Addendum to: Marine Mammal Monitoring and Mitigation During Open Water Seismic Exploration by Statoil E&P Inc. in the Chukchi Sea, August–October 2010: 90-day Report

The following materials were prepared in response to comments and questions received from the National Marine Fisheries Service – Office of Protected Resources on the draft 90-d report submitted by Statoil in early January, 2011. The report chapter and page numbers associated with each comment and response are included below for reference to the original document.

NMFS Comment 1:

Chapter 3, pages 3-4 – 3-5

In the section discussing computation for SPL and SEL (pages 3-4 and 3-5), it provides the formula to calculate the LE and states that the SEL is a measure of the total sound energy contained in one or more pulses. However, no pulse durations are reported for the calculation of SEL in the report. I assume that pulse durations would be different depending on the distance from the source, as multipath arrivals come into play at long distance.

Response 1:

Yes the duration varies from shot to shot (and with range) but we did not report these times directly. Modal sound propagation in this environment shows strong frequency-dependent dispersion that affects pulse durations. The actual durations can be computed easily from the numeric difference of SEL (LE) and rms (LP90) levels using equation (7): LE = LP90 + 10*log(T90) + 0.458.

NMFS Comment 2:

Chapter 3, page 3-5

On page 3-5, it states that "[to] compute SPL and SEL of pulses in the presence of high levels of background noise, Equations 2 and 3 are modified to subtract the background noise contribution from the pulse energy". However, if background noise (assuming that most in the lower frequency range as the airgun signals) was subtracted, it would likely affect the accuracy of airgun measurements. How is this being compensated?

Response 2:

Yes, some inaccuracy would occur if you applied this method to seismic levels approaching ambient noise levels. To avoid this inaccuracy we typically truncate the results at distances where the levels approach ambient. The noise subtraction for this study was performed on broadband SEL and rms levels (not per band). When levels are a few dB above ambient this method provides increased accuracy. For this study the seismic levels were well above ambient, even at the most distant ranges monitored, and therefore all results presented are believed to be accurate.

NMFS Comment 3:

Chapter 3, page 3-5

Equation (7) on page 3-5 states that LE = LP90 + 10*log(T90) + 0.458, and that "the 0.458 dB factor accounts for the rms level containing 90% of the total energy from the per-pulse SEL". It is not clear to me how the 0.458 dB factor was derived.

Response 3:

The 0.458 factor arises because the LP90 (rms) level is computed from a time window containing just 90% of the overall pulse SEL. 90% of the pulse SEL in decibels is SEL + 10*log(0.9) = SEL – 0.458. Another way to think of this is that LP90+10*log(T90) equals 90% of SEL (power multiplied by time equals energy).

NMFS Comment 4:

Chapter 3, page 3-12

In Figure 3.6 on page 3-12, it seems that Figures 3.6C and 3.6D are reversed.

Response 4:

Yes, figure 3.6C and 3.6D are reversed in the original document. To be consistent with the Figure 3.6 caption, the pair of graphs labelled as "c" should be swapped with the pair of graphs appearing immediately below that are labelled "d".

NMFS Comment 5:

Chapter 4, page 4-2

On page 4-2, it states that the "preliminary empirical measurements of the ≥180 and ≥190 dB (rms) radii, as presented by O'Neill and MacGillivray (2010), were adopted as safety radii for Statoil's seismic survey". While in Table 4.1 it shows that the preliminary empirical measurements of distance (430 m) to 190 dB received level was 90 meters shorter than the final distance (520 m). This could be a concern as pinnipeds could have been exposed by received levels higher than 190 dB (within 520 m) and no mitigation measures were taken.

Response 5:

The distances are in fact different between the 5-day field report (430 m) and the 90-day post-season report (520 m). The distances are computed by fitting smooth curves through the level-versus-range measurements. The threshold level crossings of these fits are then used to define the threshold distances. The reason for the difference is that additional QA/QC on data takes place after the 5-day report is generated. This leads to slightly different fit parameters reported in the 90-day report with the result being the modified distances observed.

With regard to the specific question about animals being exposed to levels above 190 dB, levels in the endfire direction are lower than in the broadside direction. The distances reported are the maximum of the two directions, and they quite significantly overestimate levels in the non-broadside direction. The endfire levels fall below 190 dB at just 200 m distance versus 520 m in the broadside direction.

