Measurement of Noise in Eagle Bay (Knik Arm) due to Land-Based Explosions

Report for Opportunistic Measurements Taken 21-22 October 2012

Prepared for Joint Base Elmendorf- Richardson

Prepared by the Navy Marine Mammal Program

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Introduction

Explosions at the existing demolition and Explosive Ordnance Disposal (EOD) sites located on Joint Base Elmendorf-Richardson (JBER) may have the potential to produce in-water sounds that could exceed thresholds associated with marine mammal behavioral disturbance. The current National Marine Fisheries Services (NMFS) criteria for behavioral disturbance, or Level B harassment, is a 160 dB re 1 μPa root-mean-square (hereafter simplified as dB_{rms}) threshold for impulsive sounds; sounds that meet or exceed this threshold are considered to behaviorally harass marine mammals (70 FR 1871).

Sound propagation from a land-based explosion to an underwater receiver involves multiple pathways through non-homogeneous media, and no general models exist to accurately predict underwater sound pressure levels in a unique environment. Additionally, there have been few efforts to collect data on in-water sound levels due to land-based explosions at JBER. Therefore, direct measurements of in-water noise from land-based explosions in Eagle Bay are appropriate to develop a site-specific predictive model of in-water noise due to land-based explosions.

Field measurements of in-water noise from land-based explosions were taken on 21-22 October 2012 and are presented herein. The October 2012 measurements are a preliminary sub-set of a larger number of explosive recordings planned tentatively for late spring 2013. The October 2012 measurements were undertaken to take advantage of a time window in mid-fall, during which beluga whales and significant ice are less likely to be present in the Eagle Bay area, and to inform the design of the remainder of the overall noise study (i.e., charge sizes, charge locations, recording locations, and recording design). The overall noise study, including the remainder of the shots to be recorded in Spring 2013, will examine the effects of explosive weight, charge burial, and charge distance from shoreline on in-water sound levels. Additionally, the overall study results should illustrate the effect of different sound transmission pathways on in-water noise (*i.e.*, air-to-water or ground-to-water). A predictive transmission loss model will be based on the complete set of recordings and will be provided at a future date.

Per an informal consultation with NMFS under Section 7 of the Endangered Species Act (NMFS 2012) regarding endangered Cook Inlet beluga whales, the October 2012 detonations were limited to 11 shots not to exceed 15 lb. net explosive weight (NEW) on the surface and 75 lb. NEW buried at Demo III.

The Cook Inlet beluga whale (*Delphinapterus leucas*) distinct population segment is the only beluga whale stock listed as endangered under the Endangered Species Act and designated as depleted under the Marine Mammal Protection Act (16 U.S.C. 31). The Cook Inlet waters adjacent to JBER are designated as critical habitat for the Cook Inlet beluga whales (NMFS 2012). Cook Inlet beluga whales may be present in the Knik Arm of Cook Inlet adjacent to (JBER) throughout the year, although they are much more likely to be present August through November, generally coincident with the coho salmon run. Beluga whales mill and forage around river mouths, including the Eagle River, Eagle Bay, and Six Mile Creek areas at JBER. During high tide, belugas are more likely to be present in the upper Knik Arm than in the area around Eagle Bay.

