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Hovercraft Underwater Noise Measurements in Alaska

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1.0 Introduction

The United States Postal Service (USPS) is finishing a two-year demonstration project examining the feasibility of mail delivery via hovercraft to remote Alaskan villages. Prior to this demonstration project, and in support of the Environmental Assessment (EA) for the project[1], the Volpe Center Acoustics Facility (VCAF) conducted a "Noise Characterization Study"[2] of the AP.1-88, the proposed hovercraft for the project. This study took place in Anchorage, Alaska.

Early in the demonstration project, the Hovercraft Resolution Committee (HRC), a task force made up of representatives from the villages neighboring Bethel, Alaska, as well as local and federal resource agencies, was made aware of public concern regarding hovercraft noise in the remote villages. As a result, sound level monitoring was undertaken during September 1997 in order to: (1) study hovercraft noise in the village environment to confirm the applicability of the data in the Noise Characterization Study; (2) study village ambient sound levels to determine the reasonableness of the 40 dB value assumed in the EA; and (3) compare in-situ hovercraft sound levels with those of other village noise sources. The results of this monitoring program are presented in Reference 3.

Later in the demonstration project, the HRC was made aware of a new public concern, that being the potential for harmful effects of underwater hovercraft noise on fish. Since the primary route of travel for the hovercraft was along the river system connecting the remote villages surrounding Bethel, village residents were particularly concerned with the potential effects on blackfish, a species commonly utilized for subsistence fishing. As a result, an underwater sound level monitoring program of limited scope was undertaken in the village environment during the period January 23-28, 2000. The results of this monitoring program are presented herein.

The objectives of the underwater sound level monitoring program were as follows:

(1) quantify hovercraft underwater sound levels for use in determining any potential effect on blackfish;
(2) determine relative differences between hovercraft underwater sound levels and those of other transportation noise sources, specifically snowmobiles, in the village environment surrounding Bethel, Alaska; and
(3) measure hovercraft in-air sound levels during the winter months (i.e., with ice- and snow-covered ground) for comparison with those measured as a part of the Noise Characterization Study, when no ice or snow were present.

In addition to underwater and in-air acoustic measurements, blackfish behavioral data were collected by the environmental consulting firm of CH2MHill, while under contract to the Volpe Center. Data collected included underwater video of blackfish activity, anecdotal interviews with local fishermen and others, as well as data on the dissolved oxygen concentration in the local rivers. These data were collected simultaneous to the acoustic data on days when the hovercraft was operating near the villages, as well as on days when the hovercraft was not operating in the area.

2.0 Instrumentation

Underwater acoustic instrumentation included a Brüel and Kjaer (B&K) Model 8103 hydrophone, B&K Nexus conditioning amplifier, Larson Davis (LD) Model 2900 real-time one-third octave-band spectrum analyzer, a B&K Model 4229 pistonphone and a Sony TCD-D100 digital audio tape (DAT) recorder. In-air acoustic instrumentation included a B&K Model 4155 microphone with B&K Model UA0207 foam windscreen, LD Model 827-0V preamplifier and a LD Model 820 integrating sound level meter (SLM). Additionally, a wind speed anemometer and thermometer were used to monitor local meteorological conditions. Measurement locations were noted using a Magellan Pioneer global positioning system (GPS) receiver, and closest-point-of-approach (CPA) distances for hovercraft and other vehicles were measured with a Bushnell LyteSpeed Model 800 Laser Ranging System.

3.0 Measurements

Underwater measurements were made by placing the hydrophone in the water, either 1.5 or 5 ft. beneath the ice and snow line (see Table 1). This involved clearing the snow, and drilling through the ice using a gasoline-powered auger. The hydrophone was placed in the water with the cable supported by a tripod above the ice and snow (see Figure 1). The cable was run 5 to 10 feet away from the hole to the electronics, which were housed in a portable ice-fishing tent to help minimize their exposure to the elements. Each electronic component was further stored in specially-built, sealed containers, suspended over disposable, passive heating elements to help ensure functionality in the extreme, Alaskan environment. The in-air microphone/windscreen/ preamplifier/SLM combination was secured on a 4-foot tripod and co-located with the hole used for the hydrophone.

