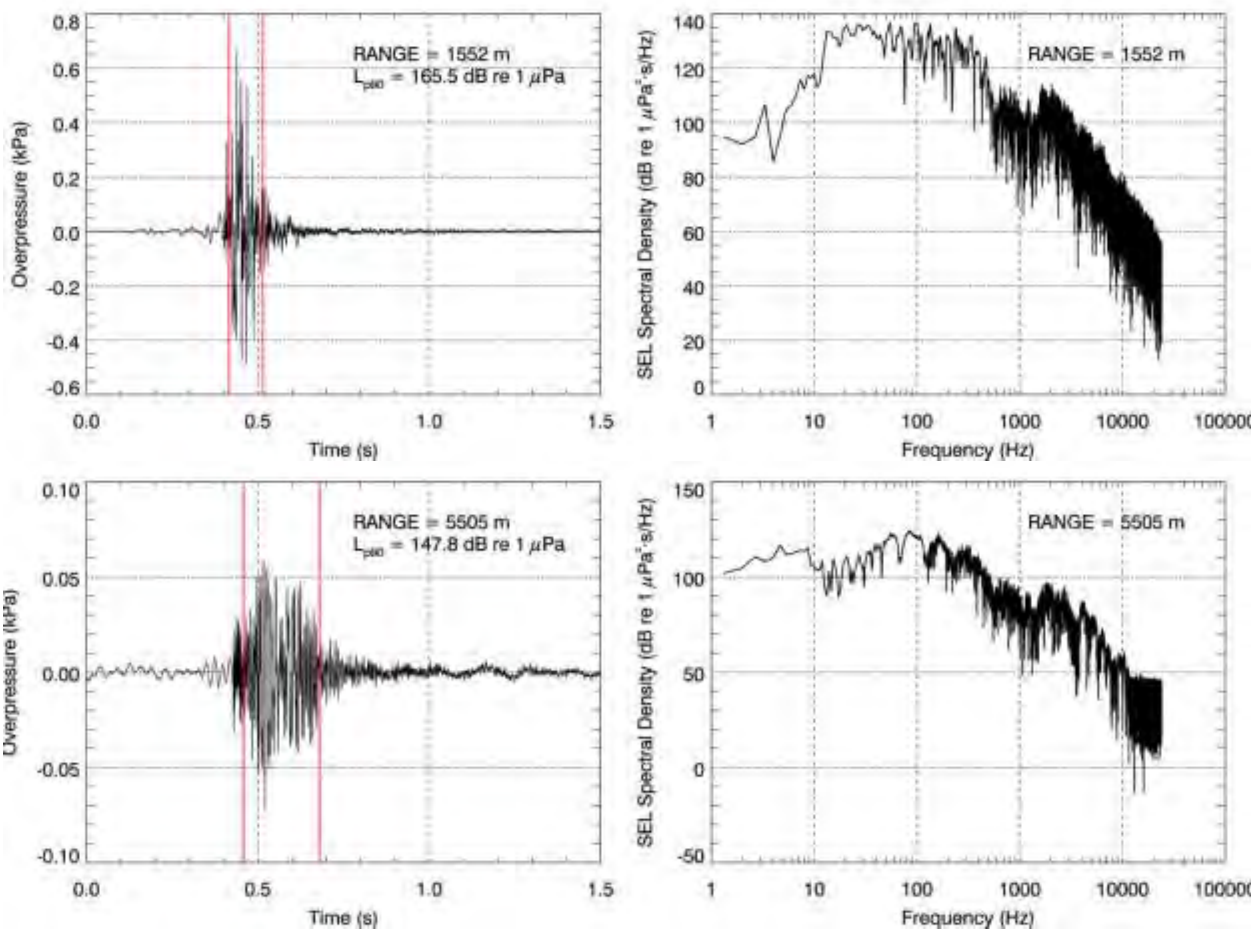


Figure 31. Waveform (left) and corresponding SEL spectral density (right) plots of 440 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

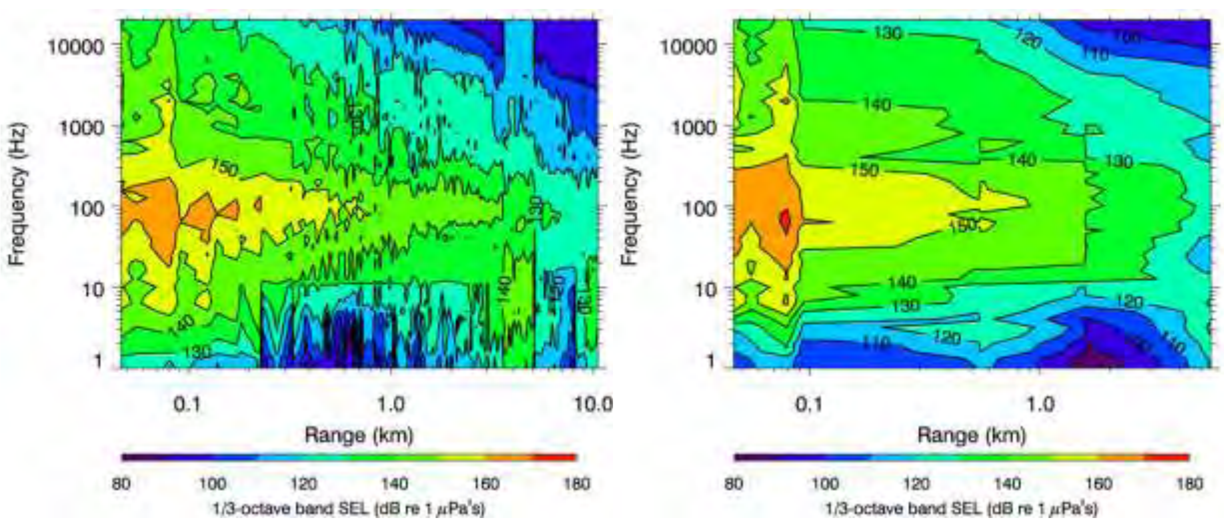


Figure 32. 1/3 octave band SEL levels as a function of range and frequency for the 440 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

4.3. 1200 in^3 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.

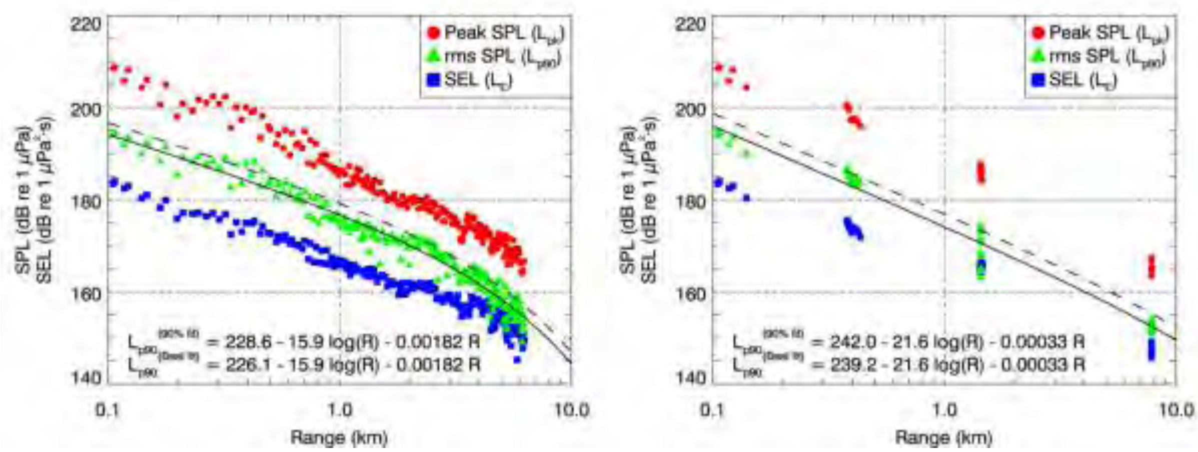


Figure 33: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 1200 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the nearshore site (Track 1). Solid line is best fit of the empirical function to SPL$_{rms90}$ values. Dashed line 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	Range (m) in endfire direction		Range (m) in broadside direction	
(dB re 1 μPa)	Best fit	90^{th} percentile fit	Best fit	90^{th} percentile fit
190	180	250	190	250
180	670	910	540	720
170	2000	2500	1500	2000
160	4500	5300	4000	5200

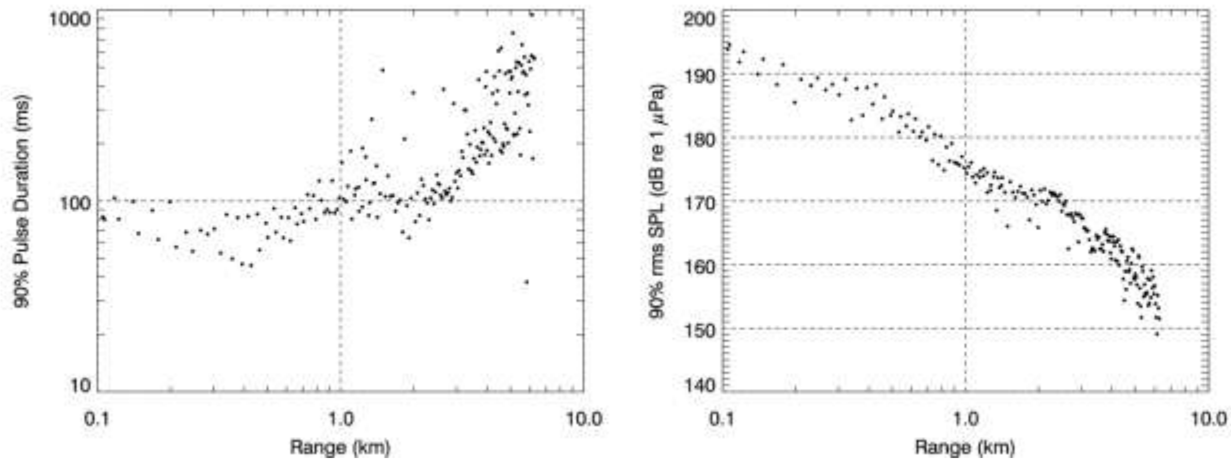


Figure 34. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

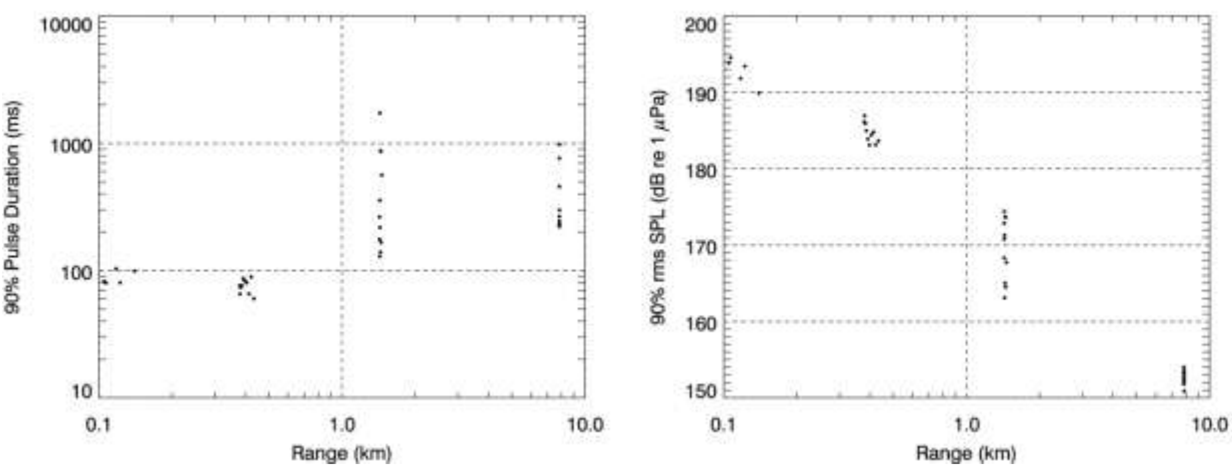


Figure 35. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

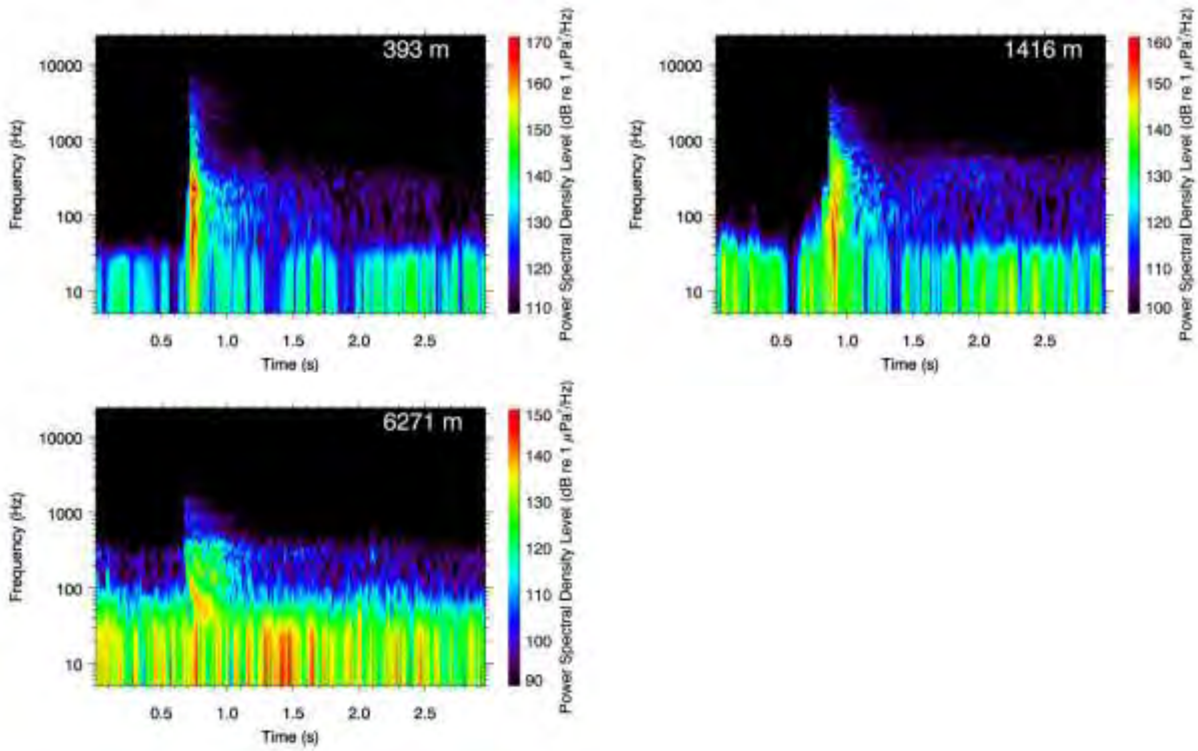


Figure 36. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

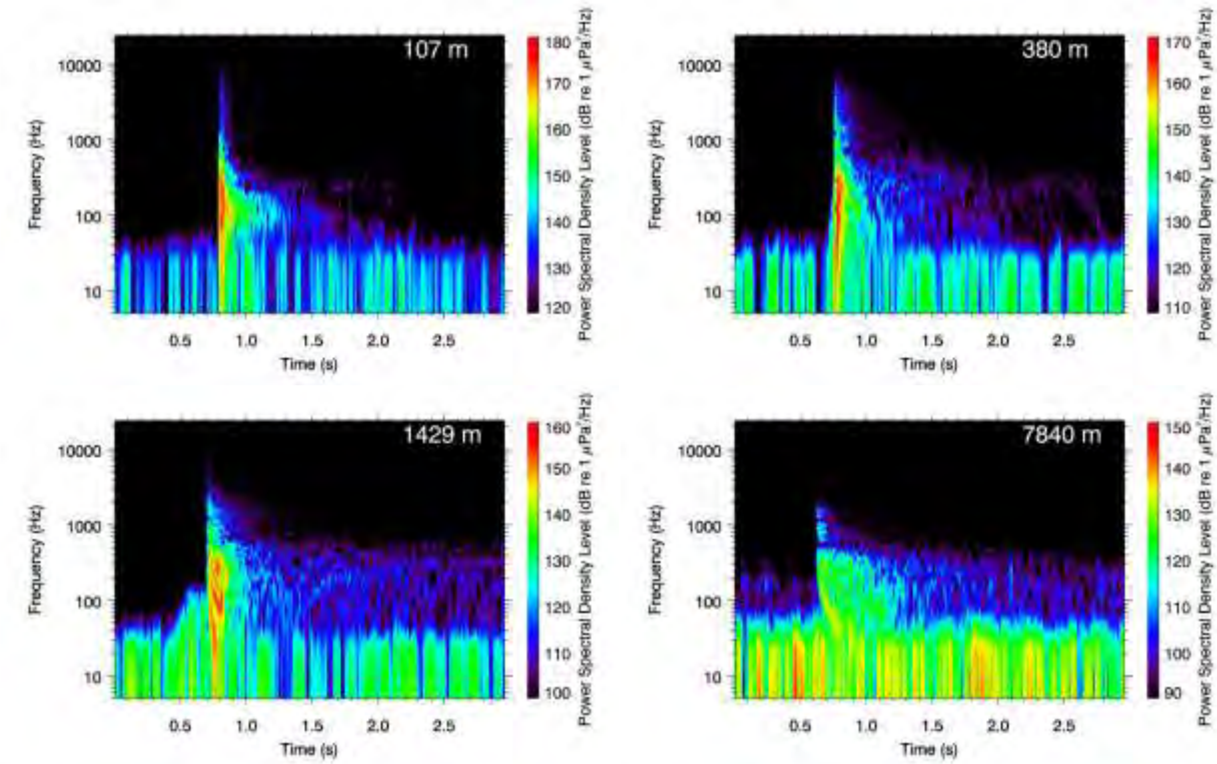


Figure 37. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

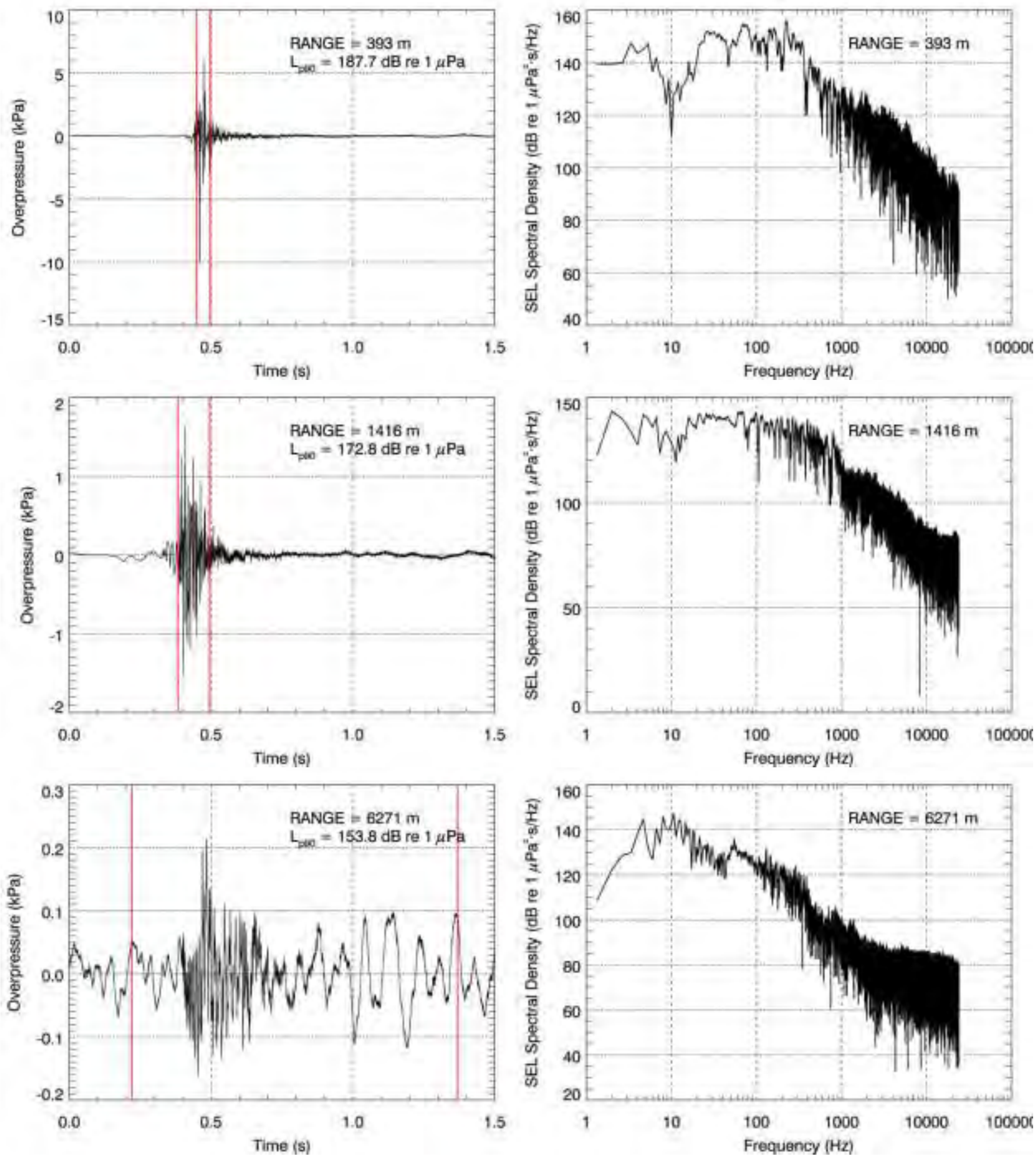
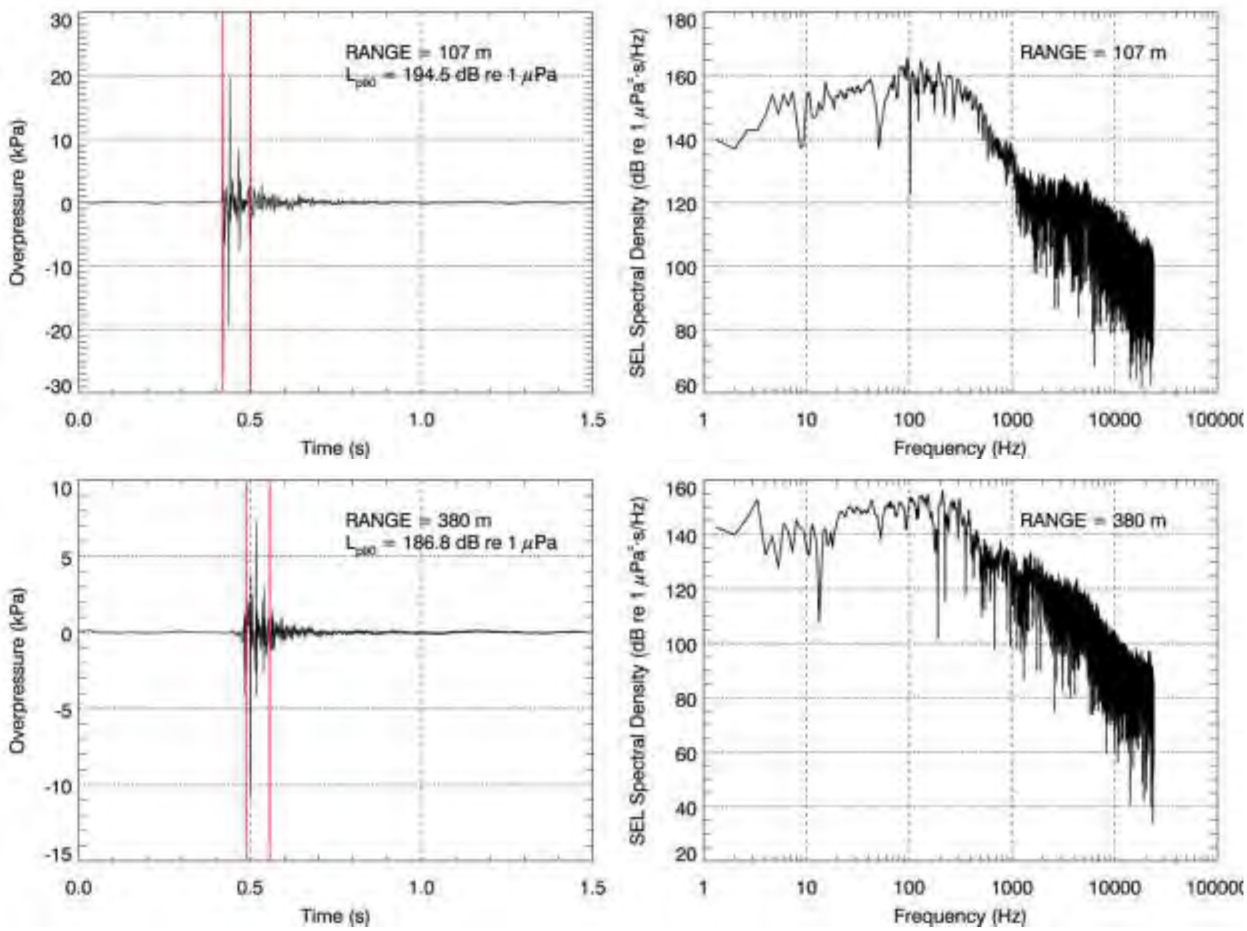


Figure 38. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


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)

