

WESTERN GRAY WHALE ADVISORY PANEL
9th Meeting
PUBLIC

WGWAP 9/14
4-6 December 2010
ENGLISH

SEIC 2010 Astokh 4D Seismic Survey
Seismic Sound Source Verification (SSV) report v2.0
Submitted by: SEIC



Sakhalin Energy Investment Company, Ltd Controlled Document

Sakhalin II Assets								
	Asset	Origin	Module	Discipline	Doc Type	Doc No.	Sheet No.	Rev No.
Document Number:	1000	S	90	04	T	0709	00	02
<i>Seismic Sound Source Verification (SSV), SEIC 2010 Astokh 4D Seismic Survey. Version 2.0</i>								
Custodian: <i>Doug Bell, Environmental manager</i>					Classification: <i>Unclassified</i>			
Issue Purpose		IFR For Information/Review AFD Approved for Design AFC Approved for Construction AFU Approved For Use			SUP/OBS ASB PUR ENQ		Superseded / Obsolete As-Built Issued for Purchase Issued for Enquiry	
Rev	Issue Purpose	Description	Originator: Name (Company)		Signature		Date	
			Checked by: Name (Company)		Signature			
			Approved by: Name (Company)		Signature			
02	AFU	Approved for Use	Originator: Roberto Racca (JASCO app.sciences) Checker: Koen Broker (Sakhalin Energy) Technical Assurance: Koen Broker (Sakhalin Energy) Approver: Richard Evans (Sakhalin Energy)				29 Nov. 2010	
Location of Change			Brief Description of Change to Latest Revision (For the new /current revision)					

This document contains proprietary information and is intended for use by Sakhalin Energy Investment Company, Ltd (Sakhalin Energy) authorised personnel or companies only. The copyright of this document is vested in Sakhalin Energy. All rights reserved. The contents of this controlled document shall not be altered without formal approval of the document Custodian.

It is the responsibility of each user of this document to verify the current revision prior to use. The Sakhalin Energy Electronic Document Management System is the only Sakhalin Energy approved source for verifying current revisions.

All revision controls and note on updates are maintained electronically through LiveLink. This is governed through the following Sakhalin Energy document control procedures:

- Document Control Procedure 1000-S-90-01-P-0002-00

Seismic Sound Source Verification (SSV), SEIC 2010 Astokh 4D Seismic Survey

Summary Report Version 2.0

Date: 22 November 2010

**Prepared By: Pacific Oceanological Institute, FEBRAS, Russian Federation
and JASCO Applied Sciences, Canada**

1. Objectives and Scope

The objective of the Sound Source Verification (SSV) study discussed in this brief report was to measure underwater acoustic levels as a function of distance in the broadside direction from the Astokh 4D seismic survey operations, and thus confirm or revise the conservatively estimated marine mammal exclusion zone radii used in the early portions of the survey. Acoustic recordings were collected on three dedicated mini-AUAR recorders (Pacific Oceanological Institute). The acoustic recordings were processed upon retrieval of the units to compute distances (radii) corresponding to the marine mammal exclusion sound level thresholds of 180 and 190 dB re μPa rms for cetaceans and pinnipeds used in general practice for implementing shut-down criteria during surveys. The primary goals of the SSV measurements were:

