ALION
SCIENCE AND TECHNOLOGY

TECHNICAL MEMORANDUM

Waterborne and Airborne Noise Survey for Washington State Ferries

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Executive Summary

Washington State Ferries tasked JJMA to assess the noise created by ferries in the existing fleet and estimate the noise that may be generated by the New 144-Auto Ferry. To accomplish this task, JJMA measured the underwater and airborne noise produced by eight ferries, representing five classes within the Washington State Ferry system, between January 18 – 24, 2005. The airborne noise generated by ferries themselves does not appear to be as significant as the noise created by vehicular traffic departing and entering the ferry; noise generated by the ferry can only really be heard above ambient noise levels at rural ferry terminals. We anticipate that the New 144-Auto Ferry will generate similar levels of airborne noise as the other vessels in the fleet. For underwater noise, the average underwater noise generated by the eight tested vessels was between 175 dB: re 1µPa. and 188 dB re: 1µPa at 1 meter from the propeller. Based on the characteristics of the New 144-Auto Ferry, the predicted underwater noise generated by the New Ferry is approximately 178 dB: re 1µPa at 1 meter from the propeller.

SECTION 1. Purpose and Background Information

The purpose of this task was to assess the airborne and underwater noise generated by the existing WSF ferries and predict the noise that may be generated by the New 144-Auto Ferry class. During discussions with Washington State Ferries (WSF), it became apparent that it was necessary to:

- Measure the underwater noise levels generated by the existing fleet
- Estimate the underwater noise that could be generated by the New 144-Auto Ferry

As regards airborne noise measurements, we were asked to focus on noise heard by people such as residents, shoppers, and park visitors in the environment around the ferry.

1.1. *Reason for this Task*

Airborne noise is an element of the SEPA checklist, required to be evaluated for all new projects. Underwater noise, on the other hand, is a relatively new area of interest. It is only recently that the environmental advocates and environmental regulatory and resource agencies have become interested in understanding the potential impact from underwater noise. Whereas airborne noise has existing and controlling rules and regulations, there are no current rules affecting underwater noise produced by ships. WSF, however, is attempting to develop an accurate measure of the noise generated by the existing fleet and the New 144-Auto Ferry.

1.2. *The Characteristics of Noise*

"Noise" generally means "unwanted sound." In the case of marine vessels, this refers to the noise emitted either to the air (airborne noise) or to the water (underwater noise.)

According to acoustical engineers, sound may be defined as pressure variations in air or water which can be perceived by human hearing. Sound moves through the air somewhat like waves in the ocean. The waves are alternate rings of compressed and then rarefied air moving away from a central source at a constant speed. As each wave encounters an object, it exerts a force - a push (compression), then a pull (rarefaction) on the object.

Sound pressure is the measurement of air pressure fluctuation a noise source creates. We "hear" or perceive sound pressure as loudness. The higher the sound pressure, the louder the sound.

Sound pressure depends on the environment in which the source is located and the listener's distance from the source. Generally, as distance from the source increases, sound pressure decreases and the quieter it sounds. Hard surfaces that reflect the sound (e.g. walls in a room), cause the sound to be louder than if you heard the same sound, from the same distance, in an open field.

Sound pressure is usually expressed in units called pascals (Pa). A healthy young person can hear sound pressures as low as 0.00002 Pa. A normal conversation produces a sound pressure of 0.02 Pa. A gasoline-powered lawn mower produces about 1 Pa. Sound is painfully loud at levels around 20 Pa. Thus the common sounds we hear have a wide range of sound pressure (0.00002 Pa - 20 Pa).

It is difficult to work with such a broad range of sound pressures. To overcome this difficulty, we use the unit decibel. The decibel or dB scale is more convenient because it compresses the scale of numbers into a smaller range.

Sound pressure converted to the decibel scale is called sound pressure level (SPL) and in calculations (Lp). Different reference levels are used for SPL in air and in water. In air the zero of the decibel scale (0 dB) is the sound pressure of 0.00002 Pa. This means that 0.00002 Pa is the reference sound pressure to which all other sound pressures are compared on the dB scale. This is the reason the decibels of sound are often indicated as dB re 0.00002 Pa, or dBA for an A-weighted rating.

In water the zero of the scale is at one micro-Pascal (0.000001 Pa), and thus underwater SPLs are presented re: 1μPa.

Typical underwater noise levels, for comparison purposes, are given in Table 1. Typical airborne noise levels are given in Table 2.

Table 1 - Typical or Average Underwater Noise Sources and Levels

Lightning on surface	260 dB
Seafloor volcanic eruption	255 db
Low frequency sonar	235 dB
Seismic oil exploration	210 dB
Blue whale moan	188 dB
Gray whale moan	185 dB
Ice breaker breaking ice	183 dB
Large tanker underway	177 dB
Humpback whale moan	175 dB
Supply ship underway	174 dB
Southern right whale moan	172-187 dB
Whale watching boats	145 to 169 dB
Fin whale moan	160-186 dB
Bowhead whale moan	158-169 dB
Harp seal call	130-140 dB
Undersea earthquake	93-125 dB
Bottlenose dolphin call	~150 dB
Wind and waves	~ 85 dB

Table 2 - Typical or Average Airborne Noise Sources and Levels

Jet takeoff, artillery fire, riveting	120 dB or more
Rock band or very loud orchestra	100-120 dB
Unmuffled truck, police whistle	80-100 dB
Average radio or TV	70-90 dB
Human voice at 1 m	55-60 dB
Background in private office	35-40 dB
Quiet home	25-35 dB
Threshold of hearing	20 dB

The final elements of noise measurement concerns the bandwidth used and the weighting factors used.

Humans do not hear all frequencies of sound equally well. We are more sensitive to mid-range frequencies than we are to very high or very low pitches. So, when we wish to report one sound as being louder or softer than another it is important that we account for this frequency sensitivity. For example, a very low note with a given sound pressure level will sound quieter (to a human) than a soprano note of the same SPL.

To compensate for this phenomenon, acousticians apply a standard frequency weighting curve. We have used the A-Weighting curve in our acoustic results below. This curve corresponds to normal human hearing, and allows us to compare the loudness of all sounds.

When we use a weighting curve such as the A-weight curve, we are providing a weighted average of the loudness of the entire noise spectrum. Thus we might say that "Source 1 measured 50 dBA while Source 2 measured 60 dBA". This statement contains no information about the pitch of the two sounds, just their relative loudness.

To address pitch we represent each airborne sound source as a spectrum. That is to say that we measure the sound pressure level found at each group of frequencies. Sometimes spectra are reported in octaves, saying, for example, that the source had a sound pressure level of "X" in the first octave, "Y" in the second octave, "Z" in the third octave, etc.

An octave-band spectrum is rather coarse, and finer divisions of the frequency scale are usually sought. In this report we have therefore used one-third octave band divisions, an example of which is as depicted in Figure 3, near the end of this report.

SECTION 2. Measurement Procedure

The measurement plan and work schedule were designed to obtain as much waterborne and airborne noise data as possible over a range of ferry classes within the time frame allocated. A detailed Test Plan was published and is included as Appendix A.

Efforts were coordinated with WSF; Captain Greg Sugden from WSF attended most of the airborne noise measurements and terminal underwater measurements. He provided valuable assistance and explained ferry operating procedures that affected the noise levels. All measurements were made by Bill Daube and Chris McKesson of JJMA.

Instrumentation was selected that would allow the measurement and storage of the airborne and underwater noise time histories and frequency spectra so that noise transients and frequency characteristics could be evaluated at a later date. (It should be noted that this instrumentation did not store an exact replica of the noise for playback as a tape recorder does.)

2.1. *Underwater noise measurements*

Underwater ferry noise was measured in the open water and at several terminals. Table 2 identifies the ferries measured and measurement locations. Open water measurements were made with a hydrophone lowered into the water at a known depth from the anchored vessel ASAGI. Underwater ferry noise was measured as the ferry approached, passed, and moved away from the vessel. We measured the distance from the vessel to the ferry with a hand-held laser rangefinder and recorded the distance at the ferry's closest-point-of-approach (CPA). We also measured ferry underwater noise as it approached the terminal, docked, and pulled away using a hydrophone lowered over the side of the pier. We periodically measured the ambient underwater noise during the pass-by and terminal measurements. In all cases, the ferry noise was monitored audibly by listening to the hydrophone output through headphones.

Since the frequency range of interest for the underwater noise measurements was from about 10 Hz to 20 kHz, we were able to use the same sound level meter for underwater noise as for the airborne noise measurements. The only difference was that the microphone for airborne noise was replaced by a hydrophone, signal conditioner, and special pre-amplifier for underwater noise measurements. Table 4 provides the instrumentation details. This instrumentation set-up was approved by the sound level meter manufacturer (Larson Davis). We prepared a detailed procedure for converting the sound level; meter output into underwater sound level, see Appendix B.

2.2. *Airborne noise measurements*

The A-weighted and one-third octave band airborne noise were measured at the terminals listed in Table 5, which represent different environmental settings. Instrumentation is listed in Table 6. The sound level meter and microphone were calibrated daily before the first measurement. Each measurement was stored electronically for later analysis.

Airborne noise was measured during ferry arrival, vehicle unloading and loading, and ferry departure. Ambient noise levels were also measured periodically. In addition to the terminal airborne noise measurements, the airborne noise on board several ferries was measured during transits between terminal locations. Noise was measured in the passenger spaces and at the sources of noise from vessel deck operations (near the engine air intakes and exhausts and HVAC inlets, as available) for later evaluation as necessary.

Table 3 - Compilation of Ferry Underwater and Airborne Noise Measurements

	Ferry	Class	Underwater Pass-by Noise Measurements	Terminal Underwater Noise Measurements	Terminal Airborne Noise Measurements
1	KITSAP	Issaquah 130	Bainbridge Reef	Bremerton and Seattle	Bremerton and Seattle
2	TACOMA	Jumbo Mark II	--	Seattle	Seattle
3	WENATCHEE	Jumbo Mark II	--	Seattle	Seattle
4	ILLAHEE	Steel Electric	--	Shaw Island	Shaw Island
5	YAKIMA	Super	Flat Point	Friday Harbor	Friday Harbor
6	ELWHA	Super	Flat Point	Friday Harbor	Shaw Island
7	HYAK	Super	Bainbridge Reef	Bremerton and Seattle	Bremerton and Seattle
8	EVERGREEN STATE	Evergreen State	South of Shaw Island and Flat Point	Friday Harbor	Friday Harbor and Shaw Island

The hydrophone location at Bainbridge reef was: 47° 34.25 N 122° 31.00 W.

The hydrophone location south of Shaw Island was: 48° 32.66 N 122° 56.75 W (note weather and safety caused us to relocate the hydrophone after the EVERGREEN STATE readings to Flat Point).

The hydrophone location at Flat Point was: 48° 33.00 N 122° 55.33 W.

Table 4 - Instrumentation Used for Underwater Noise Measurements

	Instrument	Manufacturer	Model
1	Hydrophone (with sensitivity = 1.216×10^{-9} volt/μPa)	Wilcoxon	M H507A
2	Integrating sound level meter (Type 1) with one-third octave band filters	Larson Davis	824
3	Signal conditioner / power unit	PCB	483B07
4	Pre-amplifier	Larson Davis	ADP005

Table 5 - Terminals Selected for Airborne Noise Measurements

Terminal	Setting
Bremerton	Industrial-urban
Seattle	Large urban
Friday Harbor	Small urban
Shaw Island	Rural

Table 6 - Instrumentation Used for Airborne Noise Measurements

	Instrument	Manufacturer	Model
1	Integrating sound level meter (Type 1) with one-third octave band filters	Larson Davis	824
2	Microphone, 1/2 inch, free field	Larson Davis	2541
3	Signal conditioner / power unit	PCB	483B07
4	Sound level meter calibrator	Larson Davis	CAL 200

SECTION 3. Measurement Results

Table 3 identifies the ferries and classes for which underwater pass-by, terminal underwater, and terminal airborne noise measurements were made. The five classes of ships listed represent 20 of WSF's 23 car ferries, and include vessels that are both larger and smaller than the New 144-Auto Ferry. These facilities were tested because they represent both the terminals and the vessels that will be affected by the introduction of the New 144-Auto Ferry into the existing fleet.