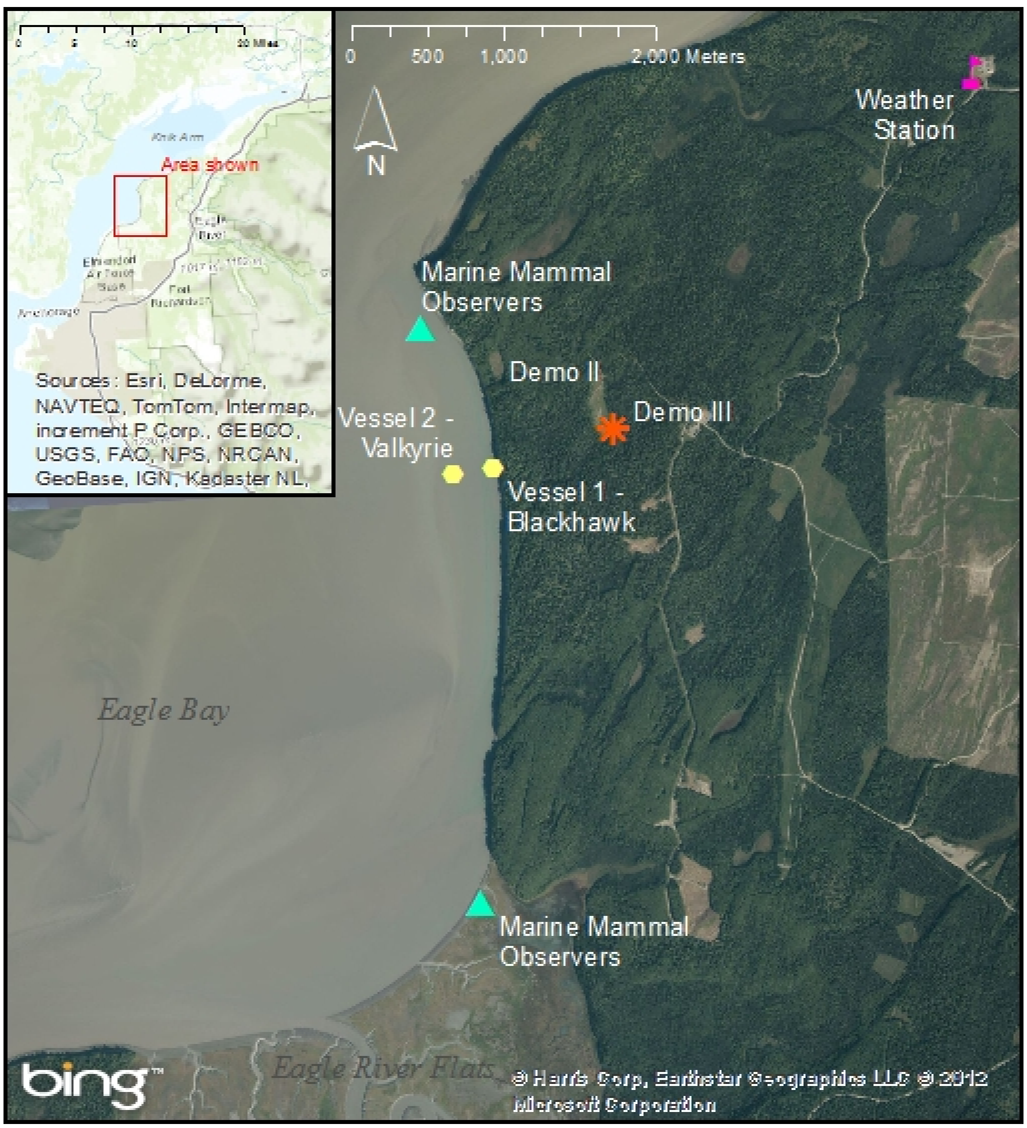

Figure 1 – Locations of the Army Explosive Ordnance Disposal (EOD) team (in red), recording vessels (in yellow), marine mammal observers (in blue), and weather station (in pink).

Location and Environment

Eagle Bay is contained by the cliffs to the north and Eagle River Flats, a silty estuarine area, to the southeast. A relatively deep channel, approximately 300 m wide at the latitude of the demo sites and 30 - 40 ft. (10 – 13 m) deep at maximum high tide, runs along the shoreline. Beyond this distance, Eagle Bay contains shallow flats that are exposed at low tide. Tidal ranges are extreme; the average tidal flux is just over 30 ft., from a minimum of 12 ft to a maximum of about 40 ft. (Griese et al., 2011; Figure 2). Cook Inlet beluga whales are known to use the near-shore channel to access Eagle River, where they have been observed foraging more than a mile upstream in very shallow waters. The water in Eagle Bay is very turbid, with no visibility. Demo III is located approximately 800 m east of the Eagle Bay shoreline (N61 21' 43.7", W149 41' 52.4"; Figure 1), and consists of a lightly sloped clearing fully surrounded by woods.

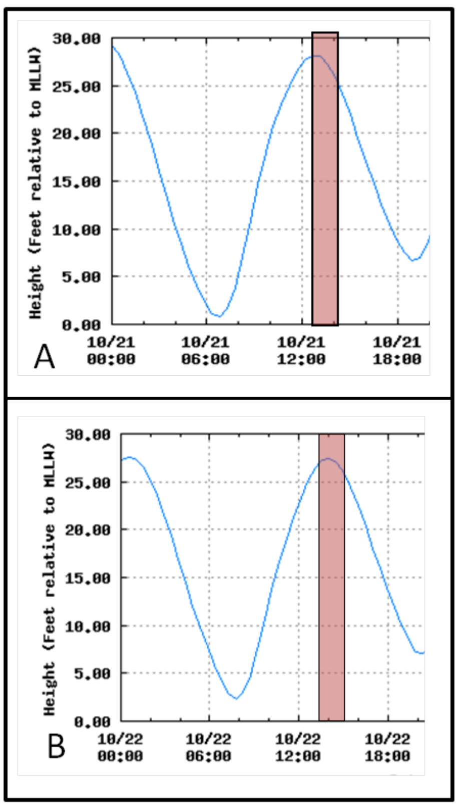

Figure 2 – Tidal range for (A) 10/21/12 and (B) 10/22/12, with hours of small boat operations highlighted in red (adapted from Chris Garner; http://tidesandcurrents.noaa.gov/tide_predictions.shtml).

Detailed subsurface data is limited, but in general the local geology consists of glacial sediments over bedrock (Hunter et al. 2000). The bedrock extends below the Knik Arm (approximately at a depth of low hundreds of meters). Silty sand cliffs (height approximately 100 ft.) line the north Eagle Bay shoreline, west of Demo II and Demo III. These cliffs are permeable, with observable water flow, and actively eroding, with small slides regularly entering the water. The land cover between the demo sites and the shoreline is forest.

Methods

Field methods

On October 21 and 22, 2012, a pilot explosive ordnance field test was conducted on land adjacent to the Knik Arm of the Cook Inlet, AK in order to measure the underwater received levels from land-based explosions. Participants included three acousticians from the National Marine Mammal Foundation (under direction from the Navy Marine Mammal Program) and six expert marine mammal observers from the JBER Conservation Team, collaborating with the Army Explosive Ordnance Disposal (EOD) Unit and Army Range Control. Visual observers were stationed on land at a site south of the demolition range, near the mouth of Eagle River, and on a 13-ft rigid-hulled inflatable boat with a 20 hp outboard motor north of the point; observers were monitoring for belugas and other marine mammals that could approach the recording zone from the north or the south (Figure 1). Visual observers were also stationed on each of the two recording vessels, the Valkyrie, a 26-ft cabin cruiser with twin 150 hp outboard motors, and the Blackhawk, a 20-ft open sport fishing boat with a single 115 hp outboard motor. The two recording boats were stationed in the Knik Arm channel in a line perpendicular to the shore west of Demo III (Figure 1), with Blackhawk (Vessel 1) approximately 25 m from shore and Valkyrie (Vessel 2) approximately 300 m from shore (Figure 3). Both vessels were in water depths of about 25 – 40 ft (8 – 13 m) at maximum high tide. Due to the extreme tidal fluctuations, all operations had to be conducted within a four-hour time window. These operations included: the launch and recovery of the boats from a boat launch about 11.5 miles away at Ship Creek; a one-hour observation period before the firing of any shots to ensure no marine mammals were present in the area; a series of four to five shots per day; and a final observation period to verify that no undetected marine mammals in the area were impacted. The shot matrix is presented in Table 1; each series began with a small 5 lb NEW surface shot and then ramped up in size, culminating in a 74 lb NEW buried shot. A final clean-up shot was also needed to guarantee all remaining C4 debris had been detonated; however, precise NEWs for the clean-up shots are unavailable.