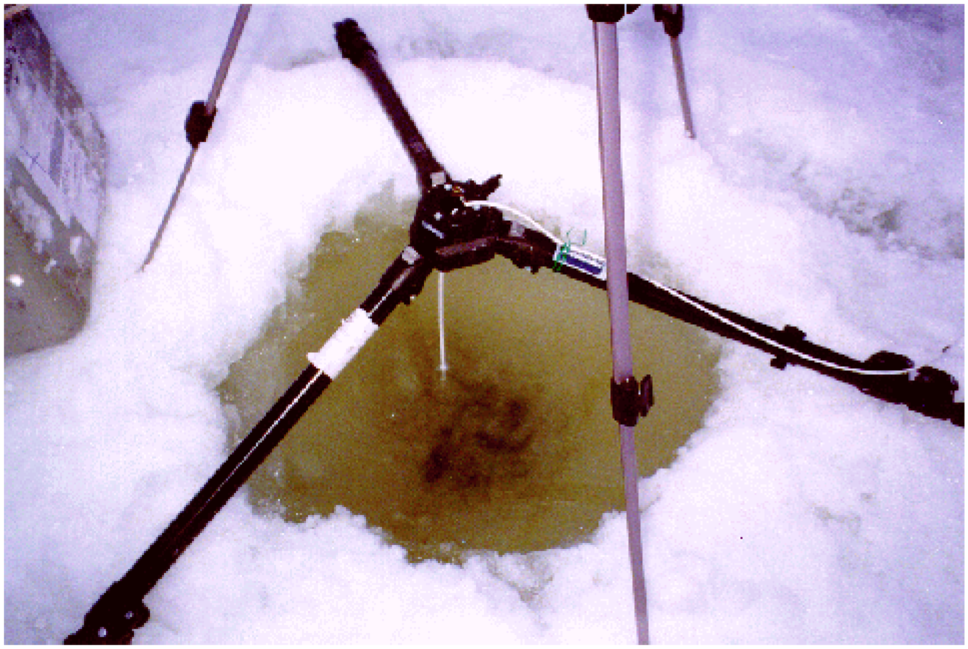

Figure 1. Hydrophone/Microphone Orientation

Table 1 presents a summary of the measurements.

Table 1. Summary of Measurements

Date	Location	# of Events		Snow Depth (ft)	Ice Thickness (ft)	Water Depth (ft)	Hydrophone Depth in Water (ft)	Hovercraft Cargo	
		Hovercraft*	Snow Mobile					Freight (lbs)	# of Passen-gers
1/24	Kuskokwim River, near Knik's Yard *Bethel*	5	16	1	3	10	5	1000	18
1/25	Johnson River *Kasigluk*	1	10	1	3	3	1.5	6000	13
		11						500	1
1/26**	Kuskokwim River, near Knik's Yard *Bethel*	9	9	0.5	3.5	3	1.5	12,500	6

(*) Nominal hovercraft power settings, as noted in the tables in Appendix A, were either 1800 or 2100 RPM for each event.

(**) In addition to the variables outlined in Table 1, due to the warmer temperatures experienced on January 26th, the snow was significantly wetter and consequently heavier on that day.

Figures 2 and 3 depict the measurement locations near Kasigluk and Bethel, respectively. The

Bethel measurements on January 26th were conducted at a new hydrophone hole (as compared with that used on the 24th), in an attempt to more closely match the conditions present during measurements made on the Johnson River on January 25th. These two holes were within approximately 100 feet of each other. The measurement locations are denoted by the symbol ✧ on the two figures. In addition to the underwater acoustic data collected with the hydrophone, in-air acoustic data were collected with a standard 4-foot microphone on both the 25th and 26th.