In many cases, multiple underwater and airborne noise measurements were made on the same ferry since it made several trips into and out of a terminal during the measurements. Terminal airborne and underwater measurements included the noise during ferry arrival, vehicle unloading and loading, and ferry departure. The terminal underwater measurements included the noise during ferry arrival and departure. In addition to the ferry noise measurements, numerous ambient underwater and airborne noise measurements were made. Appendix C provides details on the type of noise measurement, measurement conditions, and other pertinent information for each recorded measurement.

3.1. *Results of Underwater Noise Measurements*

Figures 2 through 9 show the underwater noise time history at the hydrophone and the corresponding one-third octave band spectra at the closest-point-of-approach (CPA) as KITSAP, HYAK, EVERGREEN STATE, and YAKIMA passed by. (The ILLAHEE was not available on the days the tests were run). The time histories generally show how the noise measured at the hydrophone increases as the ferry approaches the test vessel, reaches a maximum value, and then decreases as the ferry moves away. The noise time history is affected by the directionality of the ferry noise radiation. This directionality could be affected by the specific character of the noise generation mechanism, the frequency of the noise, the water current, and other factors.

Aural observations during the measurements seemed to confirm that sometimes the maximum underwater noise did not occur at the CPA due to the radiation directivity. This will cause a slight error in the computation of the predicted underwater noise at the propeller equal to $10 \log_{10} (D/C)$, where D is the actual distance from the ferry when the maximum noise level occurred, and C is the recorded CPA. A 10% distance error will cause less than a 0.5 dB difference. In other words, if the measurement was 140 dB, 0.5 dB is approximately a .3% difference, judged to be insignificant.)

Table 7 shows the underwater noise measured at the hydrophone and the predicted underwater sound level at the ferry propeller for each ferry pass-by measurement. The method and calculations are detailed in Appendix B – in brief, the method converts the measured sound level into a Source Level one meter from the ferry using a combination of cylindrical and spherical spreading (called the practical spreading model), considering the depth of water at the ferry and at the hydrophone location. The practical spreading model assumes that noise attenuates at 4.5 dB per doubling distance from the source. Based on the raw data gathered, the underwater noise of the eight tested ferries in the open water ranged from 135 - 149 dB re: 1µPa, and the calculated underwater noise one meter from the vessel's propeller ranged between 174 - 190 dB.

Figures 10 through 17 show representative time histories of the underwater noise for several ferries and terminals during arrival and departures. The higher underwater noise levels at the end of the arrival time history and beginning of the departure time history are most likely due to the propeller-generated waves being pushed into the confines of the dock area, causing an increase in the underwater pressure signal. Because of these reflected pressure waves at the terminal areas, the 1m-distant Source Level calculation was not applicable.

3.2. *Results of Airborne Noise Measurements*

Figures 18 through 21 show representative airborne noise time histories for several ferries measured at the four terminals and at the locations shown in Table 8. In general, the airborne noise levels were quite low, and often the noise from motorcycles and cars driving off the ferry was the major noise source. Measured noise levels during the unloading operation typically exceeded 60 dBA at the measurement location, whereas the noise levels during the ferry approach, prior to unloading the vehicles, was in the range of 50-55 dBA.

Interestingly, vehicle unloading was typically noisier than vehicle loading, apparently because the traffic must slow down when entering the ferry, whereas the motorcycles and cars tend to speed away from the ferry upon unloading. The propeller generated waves splashing onto the dock area was generally the second most significant noise source, while the noise of the ferry itself was probably the third ranking noise source.

Table 7 - Computation of Underwater Noise at 1 Meter from Ferry Propeller from Hydrophone Measurements

Log no.	Date	Ferry	Class	Maximum underwater sound level at yacht, dB (MLp)	CPA meters (R)	Estimated channel depth, meters (H)	Underwater sound level at hydrophone dB re 1 μPa (HLp)	Predicted underwater sound level at 1 meter from ferry propeller dB re 1 μPa (FLp)
2	1/18/2005	HYAK	Super	81.9	400	30.5	138.7	179.6
5	1/18/2005	HYAK	Super	84.1	271	30.5	140.9	180.1
7	1/18/2005	HYAK	Super	80.9	729	30.5	137.7	181.2
11	1/18/2005	HYAK	Super	84.7	258	30.5	141.5	180.5
16	1/18/2005	HYAK	Super	78.5	650	30.5	135.3	178.3
119	1/22/2005	YAKIMA	Super	89.5	304	39.6	146.3	187.1
120	1/22/2005	YAKIMA	Super	91.9	281	39.6	148.7	189.2
114	1/22/2005	ELWHA	Super	90.8	225	39.6	147.6	187.1
7	1/18/2005	KITSAP	Issaquah 130	81	174	30.5	137.8	175
9	1/18/2005	KITSAP	Issaquah 130	80.1	173	30.5	136.9	174.1

17	1/18/2005	KITSAP	Issaquah 130	80	203	30.5	136.8	174.7
107	1/22/2005	EVERGREEN STATE	Evergreen State	79.9	597	91.1	136.7	184.1
110	1/22/2005	EVERGREEN STATE	Evergreen State	84.7	806	91.1	141.5	190.2
115	1/22/2005	EVERGREEN STATE	Evergreen State	82.9	310	39.6	139.7	180.6

Table 8 - Terminal Airborne Noise Measurement Locations

Terminal	Measurement Location	Approximate Distance to Ferry
Bremerton	Near dock and on elevated walkway near bus stop in front of terminal.	Dock location – 212 ft Elevated walkway – 295 ft
Seattle	Near dock; approximately midway between slips #1 and #2.	Ferry in slip #1 – 230 ft Ferry in slip #2 – 207 ft
Friday Harbor	On elevated walkway in front of bookstore.	230 ft
Shaw Island	Near small grocery store.	216 ft

SECTION 4. Noise Predictions for the New 144-Auto Ferry

JJMA produced predictions of the noise levels that would be generated by the New 144-Auto Ferry. Predictions are described below. In general, they are simplified predictions, not comprehensive acoustic modeling projects. As such, they may not capture the benefits of all the noise control features that WSF required in the New 144-Auto Ferry design. Such features include:

- **Internal ship noise control**: WSF required in the specification to control noise by indicating the attenuation required to reduce the transmission of high-sound pressure level source areas (noisy – loud) into low sound pressure level receiving areas (quiet – not as loud). This is accomplished by a combination of absorbing, blocking and damping the sound pressure levels before they are transmitted through the air.

- **Resilient machinery mounts**: Internal combustion diesel engines and other rotating machinery excite structural vibrations which produce structure-borne noise. WSF required the shipbuilder to install major rotating machinery on isolation mounts in order to reduce structure-borne noise by limiting transmission of the vibrating equipment into the surrounding structure. Resiliently mounted machinery includes the main engines, diesel generator sets, air compressors and air conditioning and refrigeration compressors, fans and blowers. In addition to the resilient mounts, WSF required all connections to the machinery to be flexible. Typical connections are hoses and piping. This further reduces vibration transmission into the structure.

- **Diesel engine exhaust mufflers**: Internal combustion diesel engine exhaust is very noisy (100+ dBA). To limit the noise of the engines, WSF required all engine exhaust outlets to have noise attenuators (mufflers). The main engine mufflers must reduce the exhaust noise to 90 dBA.

4.1. *Underwater Noise Predictions*

SNAME Technical and Research Bulletin 3-37, Supplement to the Design Guide for Shipboard Airborne Noise Control, gives a procedure for calculating the propeller noise generated by tip vortex and blade surface cavitation. Section 6.3.13 of Bulletin 3-37 provides the methodology and equations and Section 11.4 provides an example set of calculations.

In order to evaluate the usefulness of this method for estimating the underwater noise of the New 144-Auto Ferry, this procedure was used to estimate the underwater noise on the ferries for which we had pass-by measurements and had already computed the underwater noise at the propeller. Table 9 shows the results of the SNAME calculations and compares these results with the results from our measurements. The fourth column of this table provides the predicted noise at the propeller based on the underwater pass-by measurements. The 5th through 14th columns show the intermediate results calculated by the SNAME equations. The 15th column shows the total SNAME predicted underwater noise level at the propeller due to the vortex tip and blade cavitation noise. The next-to-last column compares the difference in the underwater noise level determined by our measurements and the SNAME method and the last column gives a qualitative assessment of the accuracy of the SNAME method prediction.

Good - difference between the Predicted and SNAME calculation value was less than 3 dBA
Fair --- difference between the Predicted and SNAME calculation value was 4 to 6 dBA

Not Well -- difference between the Predicted and SNAME calculation value was 7 to 10 dBA
Poor ------- difference between the Predicted and SNAME calculation value was greater than 10 dBA.

The same information is presented graphically in Figure 1 below. The vertical bars in Figure 1 represent the sound level as derived from the measurements. The black diamonds represent the sound level predicted by the SNAME method. As noted, the correlation with the HYAK is good (less than 2.5 dB difference between the measured and predicted underwater noise level), the correlation with the Issaquah 130 Class is fair (less than 5 dB), and the correlation with the Evergreen State Class is poor (more than 10 dB).

Based on this evaluation of the existing ferries, it is not conclusive that the SNAME method reliably predicts the underwater noise for WSF ferries. However, since the New 144-Auto Ferry has a similar hull form to the Issaquah 130 Class, and the prediction of the Issaquah Class was within 3% of the measured noise, the SNAME method for the New 144-Auto Ferry might be reasonably accurate. The last row of Table 9 shows that the SNAME method predicts an underwater sound level of 178 dB at 3 feet (approximately 1 meter) from the propeller for the New 144-Auto Ferry for a ferry speed of 16 knots and 150 rpm. It is reasonable to expect that the actual underwater noise level of the New 144-Auto Ferry will be within ± 5dB of 178 dB.

4.2. *Airborne Noise Predictions*

Based on airborne noise measurements and aural observations, it is likely that the airborne noise of any new ferry class will be less than the noise generated by loading or unloading vehicular traffic. Consequently, it is believed that detailed airborne noise predictions are necessary for this study.