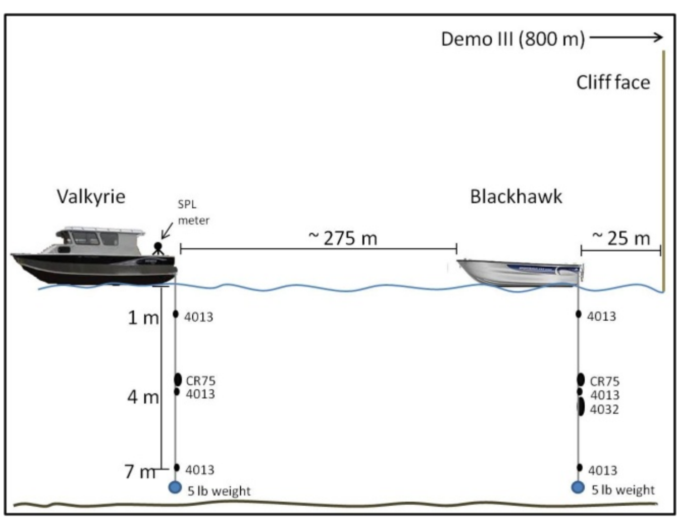

Figure 3 – Depiction of boat distances from shore and array configuration on each boat. Note the sound pressure level (SPL) meter was onboard the Valkyrie (Vessel 2) while the Reson 4032 hydrophone was onboard the Blackhawk (Vessel 1). All other hydrophones were configured the same between the two vessels.

Underwater recordings were made using two vertical hydrophone arrays. Both arrays had Reson TC 4013 hydrophones at depths of 1 m, 4 m, and 7 m from the surface (Figure 3). These hydrophones are omnidirectional, with a usable frequency range from 1 Hz to 170 kHz and a nominal sensitivity of -211dB ±3dB re 1V/µPa (http://www.reson.com/products/hydrophones/tc-4013). Both arrays also had a Cetacean Research C75 hydrophone, deployed at 4 m depth just above the 4013. The C75 hydrophone is also omnidirectional, with a usable frequency range from 11 Hz to 85 kHz and a sensitivity of -206 dB re 1V/ µPa (http://www.cetaceanresearch.com). In addition, the array on the Blackhawk had a Reson TC 4032 hydrophone, deployed at 4 m depth just below the 4013. The 4032 hydrophone has a usable frequency range of 5 Hz to 120 kHz, with a sensitivity of -170 dB re 1V/µPa, and a built-in 10 dB preamplifier (http://www.reson.com/products/hydrophones/tc-4032). Finally, the Valkyrie recorded in-air sound levels using a digital sound pressure level (SPL) meter (Figure 3). All of the Reson hydrophones on both vessels were connected to Reson VP1000 preamplifiers, with a high pass filter set to 5 Hz. The data from all hydrophones and SPL meter were digitized using an UltraLite mk3 MOTU audio device (www.motu.com) with a sampling rate of 192 kHz and 24 bits. Finally, the data were recorded to laptop computers in .wav format using the digital audio workstation software Reaper (www.reaper.fm). Gain levels could be adjusted on both the VP1000 and within the MOTU; levels were increased over the course of the study, as initial levels were determined to be too low (Table 1).

Once the one-hour period of marine mammal observation was completed with no marine mammal sightings, the series of shots commenced with the following order of operation for each shot. Both recording vessels positioned themselves at their designated locations (see Figure 1 and Table 1 for exact positions). Both marine mammal observer platforms confirmed that there were no marine mammals present, and then EOD was contacted to let them know the recording teams were ready. EOD responded with a 10-minute shot window, at which time final confirmations would be made with all teams that no marine mammals were present and that all boats were in position. At that time both recording vessels turned their engines off and the hydrophone arrays were deployed off the side of the boats and immediately began recording. EOD was notified that the vessels were recording; EOD responded with a 5-second countdown and then the shot was fired. After EOD confirmed the shot was fired (as not all shots were audible from the boats), the GPS coordinates for each boat were noted, and recording continued for another 5 seconds and then was stopped. The hydrophone arrays were immediately recovered and boat engines turned back on, and the process was repeated. Since the tidal current was very strong, the boats could not drift without power for extended periods of time without the concern of getting pushed on the shallow sandbar or onto the beach, so it was imperative that the recording and shot sequence happened quickly. Once all the shots and the final period of marine mammal observation were completed, the vessels returned to the boat launch and were recovered. In addition, environmental conditions were recorded by the visual observers throughout the operation, a temperature-salinity meter was deployed to measure water conditions, and a weather station closest to Demo III recorded atmospheric conditions (Table 2).