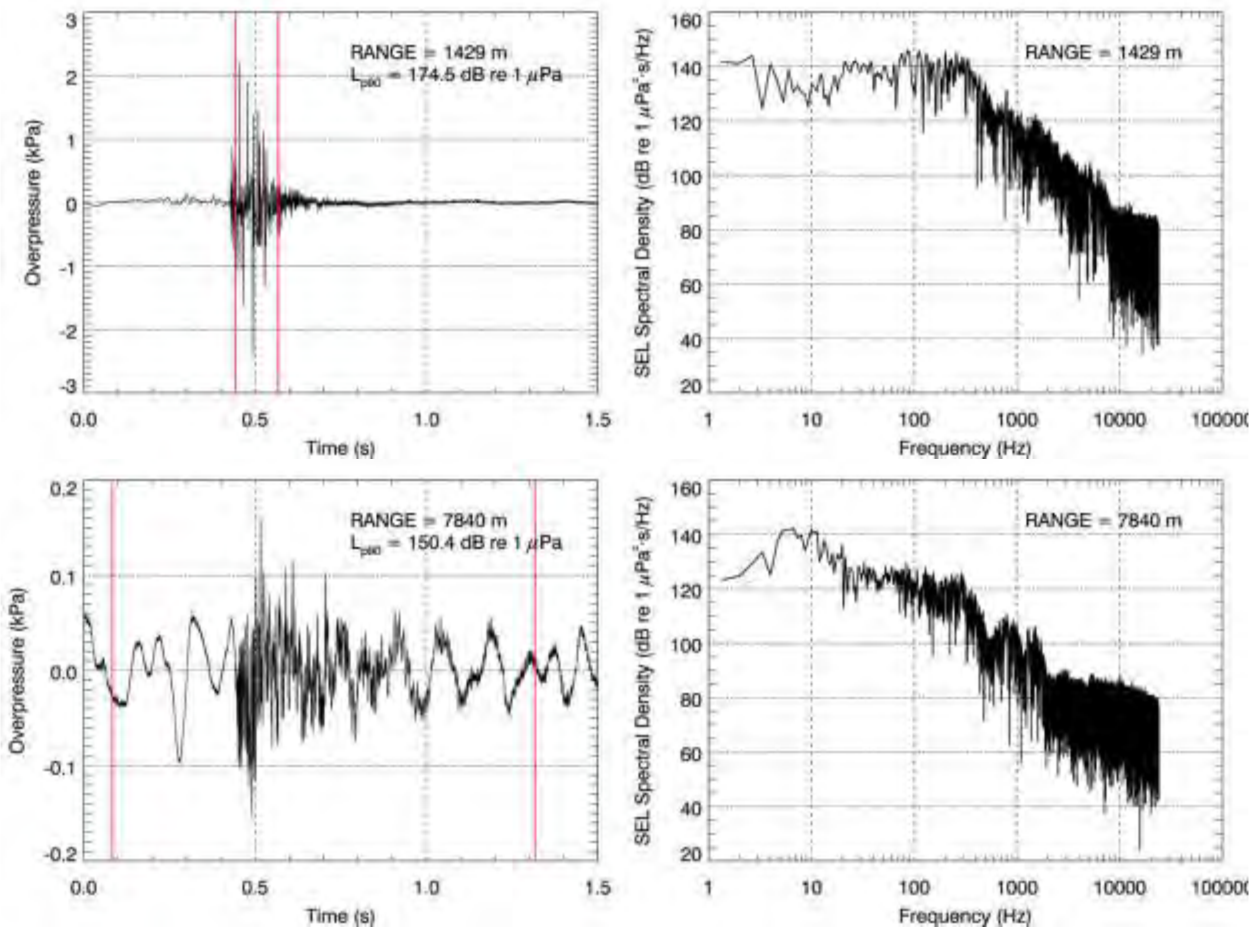


Figure 39. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

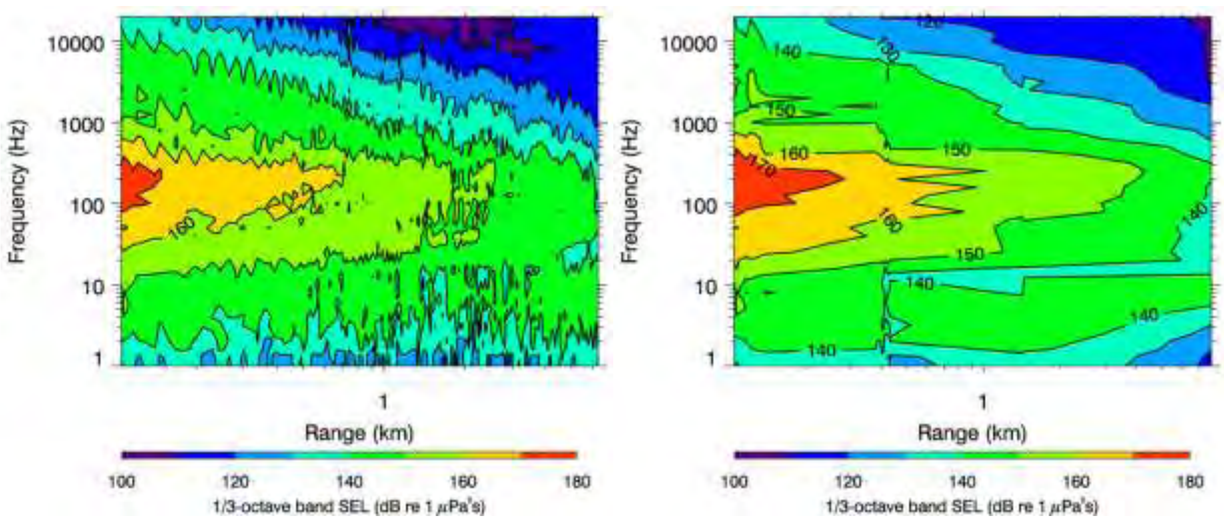


Figure 40. 1/3 octave band SEL levels as a function of range and frequency for the 1200 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

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.

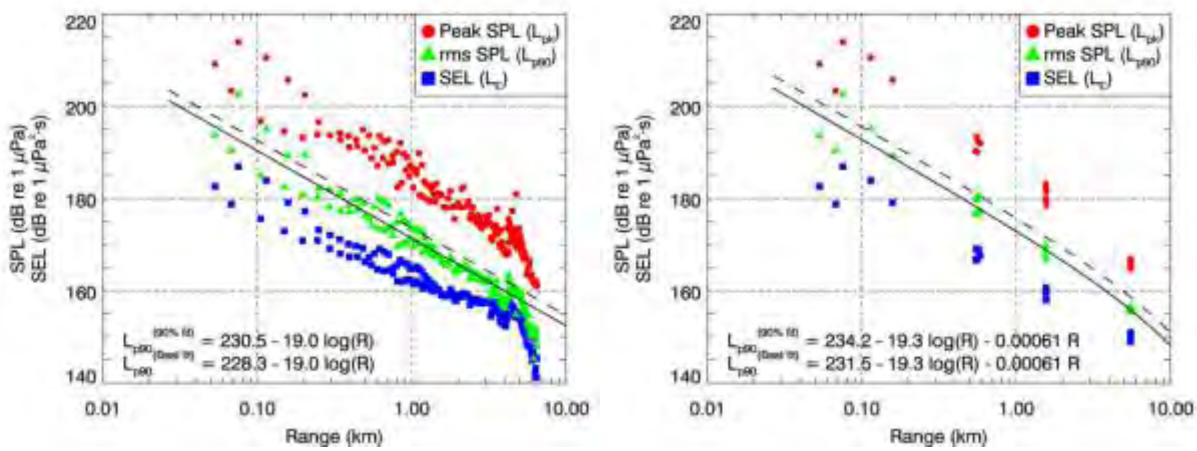


Figure 41: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 1200 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore sites (Track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is 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 Best fit	90th percentile fit	Range (m) in broadside direction 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

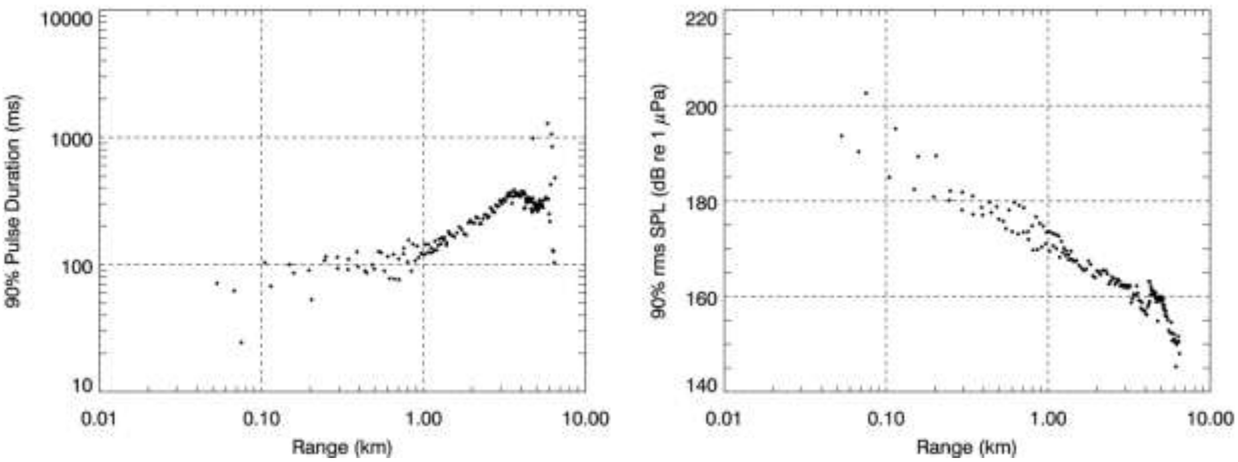


Figure 42. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

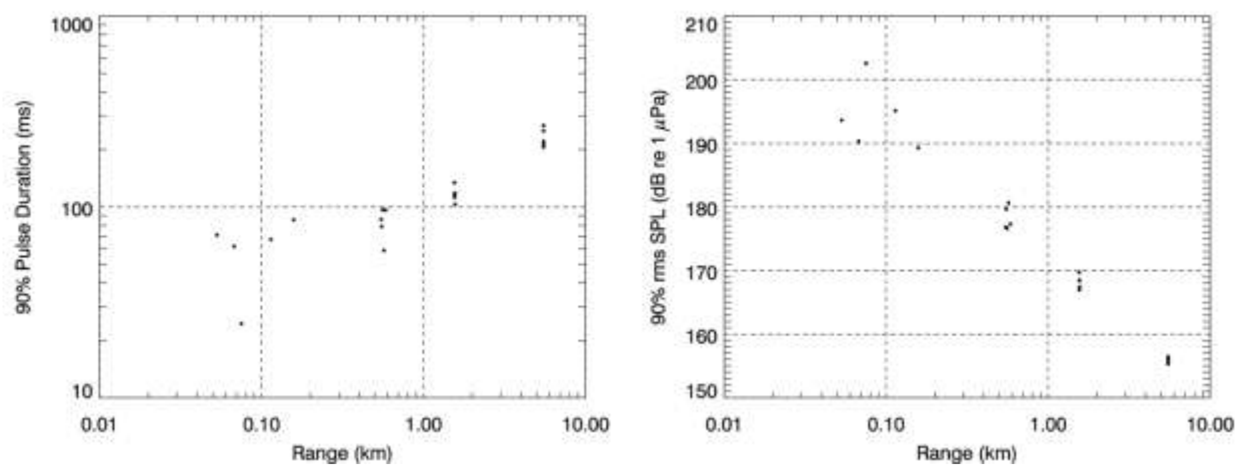


Figure 43. 1200 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

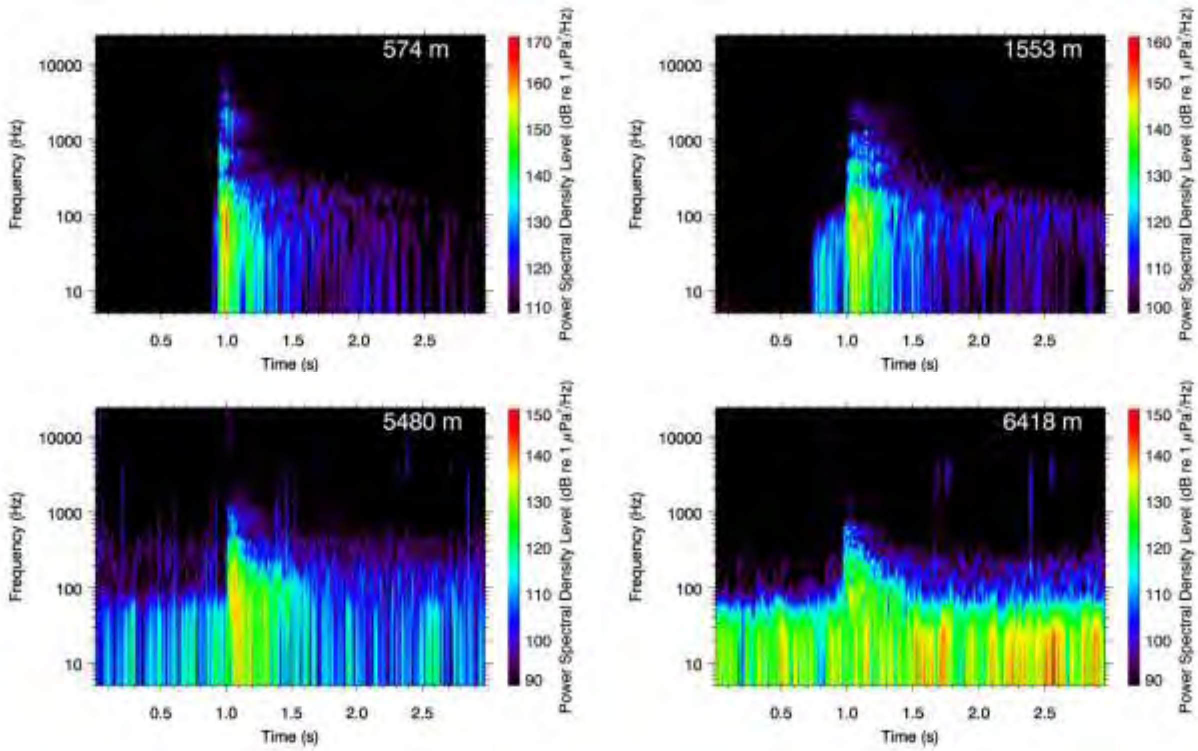


Figure 44. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

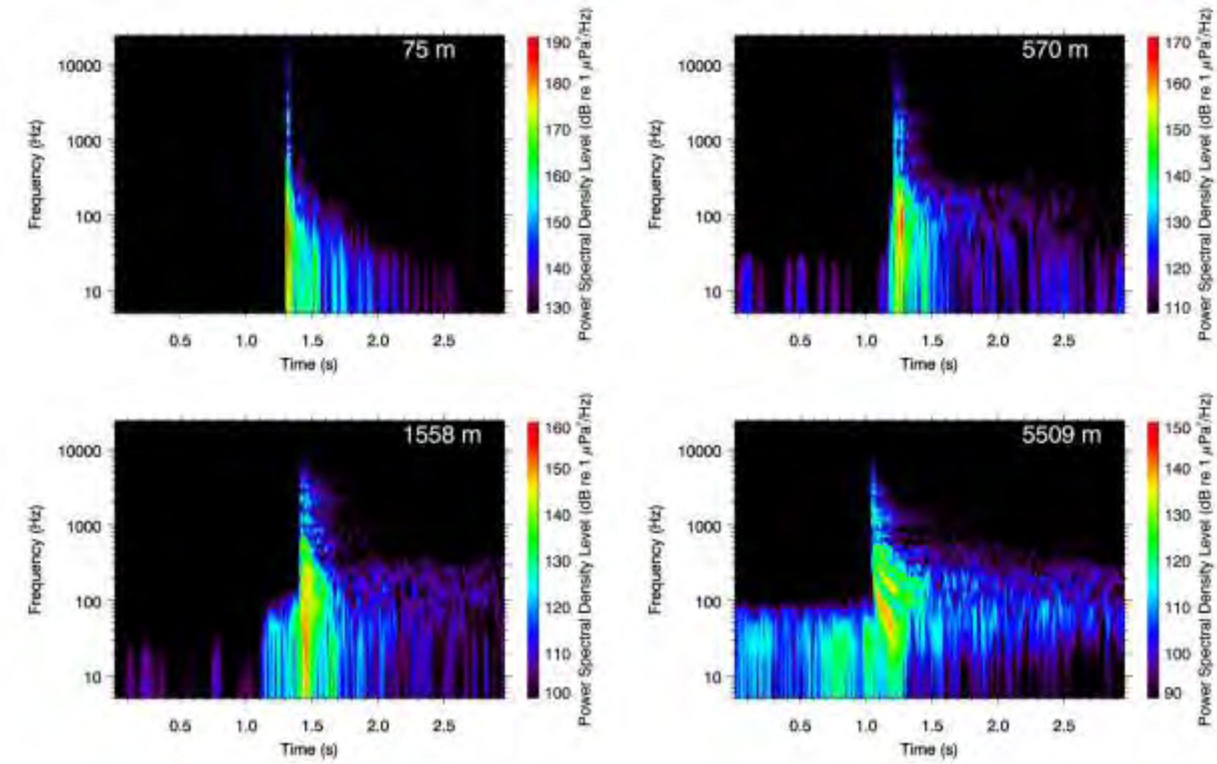
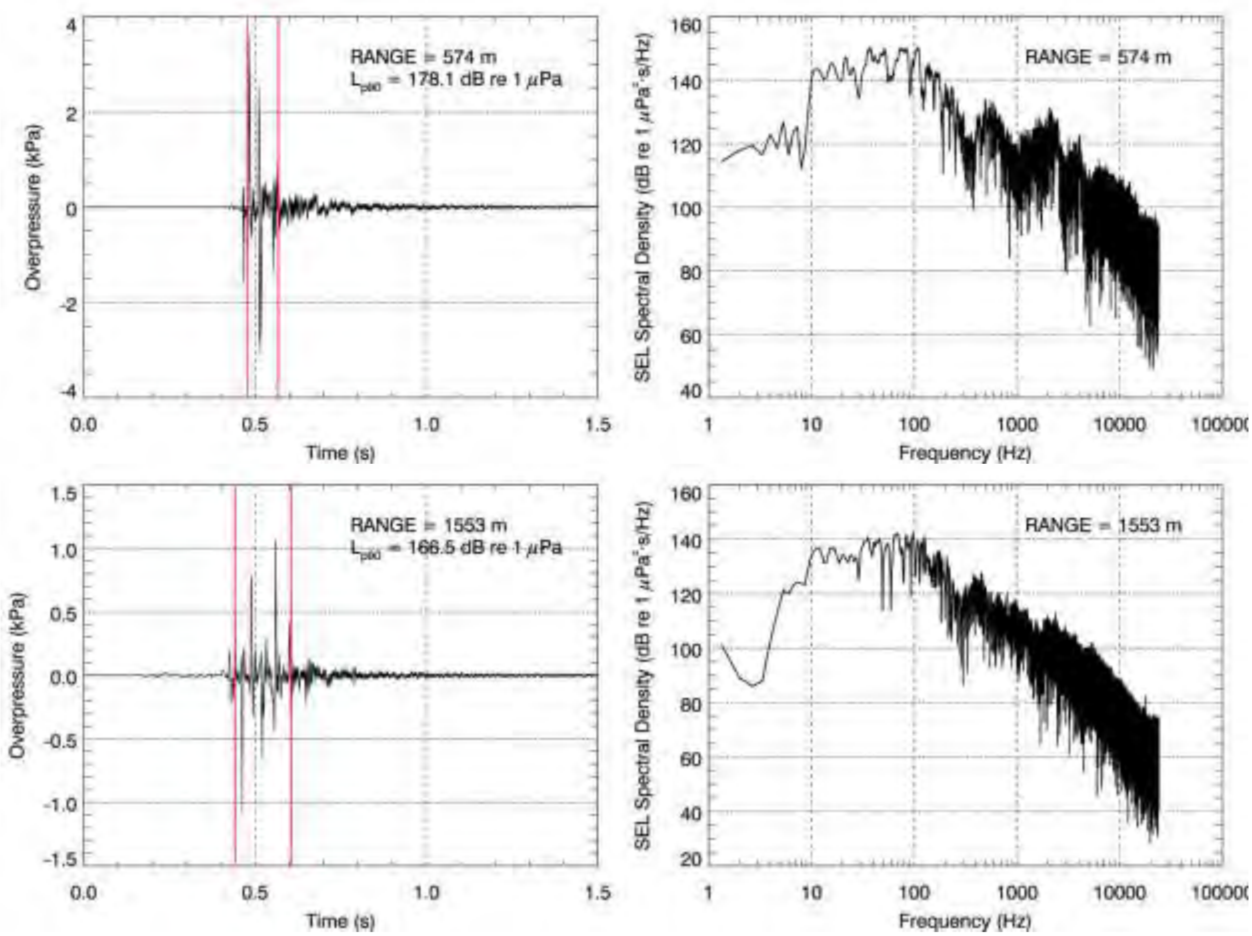


Figure 45. Spectrograms of airgun pulses from the 1200 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5509 m spectrogram is 2048-pt FFT, 48 kHz sample rate).



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)

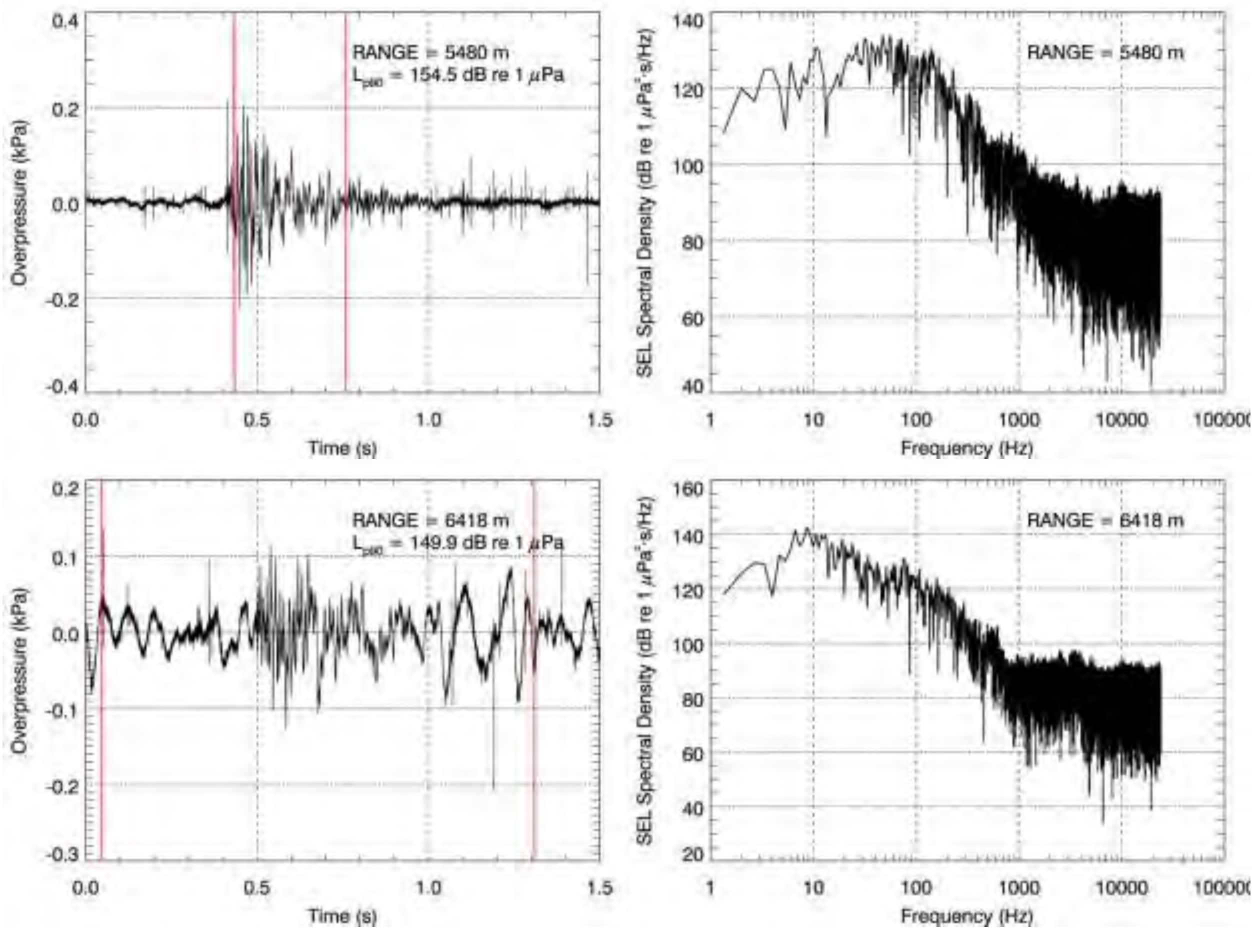
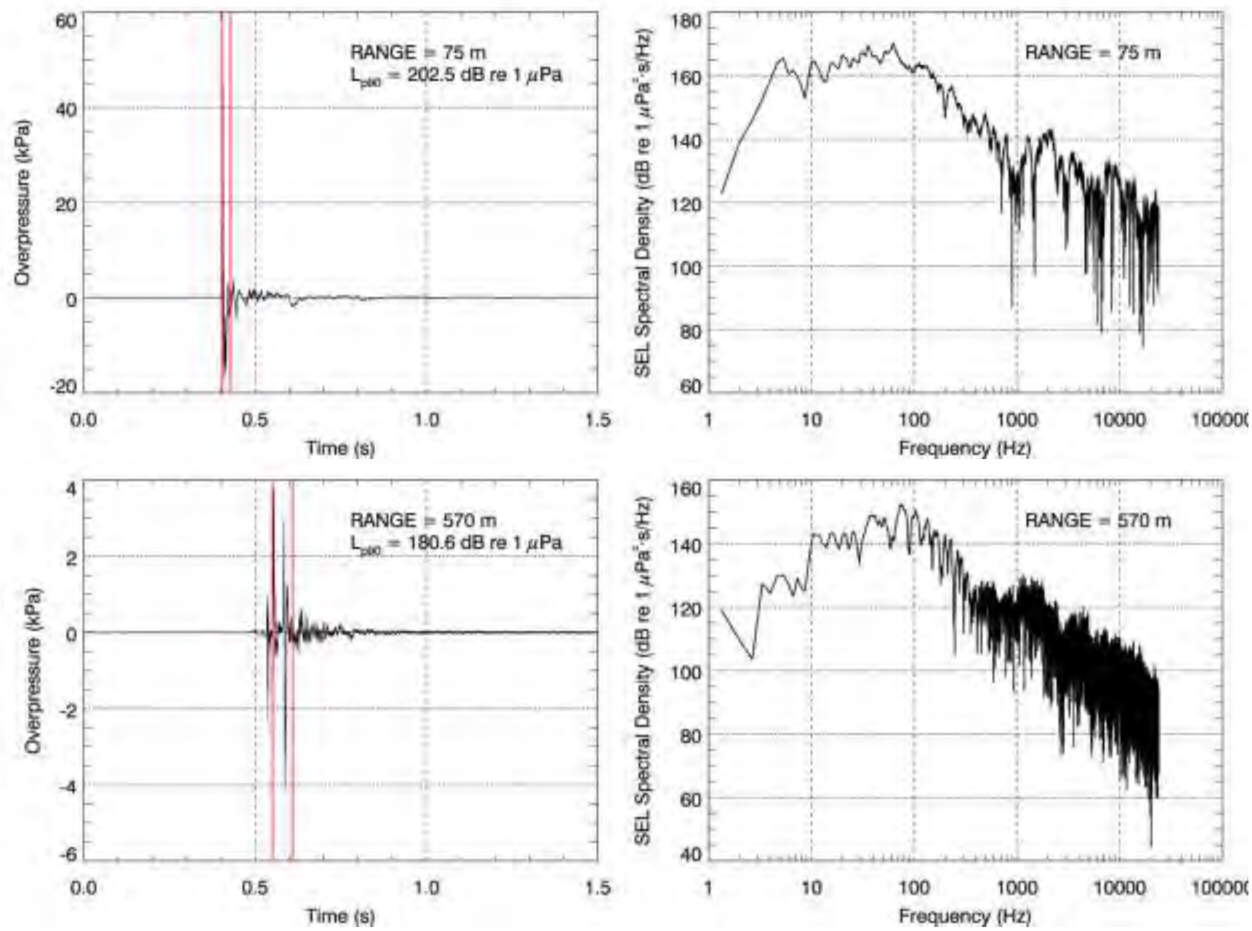