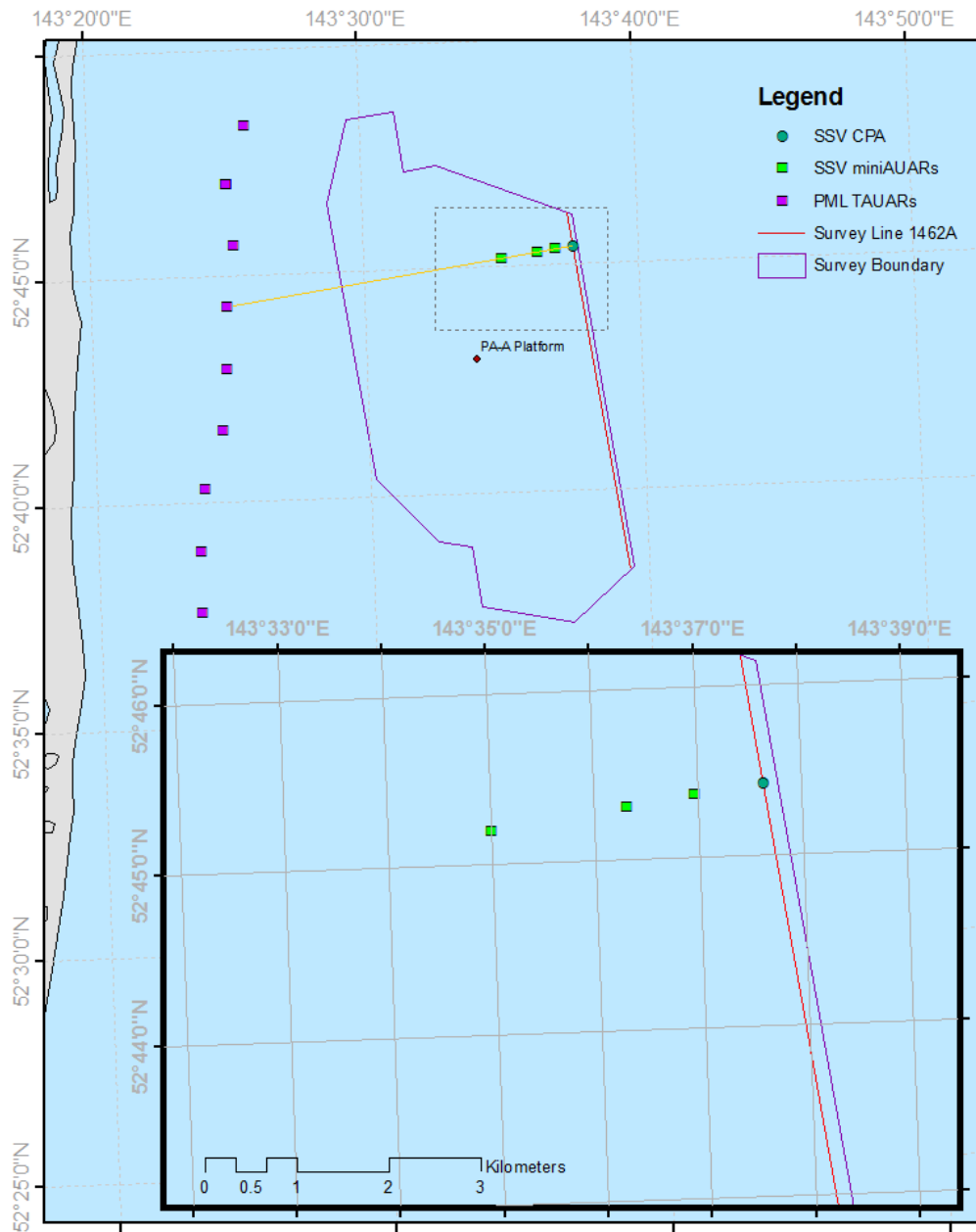
- To estimate from direct measurements the 180 and 190 dB re μPa (rms) distances in the broadside direction.
- To update the safety radii predicted by pre-season modelling with the corresponding distances from the measurements.
- To communicate the adjusted radii to marine mammal observers who will be implementing the safety/exclusion zones.

This expanded second version of the report contains an additional section presenting a more accurate calculation of the relationship between range and levels at the three mini-AUAR sites, making use of geographic tracking data for the seismic survey vessel that were decoded in post-processing from logged AIS (Automatic Identification System) records.

2. Deployment Configuration

The deployment configuration of the SSV acoustic recorders was defined to capture sound levels as a function of distance broadside of the array (perpendicular to shooting direction). The figure on the next page shows a large-scale view of the work area, seismic survey area and mini-AUAR deployment locations. The latter are also shown in greater detail in the inset map and their coordinates are listed in the subsequent table. The mini-AUARs were aligned along a perpendicular to the seismic survey lines.

On 17 June 2010 the seismic vessel sailed from north to south along the most eastern traverse of the survey pattern, identified as 1462A in the seismic operation plan, performing a full geophysical data acquisition (in other words the SSV was conducted during a regular survey line). The line began approximately 1.5 km from the point of closest approach to the row of SSV recorders and extended about 13.5 km past it. Only the shot levels recorded at the closest point of approach were analyzed for the purpose of the SSV study.



AUAR SSV Deployment Layout

SSV transit line markers and AUAR recorder locations for SSV study.