Figure 1 – Comparison of underwater sound source levels derived from measurement as compared with SNAME method prediction

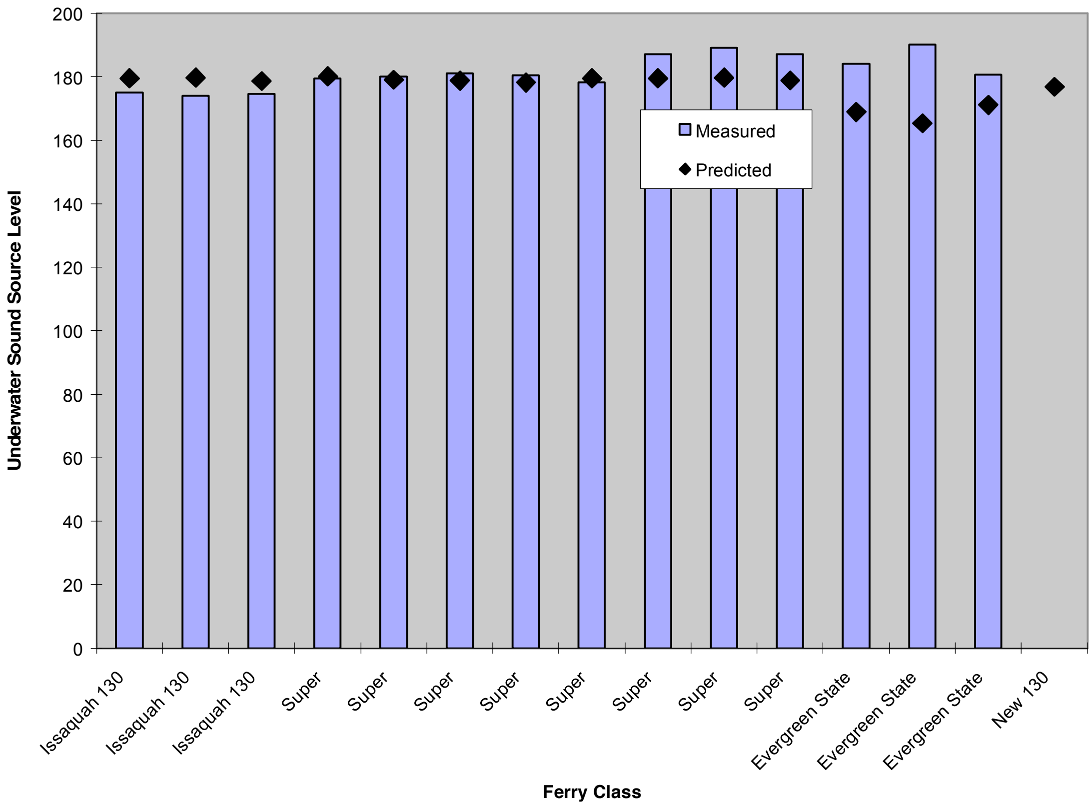


Table 9 – SNAME Method Prediction of Underwater Noise

Log no.	Ferry	Class	COL.I Predicted under-water sound level at 1 meter from prop. dB re 1 μPa (FLp) based upon measure-ments	Prop. dia., ft	Ferry length, ft	Ferry speed, knots (V)	Prop. rpm	Cavitation inception speed, knots (Vo)	V/Vo	Break freq. for tip vortex, SNAME Fig 6-1, Hz	Tip vortex SPL at 3 ft from tip at tip vortex brk freq, SNAME eqn 6-29, dB	Break freq. for blade surface cavitation, SNAME Fig 6-2A or 6-2B, Hz	Blade cavitation SPL at 3 ft from prop at blade cav brk freq, SNAME eqn 6-30	COL.W Approx. total predicted under-water sound level at 3 ft from propeller predicted per SNAME, dB	Difference between measured (col I) and predicted result (col W)	How does SNAME prediction agree with results from measure-ment ? (compare Col W and Col I)
7	KITSAP	Issaquah 130	175.0	11.5	328.0	17.0	170	8.64	1.97	80	169.1	200	173.8	179.5	-4.5	fair
9	KITSAP	Issaquah 130	174.1	11.5	328.0	17.4	170	8.64	2.01	80	169.3	200	174.0	179.7	-5.6	fair
17	KITSAP	Issaquah 130	174.7	11.5	328.0	16.9	160	8.64	1.96	80	168.2	200	173.0	178.7	-4.0	fair
2	HYAK	Super	179.6	12.0	382.2	17.0	170	8.91	1.91	85	169.3	190	174.5	180.1	-0.5	good
5	HYAK	Super	180.1	12.0	382.2	16.9	159	8.91	1.90	85	168.4	195	173.5	179.1	1.0	good
7	HYAK	Super	181.2	12.0	382.2	17.8	150	8.91	2.00	80	168.3	200	173.1	178.8	2.4	good
11	HYAK	Super	180.5	12.0	382.2	16.8	150	8.91	1.89	85	167.5	195	172.6	178.2	2.3	good
16	HYAK	Super	178.3	12.0	382.2	18.5	152	8.91	2.08	80	168.8	180	174.0	179.6	-1.3	good
119	YAKIMA	Super	187.1	12.0	382.2	17.5	160	8.91	1.96	80	169.0	195	173.9	179.5	7.6	not well
120	YAKIMA	Super	189.2	12.0	382.2	18.0	160	8.91	2.02	80	169.3	200	174.0	179.7	9.5	not well
114	ELWHA	Super	187.1	12.0	382.2	17.0	155	8.91	1.91	85	168.1	190	173.3	178.9	8.2	not well
107	EVERGREEN STATE	Evergreen State	184.1	10.5	310.0	12.5	140	8.55	1.46	130	159.7	420	162.7	169.0	15.1	poor
110	EVERGREEN STATE	Evergreen State	190.2	10.5	310.0	11.6	130	8.55	1.36	190	155.9	520	159.2	165.4	24.8	poor
115	EVERGREEN STATE	Evergreen State	180.6	10.5	310.0	13.5	140	8.55	1.58	115	161.2	320	165.1	171.1	9.5	poor
	n/a	**New 144-Auto SNAME Calculation**	n/a	11.5	362.3	16.0	150	8.81	1.93	83	167.1	195	172.1	**177.6**		
Note: all propellers have 4 blades																

Note: "Good" represents a difference of less than 3 dB.
"Fair" represents a difference of 4-6 dB.
"Not Well" represents a difference of 7-10 dB.
"Poor" represents a difference of greater than 10 dB.

SECTION 5. Conclusions

Airborne Noise

- At WSF terminals, the motor vehicle traffic is louder than the ferry-generated noise.
- Only in very quiet rural settings, such as the Island run, is the ferry airborne noise discernable above the ambient noise.
- No discernable change from existing WSF ferries in airborne noise is expected to be created by the New 144-Auto Ferry.

Underwater Noise

- Measured underwater noise of the current fleet has source levels ranging from 175-190 dB re: 1μPa at 1m from the source.
- The New 144-Auto Ferry will have about the same underwater sound level as an existing Issaquah 130 Ferry and calculated at 178 dB re: 1μPa.
- The introduction of the New 144-Auto Ferry should produce no appreciable change in the acoustic 'footprint' of WSF operations.

SECTION 6. Abbreviations and Acronyms

dB	Decibel. The decibel is the standard means of expressing sound "volume". Decibels are related to sound pressure levels by referring to a standard reference pressure, (usually one micro Pascal) at a standard distance (usually one meter) per the equation: Decibels (dB) = 10 log(P2/P1) (Where P2 is the pressure being measured, and P1 is the reference pressure.)
dBA	A-weighted decibel. The A-weighting scale places more emphasis on mid frequencies in order to more closely match human acoustic sensitivity.
Pa	Pascal – The SI unit of pressure, equal to one Newton per square meter
SEPA	Washington State Environmental Policy Act
SNAME	The Society of Naval Architects and Marine Engineers
SPL	Sound pressure level, in Pascals
WSF	Washington State Ferries