Data Processing Methods

The Reson 4032 and 4013 hydrophones were calibrated before and after the experiment using a B&K 4223 pistonphone. The calibrated functional sensitivities following recording by the MOTU device were determined to be -187 dB re 1V/µPa for the Reson 4032 and -231 re 1V/µPa for the Reson 4013 (we were unable to calibrate the CR75 hydrophones). These values were used to determine the received levels of the shots. To reduce high-frequency noise in the data, the data were decimated by a factor of 40, creating a new sampling rate of 4800 Hz and effective bandwidth of 2400 Hz. In order to estimate the received levels of each signal, a window was selected around the approximate start and end of the signal (typically 0.7 – 2 s), the cumulative sum of the energy in the window was calculated and a start point was set at 5% of the cumulative energy and an end point at 95% of the cumulative energy (Figure 4). The received levels were given in values of peak SPL and root-mean-square (rms) SPL. Ambient noise levels were measured in rms SPL using the same method; in this case, 80 1-second windows were taken from the 4032 recordings in order to broadly characterize the background noise.

Table 1 - Shots, Recording Vessel positions, and Recording Gain Levels

			Vessel 1 - Blackhawk			Vessel 2 - Valkyrie		
Date	Shot[1]	Shot time (AKST)	GPS location	Hydrophone	Gain	GPS location	Hydrophone	Gain
10/21/2012	5 lb NEW surface (3 blocks C-4)	12:22:17	N 61.362 W 149.713	4013 4032 CR75	+ 26 dB +20 dB 0	N 61.362 W 149.719	4013 CR75 SPL meter	+ 26 dB 0 NA
10/21/2012	14 lb NEW buried (8 blocks C-4)	13:10:56	N 61.362 W 149.714	4013 4032 CR75	+32 dB +20 dB 0	N 61.362 W 149.719	4013 CR75 SPL meter	+32 dB 0 NA
10/21/2012	14 lb NEW surface (8 blocks C-4)	13:22:29	N 61.361 W 149.713	4013 4032 CR75	+32 dB +20 dB 0	N 61.362 W 149.719	4013 CR75 SPL meter	+32 dB 0 NA
10/21/2012	74 lb NEW buried (43 blocks C-4)	13:29:51	N 61.362 W 149.714	4013 4032 CR75	+32 dB +20 dB 0	N 61.362 W 149.719	4013 CR75 SPL meter	+32 dB 0 NA
10/21/2012	clean up	14:14:15	N 61.362 W 149.714	4013 4032 CR75	+42 dB +20 dB 0	N 61.362 W 149.719	4013 CR75 SPL meter	+42 dB 0 NA
10/22/2012	5 lb NEW surface (3 blocks C-4)	13:04:35	N 61.362 W 149.714	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.718	4013 CR75 SPL meter	+48 dB +20 dB 0
10/22/2012	14 lb NEW buried (8 blocks C-4)	13:11:21	N 61.362 W 149.713	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.719	4013 CR75 SPL meter	+48 dB +20 dB 0
10/22/2012	14 lb NEW surface (8 blocks C-4)	13:16:59	N 61.362 W 149.713	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.719	4013 CR75 SPL meter	+48 dB +20 dB 0
10/22/2012	14 lb NEW surface (8 blocks C-4)	13:22:47	N 61.362 W 149.713	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.719	4013 CR75 SPL meter	+48 dB +20 dB 0
10/22/2012	74 lb NEW buried (43 blocks C-4)	13:40:46	N 61.362 W 149.713	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.719	4013 CR75 SPL meter	+48 dB +20 dB 0
10/22/2012	clean up	13:47:49	N 61.362 W 149.713	4013 4032 CR75	+48 dB +20 dB +20 dB	N 61.362 W 149.719	4013 CR75 SPL meter	+48 dB +20 dB 0

[1] One block of C-4 weighs 1.25 lb. Net explosive weight (NEW) is the equivalent explosive energetic material expressed as weight of trinitrotoluene (TNT). One lb. of C-4 is equivalent to 1.37 lb. TNT. Buried charges are detonated in an approximately 5-ft. (1.5 m) open earthen pit.

Table 2 – Environmental Conditions

Day	Land Conditions[1]	Water conditions[2]	Tides	Observations
10/21/2012	32 F 40% relative humidity wind 9 mph WNW (22 mph peak)	7.4 ppt salinity 37° F water temp	High tide 1246	Clear skies, no precipitation, Beaufort sea state 1-2, flood tide
10/22/2012	6 F 85% relative humidity wind 0 mph (2 mph S peak)	7.5 ppt salinity 36.9° F water temp	High tide 1357	Clear skies, no precipitation, Beaufort sea state 1-2, flood tide

[1] Conditions are for JBER weather station near Malamute DZ, elevation 262 ft., location N 61.3819 W 149.6503. Conditions recorded at 1216 on both days.
[2] Obtained using a YSI handheld meter at approximately 1-m depth.