Since the primary impetus for these measurements was to provide data which could be used to help determine if the sound associated with hovercraft operations on the Johnson River had any negative effect on blackfish in the river, the focus for the remainder of this report will be on the data collected on January 25th in Kasigluk. All acoustic data, however, are presented in Appendix A.

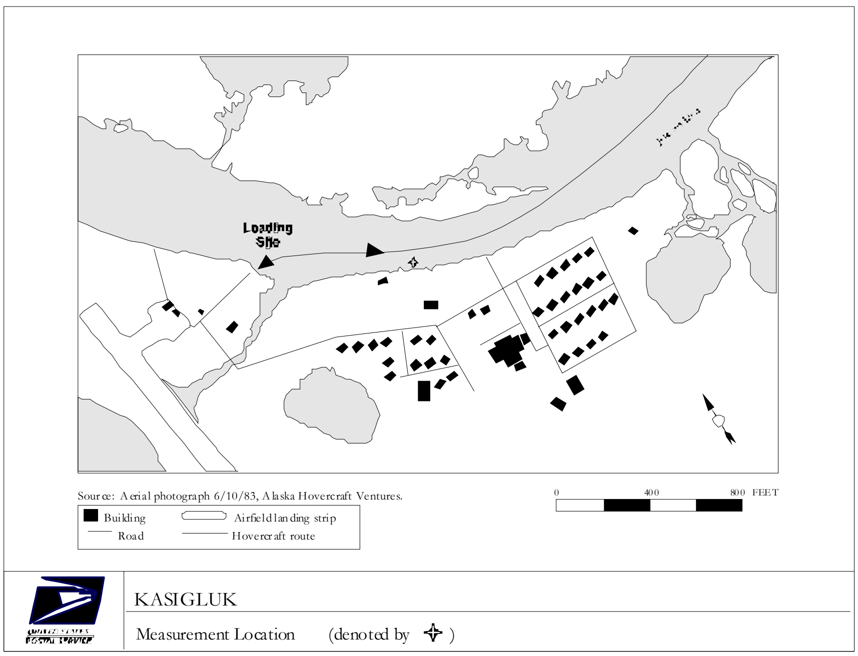

Figure 2. Measurement Location in Kasigluk

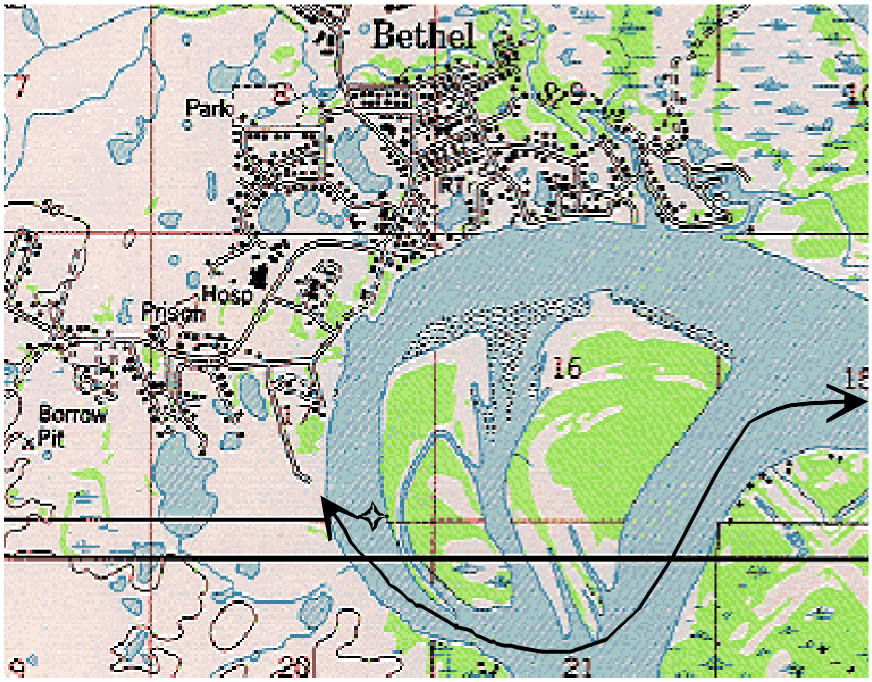

Figure 3. Measurement Location in Bethel

4.0 Data

4.1 Comparison of Hovercraft and Snowmobile Underwater Acoustic Data

Figures 4 and 5 present comparisons of hovercraft and snowmobile underwater acoustic data as a function of source-to-receiver distance for the maximum sound pressure level (L_{Smx}) and sound exposure level (L_E) descriptors, respectively. L_{Smx} provides a measure of the "instantaneous" maximum sound level, while L_E represents the total sound energy associated with a given hovercraft or snowmobile operation. Circles and squares represent average data, for hovercraft and snowmobiles respectively, and horizontal bars indicate the standard deviation when multiple events are represented by a single data point.