Figure 46. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


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)

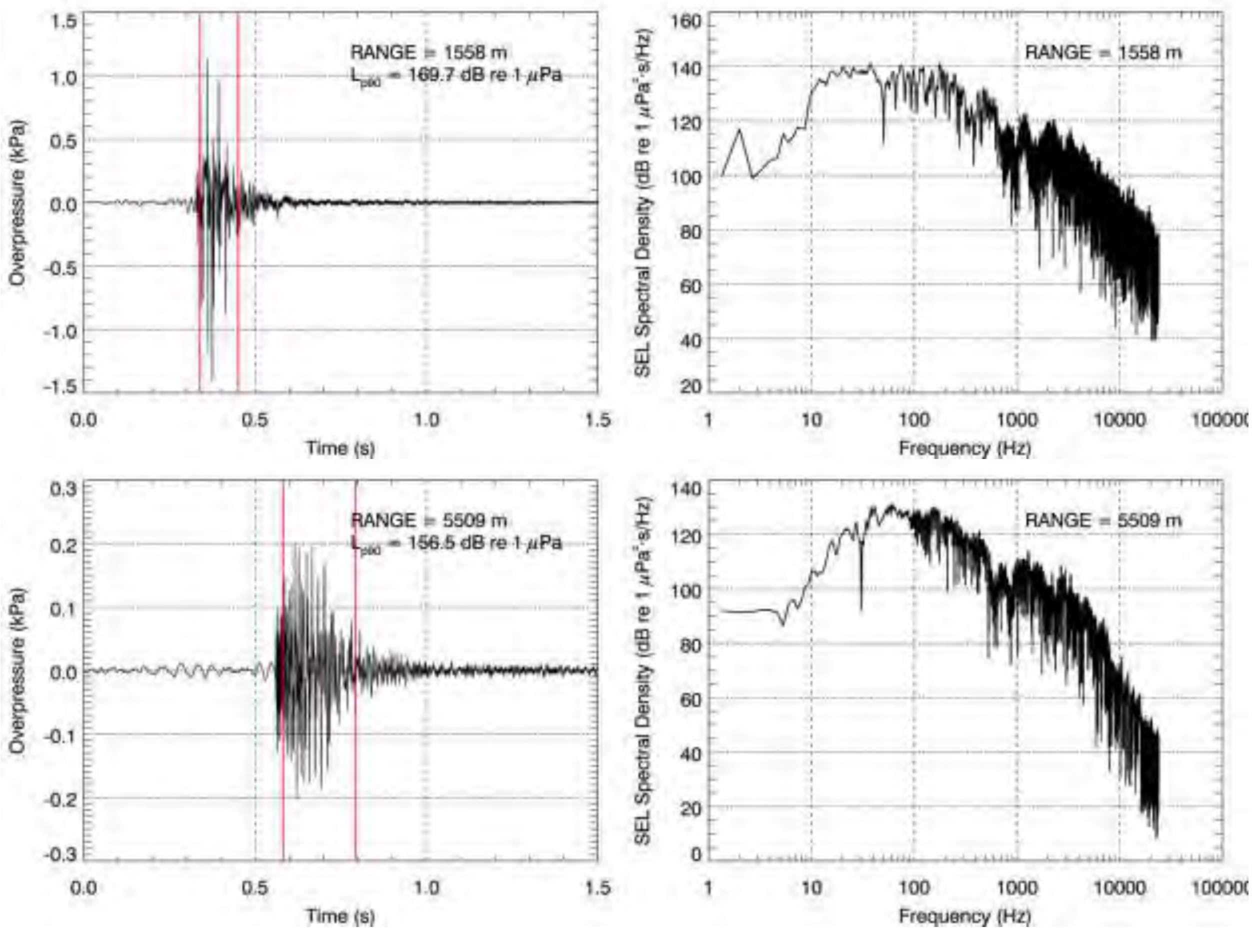


Figure 47. Waveform (left) and corresponding SEL spectral density (right) plots of 1200 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

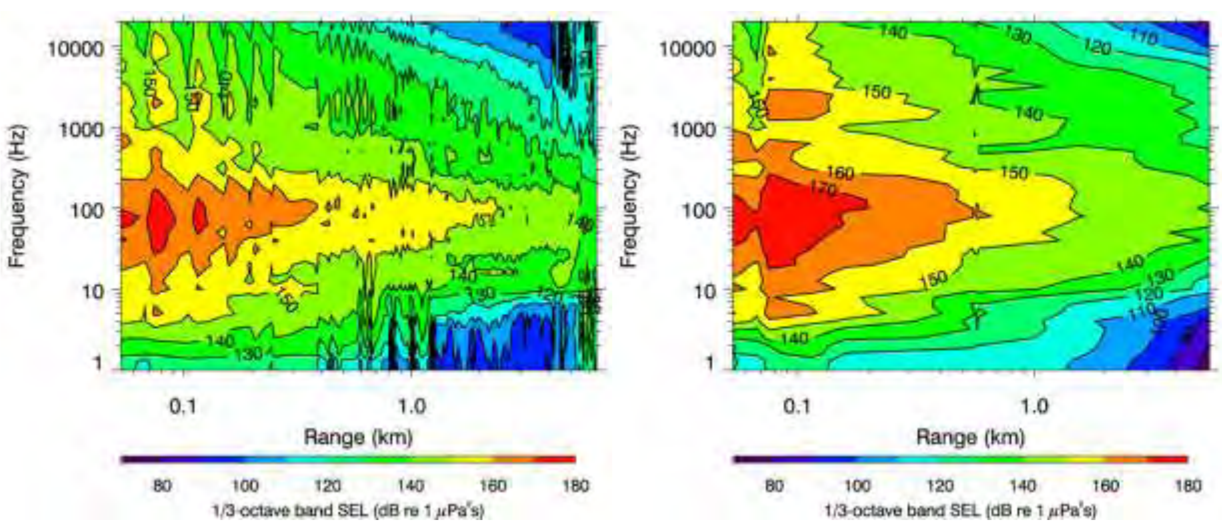


Figure 48. 1/3 octave band SEL levels as a function of range and frequency for the 1200 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

4.4. 2400 in^3 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 in^3 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 in^3 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 in^3 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.

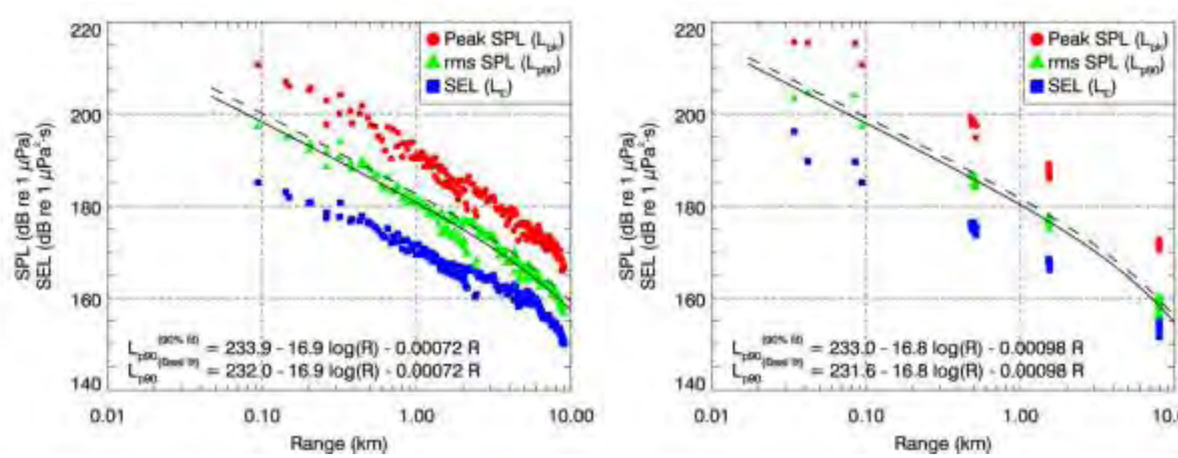


Figure 49: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 2400 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the nearshore sites (track 1). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is 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 Best fit	90^{th} percentile fit	Range (m) in broadside direction Best fit	90^{th} percentile fit
190	300	380	290	350
180	1100	1400	1030	1210
170	3400	4100	3080	3500
160	8200	9500	7070	7770

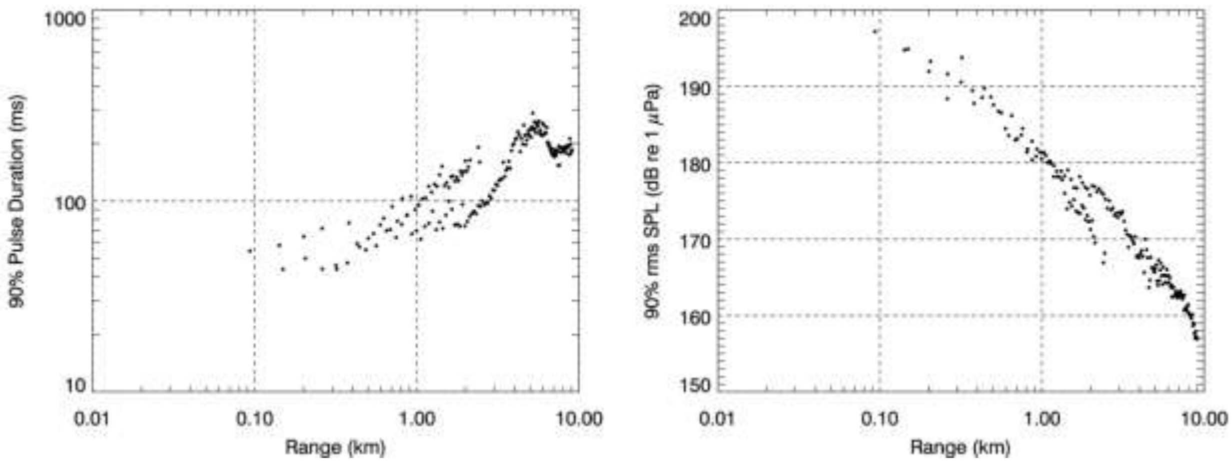


Figure 50. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the nearshore site.

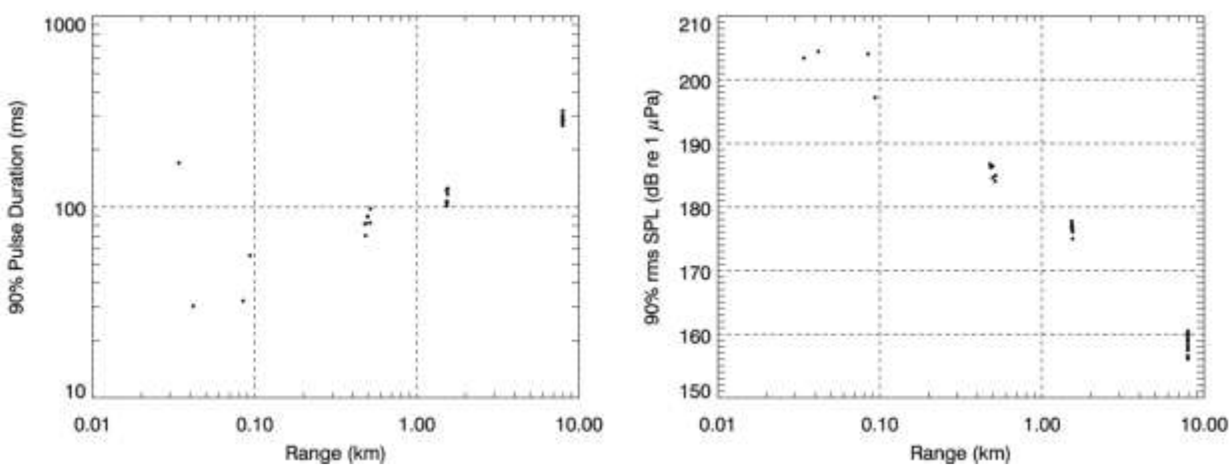


Figure 51. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the nearshore site.

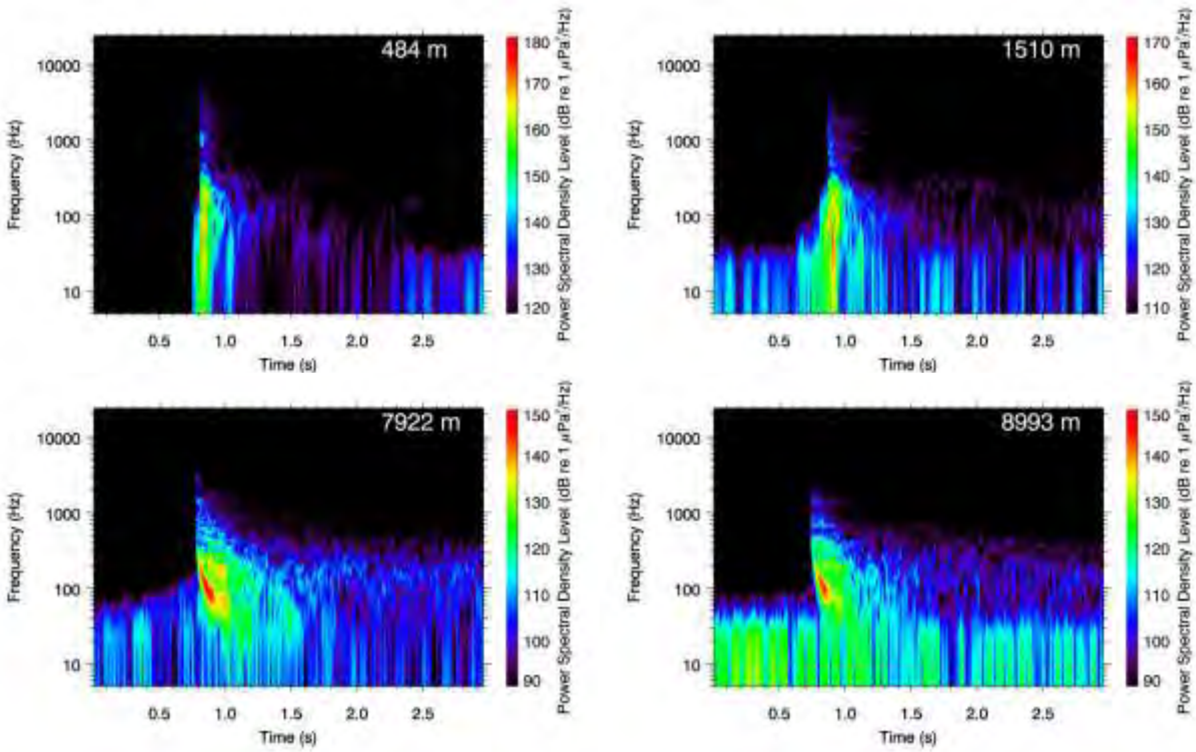


Figure 52. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the endfire direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.

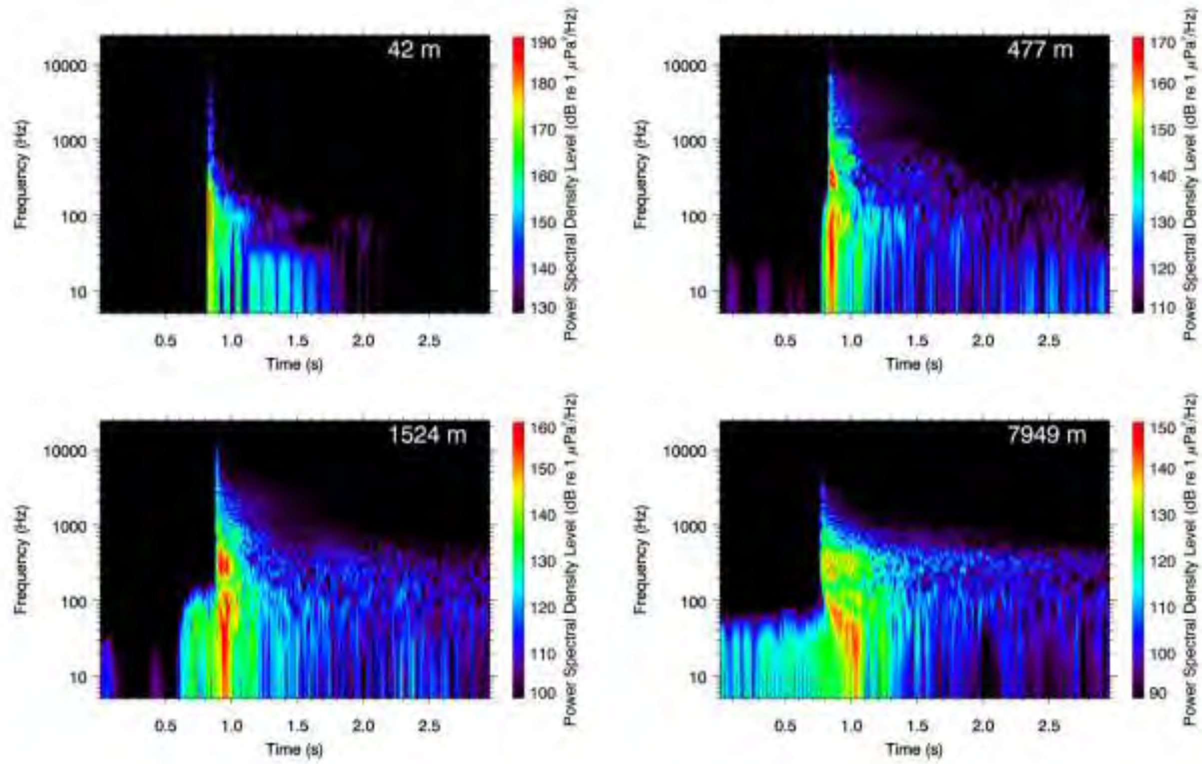
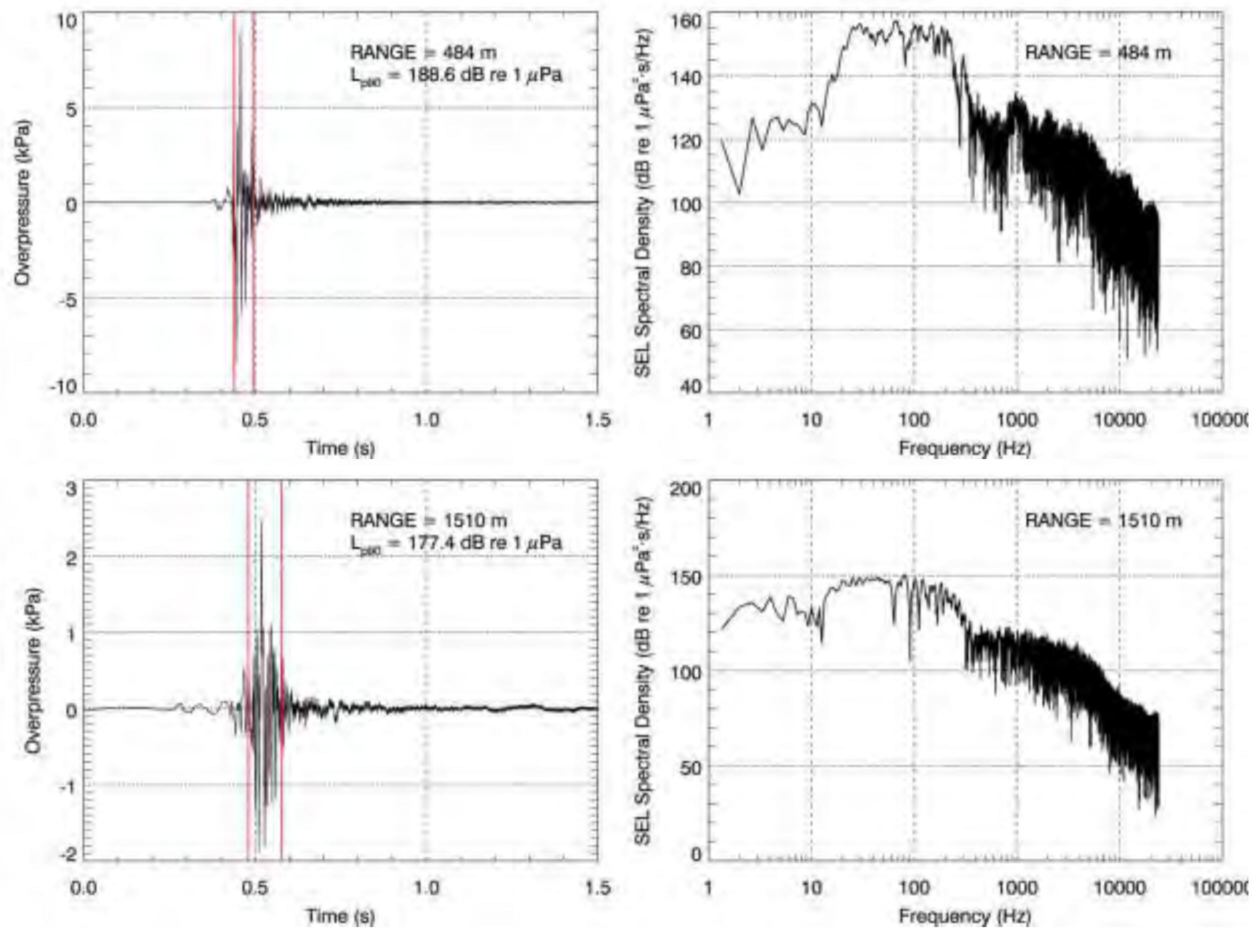


Figure 53. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the broadside direction at the nearshore site. 2048-pt FFT, 48 kHz sample rate, Hanning window.