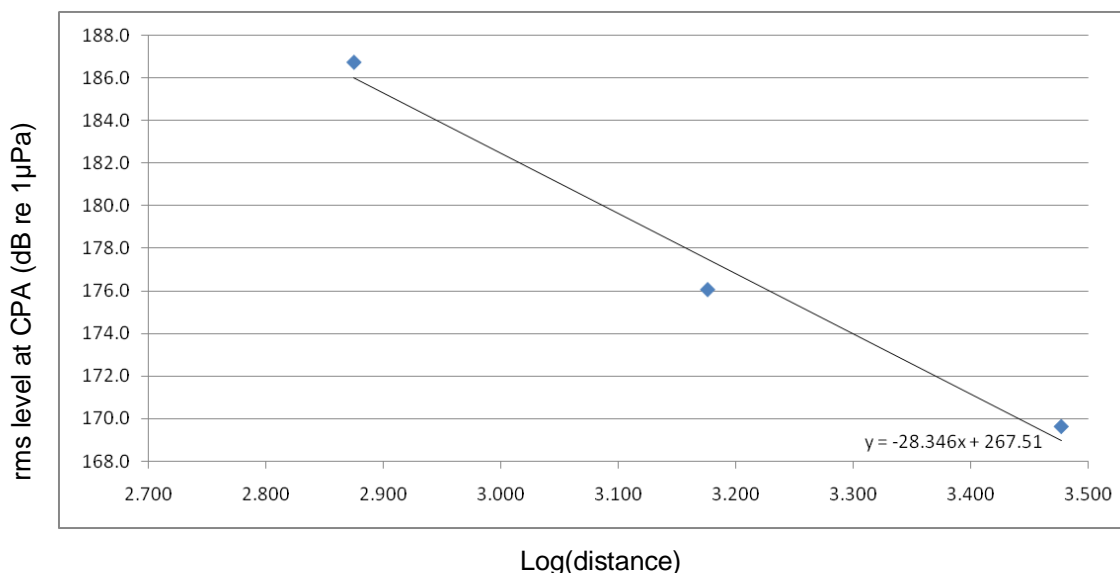
	UTM Easting	UTM Northing	Latitude	Longitude
Line Start Point	677032	5849856	52°46'10.1"N	143°37'27.2"E
Closest Point of Approach	677277	5848478	52°45'25.3"N	143°37'37.5"E
Line End Point	679636	5835236	52°38'14.4"N	143°39'17.2"E
mAUAR M1 – 0.75km offset	676539	5848347	52°45'21.9"N	143°36'58.0"E
mAUAR M2 – 1.5 km offset	675800	5848215	52°45'18.5"N	143°36'18.3"E
mAUAR M3 – 3.0 km offset	674324	5847952	52°45'11.7"N	143°34'59.2"E

3. Initial Calculation of Safety Radii

The calculation of exclusion zone radii was performed through an analysis of root-mean-square sound levels measured at the closest point of approach (CPA) as a function of receiver distance from the line. This analysis involved fitting a least-squares linear function through the rms levels measured at the three acoustic recorders plotted against the logarithm of the receiver range. The table below shows the data used in the calculation, with the regression graph and corresponding formula in the associated figure.

Measured pulse levels and nominal distances used in the SSV calculation.

	Distance (m)	Log (distance)	rms at CPA (dB re μ Pa)
mAUAR M1	750	2.875	186.7
mAUAR M2	1500	3.176	176.1
mAUAR M3	3000	3.477	169.7



Regression plot through rms levels vs. logarithm of distance from the seismic line.

The regression equation above provides the following distances corresponding to values of 180 and 190 dB re μ Pa (rms):