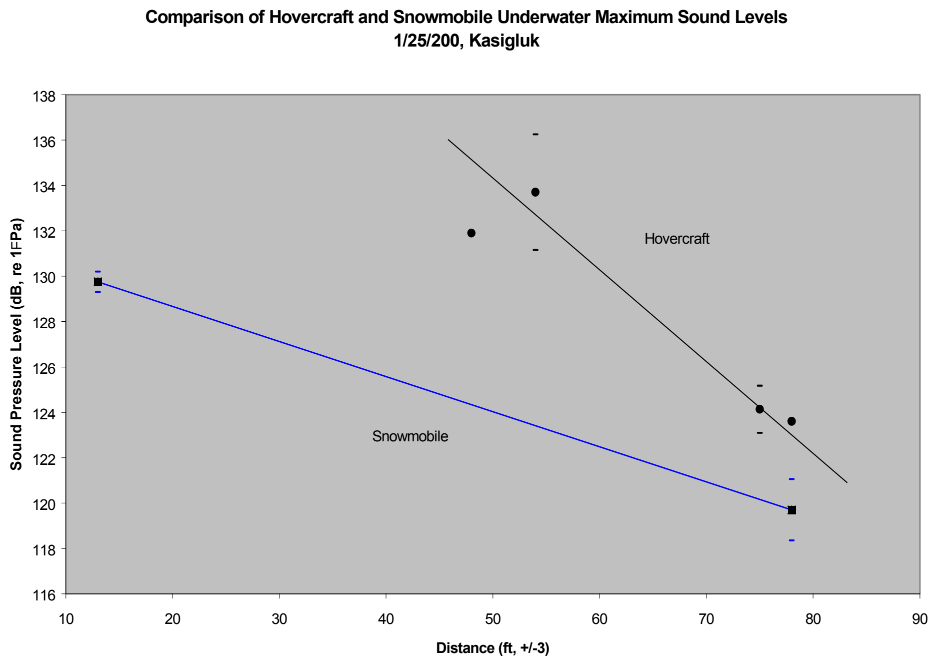

Figure 4

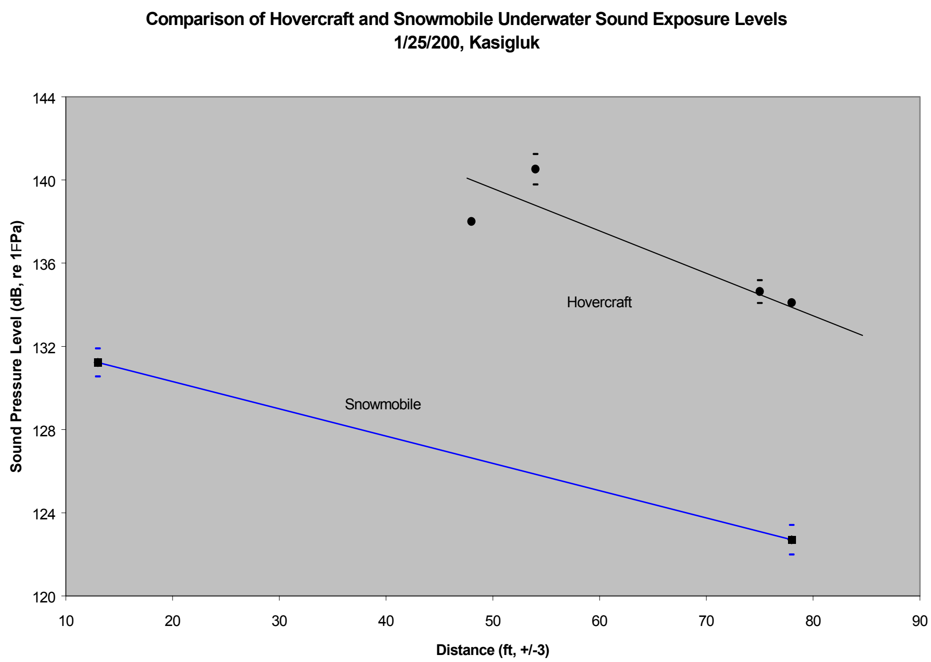

Figure 5

As expected, a drop-off in sound level as source-to-receiver distance increases is depicted. It is interesting to note that the slopes for the two noise descriptor plots as a function of distance are similar for the snowmobile data, yet slightly different for the hovercraft data. In fact, an approximate 4 to 12 dB difference in L_{Smx} data was observed (with the hovercraft being higher in level), whereas the differences for L_E data range from 10 to 14 dB. This difference is likely due to the fact that snowmobile events were typically less than 10 seconds in duration. Consequently, due to the relatively short duration associated with the snowmobile pass-bys, the total sound energy of the pass-by (represented by the L_E descriptor) behaved in a similar fashion to the maximum sound level. On the other hand, since the duration of the hovercraft pass-bys tended to be on the order at least 60 seconds, the total sound energy of the event and the maximum sound level tended to behave differently.

4.2 Comparison of In-Air Acoustic Data from Current Study and Noise Characterization

Figure 6 presents a comparison of the hovercraft L_{ASmx} data measured during the January measurements and those collected in support of the Noise Characterization Study.

As can be seen in the figure, in-air acoustic data collected during the most recent measurements are substantially lower than those measured in the Noise Characterization Study, by as much as 8 to 18 dB. There are several reasons for this difference, including: (1) time-of-year differences (i.e., difference in temperature as well as snow cover during the winter months); (2) a "worst-case"