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)

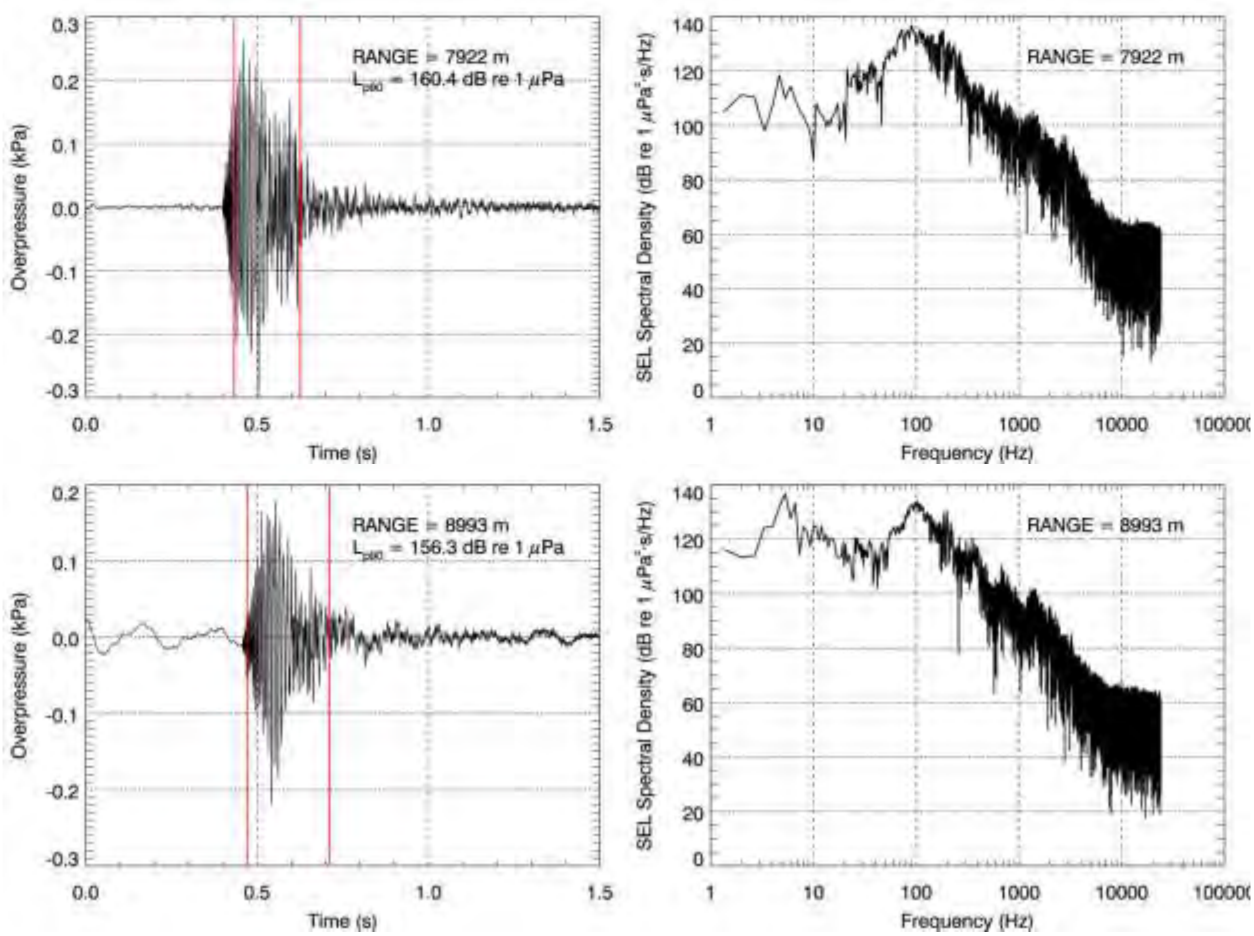
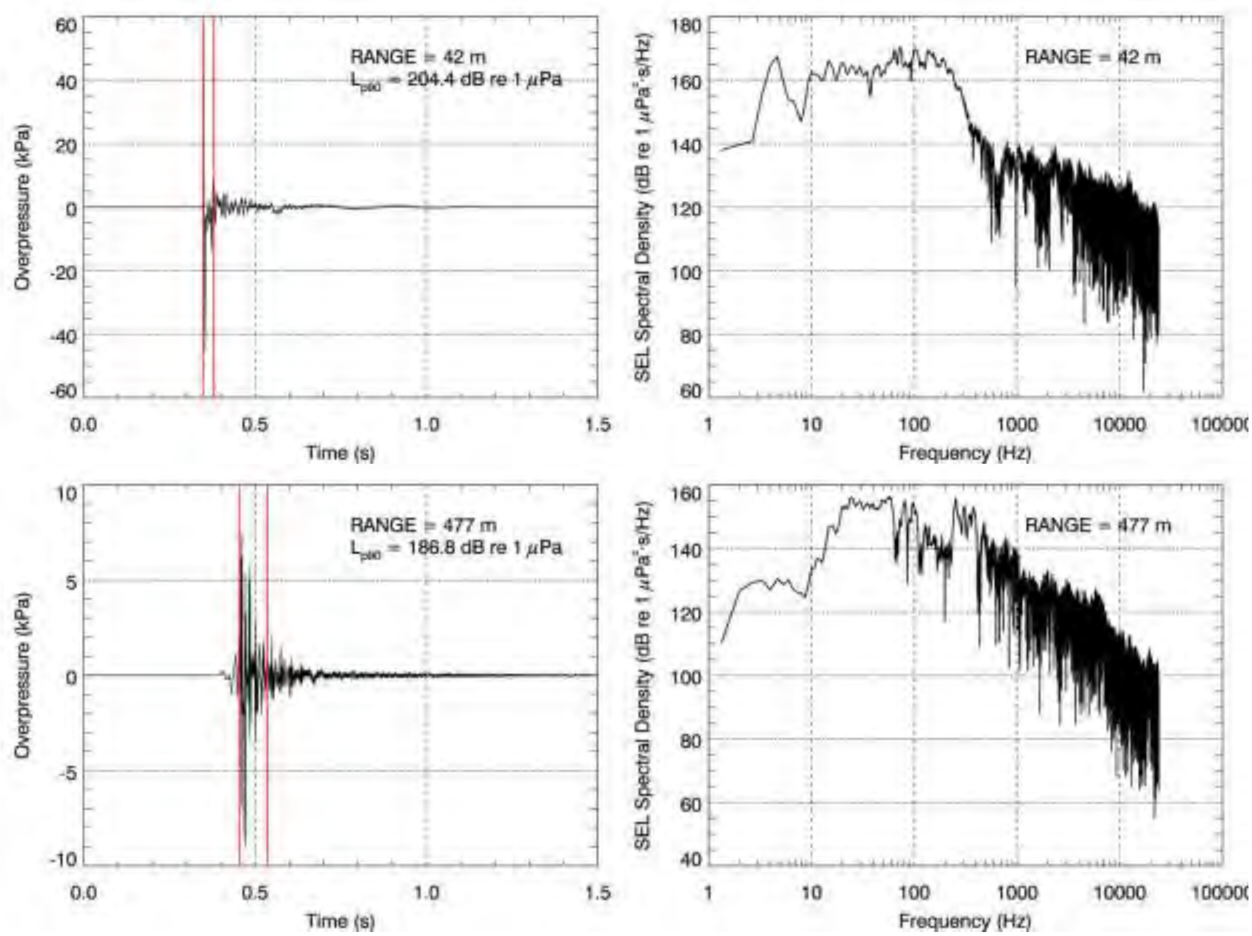


Figure 54. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the endfire direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.



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)

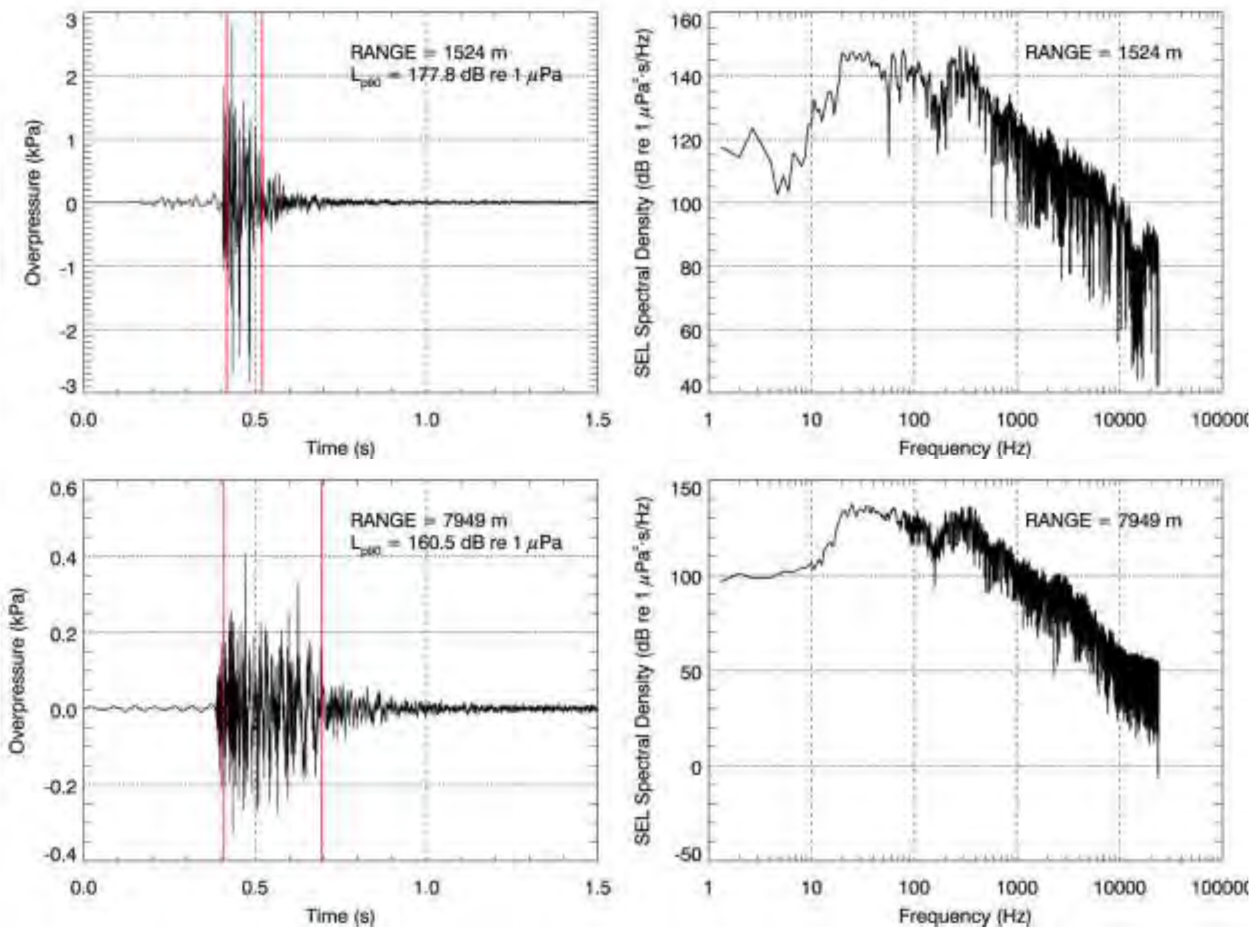


Figure 55. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the broadside direction at the nearshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

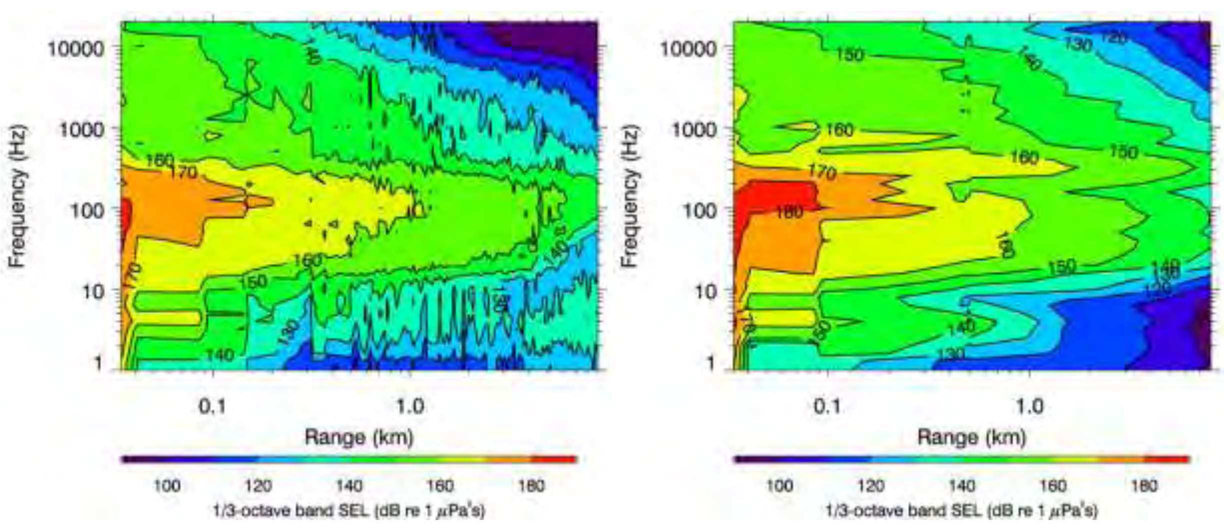


Figure 56. 1/3 octave band SEL levels as a function of range and frequency for the 2400 in³ airgun array in the endfire (left) and broadside (right) directions at the nearshore site.

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 in^3 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 in^3 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.

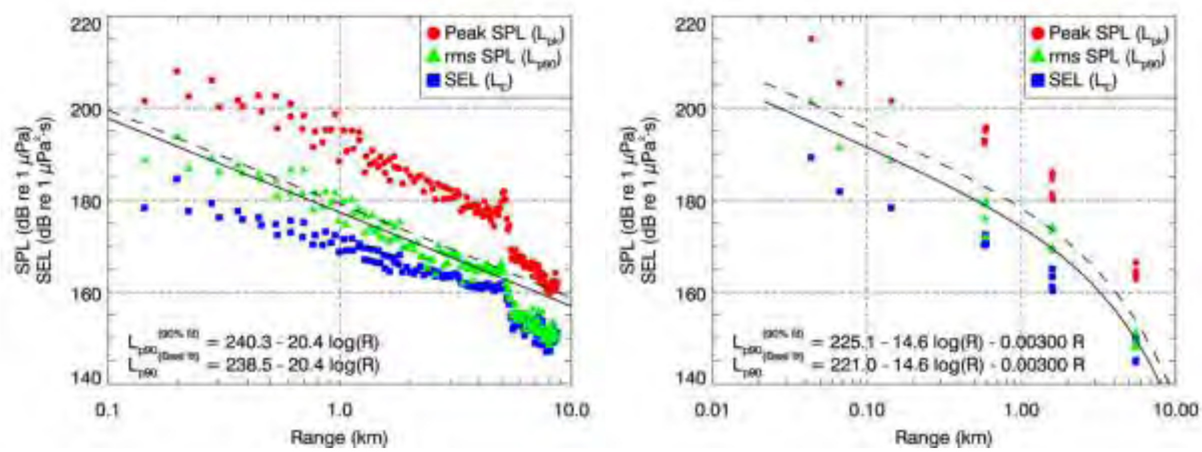


Figure 57: Peak SPL, rms SPL, and sound exposure level (SEL) versus slant range for the 2400 in^3 airgun array pulses in the endfire (left) and broadside (right) directions measured at the offshore site (Track 2). Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is 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	90^{th} percentile fit	Best fit	90^{th} 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

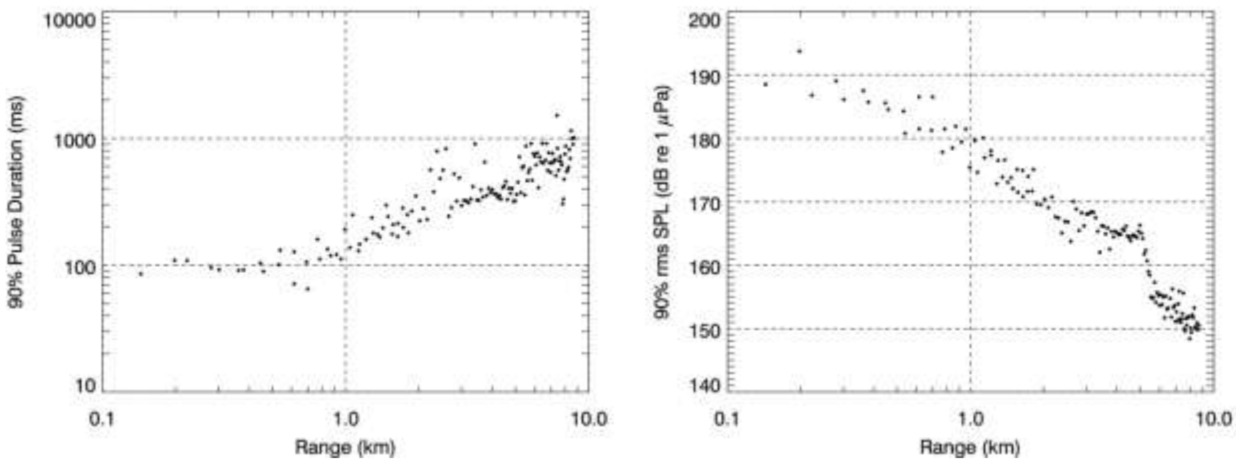


Figure 58. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the endfire direction as a function of range at the offshore site.

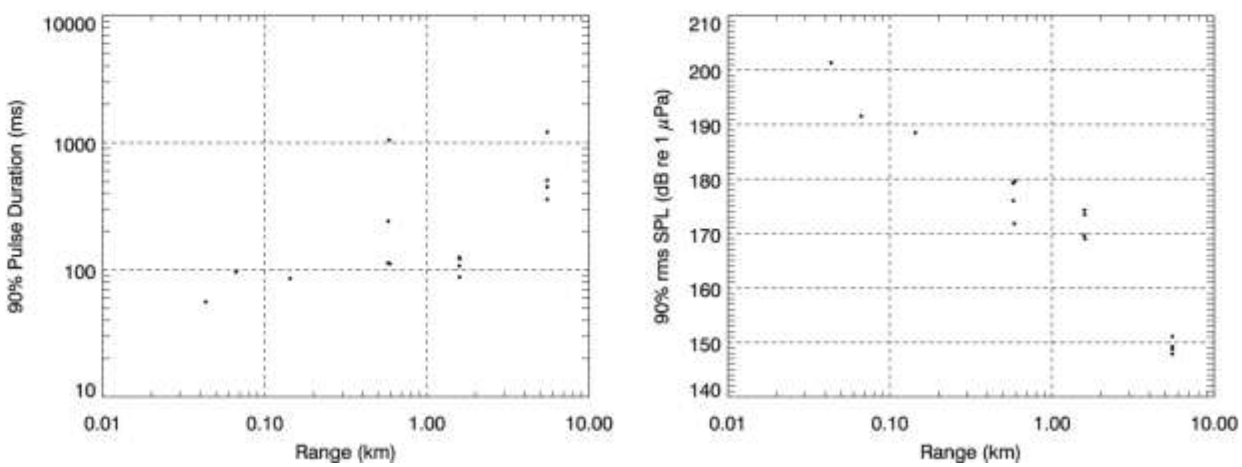


Figure 59. 2400 in³ airgun array 90% pulse duration (left) and rms SPL (right) in the broadside direction as a function of range at the offshore site.

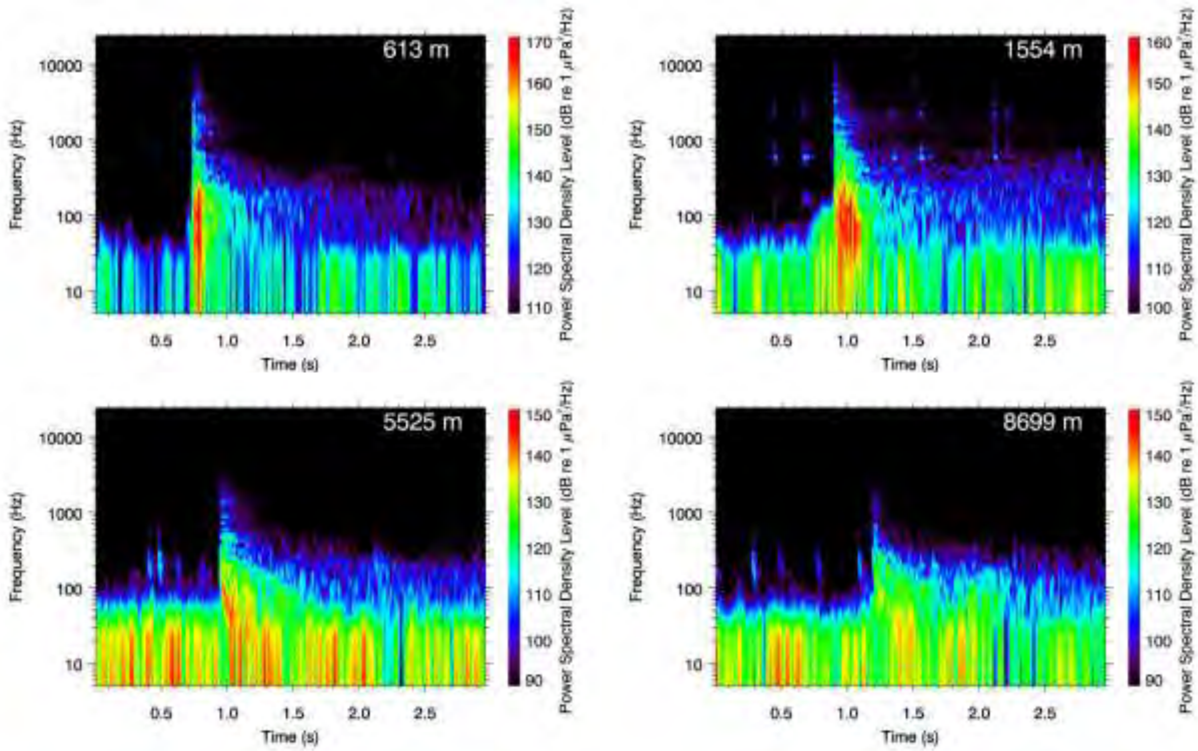


Figure 60. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the endfire direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window.

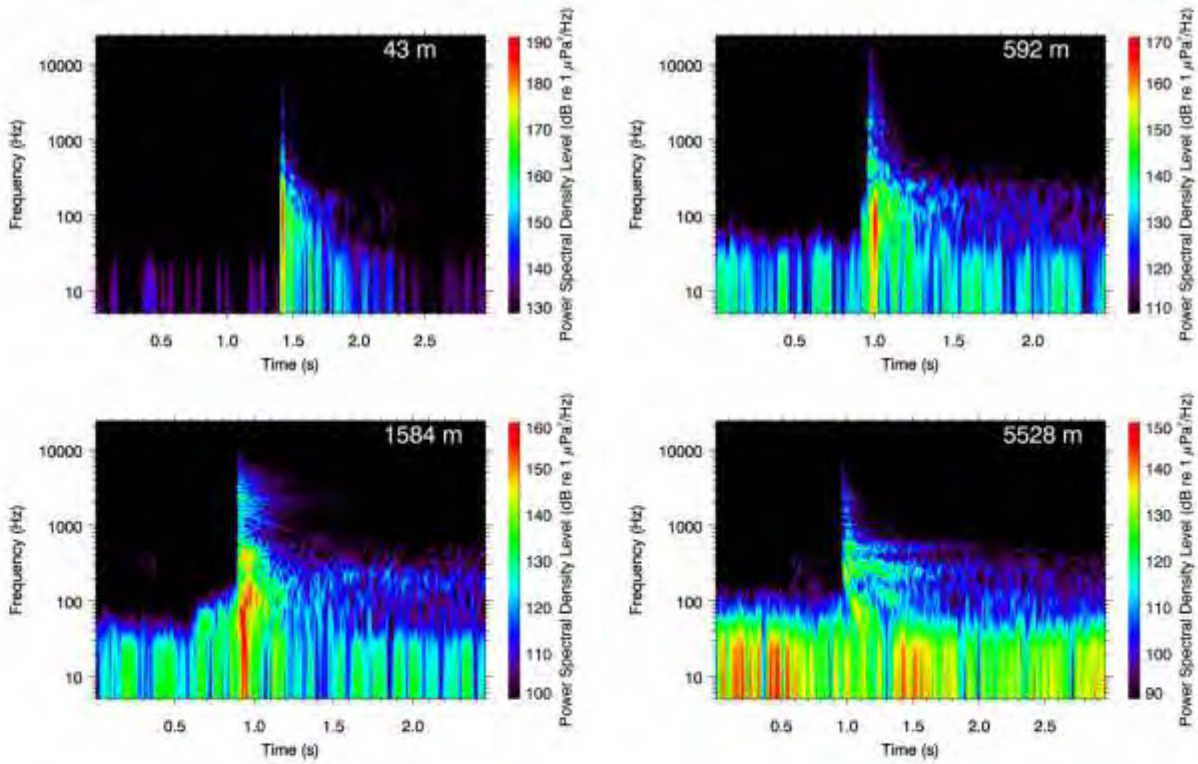
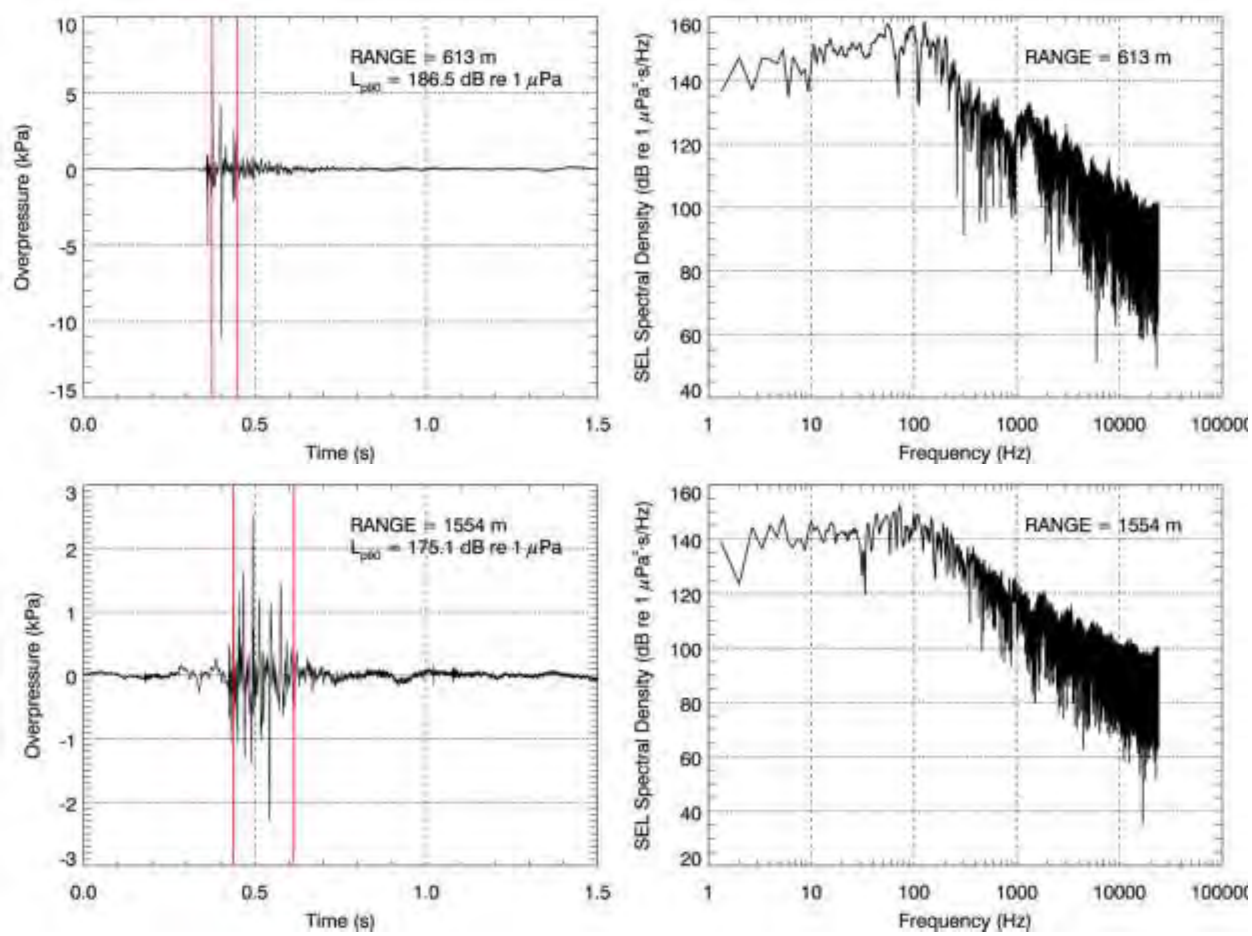


Figure 61. Spectrograms of airgun pulses from the 2400 in³ airgun array at various distances in the broadside direction at the offshore site. 4096-pt FFT, 96 kHz sample rate, Hanning window (5528 m spectrogram is 2048-pt FFT, 48 kHz sample rate).