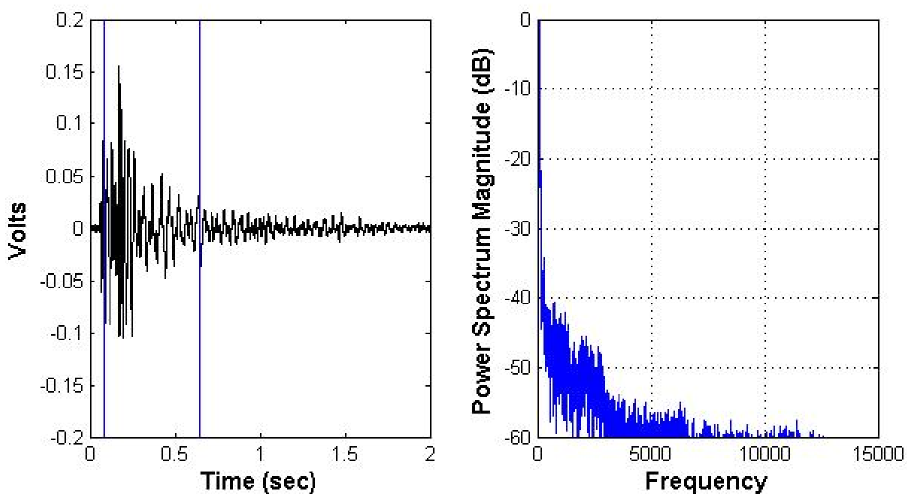

Figure 4 – An example of the method used to calculate received levels for each of the shots. The plot on the left shows the amplitude of the wave form using a 2-second window around the 74-lb shot from the 4032 hydrophone; blue vertical lines indicate the 5 and 95% cumulative energy boundaries. The plot on the right is the power spectrum density of the shot, showing most of the energy occurs below about 250 Hz.

Results

In-air and underwater recordings were obtained during the period of all 11 shots over the two days of testing, however, due to high background noise levels only a few of the shots were measureable. True ambient noise levels could not be obtained due to noise from strum on the hydrophone lines, flow noise as a result of the strong currents, the presence of depth sounder noise on most of the recordings, and falling debris from the cliff face. Therefore, this will be referred to as background noise rather than ambient noise; the average background noise was 125 dB_{rms} re 1 µPa, with a range from 118 – 130 dB_{rms} re 1 µPa (Figure 5). This level is consistent with the 118 – 120 dB_{rms} re 1 µPa values measured by Blackwell and Greene (2001). The data were only calculated using recordings from the 4032 on the second day, since all recordings from both boats the first day and all recordings from the Valkyrie the second day included depth sounder noise. In addition, the received levels from the explosions were difficult to pick out from the background and electronic noise on data from the Reson 4013 and CR75 hydrophones, due in part to their smaller size, which led to increased strum noise. Consequently, these data will be left out of the received level calculations, and only the received levels from the Reson 4032 will be considered further (Table 3).

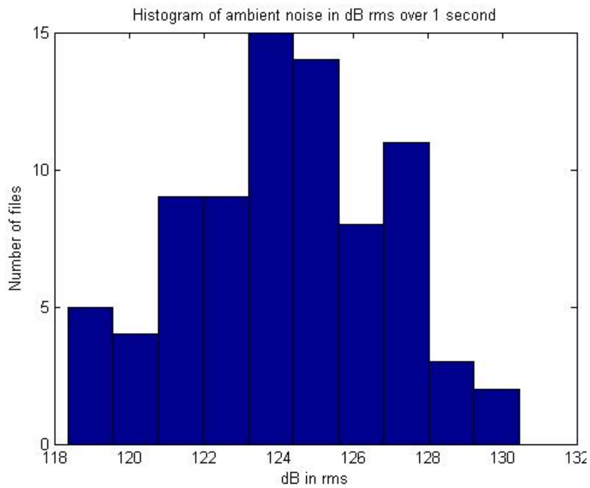

Figure 5 – Histogram of background noise from 80 1-second recording periods.

The larger 74-lb charges seemed to follow a ground-to-water sound propagation path in addition to an air-to-water path; this may be a result of being buried, or simply of being a larger size, or both. Unfortunately, it was difficult to determine which propagation path was followed for the remainder of the shots, particularly since a single in-air sound pressure meter was used on the Valkyrie (Vessel 2), and no in-air recordings were made on the Blackhawk (Vessel 1). However, the signals from the 74-lb shots that were recorded on the Valkyrie hydrophones arrive about 2.5 s sooner than the signal arrives on the sound pressure meter, supporting the hypothesis that at least the larger buried shots are following a ground-to-water path (Figure 6). The 14-lb buried shots were not recorded on any hydrophone or on the SPL meter. Table 3 summarizes the received levels for each of the shots; the main energy for all of the shots remained below 250 Hz. The maximum received level was 151 dB_{peak} re 1 µPa (139 dB_{rms} re 1 µPa) for the 74 lb buried shot ground-to-water propagation path, while the air-to-water propagation path only had a received level of 130 dB_{peak} re 1 µPa (115 dB_{rms} re 1 µPa), which was barely detectable above background noise levels. This was the only shot to have distinct ground-path and air-path signals, which were separated by 2.5 s (Figure 7).