Figure 2 – KITSAP Underwater "Pass By" Noise

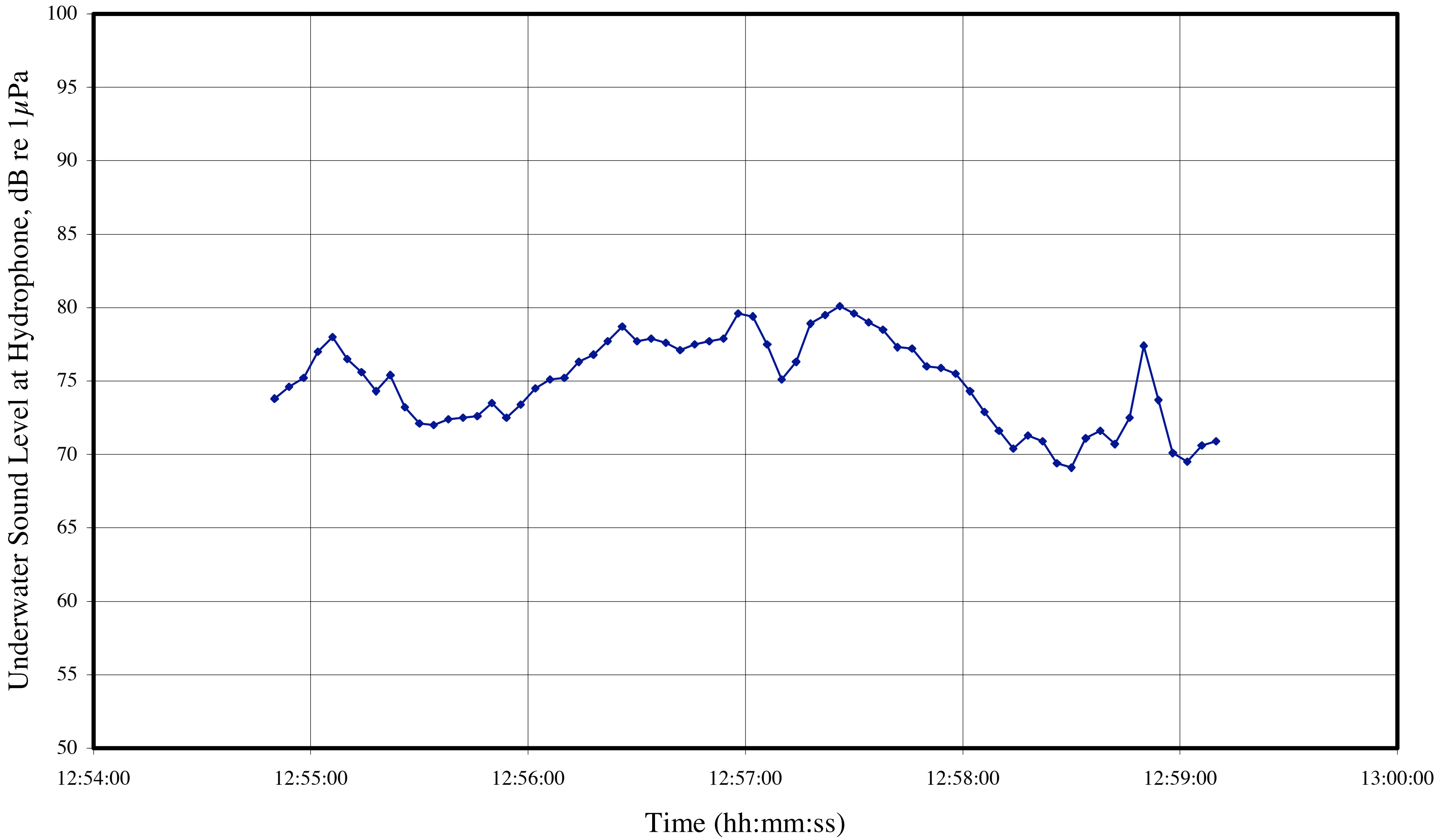


Figure 3 – KITSAP Underwater Noise "Pass By" Spectrum

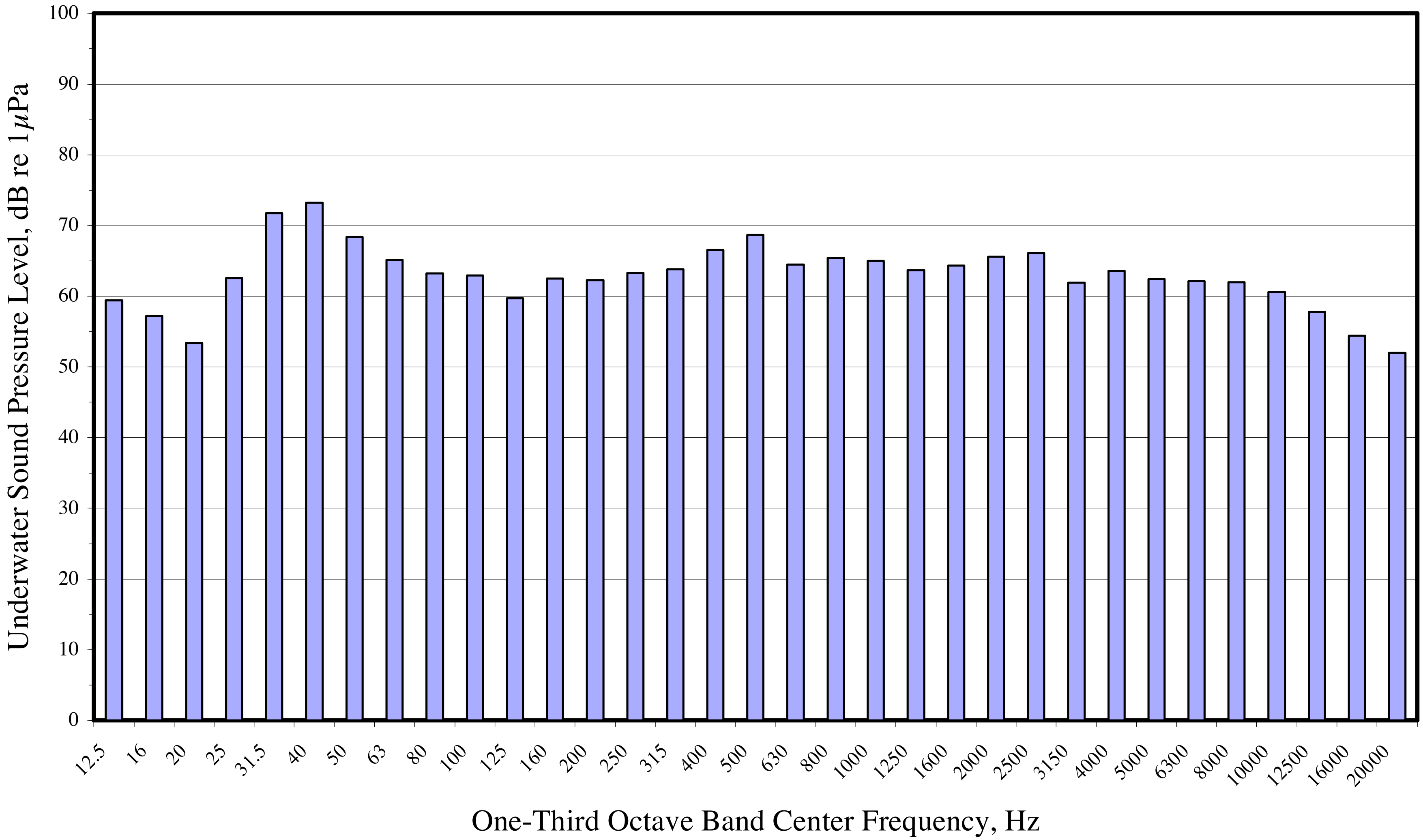


Figure 4 – HYAK Underwater "Pass By" Noise

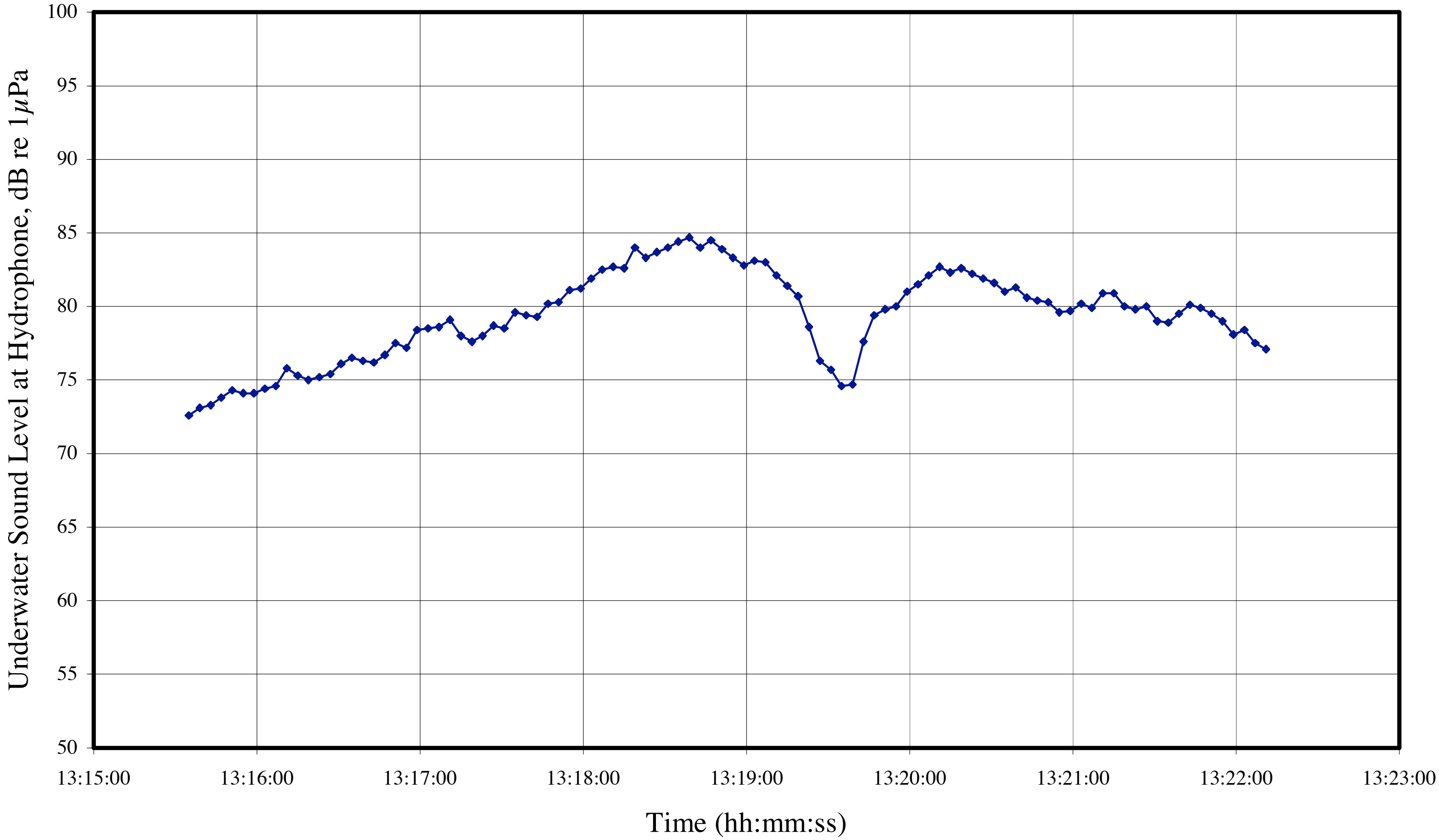


Figure 5 – HYAK Underwater Noise "Pass By" Spectrum

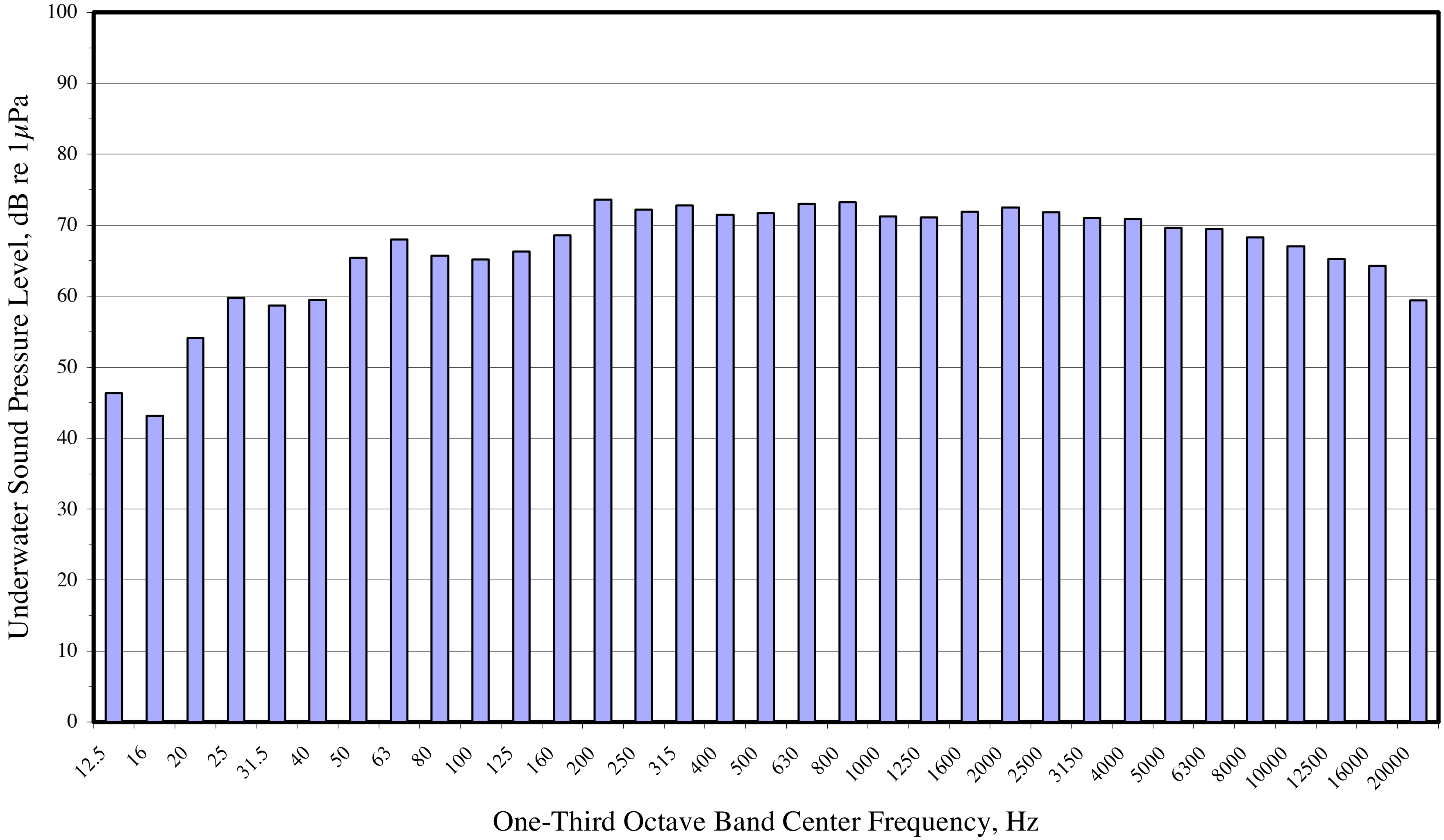


Figure 6 – EVERGREEN STATE Underwater "Pass By" Noise