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)

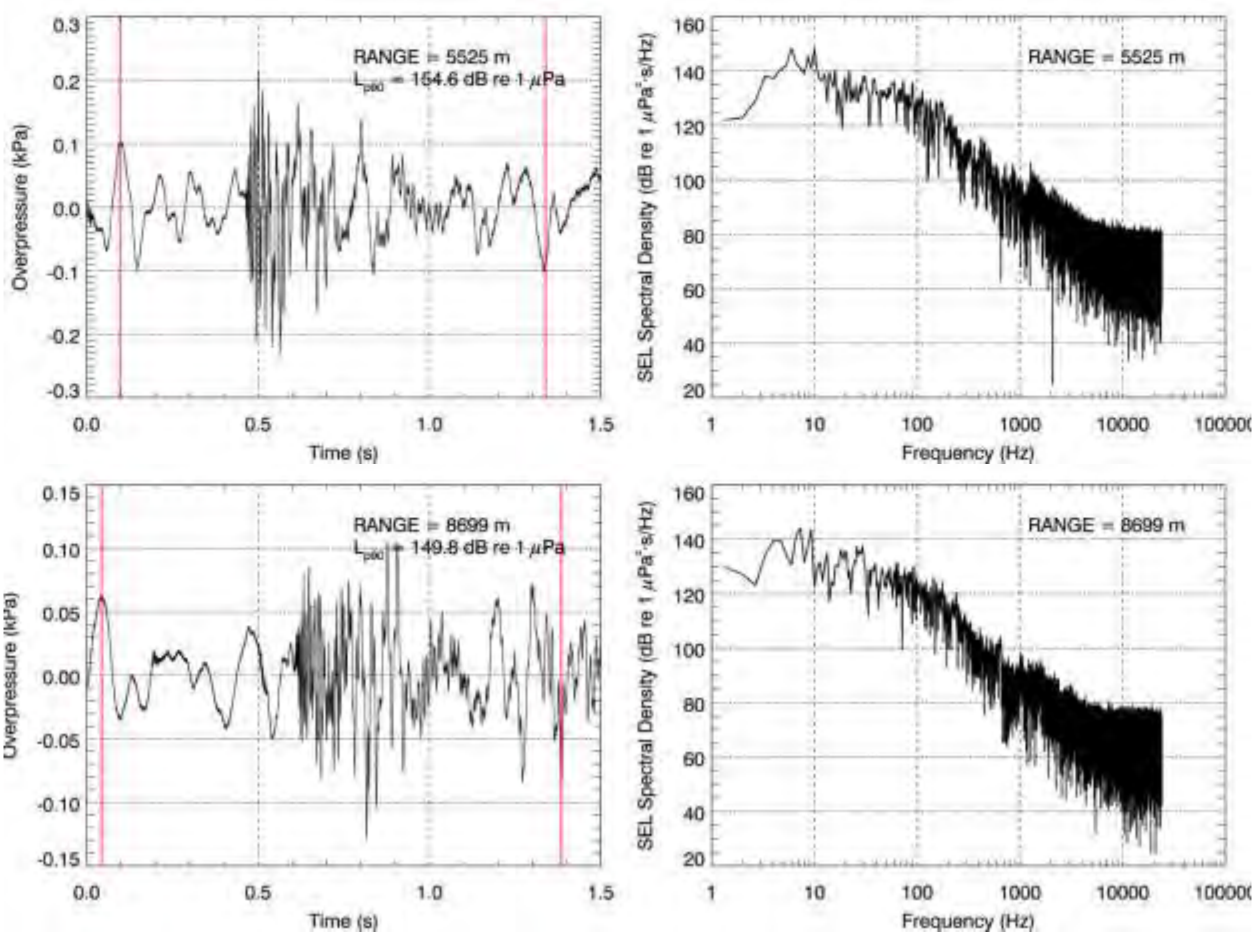
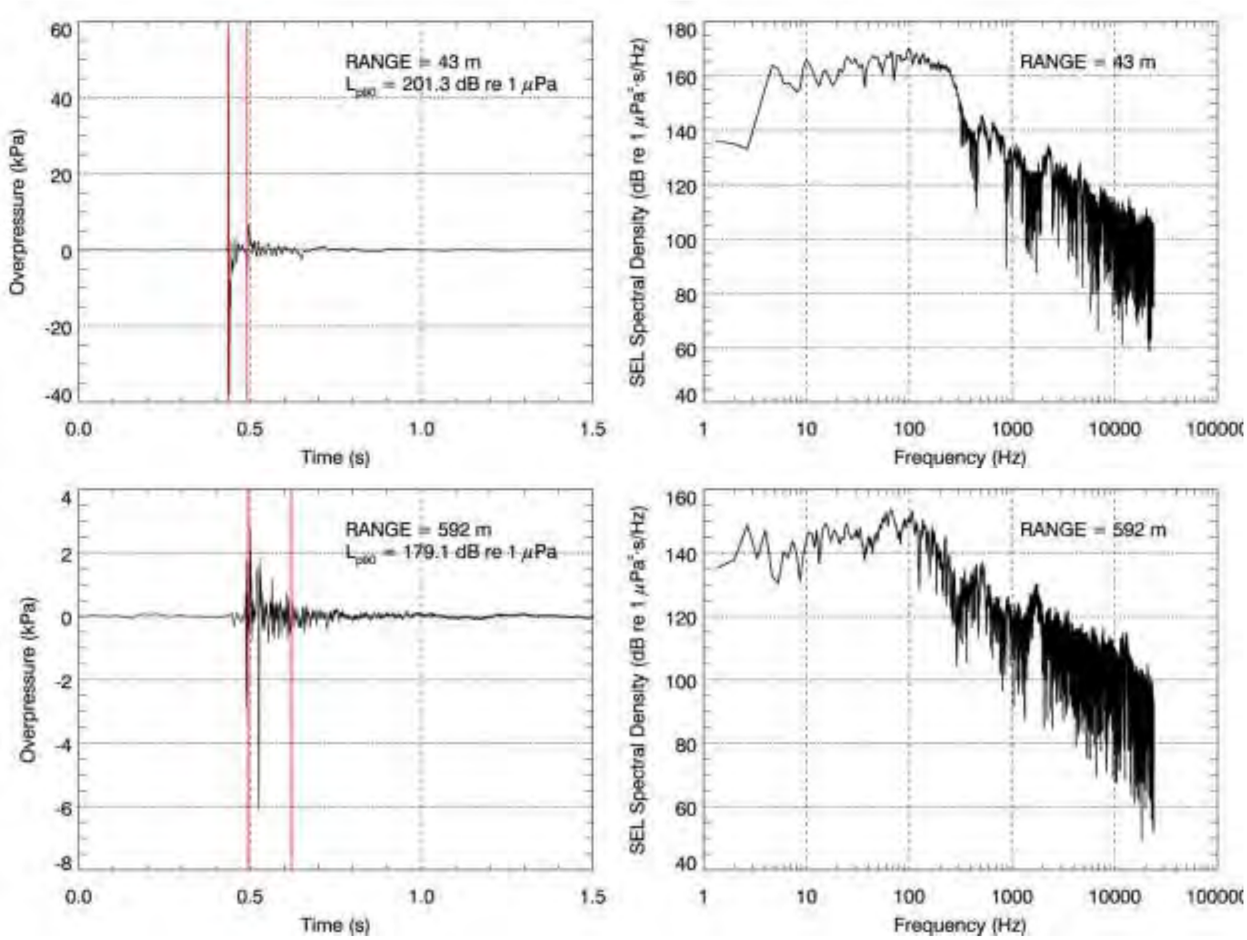


Figure 62. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the endfire direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.


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)

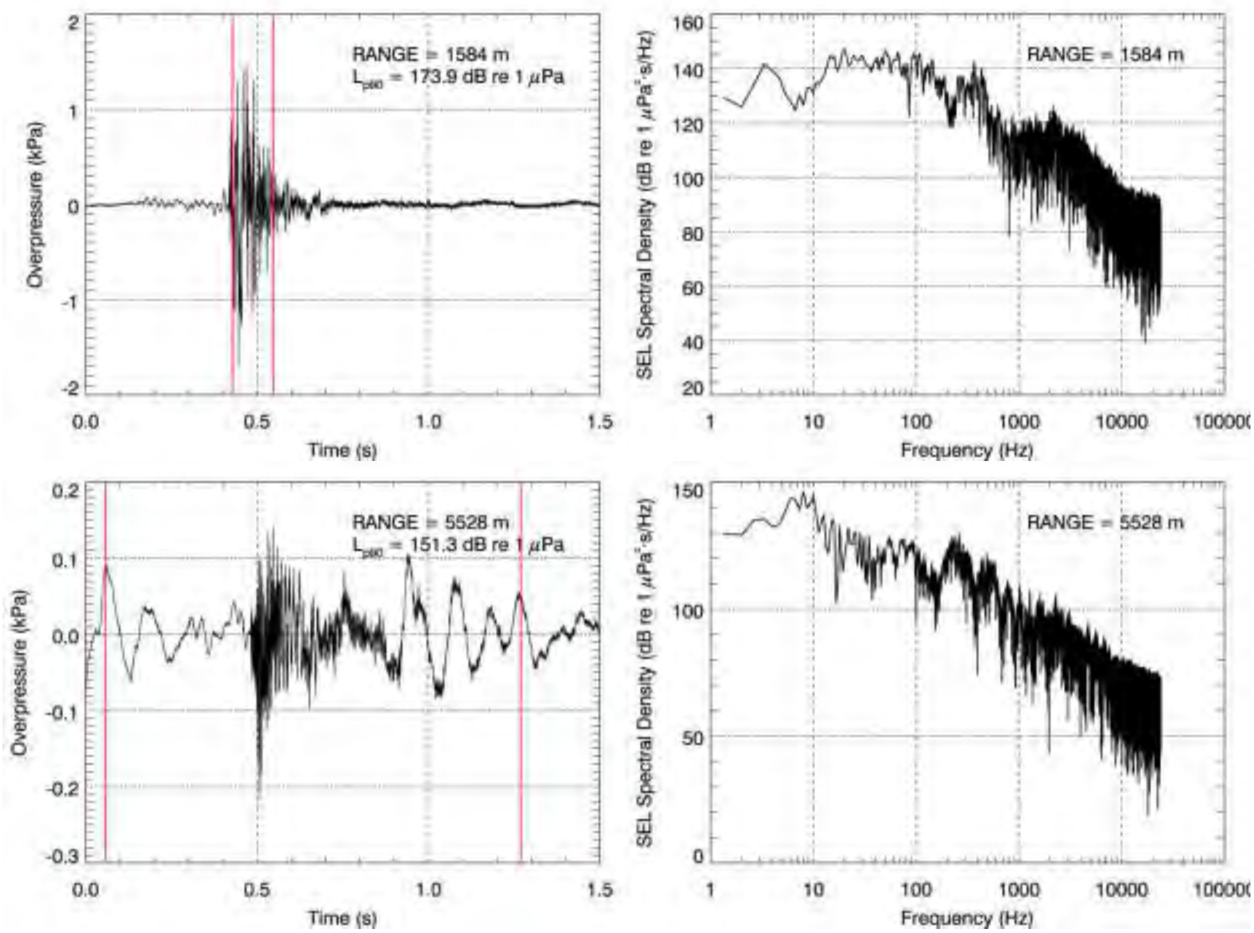


Figure 63. Waveform (left) and corresponding SEL spectral density (right) plots of 2400 in³ airgun array pulses at various distances in the broadside direction at the offshore site. The red bars on the waveform plot indicate the 90% energy pulse duration.

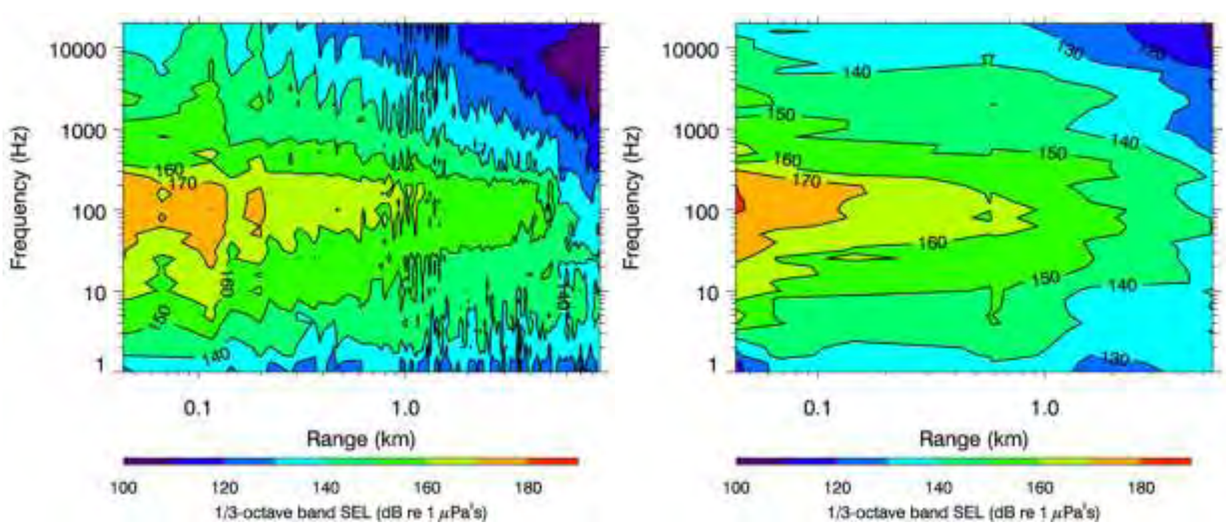


Figure 64. 1/3 octave band SEL levels as a function of range and frequency for the 2400 in³ airgun array in the endfire (left) and broadside (right) directions at the offshore site.

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 90^{th} 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 in³ 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 in³ 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

7. Literature Cited

McCrodan, A. B., C. McPherson and D.E. Hannay. 2011. *Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey*: Version 2.0. Technical report for Fairweather LLC and Apache Corporation by JASCO Applied Sciences.

Warner, G., J. Wladichuk and D.E. Hannay. *Sound Source Acoustic Measurements for Apache's 2012 Cook Inlet Seismic Survey*: Version 2.0. Technical report for Fairweather LLC by JASCO Applied Sciences. June 3, 2011.

APPENDIX C-3
PASSIVE ACOUSTIC MONITORING REPORT

Passive Acoustic Monitoring Summary Report

Apache 2012 Cook Inlet Seismic Survey

Submitted to:
Fairweather LLC for
Apache Corporation

Authors:
Melanie Austin
David Zeddies

4 January 2013

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Contents

Figures

Tables

1. Introduction

Apache Alaska Corporation completed a seismic survey in Cook Inlet, Alaska in the summer of 2012. In accordance with the Incidental Harassment Authorization for the survey, JASCO Applied Sciences conducted Passive Acoustic Monitoring (PAM) throughout the duration of the survey. The PAM activities complemented a comprehensive visual monitoring program.

The original monitoring plan envisioned use of fixed buoys to broadcast acoustic measurements using a radio-system link back to a monitoring vessel. That approach was found to be difficult to employ because the buoy would have to be moved and redeployed repeatedly as the survey progressed. Instead, the study used a PAM system consisting of a single omni-directional hydrophone lowered from the side of the M/V *Dreamcatcher*. The hydrophone was connected in real-time to a recording and display station, which was monitored by skilled operators throughout the survey. A dedicated Protected Species Acoustic Observer (PSAO) was on-shift at all times to operate the system and monitor detections of marine mammal vocalizations. PAM activities began on 11 May 2012 and continued through to 30 Sept 2012, with intermittent gaps due to poor weather or to the vessel being used for purposes other than as a monitoring platform.

The goals of the PAM program were as follows:

- Perform real-time monitoring to detect marine mammal vocalizations during all seismic survey operations and during most periods when seismic sources were inactive.
- Communicate acoustic detections to Protected Species Visual Observers (PSVOs) so they could initiate shut down of seismic activity if necessary.
- Keep a record of detected vocalizations.

This report describes monitoring methods and the equipment forming the PAM system, summarizes the obtained detections, and discusses the efficacy of the PAM system in Cook Inlet. Suggestions for future work are also discussed.

2. Environment

Apache Alaska Corporation's seismic survey was conducted along the western coast of upper Cook Inlet. This area constitutes a dynamic tidal estuary with significant currents with mean velocities approximately 3 to 6 knots. Currents can be as high as 12 knots in some locations. This environmental characteristic creates a considerable challenge for acoustic monitoring both physically, in terms of system deployment, and acoustically, in terms of flow noise that can obscure vocalizations in acoustic data. Spectrograms that show the frequency distribution of the recorded acoustic data, and how the acoustic data changed with the running tides, are in Section 4.

Other external noise sources influenced the efficacy of the PAM system; noise from the monitoring vessel was the most significant interfering source, but other project vessels also produced considerable noise at closer distances. Seismic impulses from the airgun array sources were detectable for nearly the full time of operations. PAM operators were particularly careful to distinguish clicks made by harbor porpoises or belugas from noise made by vessel-based equipment (sonars, etc.) by noting whether the presence of clicks corresponded with vessels arriving alongside the monitoring platform.

3. Methods

At the outset of the program, we intended to deploy an acoustic telemetry buoy with a hydrophone suspended from it. Acoustic data could then transmit through a radio antenna for reception at a vessel-based PAM station. The advantage of using such a buoy is that the monitoring vessel can be a distance (~2 km) from the hydrophone, which greatly reduces the amount of interfering vessel noise (Wladichuk 2011). This arrangement also allows the monitoring vessel to move about, provided it stays within reception range of the buoy. Unfortunately, in the first day of deployment rough seas exceeded stable conditions for the telemetry buoy and it inverted, immersing and damaging the telemetry equipment. The buoy was not redeployed because it would have been difficult to successfully redeploy the buoy multiple times as the survey locations changed quite quickly.

In place of using the telemetry buoy, acoustic recordings streamed in real-time from a single TC4032 hydrophone (RESON) lowered over the side of the vessel with a 32 ft (10 m) cable that was attached to a monitoring and recording station aboard the M/V *Dreamcatcher*. A hydrodynamically-shaped weight sunk the hydrophone (Figure 1) several feet below the water's surface from the side of the vessel. Hydrophone depth was affected by current strength; the depth varied throughout the monitoring period.

PSAOs performed real-time monitoring on the bridge using an Acoustic Data Acquisition and Monitoring System (ADAMS; JASCO Applied Sciences) and a laptop computer that displayed and recorded the acoustic data (Figure 2). JASCO's custom software, SpectroPlotter, displayed the signal amplitude and spectrum while continuously processing the data for acoustic event detection. The incoming acoustic signals were recorded as WAV files to analyze later. To monitor acoustic signals up to 32 kHz, we set the system to record at a sample rate of 64 000 samples per second.

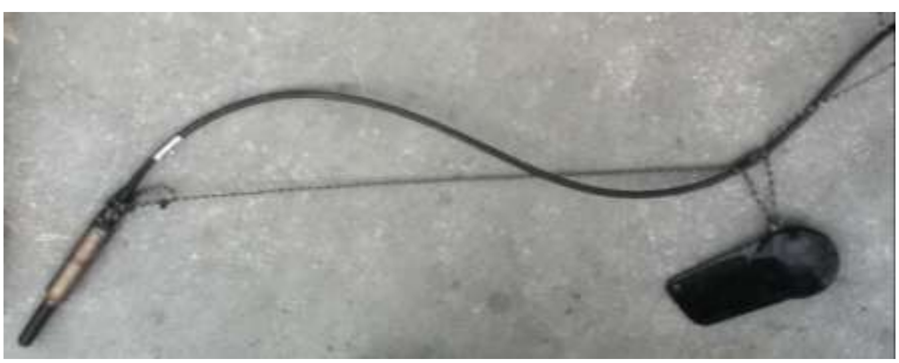


Figure 1. RESON TC4032 hydrophone on 32 ft (10 m) cable, with an 8 lb (4 kg) weight used to sink the hydrophone. The ADAMS (JASCO) is shown in Figure 2.

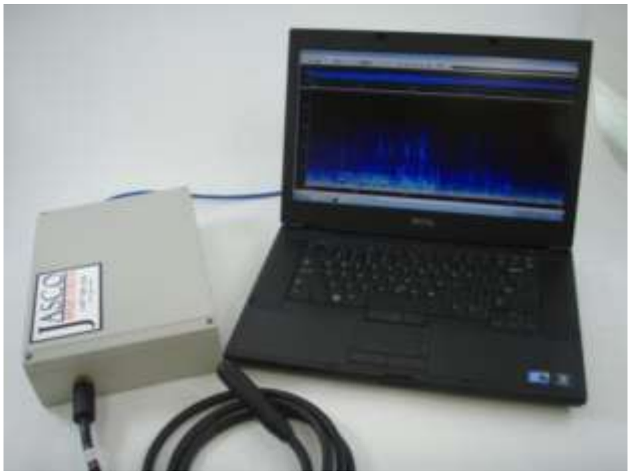


Figure 2. The Acoustic Data Acquisition and Monitoring System (ADAMS; JASCO) used for real-time monitoring and data acquisition, shown with a hydrophone and a laptop. The hydrophone used for this project is shown in Figure 1.

PAM teams consisted of two PSAOs monitoring on rotating six-hour schedules. While on shift, a PSAO visually monitored a scrolling spectrogram display (Figure 3), which visually reflected the incoming acoustic data, and listened to the data stream through headphones. The PSAOs immediately communicated all marine mammal detections to the PSVO and logged the detections in the daily report.

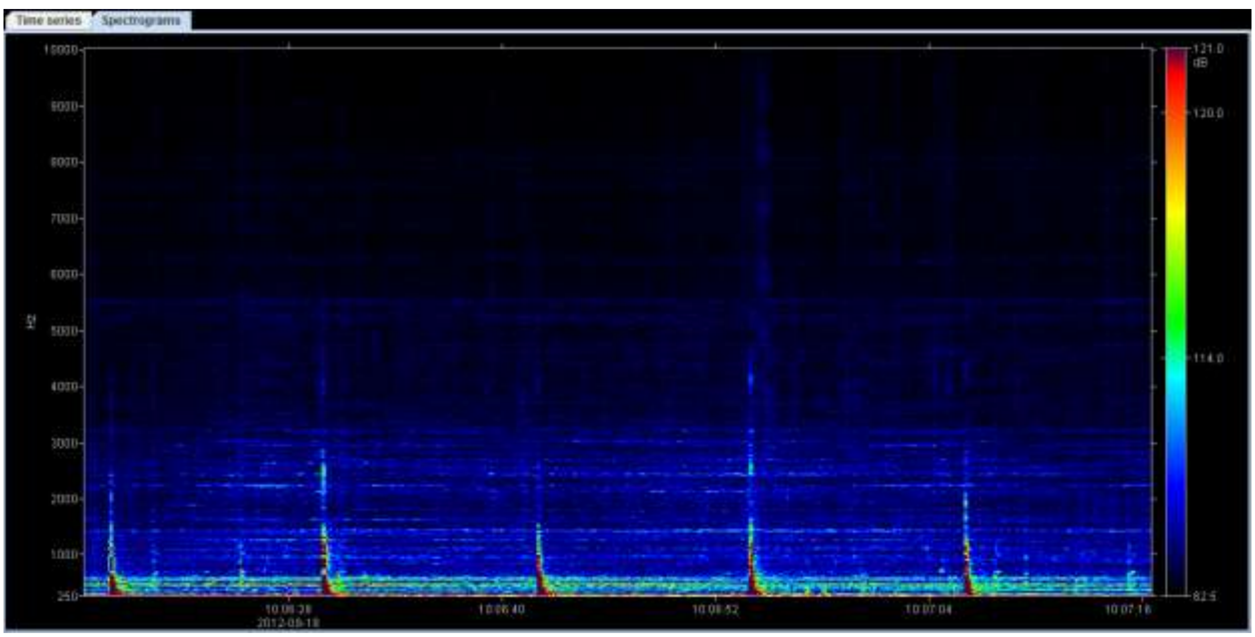


Figure 3. Photo of the PAM display during slack tide on 19 August 2012. Airgun pulses are visible as periodic impulses.

Monitoring continued as much as was feasibly practical throughout the survey, which included times when the seismic sources were not operating. Table 1 shows the PAM effort hours when the airguns were operating and when they were inactive. Occasional shutdowns of the PAM equipment were necessary due to required movement of the monitoring vessel—to obtain fuel or water, for example—or due to harsh sea conditions, which could damage the PAM equipment. Table 2 lists the reasons PAM was inactive while seismic sources were operating, by hours of effort.

Table 1. PAM effort from 11 May to 30 Sep 2012.

Effort (hours)	Airguns operating	Airguns inactive	Total
Active PAM effort	1700.5	837.0	2537.5
PAM suspended	69.25*	779.25	848.5

*See Table 2.

Table 2. Reasons and hours of suspended PAM during periods of active seismic surveying, from 11 May to 30 Sep 2012.

Condition restricting use of PAM	Hours
Rough Sea States	43.5
Monitoring platform unavailable	21.75
Equipment issues	4

4. Acoustic Recordings

All recorded acoustic data were processed to calculate the acoustic noise level conditions over the duration of the PAM program. Figure 4 shows the recorded sound pressure levels in 1/3-octave frequency bands averaged over the entire program. Low-frequency noise (below 100 Hz) was a dominant contributor to the sound field, indicating that in this environment low-frequency marine mammal vocalizations were likely masked most of the time. The lowest recorded 1/3-octave band sound levels occurred at frequencies greater than 2 kHz.