$$r_{180\text{dB}} = 1220\text{m} \qquad r_{190\text{dB}} = 540\text{m}$$

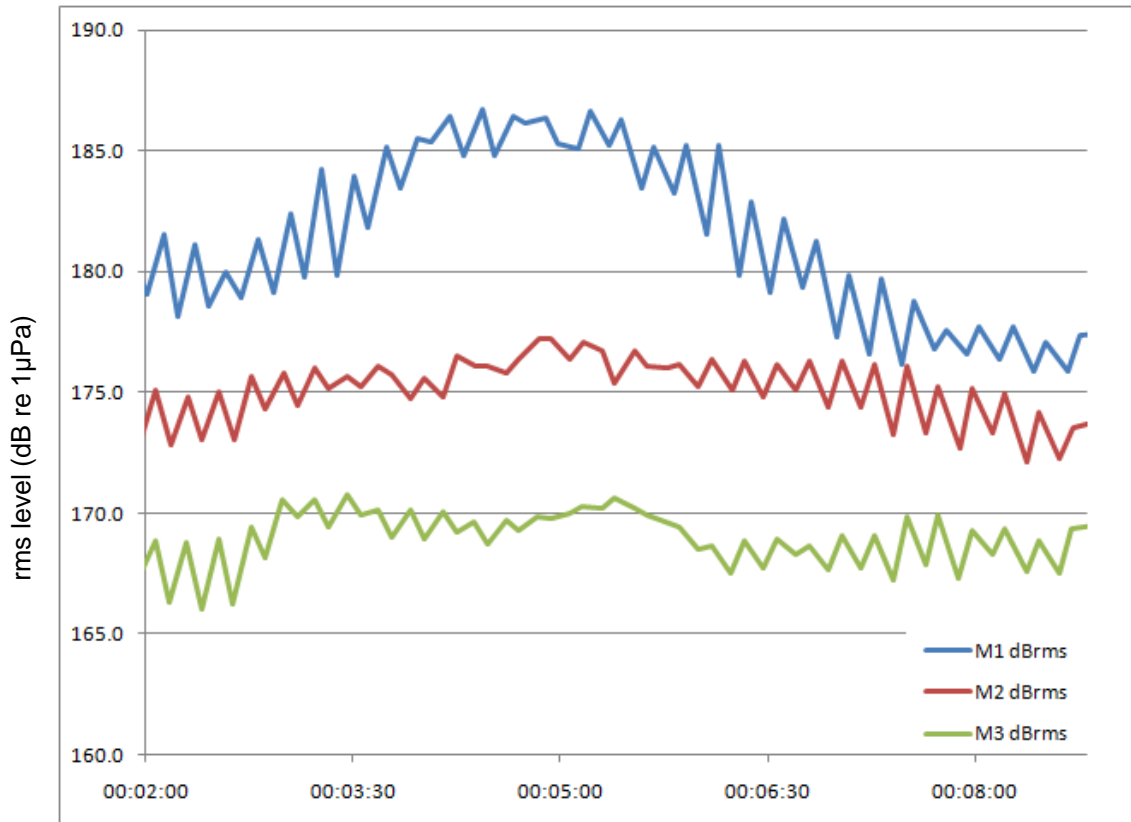
As agreed with the Western Gray Whale Advisory Panel the radius for 180 dB was to be increased as an exceptional precaution by 20%, yielding a cetacean exclusion zone distance (excluding dolphins and porpoises) of 1464m or **1.5km** in practical terms. This value replaced in the mitigation plan the estimated safety radius of 2km that had been used for the survey prior to the execution of the SSV study.

4. Refined Calculation of Safety Radii

The level-range calculations in the previous section relied on simplifications that enabled the timely assessment of safety radii based on the data immediately available. The simplifications were made so as to lean toward a precautionary estimate, using the levels from the strongest measured pulse at receiver

M1 as the seismic source transited past the line of recorders. The corresponding range from source to receivers was taken to be the nominal deployment setback of each sensor from the seismic line, which constituted a close approximation given the positional accuracy. At a later date, precise navigational information for the seismic survey vessel was obtained from stored AIS records. This enabled a more formal computation of the level-range formula based on regression through the measured levels for several pulses near CPA, which accounts for pulse strength variability.

The figure below shows the measured rms pulse levels at the three sensors M1-M3 over a period of a few minutes just after the start of the seismic line, as the source passes the CPA. The irregular strength of the pulses, most likely attributable to small operating variations between the two airgun arrays being fired in alternating sequence, is clearly observable through much of these traces.



Received rms levels at the three mAUAR sensors over the period surrounding the CPA.