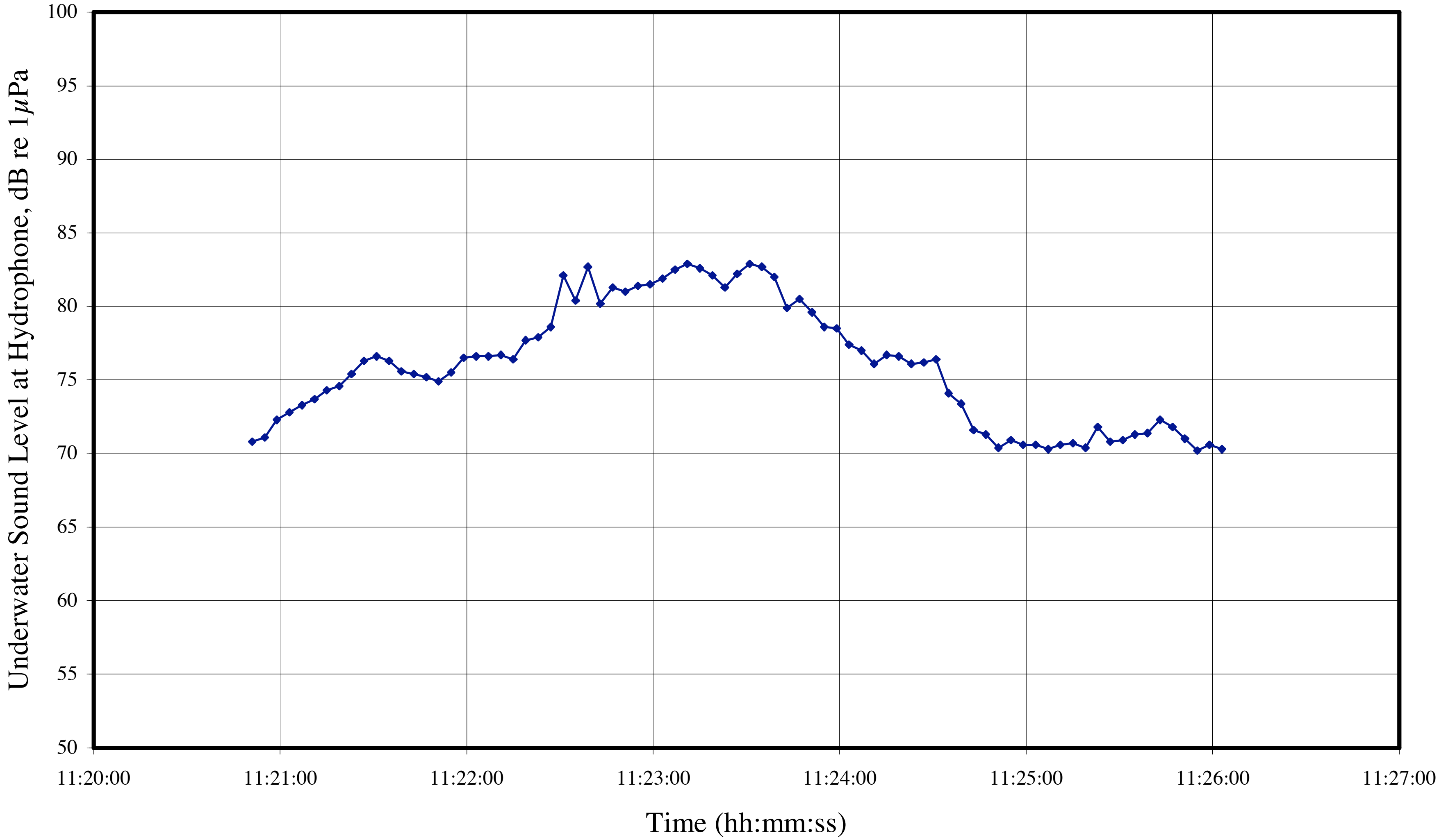


Figure 7 – EVERGREEN STATE Underwater Noise "Pass By" Spectrum

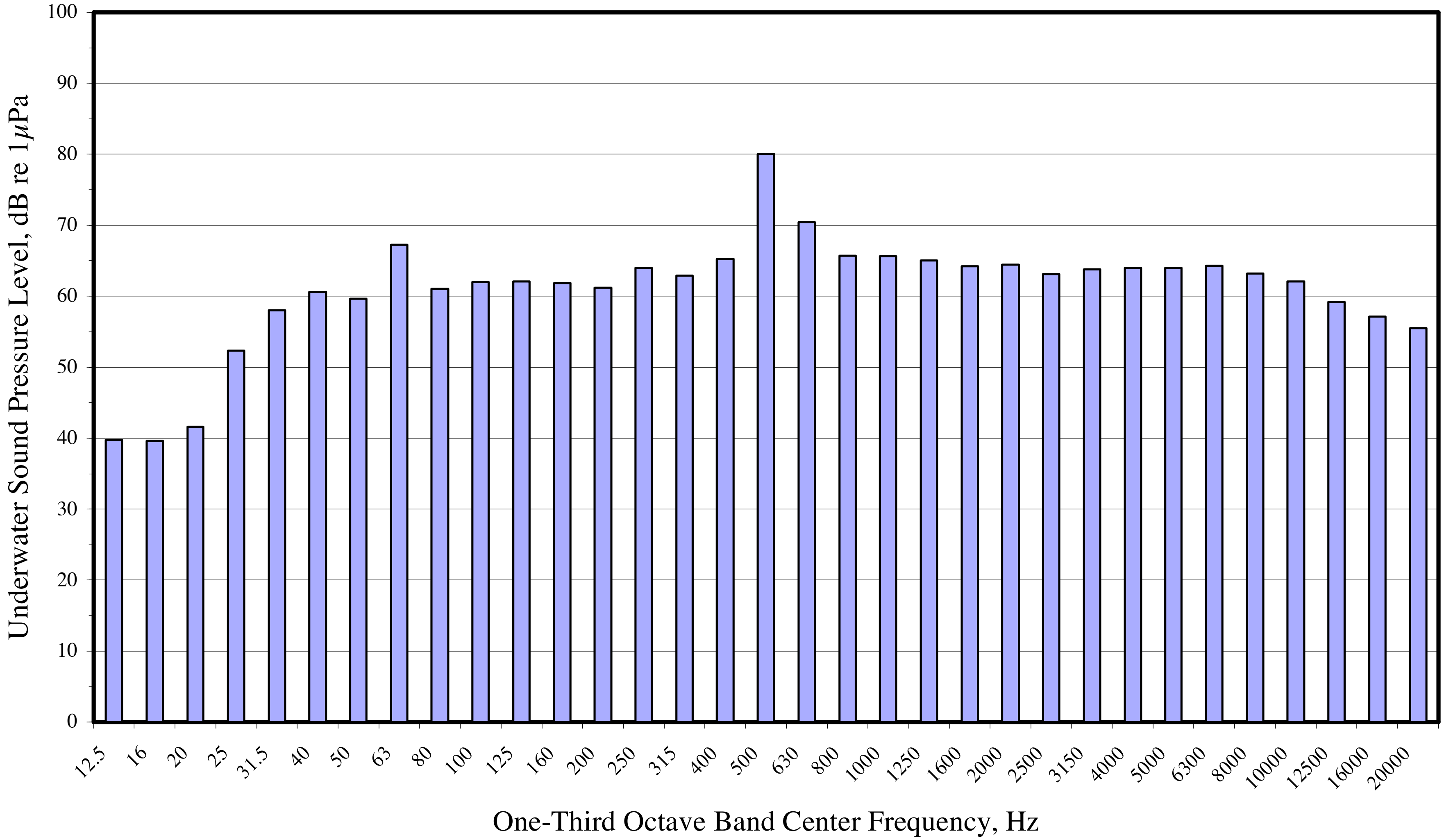


Figure 8 – YAKIMA Underwater "Pass By" Noise

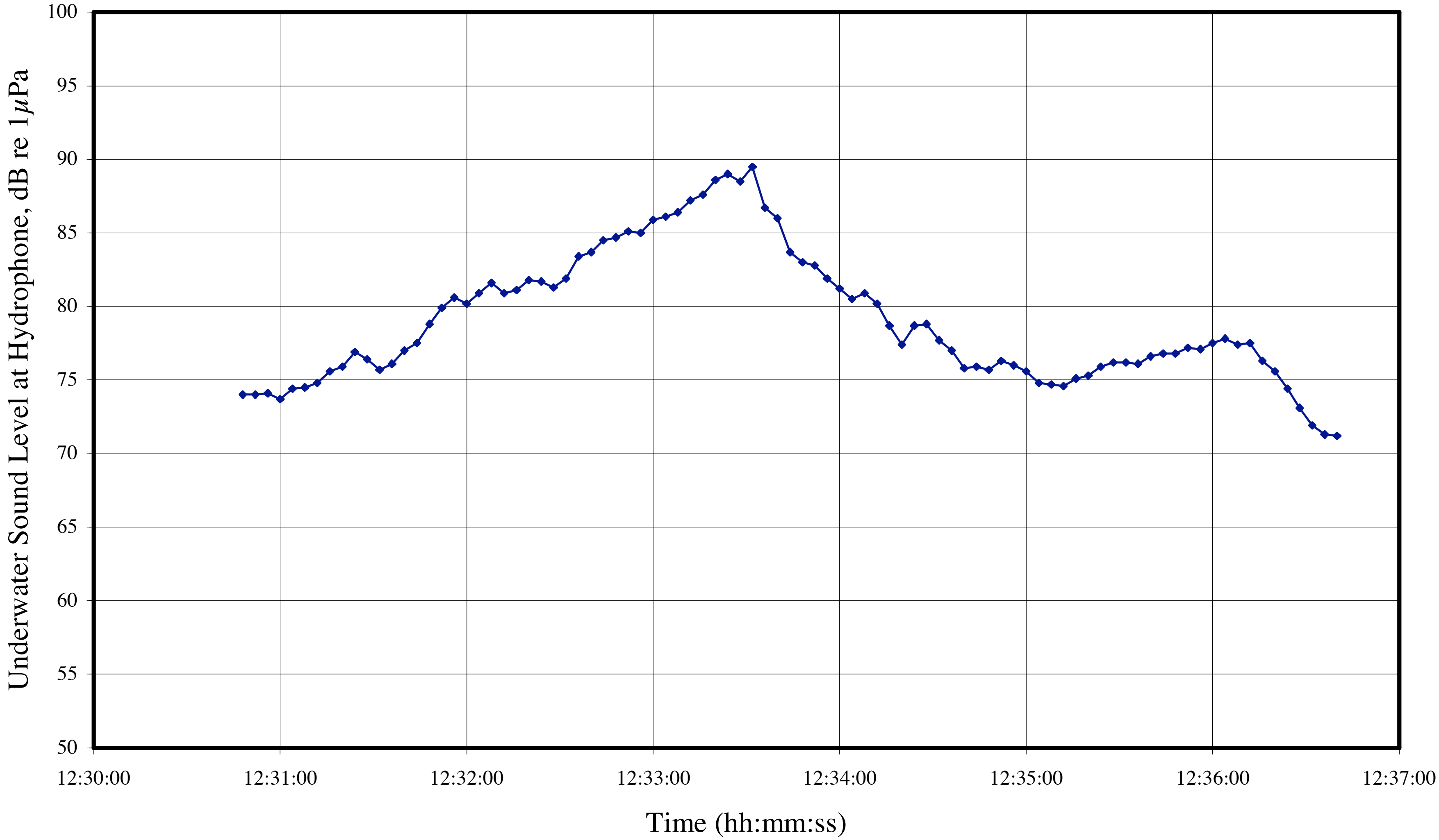


Figure 9 – YAKIMA Underwater Noise "Pass By" Spectrum

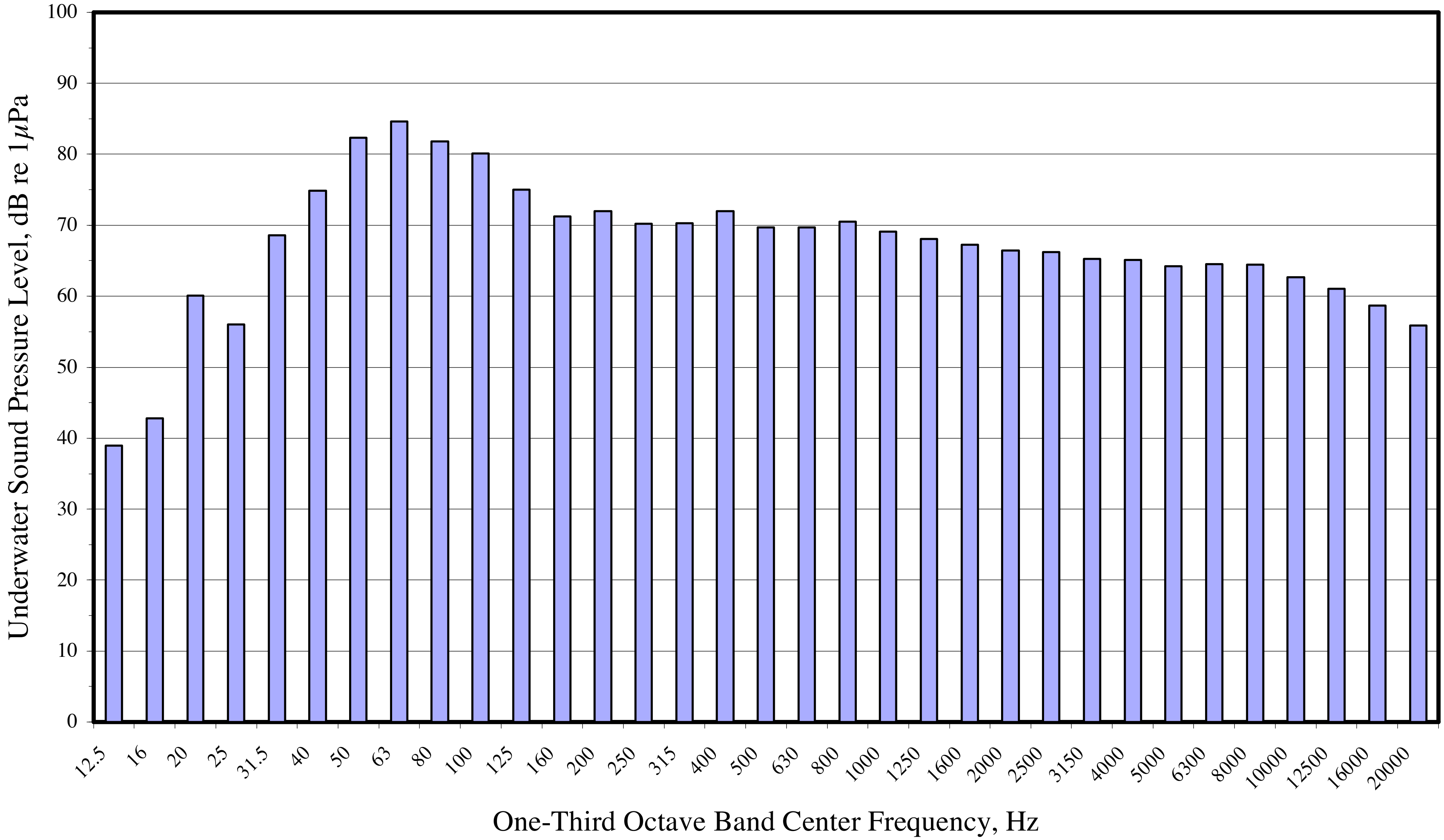
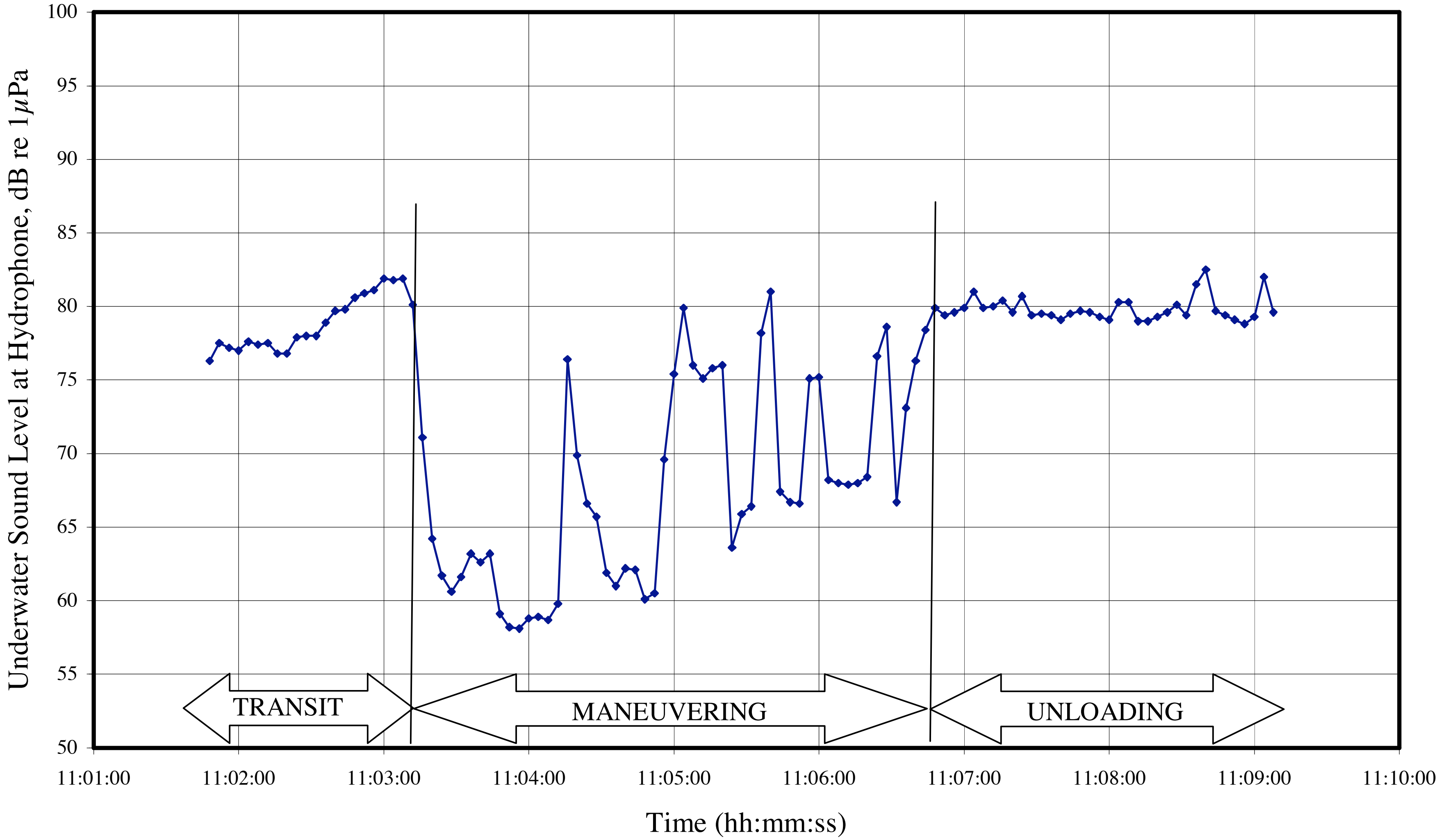


Figure 10 – HYAK Bremerton Terminal - Arrival - Underwater Noise



Comments: The following comments were made by Captain Greg Sugden of WSF, upon review of HYAK underwater noise time histories:
"When HYAK begins maneuvering the propellers are stopped and not moving at all – this is represented by the dramatic dip at the beginning of maneuvering and when power is applied and stopped during the braking process, similar to pumping the brakes in your car." HYAK has a DC electric propulsion system.