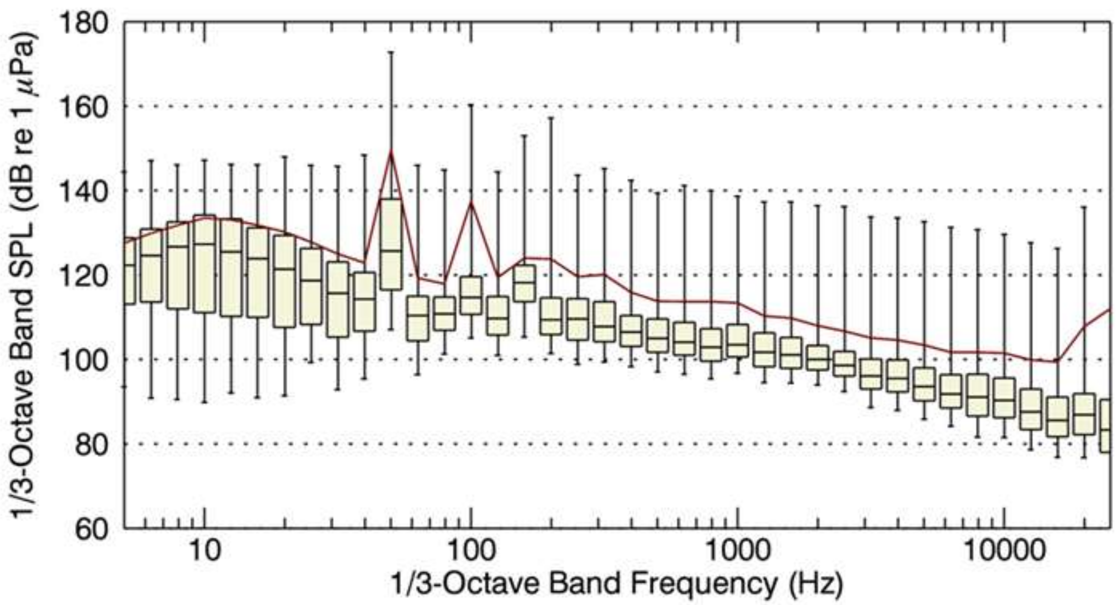


Figure 4. 1/3-octave band sound pressure levels for the entire monitoring period—11 May 2012 to 30 Sep 2012. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Figures 5 through 10 are spectrogram plots that show the distribution of acoustic energy as a function of frequency and of time for one month. The top panels of these plots show the corresponding decade-band sound pressure levels. Gaps in the spectrogram plots indicate times that PAM did not occur (see Section 3). The periodic increases in the sound levels were caused by high currents associated with running tides. While the sound levels across all frequencies increased with the changing tides, the effect was most noticeable at frequencies below approximately 1 kHz. Figure 10 shows a spectrogram plot for a single day (19 Aug 2012, chosen as an example), which details the variation of sound levels with fluctuating currents. A plot of the water level cycle for that date, recorded at nearby Nikiski, is in Appendix A. The sound levels are lowest at slack tides, when water levels are at their maximum and minimum, and highest during running tides. At times of maximum current flow, the high background sound levels mean that the probability of detecting marine mammal calls significantly reduced. The spectrogram plot in Figure 10 shows that slack-tide acoustic conditions exist for a very small portion of each day.

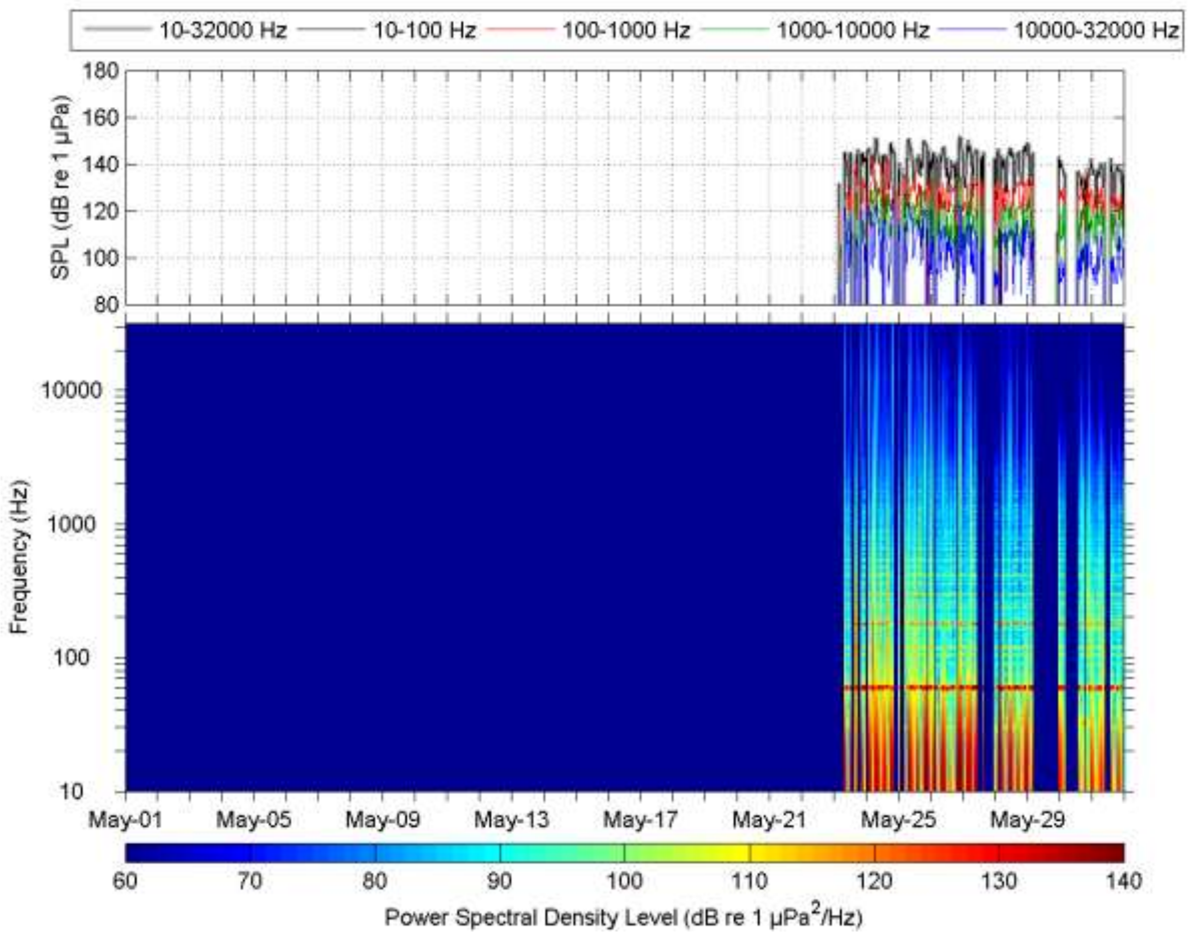


Figure 5. Spectrogram plot (bottom) and decade-band sound pressure levels (top) of acoustic data recorded 11–31 May 2012.

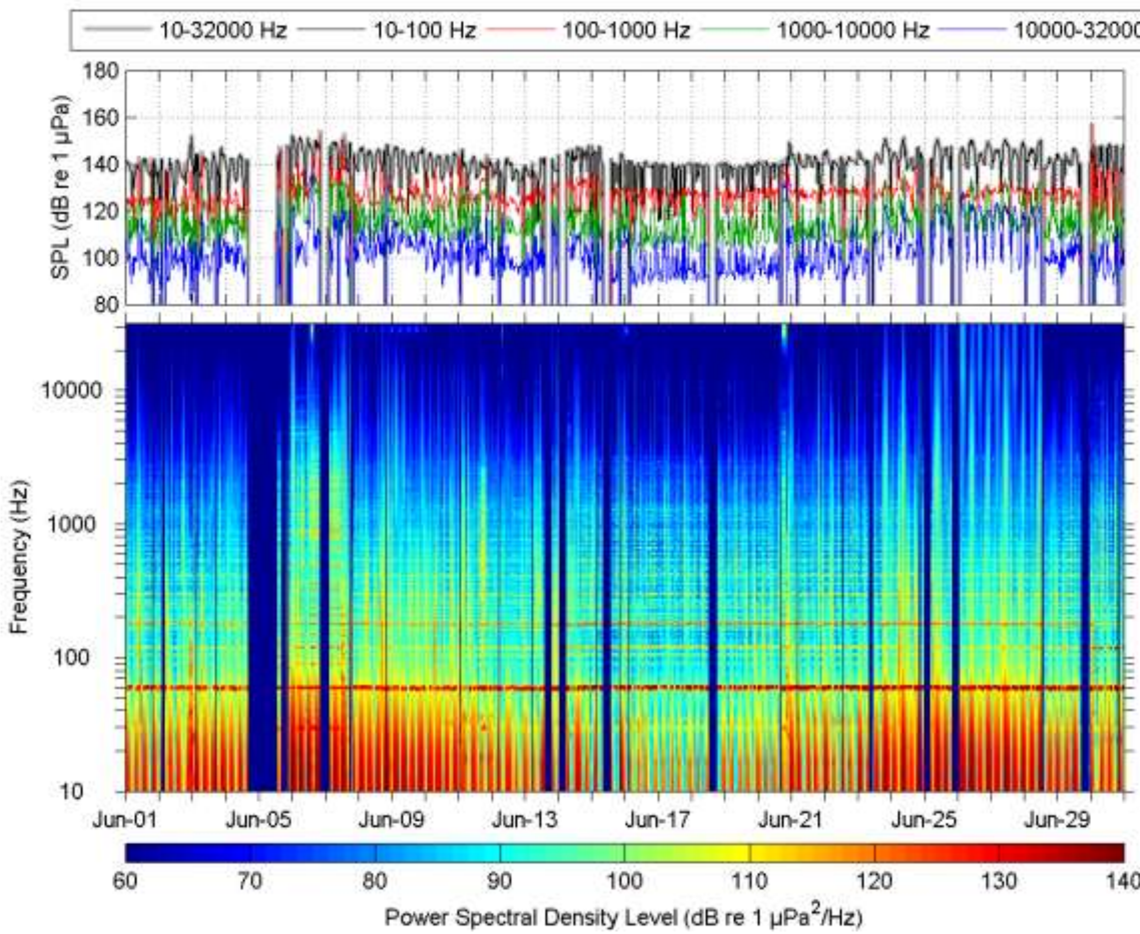


Figure 6. Spectrogram plot (bottom) and decade-band (top) sound pressure levels of acoustic data recorded 1–30 Jun 2012.

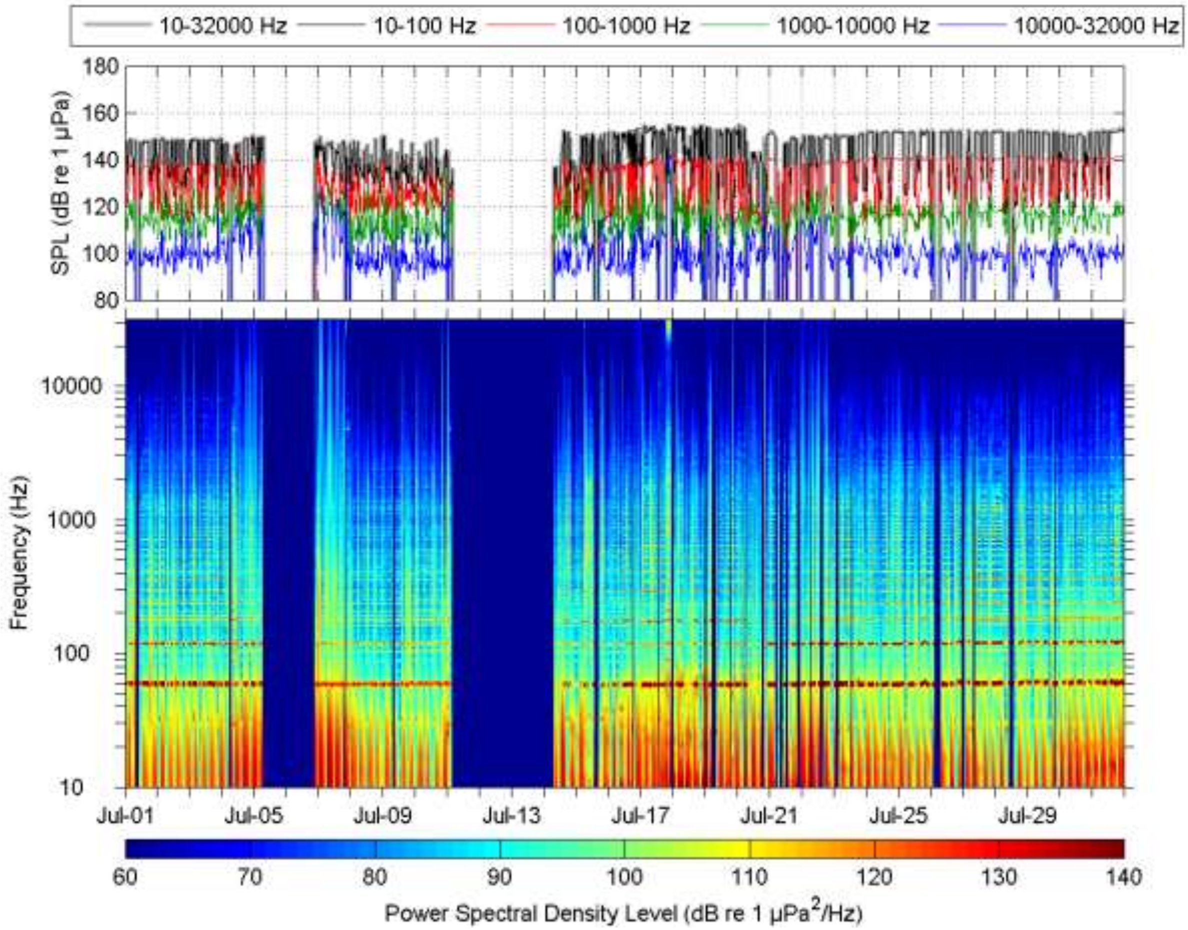


Figure 7. Spectrogram plot (bottom) and decade-band sound pressure levels (top) of acoustic data recorded 1–31 Jul 2012.

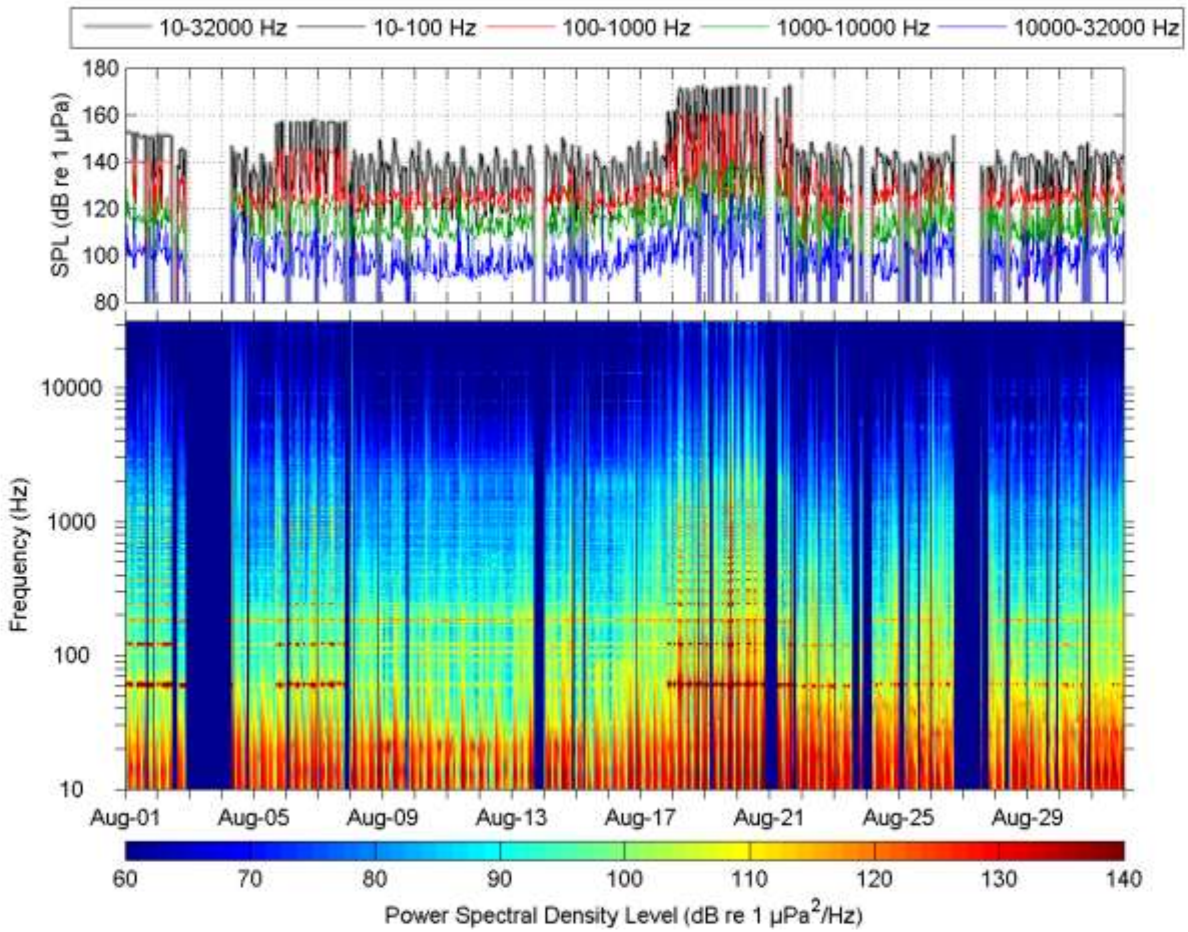


Figure 8. Spectrogram plot (bottom) and decade-band sound pressure levels (top) of acoustic data recorded 1–31 Aug 2012.

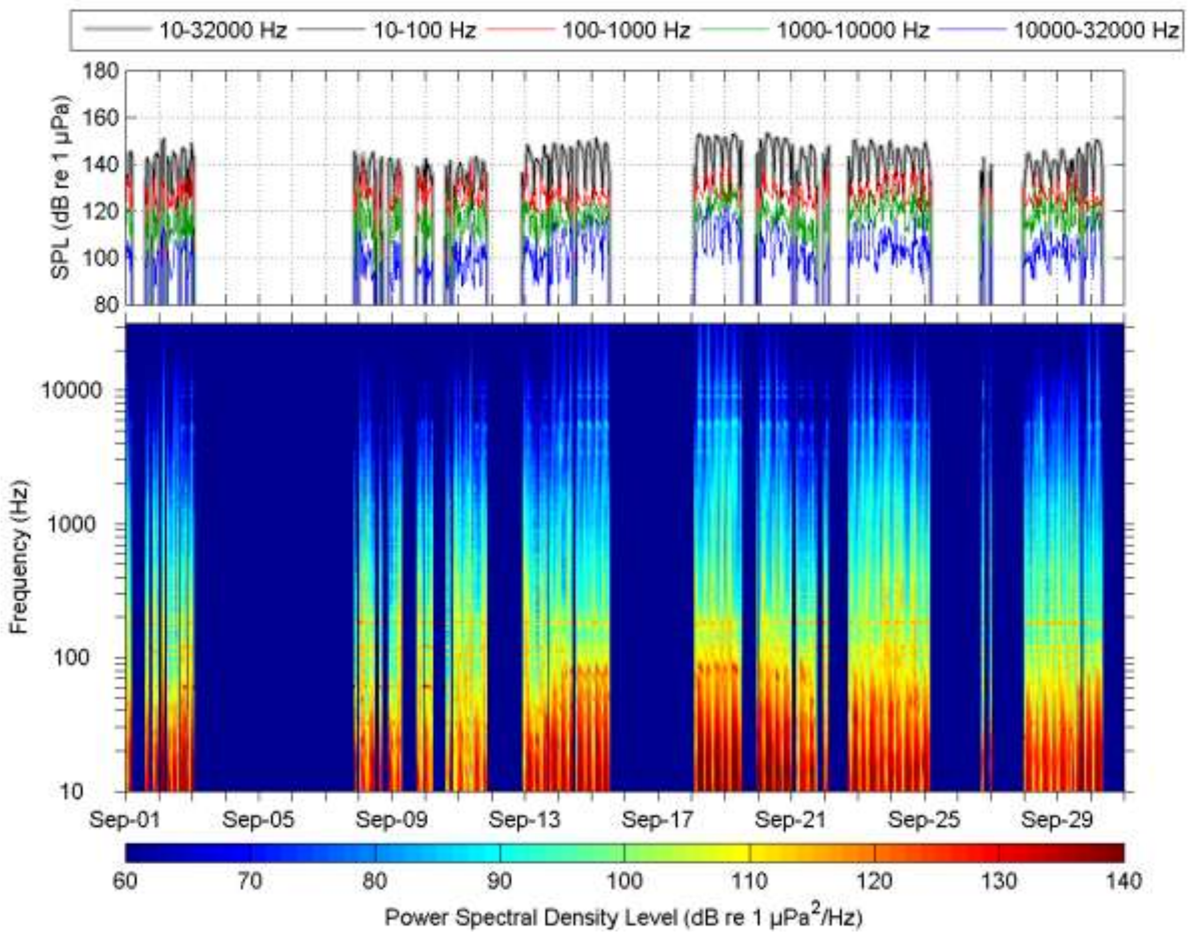


Figure 9. Spectrogram plot (bottom) and decade-band sound pressure levels (top) of acoustic data recorded 1–30 Sep 2012.

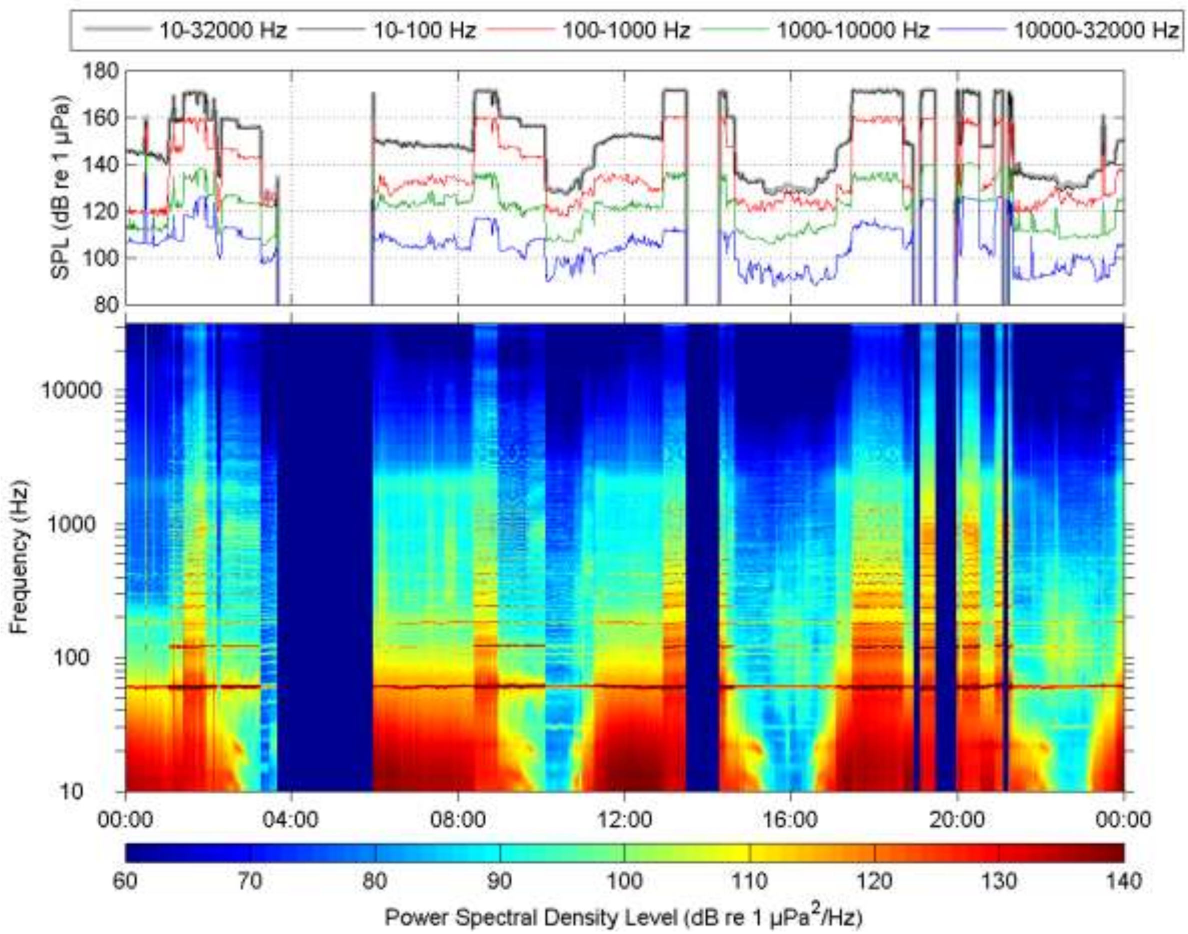


Figure 10. Spectrogram plot (bottom) and decade-band sound pressure levels (top) for acoustic data recorded 19 Aug 2012; time is in UTC.

5. Results

Confirmed marine mammal vocalizations were detected on six separate occasions throughout the survey. Detected species were identified as harbor seal, beluga, and an unspecified pinniped. Three of the acoustic detections corresponded to sightings by the onboard PSVO, confirming the assumed species. A suspected detection of harbor porpoise from Jun 15 was later identified as vessel equipment noise in post-season review. With the exception of the pinniped detection, all the detected signals extended above 1 kHz in frequency, which is above the frequency range where background noise would more likely mask calls.

Table 3 lists the acoustic detections. Sections 5.1 through 0 show spectrograms of acoustic detections for harbor seals, belugas, and pinnipeds.

Table 3. Acoustic detections during the seismic survey.

Date	Time (UTC)	Visual sighting	Seismic activity	Types of sounds heard	Assumed species	Hydrophone position when heard	Shutdown initiated
Jun 16	06:39:00	Yes	No	Clicks	Harbor seal	60° 56.343′ N 151° 33.092′ W	No
Jun 17	15:25:00	Yes	No	Clicks	Harbor seal	60° 56.392′ N 151° 33.064′ W	No
Jun 18	06:36:19	No	No	Clicks	Harbor seal	60° 56.371′ N 151° 33.143′ W	No
Jun 19	23:16:00	Yes	Yes	Clicks	Harbor seal	60° 56.403′ N 151° 33.070’W	Yes
Jul 2	19:28:25	Yes	Yes	Whistle	Beluga whale	60° 56.842′ N 51° 31.408′ W	No
Aug 31	00:21:38	No	No	Bark	Pinniped	60° 45.396′ N 51° 17.884′ W	No

5.1. Harbor Seal Acoustic Detections

Figure 11 to Figure 14 are spectrogram plots showing harbor seal clicks that were detected 16-19 Jun 2012.