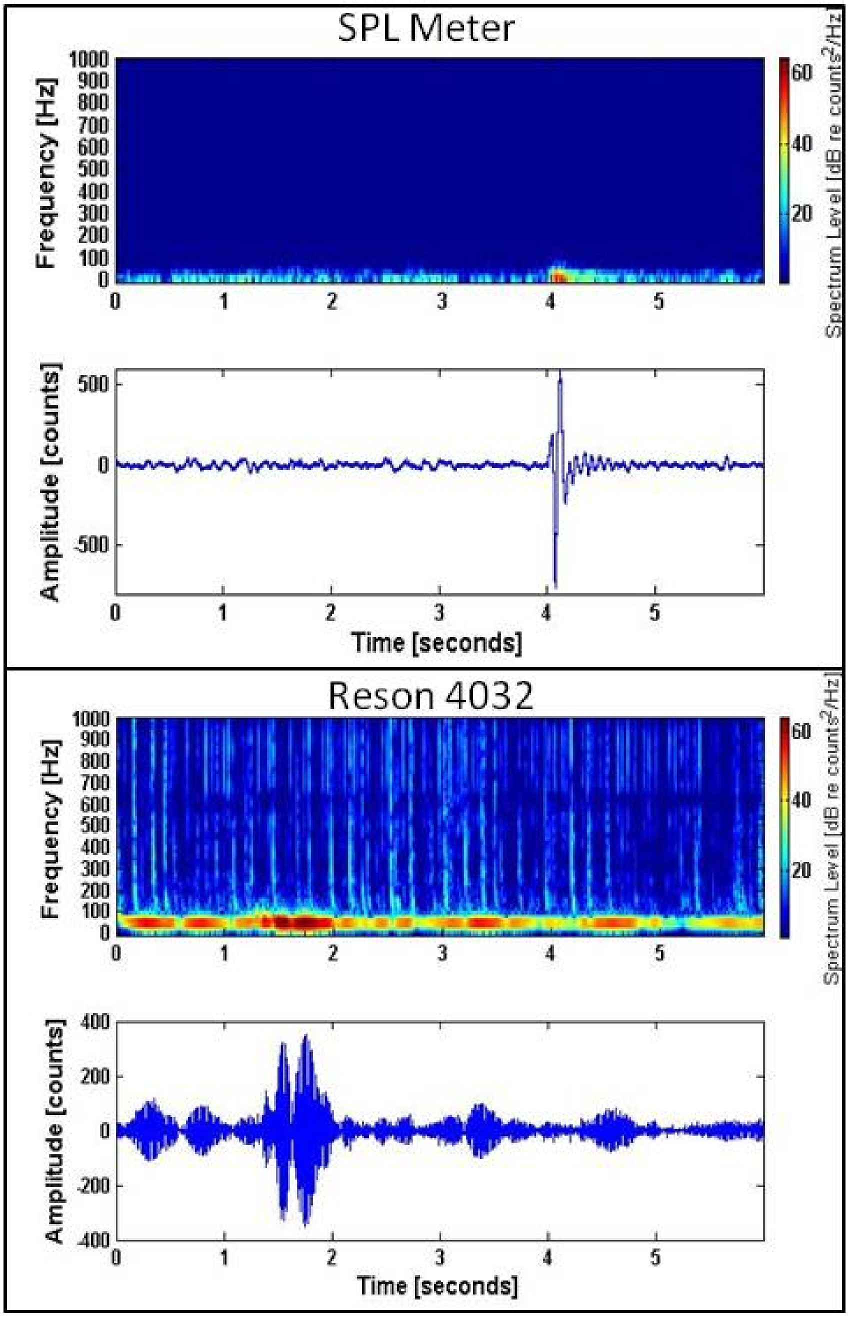

Figure 6 – The top two plots are the spectrogram and time series over 6 seconds for the 74-lb shot on Oct 21 from the SPL meter (in air), while the bottom two plots are the spectrogram and time series of the same shot on the mid-depth (4 m) 4013 hydrophone from the Valkyrie. The shot is received on the underwater hydrophone about 2.5 s before it is received in air, leading to the hypothesis that the hydrophone is receiving the signal through the ground-to-water pathway. While the shot is clearly detectable on the hydrophone, it co-occurs with elevated electronic noise and background noise, making the received level measurement potentially inaccurate. The vertical lines on the 4013 spectrogram are from the depth sounder.

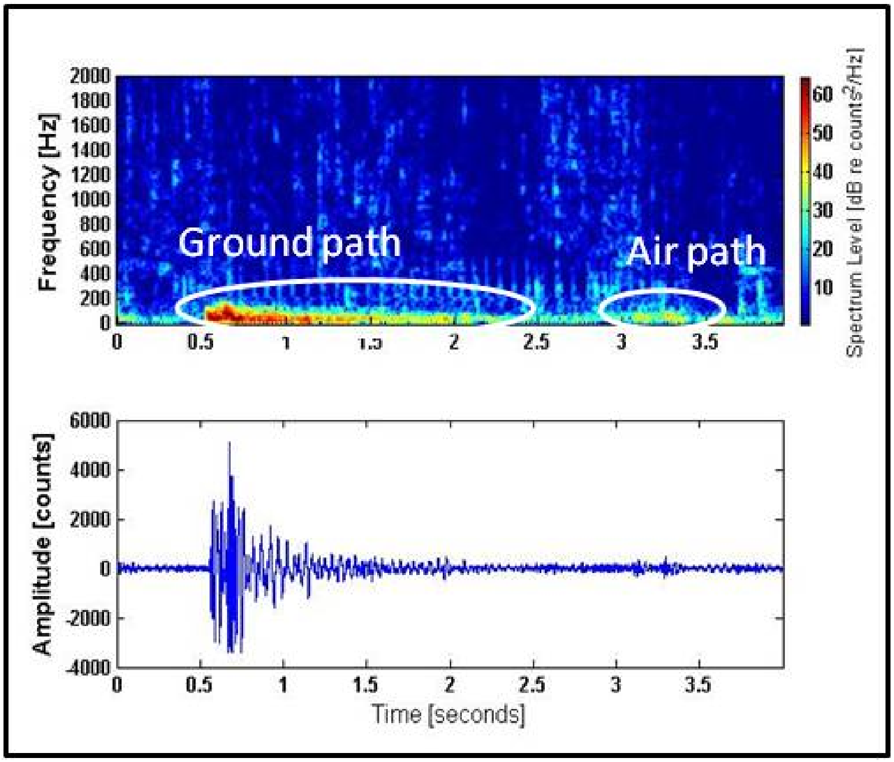

Figure 7 – Spectrogram and time series for the 74-lb shot on Oct 22 from the 4032 hydrophone. The signals from the ground and air paths are clearly visible, with the signal from the ground path received about 2.5 s sooner. The small vertical lines from 100 – 600 Hz are strum noise from the array.