Figure 11 – HYAK Bremerton Terminal - Departure - Underwater Noise

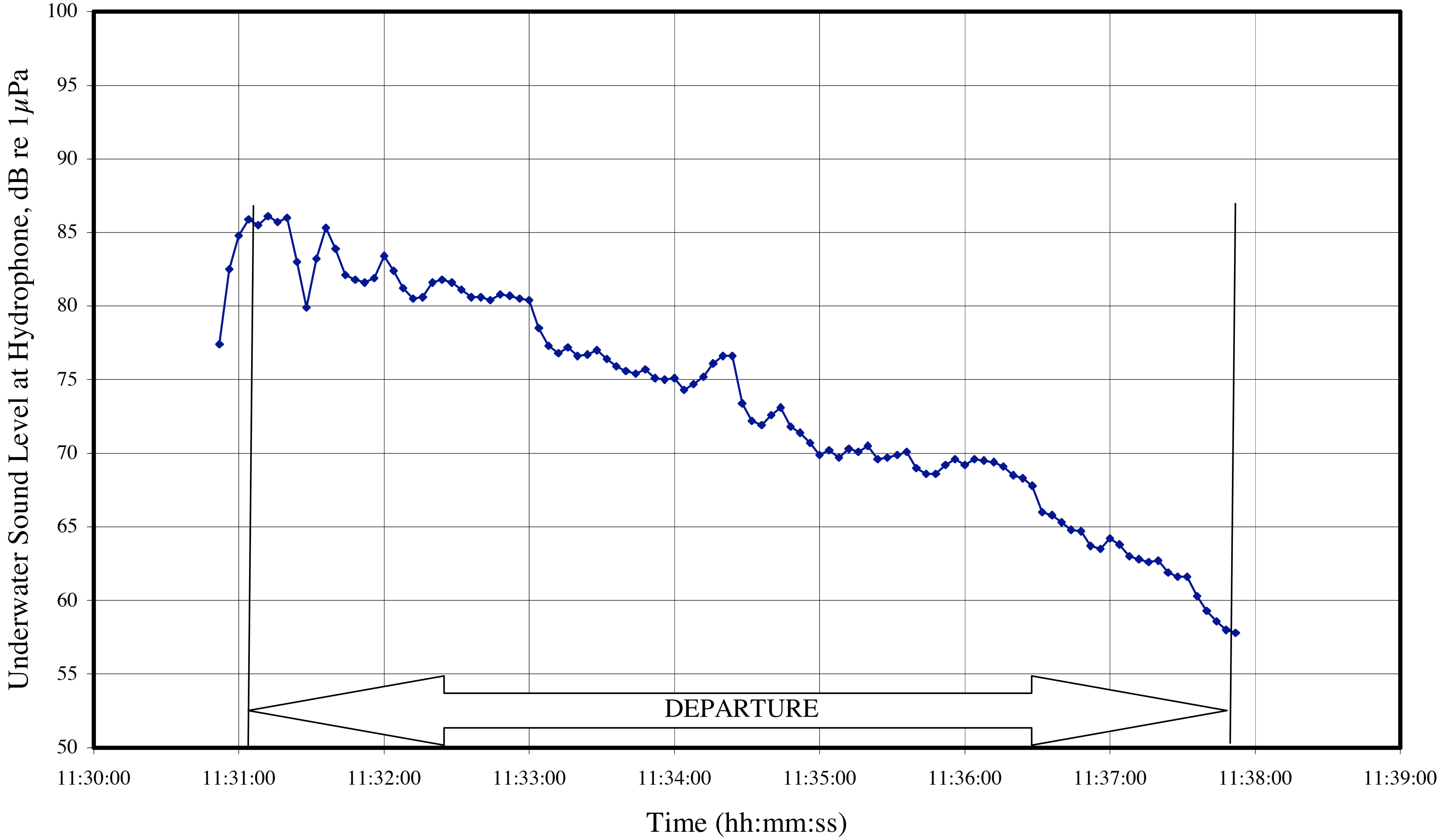


Figure 12 – KITSAP Bremerton Terminal - Departure - Underwater Noise

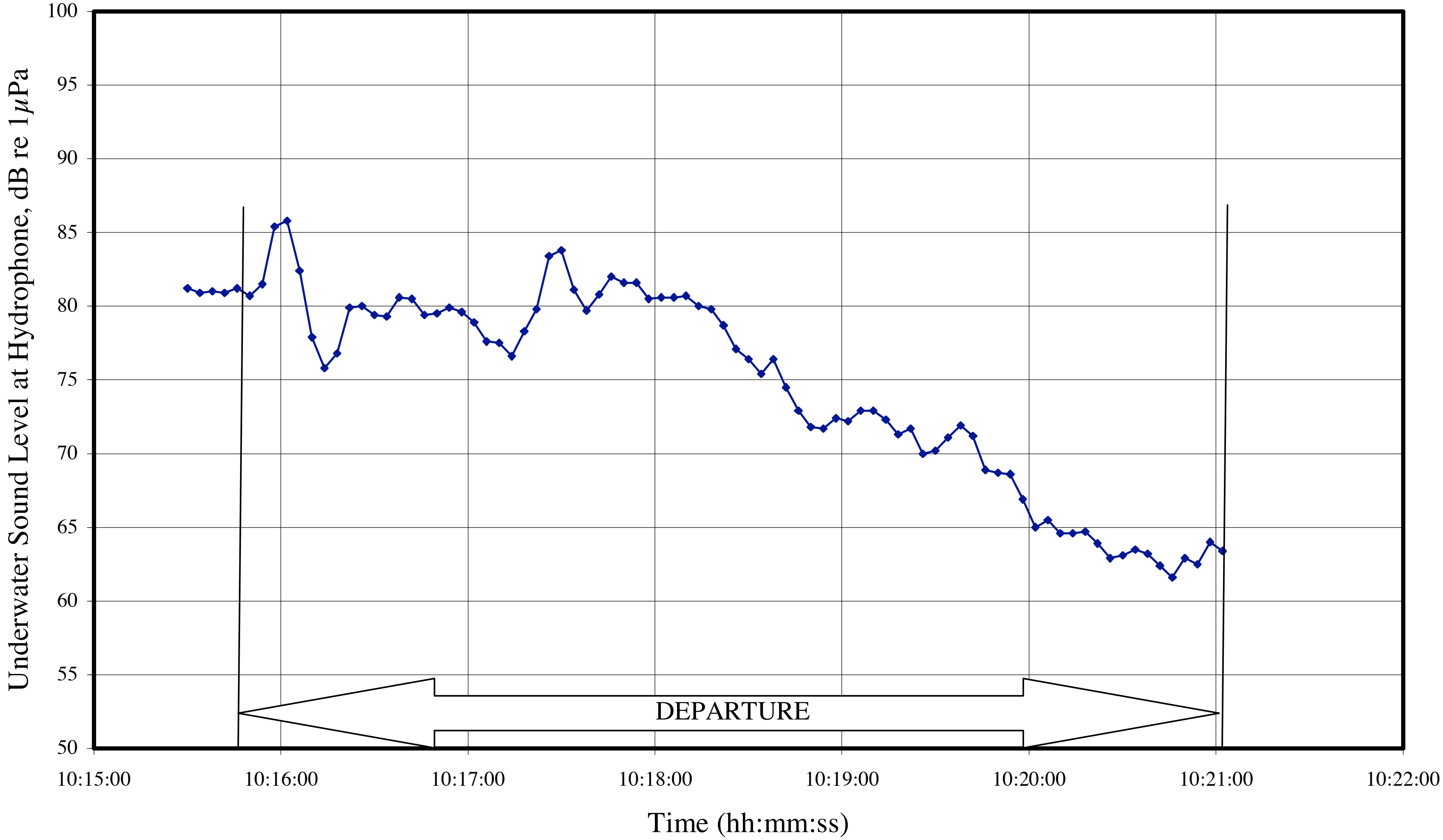
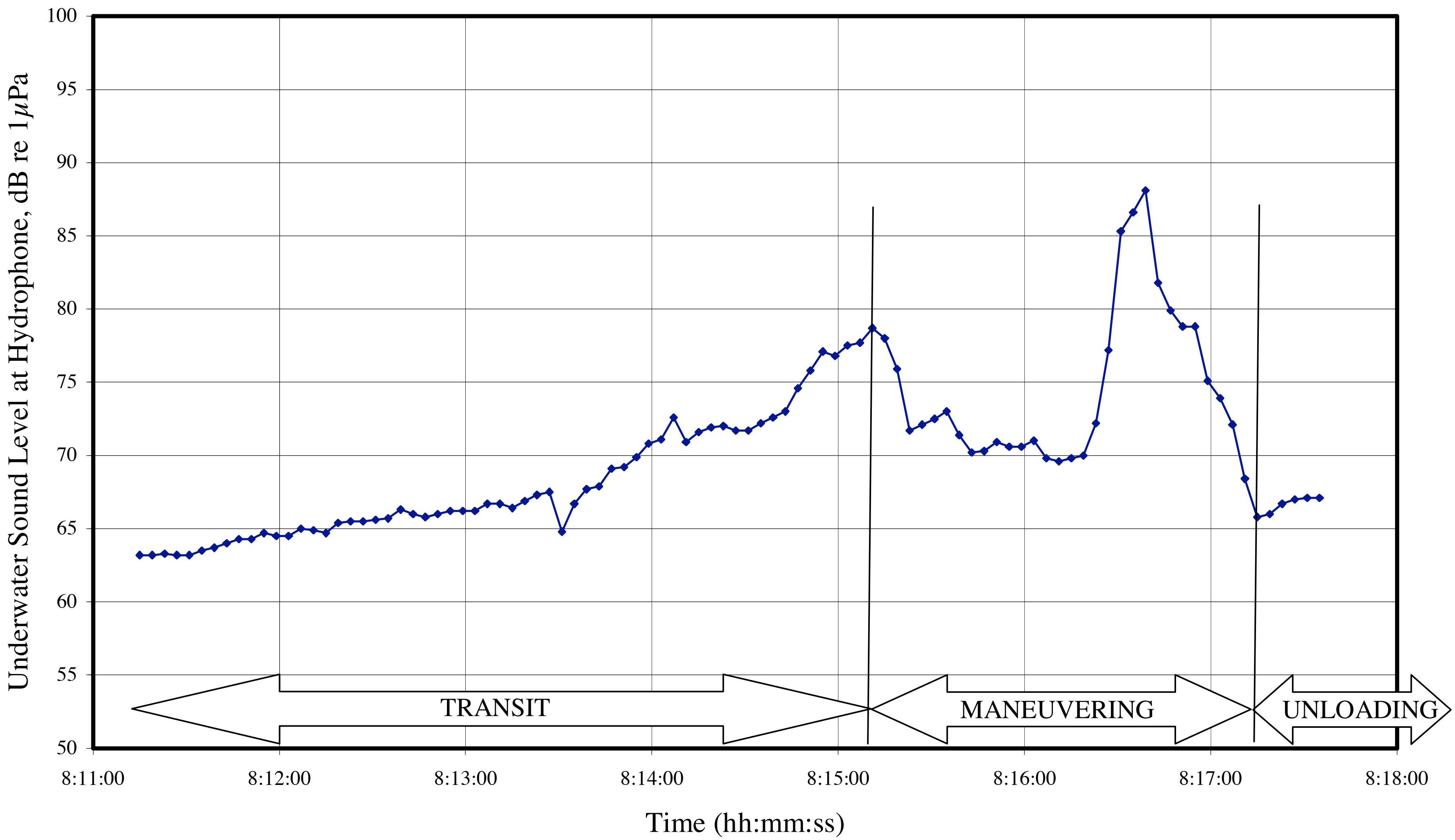


Figure 13 – KITSAP Seattle Terminal - Arrival - Underwater Noise



Comments: The following comments were made by Captain Greg Sugden of WSF, upon review of KITSAP underwater noise time histories:
"Both propellers are being used to move water while in transit and maneuver mod on KITSAP until vessel is in the dock. At that time the bow propeller is feathered (which is represented by the spike) and then is no longer pushing water (represented by the dip.)" KITSAP has CPP propulsion system.

Figure 14 – HYAK Seattle Terminal - Arrival - Underwater Noise

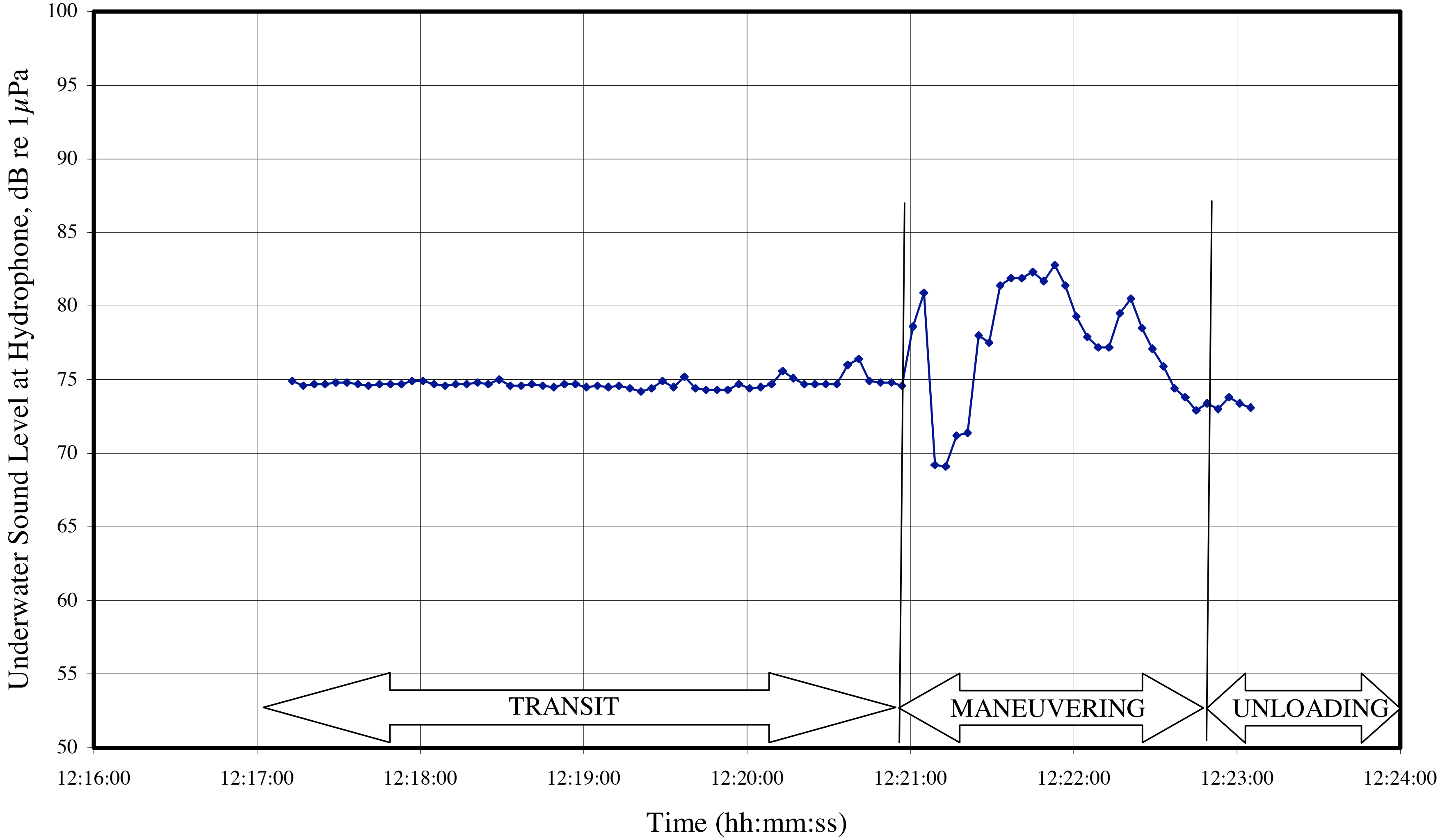
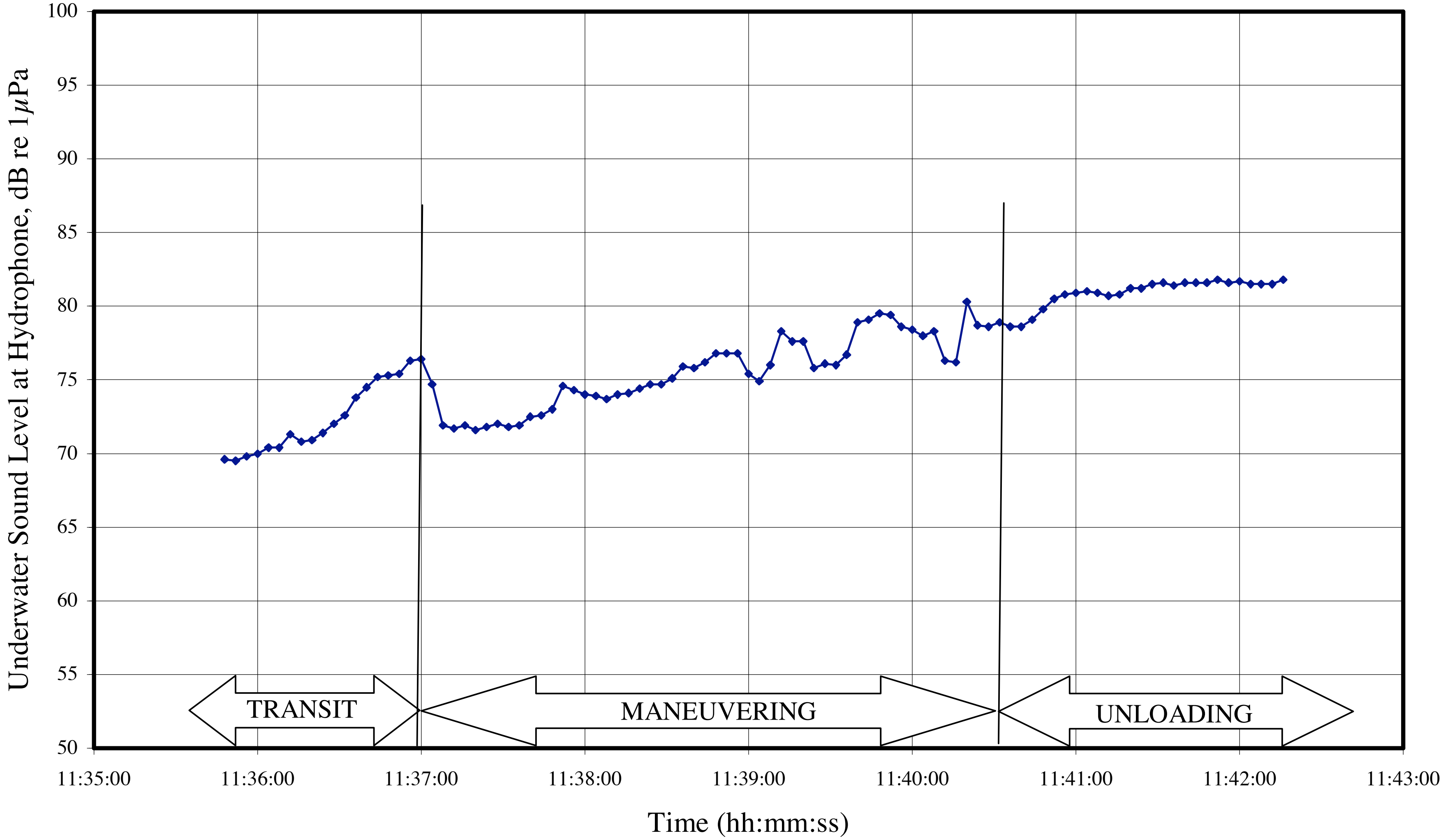