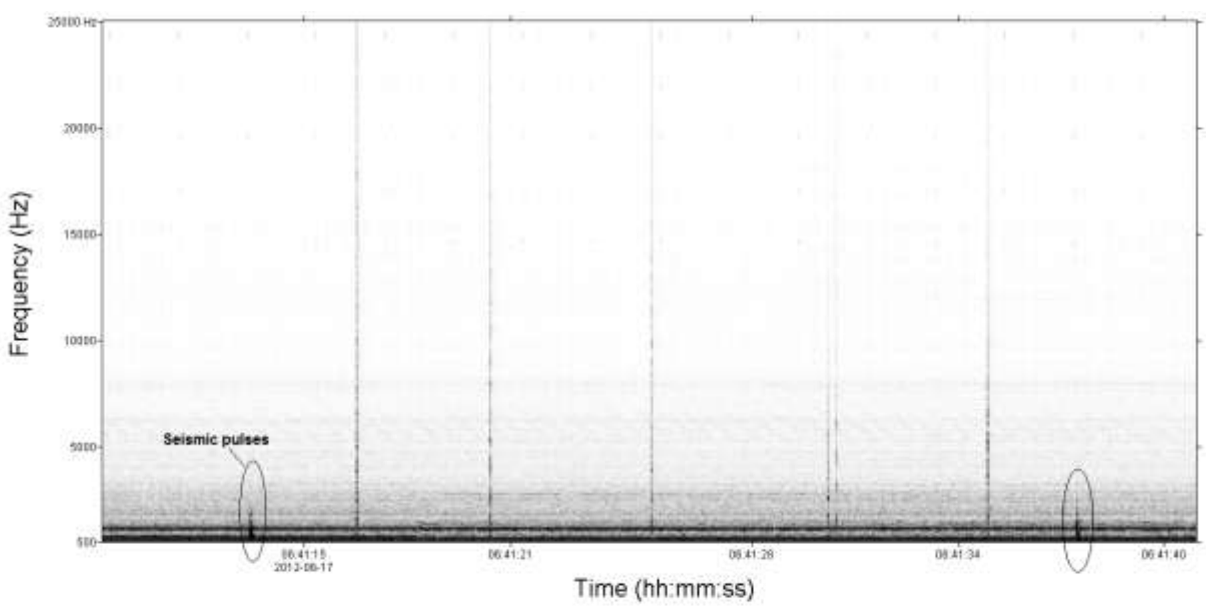


Figure 11. Spectrogram (FFT 640, 50% overlap) showing harbor seal clicks on 16 Jun 2012; time is in UTC.

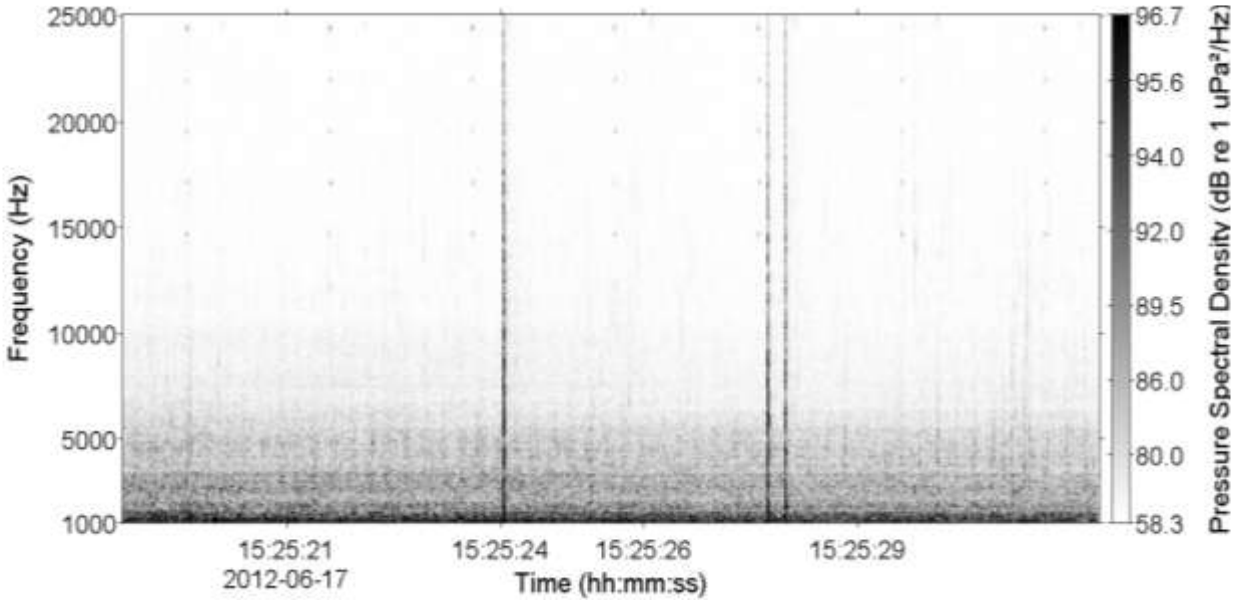


Figure 12. Spectrogram (FFT 640, 50% overlap) showing harbor seal clicks on 17 Jun 2012; time is in UTC.

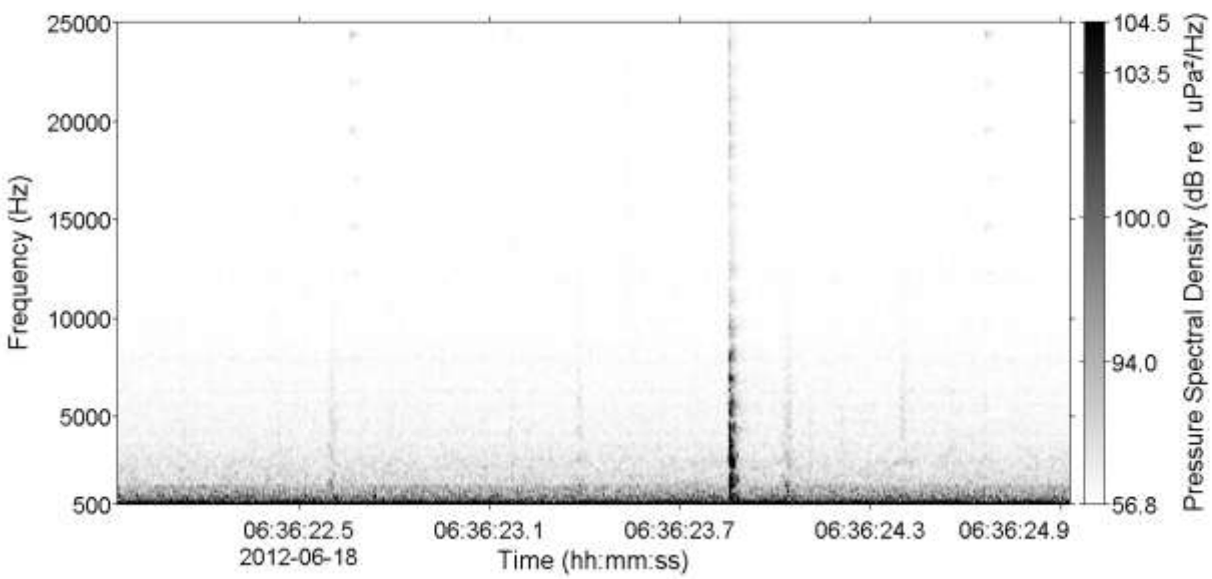


Figure 13. Spectrogram (FFT 640, 50% overlap) showing harbor seal clicks on 18 Jun 2012; time is in UTC.

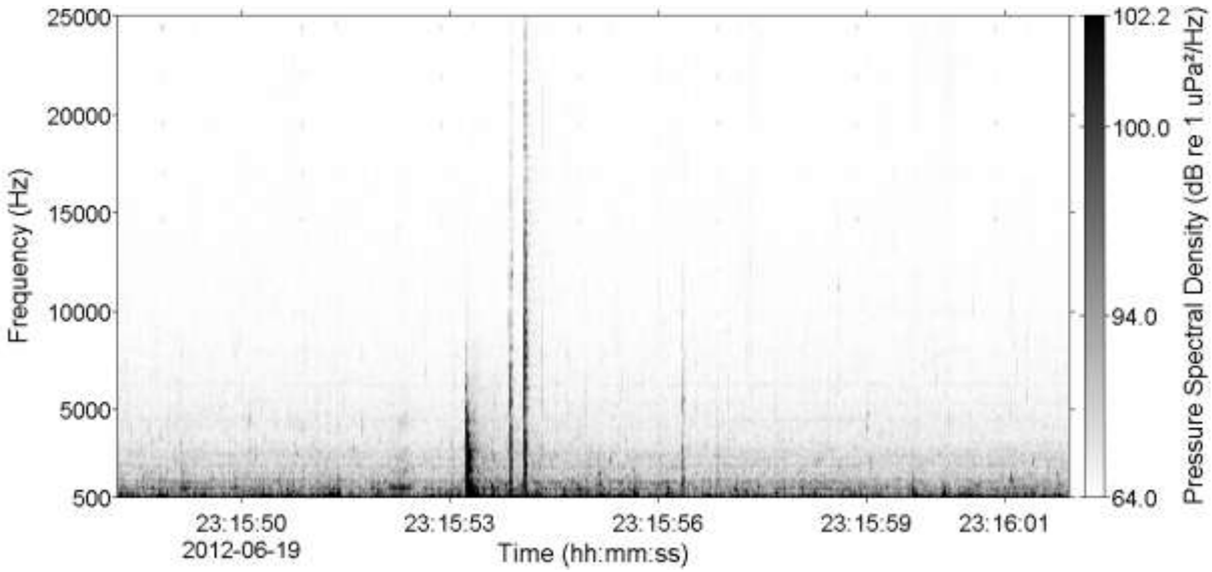


Figure 14. Spectrogram (FFT 640, 50% overlap) showing harbor seal clicks on 19 Jun 2012; time is in UTC.

5.2. Beluga Acoustic Detections

Figure 15 - Figure 17 are spectrogram plots showing beluga whistles detected on 2 Jul 2012.

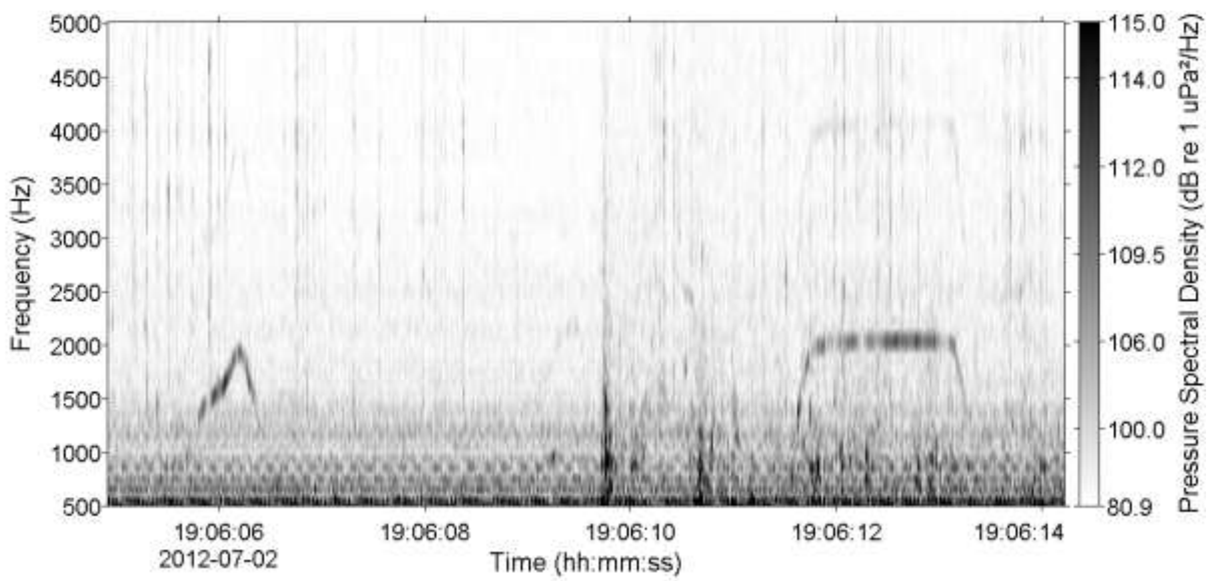


Figure 15. Spectrogram (FFT 640, 50% overlap) showing beluga whistles on 2 Jul 2012 at 19:06; time is in UTC.

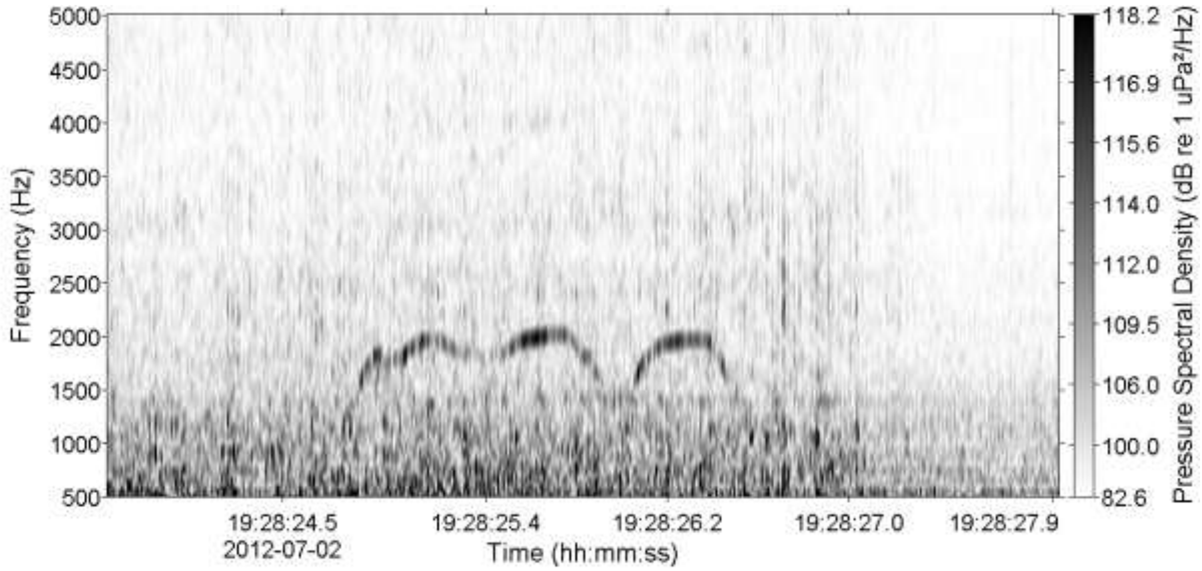


Figure 16. Spectrogram (FFT 640, 50% overlap) showing beluga whistles on 2 Jul 2012 at 19:28; time is in UTC.

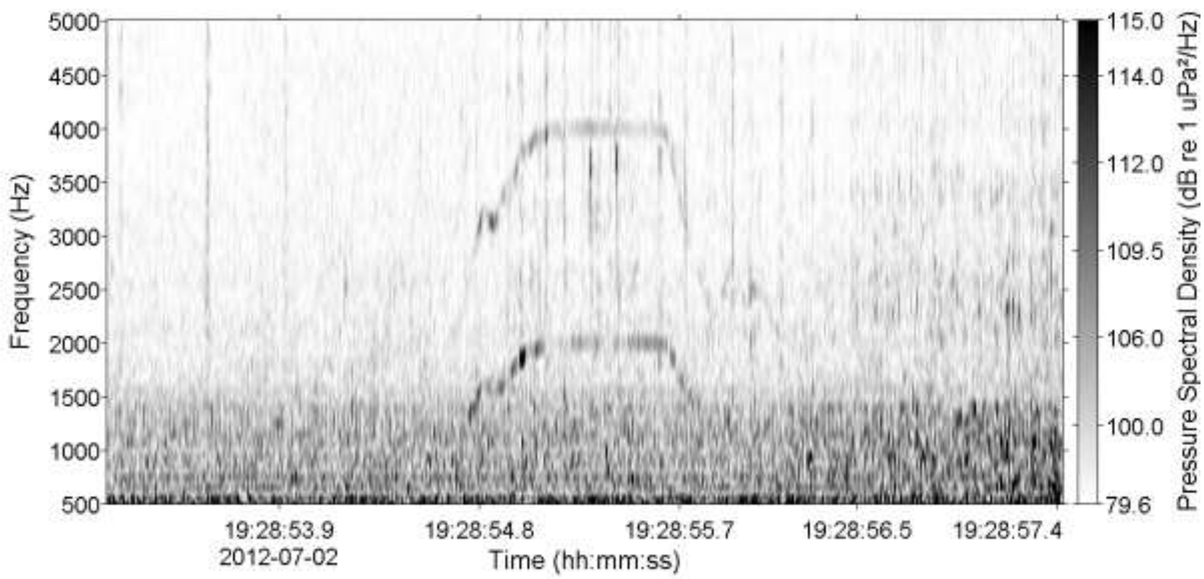


Figure 17. Spectrogram (FFT 640, 50% overlap) showing beluga whistles on 2 Jul 2012; time is in UTC.

5.3. Pinniped Acoustic Detections

Figure 18 is a spectrogram plot of low-frequency barks detected 31 Aug 2012, believed to be from an unspecified pinniped.

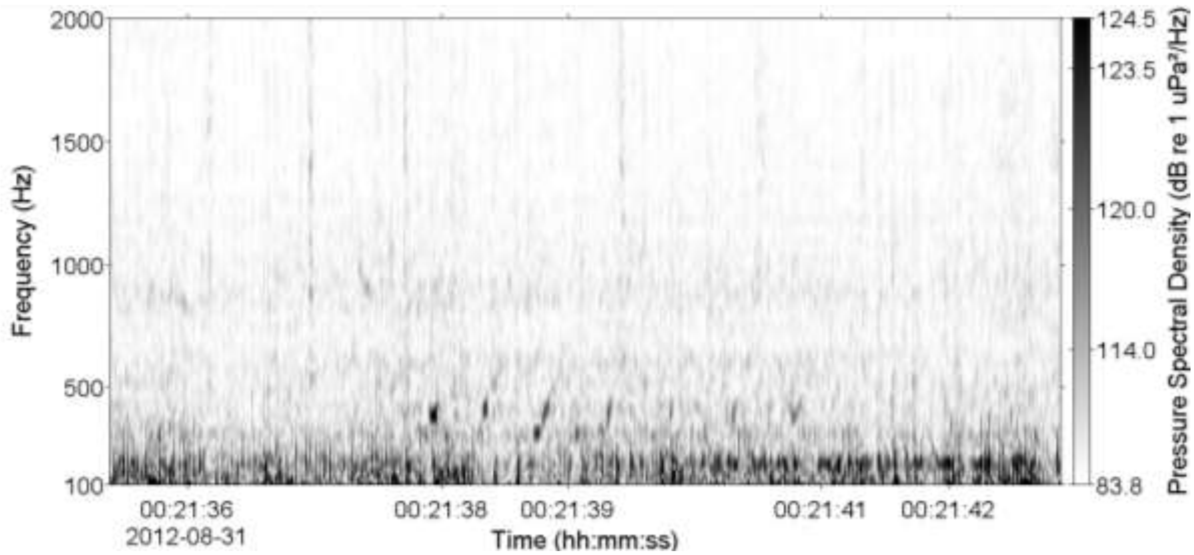


Figure 18. Spectrogram showing detection of an unidentified pinniped on 31 Aug 2012; time is in UTC.

6. Conclusions

Strong currents and large tidal changes give rise to background acoustic conditions that present a challenge to effective PAM in the Cook Inlet environment. Relatively few acoustic detections were recorded during the PAM program for the Apache 2012 Cook Inlet seismic survey. Factors that limited the performance of the PAM system included flow noise due to currents and rough weather, vessel noise from the monitoring platform, and vessel noise from other project equipment. Acoustic signals below 1 kHz were likely masked by background noise most of the time; detections at these lower frequencies occurred only at slack tides. Vocalizations at frequencies above 2 kHz were easier to discern above the background noise.

Although vessel noise can be reduced by deploying the PAM hydrophone from an acoustic telemetry buoy, the autonomous use of such a buoy in Cook Inlet requires a sophisticated mooring design engineered to withstand the strong currents and rough environmental conditions.

7. Limitations and Recommendations

Acoustic monitoring for detecting marine mammals has limitations. First, it requires that animals produce sounds, and second, it requires those sounds be of sufficient amplitude to be detected at the monitoring location, possibly in the presence of interfering noise. The amplitude of sounds produced by marine mammals decreases with increased distance from the animal. For monitoring stations to detect sounds, the received levels of the biological sounds must exceed background noise.

Despite the difficulties encountered in deploying the telemetry buoy in 2012, plans for passive acoustic monitoring work in Cook Inlet might reconsider the use of telemetry buoys to collect and stream the acoustic data, to reduce vessel background noise capable of masking marine mammal vocalizations. The challenges of successfully mooring a buoy in Cook Inlet warrant detailed and advanced planning of a mooring design for such a buoy, but the advantages gained through improved acoustic data quality justify the design effort. Sufficient design time must be factored into preparatory phases for future PAM programs.

We recommend that future PAM programs incorporate sensors deployed away from project vessels so that vessel noise does not mask marine mammal sounds. If possible, multiple monitoring stations distributed around the survey area would provide better coverage of the entire marine mammal exclusion zone.

Several types of acoustic acquisition systems can be used for PAM. The following table lists the advantages and disadvantages of each system for use in Cook Inlet.

	Advantages	Disadvantages
Telemetry buoy	• Reduces vessel noise. • Does not require a dedicated vessel as a monitoring platform. • Multiple buoys could stream to a single monitoring station.	• Difficult to deploy and requires a large vessel with a suitable crane. • Laborious to reposition. • Requires a monitoring station that can remain within approx. 2 km (1 nmi).
Cabled hydrophone over side of vessel	• Easy to deploy from a small vessel. • Easy to reposition. • Easy to service. • Relatively inexpensive.	• Subject to vessel noise contamination and flow noise. • Requires dedicated, stationary monitoring platform.
Towed system	• Mobile monitoring platform.	• Relatively shallow water presents a grounding hazard. • Requires a large vessel with sufficient deck space and appropriate winches. • Relatively more expensive.

8. Literature Cited

ANSI S1.1-1994. R2004. *American National Standard Acoustical Terminology*. American National Standards Institute, New York.

Wladichuk, J. 2011. *Apache 2-D Cook Inlet Seismic Test 2011 Passive Acoustic Monitoring (PAM) Report: Assessment of monitoring systems for marine mammal detections.* Version 1.0. Technical report for Fairweather LLC by JASCO Applied Sciences.

Acknowledgments

Several of JASCO's scientists participated in the PAM rotations for this project and they are acknowledged below. Appreciation is also extended to Kate Lomac-MacNair for assisting with coordinating crew transfers and providing project support, and to Tom Ainsworth for logistic support. We thank the vessel crews that assisted with this work, particularly the crew of the M/V *Dreamcatcher*.

JASCO PAM operators: Craig Evans, Andrew McCrodan, Zizheng Li, Xavier Mouy, Jonathan Vallarta, Jeff MacDonnell, Jennifer Wladichuk, Heloise Frouin-Mouy, Scott Trivers, and David Zeddies.

Glossary

decibel

A logarithmic unit of the ratio of a quantity to a reference quantity of the same kind, where the quantities concerned are proportional to power. Unit symbol: decibel (dB). Examples of qualifying quantities are power (in any form), sound pressure squared, sound intensity, and sound-energy density. Thus, the decibel is a unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level, when no ambiguity results from so doing (ANSI S1.1-1994 R1999).

frequency

The rate of oscillation of a periodic function measured in units of cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. For example, 1 Hz = 1 cycle per second.

hydrophone

An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

masking

Interfering noise that obscures sounds of interest at similar frequencies.

noise

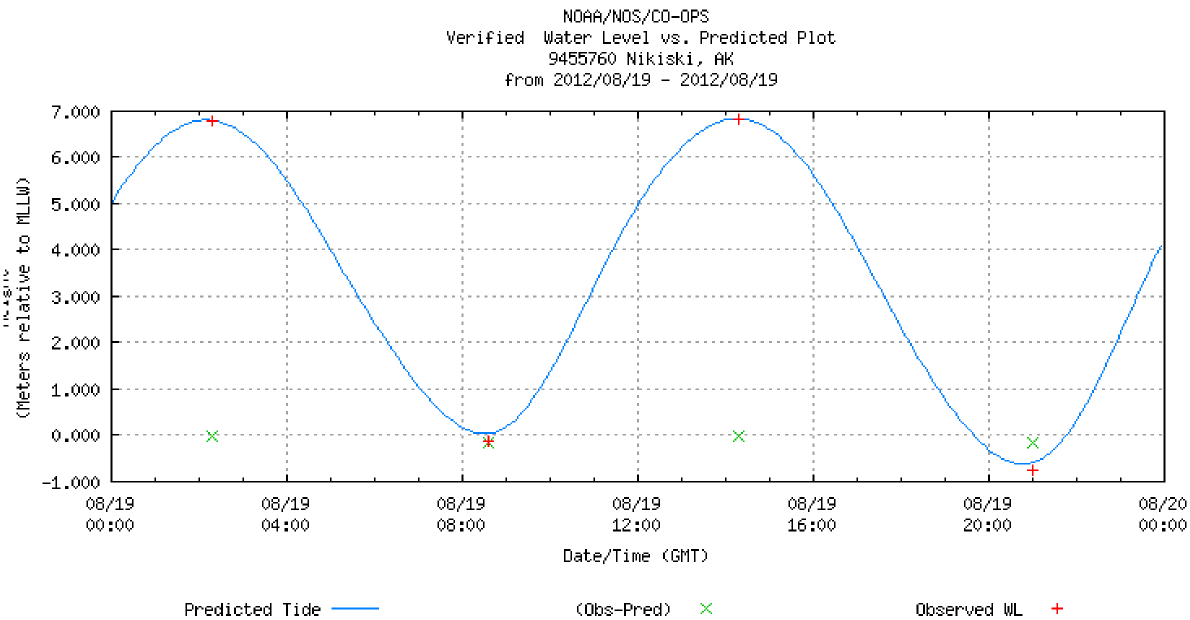
Unwanted sound that interferes with detecting other sounds.

spectrogram

An acoustic signal represented in terms of its power distribution as a function of frequency and time.