Table 3 - Summary of Received Levels (Reson 4032 hydrophone only)

Test shot number	NEW	Received Level (peak)	Received Level (rms)	Propagation Pathway
1	5 (surface)	≤ background	≤ background	?
2	14 (buried)	≤ background	≤ background	NA
3	14 (surface)	≤ background	≤ background	NA
4	74 (buried)	**144 dB re 1 µPa**	**135 dB re 1 µPa**	Ground-water
5	5 (surface)	≤ background	≤ background	?
6	14 (buried)	≤ background	≤ background	NA
7	14 (surface)	≤ background	≤ background	?
8	14 (surface)	≤ background	≤ background	NA
9	74 (buried)	**151 dB re 1 µPa** **130 dB re 1 µPa**	**139 dB re 1 µPa** **115 dB re 1 µPa**	Ground-water Air-water

Discussion

The results of this pilot study were severely limited by background noise levels and small charge sizes, and the last-minute decision not to utilize the Demo II site which was only 200 m from the channel. However, some preliminary conclusions can be drawn, and recommendations can be made for the follow-on full noise study. First, the sound from the smaller 5 and 14 lb shot sizes were either undetectable as they were similar to background noise levels (particularly when the depth sounder was running), or were barely audible, and were not detected at all when buried. Additionally, none of the demolition signals reached the 160 dB_{rms} level utilized by NMFS as the onset of behavioral harassment. Second, it appears as though the shots generate both an air-to-water propagation pathway and a ground-to-water pathway, and the latter appears to be received 2.5 s earlier on the 4032 hydrophone than the first over a land-to-shore distance of about 800 m.

Sound propagation in air is affected by variable atmospheric factors such as water vapor absorption, refraction due to temperature gradients, or wind. Higher humidity can attenuate noise (more significant for higher frequencies rather than the dominant lower frequencies of explosives). Sound may refract upwards on a warm day, reducing the noise at a surface receiver. Conversely, sound may be heard over a longer distance during a temperature inversion (temperature increasing with height), often associated with heavy cloud cover. Wind can shift noise in the direction it blows. Inversion conditions were not evident on either recording day. Winds out of the west-northwest on the first day may have shifted in-air noise away from the shore, while minimal to no winds on the second day likely had insignificant effect on in-air propagation. This may partially explain the lack of detection of many of the smaller shots, and may indicate that under different atmospheric conditions (high pressure, cloud cover, winds blowing towards the water) the air-to-water pathway may have a different contribution. One piece of evidence that supports this occurred on Oct 22; two 14-lb surface shots were fired, however the first shot was much louder in air than the second shot, and the first shot was recorded on the 4032 hydrophone (albeit not measurable above background levels) whereas the second shot was not. Weather conditions (e.g. wind speed, wind direction) could have shifted between those shots, leading to very different results for shots of identical weight.

In addition, sound enters the water through multiple pathways and its path is affected by the angle of incidence with the water surface, following Snell's Law which states that generally, sound penetrates the air-water surface when the propagation path is within about 13 degrees of the vertical. Sound is mostly reflected at greater angles of incidence from the vertical. A significant portion of sound traveling in a horizontal path (such as from the shoreline) may be reflected from a calm water surface as was observed during both field days (Beaufort sea states 1-2). All of these conditions should be considered during demolition operations, as the limited air-to-water pathway in this pilot study may be a reflection of environmental conditions and small surface charge sizes; larger charges or more favorable air-to-water transmission conditions could lead to higher received levels from this pathway.

The in-air sound pressure meter and the Reson 4032 hydrophone were on different vessels. Determining the timing of underwater recordings relative to the aerial recordings was therefore not possible, and it was difficult to determine which shots were received via which pathway. The 74 lb (buried) shot was likely received via the ground-to-water pathway on the first day and via both pathways on the second day; it is likely it was received via the air-to-water pathway on the first day as well but was masked by the depth sounder noise. A comparison of predicted travel times for sound in air versus the local ground-to-water pathway supports the explanation that the two waveforms observed in the recording of the 74 lb buried charge show the ground-to-water path followed by the air-to-water path. Sound velocities in soils and rock are highly variable, depending on porosity, density, consolidation, saturation, overburden, and bulk modulus. Approximate compressional wave (P wave) velocities for the major soil and rock types present in the vicinity of Demo III and Eagle Bay are shown in Table 4 (Delleur, 2006). The ground-to-water sound path can be estimated based on geologic profiles found in Hunter, et al. (2000). Assuming a glacial till thickness of 150 m below Demo III, that half of the glacial till layer is saturated, and that depth to bedrock (sandstone) is 150 m at Demo III and 150 m below channel bottom in Eagle Bay, the travel time to the vessels would approximately half a second. Assuming a sound velocity in air of approximately 340 m/s, the explosive noise originating at Demo III would take about 2.4 s and 3.3 s to travel to Vessel 1 and Vessel 2, respectively. The estimated time gap between the arrival times via each pathway (1.9 to 2.7 s) are similar to the 2.5 s time gap shown in the recording.

Table 4 – Sound velocities in ground, taken from Delleur 2006.