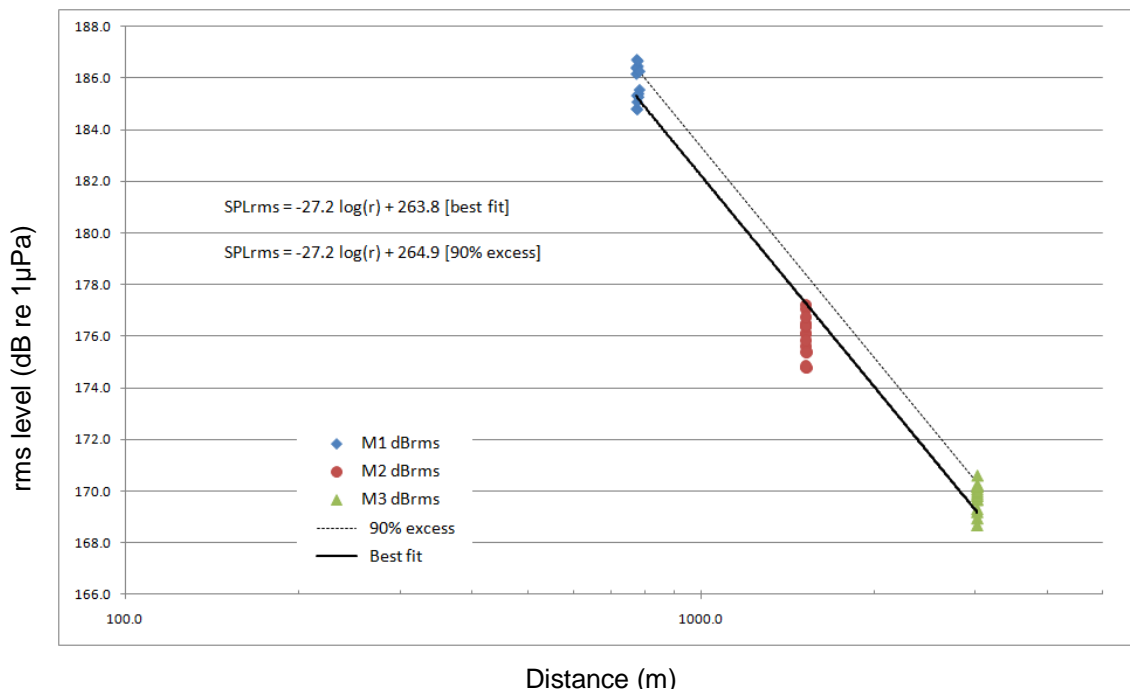
The AIS positional information for the seismic vessel was compensated for the layback of the source from the nominal GPS location of the ship by simply offsetting the time base of the positional data so that the geographic CPA coincided with the well-defined culm of the sound level trace at the proximal sensor M1. This equivalencing of layback with time delay is justifiable over an analysis period spanning only a few minutes, over which the speed of the seismic vessel can be considered to be constant. A subset of received pulse levels at the three sensors for a few consecutive pulses on either side of the CPA time, along with the corresponding computed distances between the seismic source and each of the sensors, was used as the basis for the level-range regression. The subset of levels was truncated at a roll-off of 3 dB from the CPA maximum on receiver M1 and replicated with the same temporal bounds for the other two sensors.

The table on the next page summarizes the pulse levels and ranges used in the regression analysis. The triplet of levels that were used in the original calculation of safety radii described in the previous section is highlighted for reference.

Measured pulse levels and GPS based ranges used in the refined SSV calculation.

mAUAR M1		mAUAR M2		mAUAR M3	
rms (dB re μ Pa)	Range (m)	rms (dB re μ Pa)	Range (m)	rms (dB re μ Pa)	Range (m)
185.5	781.5	174.8	1527.2	170.2	3023.2
185.4	778.6	175.6	1525.8	168.9	3022.6
186.5	776.6	174.8	1524.8	170.1	3022.2
184.8	774.5	176.5	1523.8	169.2	3021.9
186.7	773.4	176.1	1523.2	169.7	3021.7
184.8	772.3	176.1	1522.7	168.7	3021.6
186.4	771.9	175.8	1522.5	169.7	3021.6
186.2	771.9	176.3	1522.5	169.3	3021.8
186.4	772.3	177.2	1522.7	169.9	3022.0
185.3	773.4	177.2	1523.3	169.8	3022.4
185.1	774.5	176.4	1523.9	170.0	3022.8
186.7	776.5	177.1	1525.0	170.2	3023.5
185.3	778.2	176.7	1525.9	170.2	3024.0
186.3	781.4	175.4	1527.5	170.6	3025.0

In the figure below the massed data in the table are plotted as a semi-log graph of level vs. range; the best-fit regression (solid straight line) and corresponding formula are also shown.



Semi-log regression through rms levels vs. range from the source, along with 90% excess line.

The best-fit equation above yields the following distances for values of 180 and 190 dB re μ Pa (rms):

$r_{180dB} = 1205m$ $r_{190dB} = 517m$

These ranges are consistent with the safety radii obtained from the initial analysis (prior to adjustment).

Whereas for the 2010 Astokh 4D survey the computed safety radius for 180 dB was subjected to an *ad hoc* precautionary adjustment of 20% as recommended by the Western Gray Whale Advisory Panel, an established standard practice to provide conservative safety range estimates in SSV studies is to adjust upward the best fit function (by adding an offset to the constant term) so that the line exceeds 90% of the measured data. This 90% excess line (dashed) and corresponding formula are also presented in the figure on the previous page. Based on this approach the precautionary safety radius for 180 dB would be prescribed as 1322m. Clearly the *ad hoc* adjustment resulted in a greater safety margin.