Additionally, all of the threshold distance estimates are based on 90th-percentile fits so only 10 percent of the data points lie above the fit lines. Very small decibel levels lead to quite significant range differences, so the small region between 430 and 520 m in the broadside direction would be ensonified

above 190 dB by only a small percentage of the shots. The amount by which those sounds would exceed 190 dB is just a fraction of a decibel. The actual zone of interest here is limited to a small range of angles immediately to the side of the array.

Chapter 5, page 5-27

Based on Comment 5 from NMFS, seal sightings recorded during seismic activity were looked at in greater detail and the following text should replace what appears in the section "*Seals Potentially Exposed to Received Sound Level ≥190 dB re 1 µPa (rms)*" at the bottom of page 5-27.

From the *Geo Celtic,* 146 seals were observed while airguns were operating. There were 9 power downs for seals observed within or about to enter the 190 dB (rms) radius of 430 m used by MMOs during the field season. Four of those 9 power downs were for seals that were outside of even the final 190 dB distance (520 m). However, there were five seals observed within the 520 m distance, but outside of the 430 m mitigation threshold, for which a power down was not requested. These five seals had estimated closest points of approach to the airguns of: 464, 515, 488, 498, and 477 m. The first and last distances given are associated with broadside sightings (i.e. ~90 degrees off the bow of the vessel) while the middle three distances are associated with sightings either ~30 or ~60 degrees off the bow. For reasons stated above, it is possible that these animals were not exposed to sound levels at the 190 dB level and unlikely that they were exposed to sounds significantly greater than 190 dB.

MMOs aboard the monitoring vessels observed 154 seals while airguns were active (or while the vessel was beyond the 120 dB radius), none of which were within the ≥190 dB (rms) radius.

NMFS Comment 6:

Chapter 4, page 4-5

On page 4-5, it states that "In order to keep sample sizes large enough for comparisons among RSL bins, data were grouped into three broader bins: (1) ≥160dB (rms), (2) 159–120 dB (rms), and (3) <120 dB (rms)." What about RSL falls between 159 < RSL < 160? It seems to be more logical to group the data into: (1) > 160 dB (rms), (2) 160 – 120 dB (rms), and (3) < 120 dB (rms). This comment also affects the following Marine Mammal Monitoring chapter.

Response 6:

Sightings and effort that occurred in the 159<RSL<160 range were included in the 159-120 dB "intermediate" category. I understand that the notation we used to describe these categories is not precise in that instance, and perhaps we should note the intermediate category as "<160-120 dB (rms)". We chose to include sightings and effort at the 160 dB and 120 dB levels in the higher RSL level categories. If we used the suggested alternative categorization, data falling at the 160 dB level would be included in the lower intermediate category instead of the higher ≥160 dB category.

NMFS Comment 7:

Chapter 3, page 3-11

Could you also provide the numerical measurements for the 1/3-octave band levels for the airgun array?

Response 7:

We have provided below tables of the 1/3-octave band SEL levels at 4 ranges each in the broadside and endfire directions covering the distance spans of the respective measurements. The distances at

which levels are provided correspond roughly with the root-mean-square threshold radii of 190, 180, 160 dB re 1μPa, and lowest recorded dB levels in the endfire direction (Tables Ad-1 and Ad-2).

Table Ad-1. Third octave band SEL levels for the endfire direction at four distances from the airgun array source.