Layer	Sound velocity (m/s)[1]	Approximate travel distance (m)	Travel time (s)
Glacial till (unsaturated)	400-1000 (700 ave.)	75	0.1
Glacial till (saturated)	1700	75	0.04
Bedrock (sandstone)	2000-4500 (3250 ave.)	800 - 1100	0.2 - .03
Glacial till (saturated)	1700	150	0.1
water	1400	10	0.007

Due to a limited sample size it is unknown whether the ground-to-water pathway is a result of the larger 74 lb shot being buried as no surface 74 lb shot was allowed for the pilot study, or as a result of simply being the largest and best detected shot at this time. In addition, the signal from the ground-to-water pathway was at least 16 – 17 dB greater than that from the air-to-water pathway, although this could change with different atmospheric conditions. Thus a simple increase in charge size based on the air-to-water pathway cannot be undertaken without determining (a) how an increase in buried shot size may impact the received sound level, and (b) the mechanism behind the signal being received via the different pathways (e.g. is it due to charge size, being buried versus on the surface, or a combination of both). While it is clear that the current shot size limitation of 10 lb surface is highly conservative, it is too early to estimate on how large of a shot would lead to a received level of 160 dB_{rms}.

Recommendations

For the full noise study taking place in the spring of 2013, we have the following recommendations.
(1) We would like to equip both vessels with in-air microphones, two Reson 4032 hydrophones per array (deployed at approximately 3 and 5 m depth to avoid surface noise), and flow meters. Using these larger, more sensitive hydrophones should help reduce strum noise and improve our ability to compare received levels across vessels, while having in-air measurements on both boats will allow us to

determine the sound propagation pathway with more precision. A microphone on both boats will also record the detonation countdown on the radios, giving us a precise shot time. A flow meter on both boats will be used to measure the current. (2) The use of the depth sounder throughout the study created an elevated background level that prevented the recording of many of the shot signals. This was simply due to an oversight in communication and has already been discussed in relation to the spring effort; by reducing as many man-made sources of background noise as possible (e.g. depth sounder, hydrophone line strum, etc) we can improve our ability to detect all signals of interest. (3) The smaller charge sizes were not measurable above the high background noise levels, and none of the received levels reached the NMFS level B harassment threshold of 160 dB_{rms}. Therefore, we recommend using much larger charge sizes for the spring study (see below). (4) Having both boats positioned in the Knik Arm channel and separated by only about 275 m may not provide enough data to calculate transmission loss underwater, nor does it allow us to measure sound levels from different potential propagation pathways. Therefore, we recommend that we compare received levels from one vessel stationed in the channel and one vessel stationed near Eagle River Flats, as both the air-to-water and ground-to-water propagation pathways could differ in that location. (5) Shots were fired from a single location during this pilot study, giving us no information on propagation pathways over different distances on land. For the spring study we recommend firing shots from both Demo III and Army Range 4090. (6) Belugas are also known to travel up the Eagle River; therefore we would like to place an additional, land-deployed hydrophone somewhere upriver from an accessible shoreline location.

The C-4 allotment for full spring 2013 noise study is currently limited to 800 lb; Table 5 gives one possible scenario for how that C-4 may be utilized (exceeding this limit by only 23.75). The requested shot sizes would allow us to (a) compare the air-to-water and ground-to-water pathways for larger charge sizes, (b) determine how much of an increase in charge size could lead to a received level of 160 dB_{rms} via either pathway, (c) compare received levels for both pathways from the Knik Arm channel and Eagle River Flats, and (d) compare received levels for shots at different distances from the shoreline and from Eagle River Flats. We recognize that these requested shot sizes are high, but based on the received levels in the pilot study, and the Army's desire to increase their capabilities at a potential new range, we feel that these will give us the best data to develop a well-informed model and make solid future recommendations about maximum allowable shot sizes and distance from shore necessary to ensure received levels remain below 160 dB_{rms}. Furthermore, these proposed shots include replications of each shot size or location, in order to help validate our results and develop better transmission loss estimates.

Table 5 – Proposed shot list for full spring noise study with 823.75 lb C-4

Shot	NEW	Weight C-4	Blocks C	Surface or	Det location	Measurement locations	Notes
P1	74	53.75	43	Buried	Demo III	Channel x 2	buried shot (mid-wt charge) – complete Oct 2012
P2	74	53.75	43	Buried	Demo III	Channel x 2	buried shot (mid-wt charge) – complete Oct 2012
1	74	53.75	43	Buried	Demo III	Channel & Eagle R. mouth	replicate of fall shots P1 & P2
2	74	53.75	43	Surface	Demo III	Channel & Eagle R. mouth	surface shot levels (mid-wt charge)
3	74	53.75	43	Surface	Demo III	Channel & Eagle R. mouth	replicate
4	151	110	88	Buried	Demo III	Channel & Eagle R. mouth	buried shot levels (higher-wt charge)
5	151	110	88	Buried	Demo III	Channel & Eagle R. mouth	replicate
6	151	110	88	Surface	Demo III	Channel & Eagle R. mouth	surface shot levels (higher-wt charge)
7	151	110	88	Surface	Demo III	Channel & Eagle R. mouth	replicate
8	39	28.75	23	Buried	Demo III	Channel & Eagle R. mouth	buried shot levels (lower-wt charge)
9	39	28.75	23	Buried	Demo III	Channel & Eagle R. mouth	replicate
10	39	28.75	23	Surface	Demo III	Channel & Eagle R. mouth	surface shot levels (lower-wt charge)
11	39	28.75	23	Surface	Demo III	Channel & Eagle R. mouth	replicate
12	74	53.75	43	Surface/Buried	4090	Channel & Eagle R. mouth	change of distance & close to proposed site A
13	74	53.75	43	Surface/Buried	4090	Channel & Eagle R. mouth	replicate

Total = 659 blocks C-4 = 823.75 lb. C-4 = 1129 lb. NEW

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