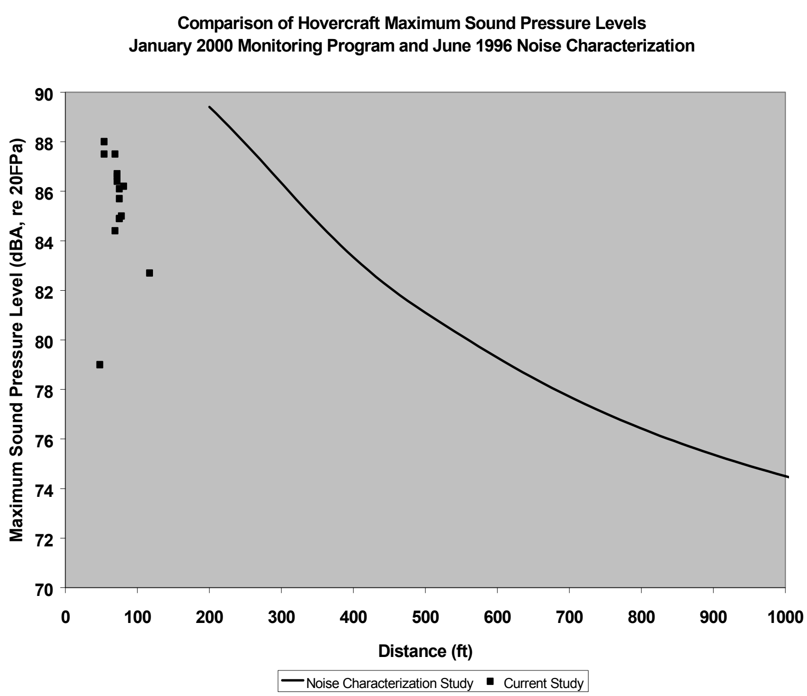

Figure 6

hovercraft load of approximately 9900 lbs was used for the Noise Characterization, whereas loads varied between about 500 and 12,500 lbs for the January measurements; and (3) a target hovercraft speed of 20 kts was originally presented as typical for travel on the rivers and thus used for the Noise Characterization, whereas the hovercraft operated at approximately 6.5 kts during the recent measurements. The Noise Characterization Study was conducted over water, an acoustically hard, reflective surface, whereas measurements for the current study were made over freshly fallen snow, an acoustically soft surface. Excess ground attenuation associated with propagation over the snow-covered surface in the current study was expected to result in a substantial reduction in hovercraft sound level as compared with data measured in the Noise Characterization Study.[4] Experience with aircraft sound levels also indicates that lighter payloads result in less mechanical strain on engines, and consequently lower sound levels. Finally, although