	Band SEL Level (dB re 1 μPa)			
Third Octave Band Center Frequency (Hz)	355 m	1,366 m	9,387 m	47,835 m
1.0*	118.4	102.9	95.7	92.3
1.3*	119.4	103.9	96.7	93.3
1.6*	129.2	104.0	95.7	89.2
2.0*	131.2	104.6	95.8	84.8
2.5*	137.8	105.4	96.1	84.5
3.2*	140.9	106.2	96.5	84.2
4.0*	142.9	107.6	97.9	86.6
5.0*	137.1	117.8	100.6	92.9
6.3*	139.2	124.1	104.3	99.4
7.9*	153.2	135.2	111.2	99.6
10.0*	153.0	141.7	111.5	95.1
12.6*	155.7	144.9	112.5	85.3
15.8	165.4	155.1	119.9	81.2
20.0	167.7	161.8	141.7	84.2
25.1	167.8	162.0	149.6	95.0
31.6	167.7	161.1	149.5	107.0
39.8	168.8	161.2	150.2	113.3
50.1	169.6	161.5	146.9	116.3
63.1	170.1	164.8	148.2	119.3
79.4	164.9	157.3	142.6	114.0
100.0	159.9	154.3	137.8	112.2
125.9	161.6	155.5	138.7	114.2
158.5	158.9	155.1	139.8	119.1
199.5	158.3	156.0	143.0	120.0
251.2	153.8	147.4	135.1	111.5
316.2	149.5	142.7	130.4	108.6
398.1	149.9	140.9	128.8	105.6
501.2	147.3	138.1	124.2	101.9
631.0	147.1	139.5	124.2	99.0
794.3	135.9	126.7	111.3	90.4
1000.0	130.6	119.2	105.3	88.7
1258.9	126.9	113.6	98.8	88.9
1584.9	129.4	114.9	99.6	89.1
1995.3	129.6	116.0	99.9	89.8
2511.9	127.9	111.7	96.3	90.6
3162.3	125.3	107.3	92.5	92.0
3981.1	121.3	103.3	92.3	92.7
5011.9	118.2	101.1	92.8	93.4
6309.6	113.6	97.2	93.5	94.2
7943.3	110.9	95.8	94.3	95.4
10000.0	108.4	96.0	95.2	96.2
12589.3	104.8	96.2	96.2	97.3
15848.9	103.0	96.9	97.2	98.2
19952.6	101.8	97.8	98.1	99.2

*Hydrophone sensitivity rolls off below 15 Hz.

Table Ad-2. Third octave band SEL levels in the broadside direction at four distances from airgun array source.

	Band SEL Level (dB re 1 µPa)			
Third Octave Band Center Frequency (Hz)	488 m	1,384 m	11,514 m	79,955 m
1.0*	115.7	103.3	98.0	108.0
1.3*	116.7	104.3	99.0	109.0
1.6*	126.0	103.9	99.3	105.9
2.0*	128.0	104.3	100.0	103.9
2.5*	130.5	104.5	100.8	102.0
3.2*	132.5	104.7	101.6	96.1
4.0*	133.6	105.5	103.3	91.7
5.0*	135.3	121.8	105.4	91.9
6.3*	137.5	125.0	108.3	91.8
7.9*	148.8	128.9	112.6	92.8
10.0*	151.2	138.2	114.1	89.0
12.6*	150.2	143.9	120.3	88.5
15.8	161.0	155.8	139.9	86.9
20.0	164.6	159.2	144.9	92.8
25.1	163.7	157.3	144.7	110.4
31.6	161.3	154.9	142.9	113.8
39.8	157.1	150.0	136.2	112.9
50.1	154.3	152.1	133.5	116.8
63.1	160.7	157.8	145.5	123.3
79.4	167.2	158.3	147.2	123.8
100.0	166.4	158.4	143.3	124.5
125.9	171.5	166.2	153.0	132.2
158.5	173.5	166.7	154.4	130.1
199.5	162.4	158.1	145.5	120.3
251.2	160.2	155.0	143.1	120.7
316.2	155.6	152.6	142.0	115.6
398.1	152.4	145.5	134.7	106.9
501.2	144.5	141.3	128.7	97.7
631.0	142.7	135.3	122.4	92.7
794.3	136.6	129.0	114.1	91.8
1000.0	132.3	123.4	109.0	91.7
1258.9	127.5	120.7	102.9	91.4
1584.9	128.3	122.3	100.5	91.9
1995.3	128.6	121.5	99.0	92.5
2511.9	125.3	115.5	95.7	92.9
3162.3	120.8	113.4	95.8	93.6
3981.1	120.8	110.1	94.4	94.4
5011.9	124.4	108.5	93.9	95.1
6309.6	140.5	104.3	94.8	95.9
7943.3	152.7	101.1	95.2	96.9
10000.0	131.5	98.5	96.0	97.7
12589.3	118.8	97.5	96.9	98.8
15848.9	119.8	97.3	97.7	99.8
19952.6	107.5	97.8	98.7	100.6

*Hydrophone sensitivity rolls off below 15 Hz.