Appendix A. Tide Data

A.1. Water level at Nikiski, AK 19 August 2012



Source: National Oceanic and Atmospheric Administration,

http:/tidesandcurrents.noaa.gov/data_menu.shtml?bdate=20120819&edate=20120819&wl_sensor_hist=W3&relative=&datum=6&unit=0&shift=g&stn=9455760+Nikiski%2C+AK&type=Historic+Tide+Data&format=View+Plot

APPENDIX D
DATA FORMS
1. VESSEL-BASED DATA FORMS
2. LAND-BASED DATA FORMS
3. AERIAL-BASED DATA FORMS
4. DATA CODES
5. BEAUFORT SEA STATE
6. INCIDENTAL TAKE FORMS
7. POWER & SHUT DOWN PROCEDURES

PSO:

VESSEL/PLATFORM:

OBSERVER EFFORT FORM

Time	Effort (WS/ON/WE)	Obs	Latitude	Longitude	Depth (m)	Vessel SOG (kts)	Vessel COG	Vessel Direction. (heading)	Beaufort Sea State	Wind Dir.	Precip	% Ice Cover	% Cloud Cover	Tidal Stage	Vis. # km.	Glare Amt.	Glare From	Glare To	Seismic Activity	Gun Array Vol.

VESSEL/PLATFORM:
PSO:

OBSERVER SIGHTING REPORT FORM

PAGE __ of __

Date (mm:dd:yy)	Time hh:mm:ss	Seismic Effort (On/Off)	Latitude N (dd° mm.mmm)	Longitude W (ddd° mm.mmm)	Platform	PSO	Sigh. ID #	Sighting Cue	Species	Group Size	Comp	Sex (M/F)	Location Relative to Vessel (Clock face)	Mvmt. Relative to Vessel	Est. Dist. to AW (m)	Est. Dist. To PF (m)	Est. Dist. To DC (m)	Beh.	Speed of Travel	Mit Request	Mit. Time Request	Mit. Time Implment	Take? Y/N, TBD	Observed leaving Safety Radius (Y/N)	# Minutes waited to start SA	CPA	Comments & Sighting Details – Use back of form for more room if necessary. Give info on MM movement relative to source vessel when applicable)

PSO:
Position (Lat./Long.):
Location Description:

PSO Land Observation: Effort Form

Page ___ of ___

Date	Time	Effort (WS/ON/WE)	Beaufort Sea State	Wind Dir.	% Ice Cover	% Cloud Cover	Precip.	Tidal Stage	Visibility (km)	Glare Amount	Glare From	Glare To	Vessels Visible (DC/PF/AW)	Seismic Activity	Gun Array Vol.	Comments

PSO:
Post Position (Lat./Long.):

PSO Land Observation: Marine Mammal Sighting

Page ___ of ___

Date (mm:dd:yy)	Time hh:mm:ss	Sighting ID #	Sighting Cue	Visual Method	Species	Group Size	Comp.	Sex (M/F)	Behavior	Direction of Travel	Speed of Travel	Distance from Shore	MM ~Dist from AW	MM ~Dist from PF	MM ~Dist from DC	Comments & Sighting Details – Use back of form for more room if necessary.

Date:
PSO:
Aircraft:
General Flight Area:

PSO Aerial Observation Form

Flight Start Time: ____
Flight End Time: ____
Total Flight Time: ____

Time	Flight Route	% Ice Cover	% Cloud Cover	Tidal Stage	Glare Amount	Sighting ID #	Species	Comp.	Behavior	DIR/SP of Travel	Position (Lat./Long.)	Comments
	TAKE OFF:											
	LAND:											

HEADING	DEFINITION	DESCRIPTION
Effort Report		
PSO Initials	Initials of PSO	Use First and Last
Vessel Name/Platform	Name of Vessel on which the PSO is observing	**AW** = Arctic Wolf **DC** = Dreamcatcher **MD** = Miss Diane **MS** = Mark Stevens **MX** = Maxime **PF** = Peregrine Falcon **PR** = Perseverance **SR** = Sleep Robber
General Area	A general description of the area that the current activity is taking place	Any identifiable landmarks or location names such as bays, river mouths, peninsulas, etc.
Date	MM/DD/YYYY	(Ctrl ;) Automatically adds date
Time	hh:mm:ss	(Ctrl Shift ;) Automatically adds time - Military time (i.e. 1pm is 13)
Effort	When effort/PSO changes take place	**WS** = Watch Start **WE** = Watch End **ON** = On Watch
Latitude	GPS location Latitude	Two digit Degrees, two digit, two decimal Minutes (i.e. 60 59.97)
Longitude	GPS location Longitude	Three digit Degrees, two digit, two decimal Minutes (i.e. 151 14.03)
Water Depth (m)	Water depth in meters	Can be read from depth finder in bridge
Vessel Speed SOG (kts)	Vessel speed – (speed over ground) in knots	Knots numerical value in knots unless on anchor (AN = Anchor)
Vessel COG	Course Over Ground	Compass value in degrees (0 – 360) AN = Anchor
Vessel Direction	Vessel direction, heading in degrees	Compass value in degrees (0 – 360) AN = Anchor
Beaufort	Beaufort Sea State	See Beaufort Chart
Wind Direction	Wind Direction	General direction from where the wind is blowing this should be compass (i.e NW for North west)
Precipitation	Type of precipitation	**NO** = No precipitation **SN** = Snow **RN** = rain **LR** = Light Rain

		FG = Fog
% Ice Cover	Percent of ice cover	Within 2km of vessel
% Cloud Cover	Percent of cloud cover in sky	Estimated in 10% increments
Tidal Stage	The PSO should have a tide chart with observation equipment and mark the tidal stage throughout the observation	**LS** = LOW SLACK **LE** = LOW EBB **LF**= LOW FLOOD **HS** = HIGH SLACK **HE** = HIGH EBB **HF** = HIGH FLOOD **MT** = MID TIDE
Visibility # Km	Visibility distance in kilometers (this is NOT sight-ability)	Number value, estimated, 10 is horizon, 6 max in CI
Glare Amt.	Estimation of amount of glare visible	**LI** = Little **MO** = Moderate **SE** = Severe **NO** = None **DI** = Diffused **VAR** = Variable
Glare Pos From	Position that glare begins	Clock Face #1-12
Glare Pos To	Position that glare reaches to	Clock Face #1-12
Seismic Activity	What type of seismic operations are taking place	**CS** = Clearing Safety Zone **RU** = Ramp Up **SD** = Shut down **PD** = Power Down **SC** = Speed/Course Alteration **SA** = Seismic Operations - guns firing
Gun volume	Write in the gun volume in number	This should be the total gun array volume i.e. 10 cu in or 2400 cu in, this is important as it shows the ramp up procedure
Sighting Form		
Date	MM/DD/YYYY	(Ctrl ;) Automatically adds date
Time	HH:MM:SS	(Ctrl Shift ;) Automatically adds time - Military time (i.e. 1pm is 13)
Seismic Effort (On/Off)	On/Off	
SD/PD/SC Required (Y/N)	Y/N	Y = If a shut down, power down, or speed/course alteration is required during the sighting.

		N = If none of these mitigation efforts are required during the sighting (i.e. seismic activity is not taking place when the animal is sighted.)
Mit. Time Requested	Time that the PSVO requests a mitigation effort	Ctrl Shift ;) Automatically adds time - Military time (i.e. 1pm is 13)
Mit. Time Implemented	Time that the mitigation effort is implemented	Ctrl Shift ;) Automatically adds time - Military time (i.e. 1pm is 13)
Sighting ID	Sequential number that correlates with this sighting	This numbers will start over at 1 with each day
Sighting Cue	The indication that a marine mammal is in the area	**MM** = Marine Mammal (actual animal is seen) **SP** = Splash **BL** = Blow
Species	Common name of species	**BW** Beluga Whale **KW** Killer Whale **HW** Humpback Whale **MW** Minke Whale **HP** Harbor Porpoise **HS** Harbor Seal **SL** Steller Sea Lion **UD** Unidentified Dolphin **UP** Unidentified Pinniped **UM** Unidentified MM
Group Size	Number of marine mammal(s) sighted	Specific number or range of number of animals
Age/Size	Approximate age or size of the marine mammal(s) in the group (if determinable)	**C** = Calf **JUV** = Juvenile **M** = Mother **A** = Adult
Sex	Sex of animals in group (if determinable)	**M** = Male **F** = Female **N/A** = Unable to Determine
MM Location Relative to Vessel	Location of MM from vessel	Clock Face 1-12
MM Distance to Vessel	Estimated distance of sighted marine mammal to vessel	Number value in meters
MM Distance to Source Vessel	Estimated distance of sighted marine mammal to source vessel	Number value in meters
MM Movement Relative to	**AB** Across Bow	Swimming across the bow of the vessel

Vessel	**ST** Swim Toward **SA** Swim Away **SP** Swim Parallel **NO** No movement **DE** Dead **UN** Unknown **DI** Dive **SP** Splash	Approaching or swimming toward vessel Swimming away from vessel Fleeing rapidly from vessel Swimming parallel to vessel Not moving Dead (follow dead/injured mm protocol) Unknown movement Dive/splash (often with pinnipeds)
Behavior (This is the overall behavior of the pod and individual. There can be more than one behavior during a sighting)	**SW** Swim **TR** Travel **SA** Surface Active **ST** Surface Active-Travel **MI** Milling **FG** Foraging **RE** Resting **OT** Other **UN** Unknown **SI** Sink **DI** Dive **LO** Look **SH** Spyhop **LG** Logging **BR** Breach **LT** Lobtail **PS** Pectoral Slap **FL** Fluke Visible **BL** Blow **BO** Bow Riding **PO** Porpoising **BN** Bottlenose (pinniped) **RA** Rafting	Animal/group is swimming, nothing else noted Animal/group is traveling in one general direction Animal/group is active at the surface Animal/group is active at the surface while traveling Milling, no general direction yet movement Foraging Resting, no movement Describe in comments Unknown behavior – not enough details to describe Animal sinks with no dive (often with pinnipeds) Animal dives, arches back and/or brings flukes up Animal looks at vessel Animal brings rostrum and eye above surface Logging/resting at surface, bobbing and breathing Breach, fully out of water Thrashing tail and tail stock on surface Slapping pectoral fin on surface Fluke became visible Blow, at surface Riding/playing with bow of vessel Jumping out of water in forward movement Bringing nose out of water during resting period Numerous animal congregated in a large raft form
Speed of Travel	**F** = Fast **M** = Moderate **S** = Slow **NO** = Stationary **N/A** = Unable to Determine from Sighting	
Observed leaving safety radius	Y/N	Was the animal observed leaving the safety radius after a mitigation

(Y/N)		effort was implemented, or before seismic activity begins	
# of Minutes waited to start SA	Time that the area is cleared after a shut down, power down, or speed/course alteration	15 minutes = pinnipeds or harbor porpoises 30 minutes = cetateans	
CPA	Closest point of approach to vessel	Check this box corresponding to the line that describes the animals CPA	
Incidental Level A Take Report			
Date	MM/DD/YYYY	(Ctrl ;) Automatically adds date	
Time	hh:mm:ss	(Ctrl Shift ;) Automatically adds time - Military time (i.e. 1pm is 13)	
Latitude/Longitude	Latitude/Longitude of the vessel at time of incident	This position can be obtained from the navigation team or the GPS in the bridge.	
Species	Common name of species	**BW** Beluga Whale **KW** Killer Whale **HW** Humpback Whale **MW** Minke Whale **HP** Harbor Porpoise **HS** Harbor Seal **SL** Steller Sea Lion **UD** Unidentified Dolphin **UP** Unidentified Pinniped **UM** Unidentified MM	
Group Size	Number of marine mammal(s) sighted	Specific number or range of number of animals	
Vessel Name/Platform	Name of Vessel on which the PSO is observing	**AW** = Arctic Wolf **DC** = Dreamcatcher **MD** = Miss Diane **MS** = Mark Stevens **MX** = Maxime **PF** = Peregrine Falcon **PR** = Perseverance **SR** = Sleep Robber	
Vessel Speed: SOG (kts)	Vessel speed – (speed over ground) in knots	Knots numerical value in knots unless on anchor (AN = Anchor)	
Water Depth (m)	Water depth in meters	Can be read from depth finder in bridge	
Wind Direction	Wind Direction	General direction from where the wind is blowing this should be compass (i.e NW for North west)	
Beaufort Sea State	Beaufort	Beaufort Sea State	See

% Cloud Cover	Percent of cloud cover in the sky	Estimated in 10% incriments	Est
Visibility (# km)	Visibility distance in kilometers (this is NOT sight-ability)	Number value, estimated, 10 is horizon, 6 max in CI	
Sound Source Status 24 hours Prior to Take	Description of the seismic activity that has taken place over the 24 hours prior to the incident	Refer to Effort Reports taken during this time period. Communicate with crew about efforts that occurred outside of the observation period.	
Marine Mammal Observation Effort 24 hours Prior to Take	Observations hours ON in 24 hours prior to the incident Observation hours OFF in 24 hours prior to the incident All marine mammal sightings in the 24 hours prior to the incident	Refer to Effort Reports for hours of observation conducted Refer to Sighting Reports for marine mammal sightings	
Description of Incident	Describe the incident in as much detail as possible		
Fate of Animal(s)	The outcome of the incident of harassment	Injury Serious injury Mortality	
Photos/Video Taken (Y/N)	Y/N	Describe any footage or photos taken and include with this report	

Beaufort Sea State Number	Observed Sea Surface Condition	Sailor's Term	Effects on Land	Typical Wind Speed (MPH)
0	Mirror smooth and glassy surface	Calm	Calm; smoke rises straight up.	0
1	Small ripples or capillary waves on glassy surface.	Light Air	Smoke drifts with wind direction.	1 - 3
2	Larger ripples or wavelets on glassy surface.	Light Breeze	Leaves begin to rustle; wind felt on face.	4 - 7
3	Wavelets of irregular direction and shape; a few crests break on glassy surface.	Gentle Breeze	Small flags extend; leaves in constant motion.	8 - 12
4	Small chop, defined direction; numerous whitecaps.	Moderate Breeze	Dust, leaves & loose paper move.	13 - 18
5	Heavy chop; many white foaming crests; some spray.	Fresh Breeze	Small trees begin to sway.	19 - 24
6	Larger surface waves form; whitecaps everywhere; more spray.	Strong Breeze	Large branches move; whistling heard in wires.	25 - 31
7	Sea heaps up; white foam starts to blow in streaks along direction of wind; spindrift forms.	Moderate Gale	Resistance strong when walking.	32 - 38
8	Moderately high waves, crests begin to break into spindrift; well marked streaks of foam.	Gale	Twigs and small branches broken off trees.	39 - 46
9	High waves, sea begins to roll; spray begins to reduce visibility; dense streaks of foam.	Strong Gale	Structural damage occurs esp. to roofs.	47 - 54
10	Sea mostly covered in white foam; visibility reduced; exceptionally large waves.	Storm	Trees uprooted; considerable structural damage.	55 - 63
11 - 17	Beach Research Cancelled Today			

Marine Mammal Incidental Level A Take Report

Date____

Time ____

Latitude_________________________ **Longitude** ____________________________

Species ____

Group Size ____

Vessel Name/Platform____

Vessel Speed (SOG kts)____

Water Depth (m)____

Environmental Conditions

Wind Direction____

Beaufort Sea State____

% **Cloud Cover** ____

Visibility (km) ____

Sound Source Status (24 hours prior)

____

____

____

Marine Mammal Observation Effort (24 hours prior)

____

____

____

Description of Incident

____

____

____

____

____

Fate of Animal(s)

____

____

____

____

*Include photographs or video footage if available **Yes** **No**

Shut Down / Power Down Procedures

Note: Times assume a start of the clock on any resights.

If animal distance is:	Power Down to:
Less than 2500 m	0 cui: Wait for full clear to start Ramp Up
2500 m to 5300 m	150 or 300 cui
5301 m to 9500 m	600 or 1200 cui
Greater than 9500 m	2400 cui – FULL POWER

PSOs can work with source technicians and navigators to decrease wear on the air guns. The following
time chart can be used to reduce the amount of seismic energy put out while waiting for a marine mammal
to clear the DZ, while also minimizing the time needed to return to full power. All steps are separated by
5 minutes, mirroring the ramp up procedure used to protect marine mammals:

Small Marine Mammals: Harbor Seal, Harbor Porpoise, Steller Sea Lion are clear 15 minutes after last resight.

If > 5300 m and < 9500 m ……….. ...Sighting + 0 to 9 minutes = 600 cui
Sighting + 10 minutes = 1200 cui
Sighting + 15 minutes = 2400 cui

If ≥ 2500 m and <5300 m ……………Sighting + 0 to 9 minutes = 150 cui
Sighting +10 minutes = 300 cui
Sighting + 15 minutes = 600 cui (continue RU procedure)

If < 2500 m……………………… ….Sighting + 15 minutes =150 cui (start RU: no time saved)

Large Marine Mammals: Beluga Whale, Killer Whale are clear 30 minutes after last resight.

If > 5300 m and < 9500 m …… ..…..Sighting + 10 minutes =150 cui (start RU)
If ≥ 2500 m and <5300 m ……… …Sighting +20 minutes =150 cui (start RU)
If < 2500 m………………………… .Sighting + 30 minutes =150 cui (start RU: no time saved)

Non-Permitted Species: E.G.: Grey Whale, Humpback Whale are clear 1 hour after last resight.

If > 5300 m and <9500 m …………...Sighting + 40 minutes = 150 cui (start RU)
If ≥ 2500 m and <5300 m ……………Sighting +50 minutes = 150 cui (start RU)
If < 2500 m Sighting +60 minutes = 150 cui (start RU: no time saved)

APPENDIX E
NMFS STRANDING REPORTS

MARINE MAMMAL STRANDING REPORT - LEVEL A DATA

FIELD #: ______ NMFS REGIONAL #: ______ (NMFS USE) NATIONAL DATABASE#: ______ (NMFS USE)

COMMON NAME: Harbor seal GENUS: Phoca SPECIES: vitulina

EXAMINER Name: Kate Lomac-MacNair Affiliation: SAExploration PSO Manager

Address: 8240 Sandlewood Place Anchorage, AK 99507 Phone: (907) 522-4498

Stranding Agreement or Authority: ______

LOCATION OF INITIAL OBSERVATION

State: Alaska County: ______

City: Nikiski

Body of Water: Cook Inlet

Locality Details: Central Cook Inlet between Nikiski (west) and Tyonek (east)

Lat (DD): 60 . 893033 N

Long (DD): 151 . 254267 W

[✓] Actual [ ] Estimated

How Determined: (check ONE)
[✓] GPS [ ] Map [ ] Internet/Software

OCURRENCE DETAILS [ ] Restrand GE# ______ (NMFS Use)

Group Event: [ ] YES [✓] NO

If Yes, Type: [ ] Cow/Calf Pair [ ] Mass Stranding # Animals: 1 [✓] Actual [ ] Estimated

Findings of Human Interaction: [✓] YES [ ] NO [ ] Could Not Be Determined (CBD)

If Yes, Choose one or more: [ ] 1. Boat Collision [✓] 2. Shot [ ] 3. Fishery Interaction

[ ] 4. Other Human Interaction: ______

How Determined (Check one or more): [✓] External Exam [ ] Internal Exam [ ] Necropsy

[ ] Other: ______

Gear Collected? [ ] YES [✓] NO Gear Disposition: ______

Other Findings Upon Level A: [ ] YES [✓] NO [ ] Could Not Be Determined (CBD)

If Yes, Choose one or more: [ ] 1. Illness [ ] 2. Injury [ ] 3. Pregnant [ ] 4. Other: ______

How Determined (Check one or more): [ ] External Exam [ ] Internal Exam [ ] Necropsy

[ ] Other: ______

INITIAL OBSERVATION

Date: Year: 2012 Month: August Day: 7

First Observed: [ ] Beach or Land [✓] Floating [ ] Swimming

CONDITION AT INITIAL OBSERVATION (Check ONE)

[ ] 1. Alive [ ] 4. Advanced Decomposition
[ ] 2. Fresh dead [ ] 5. Mummified/Skeletal
[✓] 3. Moderate decomposition [ ] 6. Condition Unknown

LEVEL A EXAMINATION [ ] Not Able to Examine

Date: Year: 2012 Month: August Day: 7

CONDITION AT EXAMINATION (Check ONE)

[ ] 1. Alive [ ] 4. Advanced Decomposition
[ ] 2. Fresh dead [ ] 5. Mummified/Skeletal
[✓] 3. Moderate decomposition [ ] 6. Unknown

INITIAL LIVE ANIMAL DISPOSITION (Check one or more)

[ ] 1. Left at Site
[ ] 2. Immediate Release at Site
[ ] 3. Relocated
[ ] 4. Disentangled
[ ] 5. Died at Site
[ ] 6. Euthanized at Site
[ ] 7. Transferred to Rehabilitation: Date: Year:____ Month:____ Day:____ Facility:______
[ ] 8. Died during Transport
[ ] 9. Euthanized during Transport
[ ] 10. Other: ______

CONDITION/DETERMINATION (Check one or more)

[ ] 1. Sick
[ ] 2. Injured
[ ] 3. Out of Habitat
[ ] 4. Deemed Releasable
[ ] 5. Abandoned/Orphaned
[ ] 6. Inaccessible

7. Location Hazardous
[ ] a. To animal
[ ] b. To public
[ ] 8. Unknown/CBD
[ ] 9. Other ______

MORPHOLOGICAL DATA

SEX (Check ONE)
[ ] 1. Male
[ ] 2. Female
[✓] 3. Unknown

AGE CLASS (Check ONE)
[✓] 1. Adult [ ] 4. Pup/Calf
[ ] 2. Subadult [ ] 5. Unknown
[ ] 3. Yearling

[✓] Whole Carcass [ ] Partial Carcass

Straight length: ______ [ ] cm [ ] in [ ] actual [ ] estimated

Weight: ______ [ ] kg [ ] lb [ ] actual [ ] estimated

PHOTOS/VIDEOS TAKEN: [✓] YES [ ] NO

Photo/Video Disposition: ______
6 photos of harbor seal head and body taken by crew of M/V Mark Stevens

TAG DATA Tags Were:

Present at Time of Stranding (Pre-existing): [ ] YES [ ] NO

Applied during Stranding Response: [ ] YES [ ] NO

ID#	Color	Type	Placement* (Circle ONE)	Applied	Present
			D DF L LF LR RF RR	[ ]	[ ]
			D DF L LF LR RF RR	[ ]	[ ]
			D DF L LF LR RF RR	[ ]	[ ]

* D= Dorsal; DF= Dorsal Fin; L= Lateral Body
LF= Left Front; LR= Left Rear; RF= Right Front; RR= Right Rear

CARCASS STATUS (Check one or more)

[✓] 1. Left at Site [ ] 4. Towed: Lat______ Long______ [ ] 7. Landfill
[ ] 2. Buried [ ] 5. Sunk: Lat______ Long______ [ ] 8. Unknown
[ ] 3. Rendered [ ] 6. Frozen for Later Examination [ ] 9. Other______

SPECIMEN DISPOSITION (Check one or more)

[ ] 1. Scientific collection [ ] 2. Educational collection
[ ] 3. Other: ______

Comments: ______

NECROPSIED [✓] NO [ ] YES [ ] Limited [ ] Complete
[ ] Carcass Fresh [ ] Carcass Frozen/Thawed

NECROPSIED BY: ______

Date: Year: ______ Month: ______ Day: ______

PLEASE USE THE BACK SIDE OF THIS FORM FOR ADDITIONAL REMARKS

ADDITIONAL REMARKS

ADDITIONAL IDENTIFIER: ______________________ (If animal is restranded, please indicate any previous field numbers here)

Description of Incident

On the Cook Inlet 3D seismic program a harbor seal carcass was observed by crew on the M/V Mark Stevens at 5:35am in central inlet waters between Nikiski and Tyonek. The seal was observed to be floating and moving northwards with current. The M/V Mark Stevens left the harbor seal carcass location at 6:15am after obtaining photos. There were no other marine mammals or birds sighted with the harbor seal carcass. The carcass appeared to be bloated with very little decomposition and potential bullet holes in along left side of the head below the ear orifice.

Photos were taken by Jaime Navarrette on the M/V Mark Stevens

An aerial overflight was conducted at 2pm and staffed by Protected Species Observers working on the Cook Inlet 3D seismic program. The aerial PSOs were instructed to fly over the last known location of the seal in attempt to resight and continue monitoring its movement. The dead seal was resighted at 15:00 at 60° 52.54N 151° 20.107W. This was approximately 5km from the initial sighting of the harbor seal carcass.

APPENDIX F
PHOTOS







APPENDIX G
LIST OF PROTECTED SPECIES OBSERVERS

PSO	Education/Degree
Kate Lomac-MacNair	MS, Environmental Science (current student) Johns Hopkins University BS, Environmental Science Union University 2006
Sasha McFarland	BA, Organismal BiologyUniversity of Colorado Boulder 2003 MS, Marine and Estuarine Science Western Washington University 2012
Bridget Watts	MS, Marine Science San Francisco State University, Moss Landing Marine Laboratories 2006 BS, Ecology University of Arizona 1999 BA, Physics Washington University 1991
Kristine Lindberg	BA, University of Montana
Heather Barbrow	BS, Marine Science Costal Carolina University 2007
Sarah Leiter	BS, Biology Stonehill College 2007
Dena Matkin	BS, Univeristy of California Santa Cruz 1974
Christine Palmeri	BA, College of the Holy Cross 2004
Vanessa James	BS Biology, San Diego State University 2010
Meggie More	BS Biology, San Diego State University 2010
Mithriel McKay	Ph.D. Candidate, Texas A&M University at Galveston; Department of Marine Biology MS, Marine Resources Management Texas A&M University at Galveston, 2009 BS, Medical Technology, Simmons College 1984
Christy Harrington	MS Environmental Science University of Sydney 2006 BS, Biology University of Oregon 2003
Paula Olson	MS University of Rhode Island BA, University of Maine
Felix Smith	MS Marine Biology - University of Southampton, England 2011
Carey Thissen	B.S. Environmental Science
Keith Rittmaster	BS Biology
Christina Goertz	BS Marine Biology Texas A&M University at Galveston 2011
Kristin Dominici	BS Marine ScienceUniversity of Hawaii 2011
Mark Tanski	BS Candidate Marine Biology UAA
Kelsey Stone	BS Marine Biology Texas A&M University at Galveston 2012

Please contact all PSOs via the provided platform phones when possible before using their personal cell phone numbers.