it is difficult to quantify the effect of lower hovercraft speeds on sound levels, it is not difficult to reason that lower operating speeds would result in lower sound levels, especially when examining the maximum sound level data, since this descriptor does not factor in duration.

4.3 Underwater Spectral Data

Figure 6 presents a comparison of average spectra at time of L_{Smx} for the hovercraft and snowmobiles at the two distances. It should be noted that distances at CPA ranged from 48 to 78 feet for the hovercraft measurements.

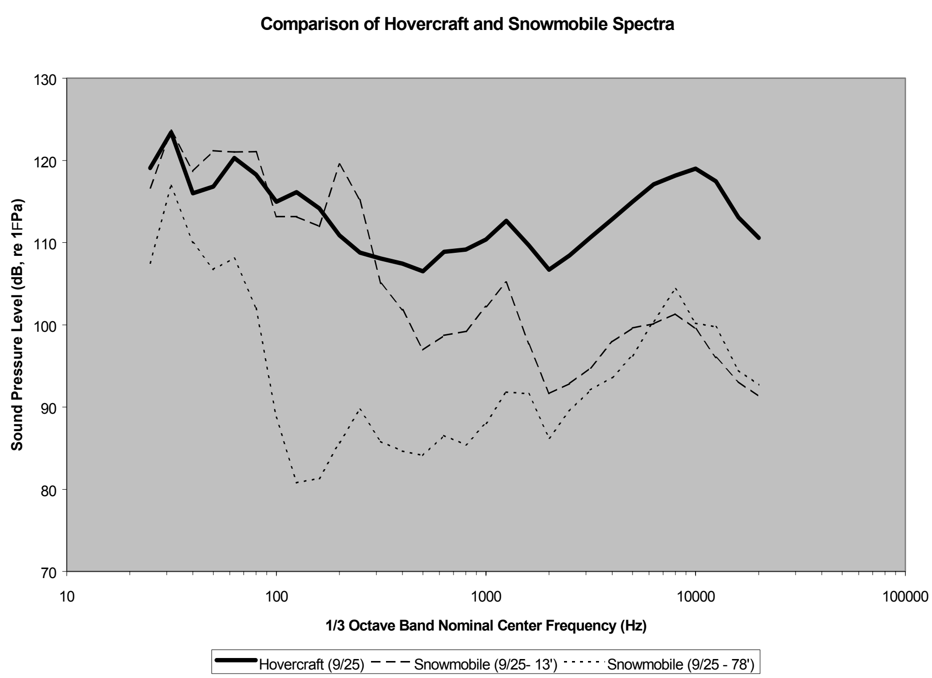

Figure 7

4.4 Digital Audio Tape Analysis

A cursory analysis was made of the DAT recordings of the underwater acoustic data. This analysis did illuminate one unexpected issue. During snowmobile pass-bys, the mechanical sound that the human ear typically associates with a snowmobile motor was only audible at the hydrophone location for approximately 2 to 5 seconds. This is not entirely counterintuitive, given the mass of the snow and ice surfaces through which the sound had to travel to reach the hydrophone.

For the hovercraft, however, little to no mechanical sound was audible on the DATs. The only sound attributable to the hovercraft is best described as the muffled sound of ice cracking. This cracking sound likely masked the mechanical sounds of the hovercraft, effectively rendering them inaudible. No observations of actual cracks in the ice were noted during the measurements. This cracking sound may be partially attributed to the relatively high temperatures experienced during the measurement period.

5.0 Results

The underwater acoustic measurements in and around Bethel, Alaska were successful. Related to the primary objectives of the measurements, it can be concluded that:

(1) Sufficient underwater acoustic data were collected for the AP.1-88 hovercraft to, given adequate knowledge of the hearing and behavioral patterns of blackfish, make generalizations regarding the potential for underwater hovercraft noise to adversely effect blackfish.

(2) Underwater acoustic data were collected enabling a direct comparison of hovercraft and snowmobile noise. As an example, a single event (pass-by) hovercraft sound exposure (L_E) of 134.1 dB measured at a distance of 78 feet is approximately equal to 14 snowmobile events at the same distance. The hovercraft typically passes by a village 6 to 8 times per week (3 to 4 deliveries). Since snowmobiles are the primary mode of transportation in the villages during the winter, and would likely pass by a given village many more times during a given day than the hovercraft, the overall sound exposure over a typical day is likely comparable for the two craft.

(3) In-air acoustic data collected allowed for comparison of hovercraft sound levels during the winter (specifically, with snow cover) to those collected during early Fall and documented in the Noise Characterization Study. Maximum sound pressure levels (L_{Smx}) were approximately 8 to 18 dB lower in the current study, as compared with the Noise Characterization Study. These differences are likely attributable to the combination of several variables.

Appendix A:

Acoustic Data

Tables 2 and 3 present a summary of the acoustic data for the hovercraft and snowmobiles, respectively. Maximum sound pressure level (L_{Smx}) and sound exposure level (L_E) data are presented for the underwater measurements, as well as the L_{ASmx} for the in-air measurements.

Table 2. Hovercraft Sound Level Data

						Hydrophone		4' Mic
DATE	**EVENT**	**T.O.D**	**DIR**	**CPA (ft, +/-3)**	**RPM**	**L_{Smx}**	**L_E**	**L_{ASmx}**
	2	18:27:30	R -> L	-	2100	128.0	137.7	-
09/24/2000	3	18:30:59	L -> R	-	2100	129.8	140.9	-
	4	18:34:05	R -> L	51	2100	141.7	150.8	-
	5	18:35+	L -> R	-	2100	-	-	-
	2	14:21:15	L -> R	54	2100	131.9	141.0	88.0
	3	14:22:26	R -> L	48	2100	131.9	138.0	79.0
	4	14:23:48	L -> R	-	2100	124.6	134.6	84.4
	5	14:26:04	R -> L	-	1800	142.4	146.7	89.6
09/25/2000	6	14:28:20	L -> R	78	1800	123.6	134.1	85.0
	7	14:30:14	R -> L	54	2100	135.5	140.0	87.5
	8	14:32:44	L -> R	75	1800	123.8	134.1	84.9
	9	14:34:27	R -> L	-	2100	136.3	138.9	91.1
	10	14:36:50	L -> R	75	2100	125.3	135.2	85.7
	12	14:42:42	L -> R	75	1800	123.3	134.6	84.9
	1	10:01:04	R -> L	117	1800	139.8	149.3	82.7
	2	10:02:52	L -> R	72	1800	143.7	154.8	86.6
	3	10:05:03	R -> L	69	1800	140.9	147.4	84.4
09/26/2000	4	10:06:54	L -> R	75	2100	138.1	143.3	86.1
	5	10:08:21	R -> L	72	2100	131.8	139.2	86.4
	6	10:09:46	L -> R	81	2100	137.5	142.2	86.2
	8	10:13:09	L -> R	87	2100	136.7	143.4	85.9
	9	10:14:25	R -> L	69	2100	129.2	139.4	87.5
	OVERALL DATA SET:		AVG:	72		133.1	141.2	85.9
			MIN:	48		123.3	134.1	79.0
			MAX:	117		143.7	154.8	91.1
	9/24 DATA SET:		AVG:	51		133.2	143.1	(NA)
			MIN:	51		128.0	137.7	(NA)
			MAX:	51		141.7	150.8	(NA)
	9/25 DATA SET:		AVG:	66		129.9	137.7	86.0
			MIN:	48		123.3	134.1	79.0
			MAX:	78		142.4	146.7	91.1
	9/26 DATA SET:		AVG:	80		137.2	144.9	85.7
			MIN:	69		129.2	139.2	82.7
			MAX:	117		143.7	154.8	87.5

Table 3. Snowmobile Sound Level Data

DATE	EVENT	T.O.D	CPA (ft)	Hydrophone L_{Smx}	Hydrophone L_E	4' Mic L_{ASmx}
	1	16:18:17	37	125.5	133.9	-
	2	16:19:36	37	125.4	135.4	-
	3	16:20:38	19	135.2	139.9	-
	4	16:21:00	19	132.9	138.0	-
	5	16:26:00	19	132.8	138.4	-
09/24/2000	6	16:28:00	19	132.6	142.9	-
60° 46' 38" N	7	16:29:00	37	124.8	137.9	-
161° 49' 7" W	X1	16:30:00	-	124.8	137.7	-
	8	16:31:00	37	124.8	135.6	-
	X2	16:35:00	-	127.5	135.0	-
	9	~16:40	19	133.6	141.2	-
	11	16:48:00	19	133.3	138.2	-
	13	16:52:00	19	135.0	138.8	-
	14	16:54:00	19	133.7	140.1	-
	X3	18:44:00	-	153.6	-	-
	1	15:16:43	13	129.7	131.8	89.1
	2	15:18:21	13	129.8	130.8	88.8
09/25/2000	4	15:23:00	13	129.2	130.5	89.5
60° 52' 28" N	5	15:24:20	13	130.3	131.8	88.6
162° 39' 57" W	6	15:26:10	>>78	106.6	114.1	67.3
	7	15:28:12	78	121.3	123.6	74.0
	8	15:29:29	78	118.0	121.9	73.6
	9	15:32:47	78	119.9	122.8	73.3
	10	15:34:27	78	119.6	122.5	73.2
	1	10:31:28	9	140.8	140.6	90.7
09/26/2000	2	10:32:33	9	139.4	139.3	90.6
60° 46' 40" N	3	10:33:34	9	140.0	140.2	91.0
161° 46' 27" W	4	10:36:25	9	138.3	139.4	88.1
	5	10:37:38	9	136.4	137.5	88.6
	6	10:38:53	9	134.8	136.9	86.3
	7	10:39:57	72	129.1	133.2	70.2
	8	10:40:54	72	128.8	123.2	69.3
	9	10:42:01	72	128.4	134.4	70.0
OVERALL DATA SET:		AVG:	32.2	130.2	134.0	81.2
		MIN:	9.0	106.6	114.1	67.3
		MAX:	78.0	153.6	142.9	91.0
9/24 DATA SET:		AVG:	25.0	131.7	138.1	
		MIN:	19	124.8	133.9	
		MAX:	37	153.6	142.9	
9/25 DATA SET:		AVG:	45.5	122.7	125.5	79.7
		MIN:	13	106.6	114.1	67.3
		MAX:	78	130.3	131.8	89.5
9/26 DATA SET:		AVG:	30.0	135.1	136.1	82.8
		MIN:	9	128.4	123.2	69.3
		MAX:	72	140.8	140.6	91.0

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