Figure 15 – EVERGREEN STATE Friday Harbor Terminal - Arrival - Underwater Noise



Comments: The following comments were made by Captain Greg Sugden of WSF, upon review of EVERGREEN STATE underwater noise time histories:
"EVERGREEN STATE has a third type of propulsion system where both propellers are always pushing water while in transit and while in the dock – thus no spikes and dips like on the SUPER class or KITSAP." EVERGREEN STATE has a DC electric propulsion system.

Figure 16 – YAKIMA Friday Harbor Terminal - Arrival - Underwater Noise

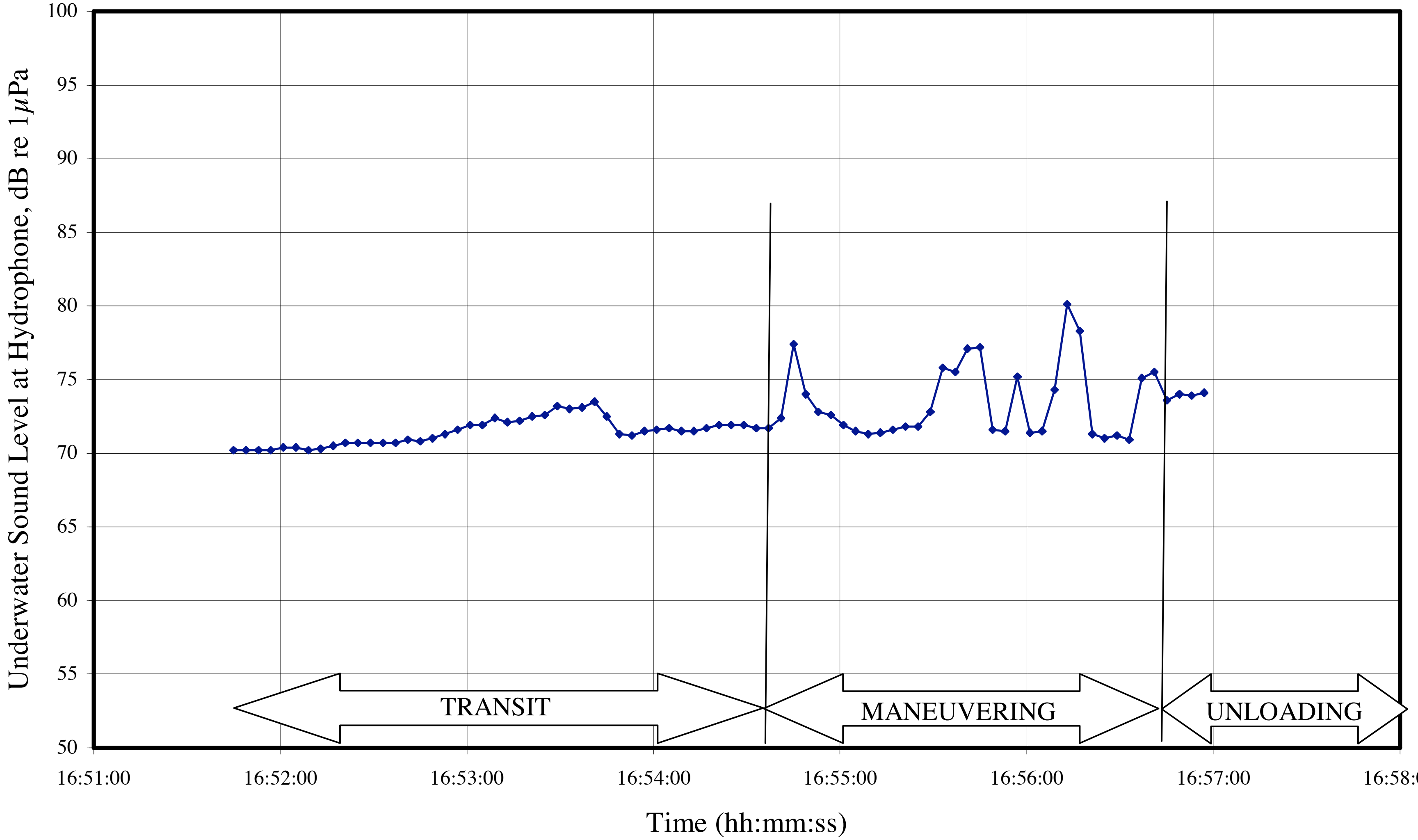


Figure 17 – EVERGREEN STATE Friday Harbor Terminal - Departure - Underwater Noise

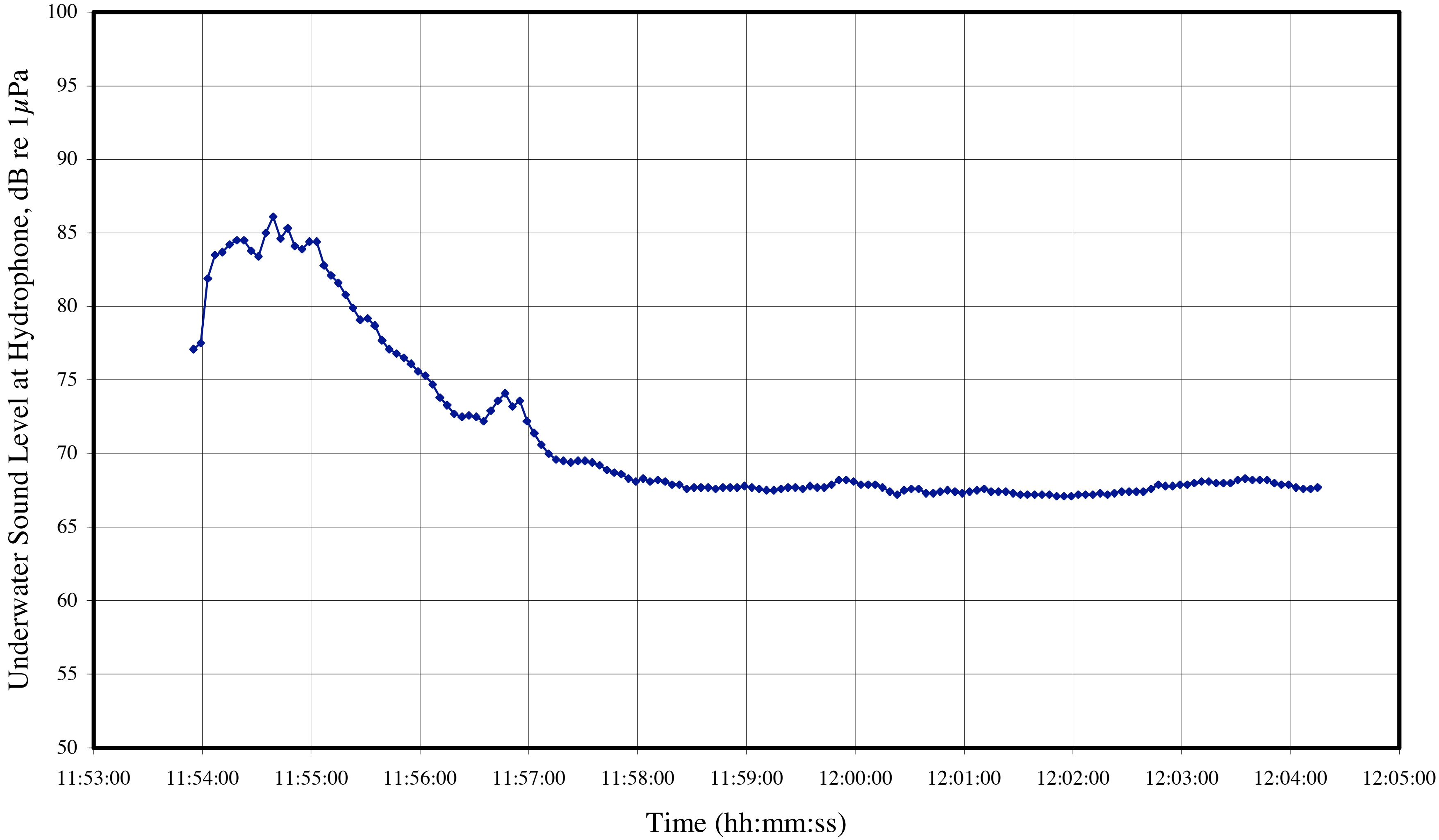


Figure 18 – HYAK – Bremerton Terminal – Airborne Noise

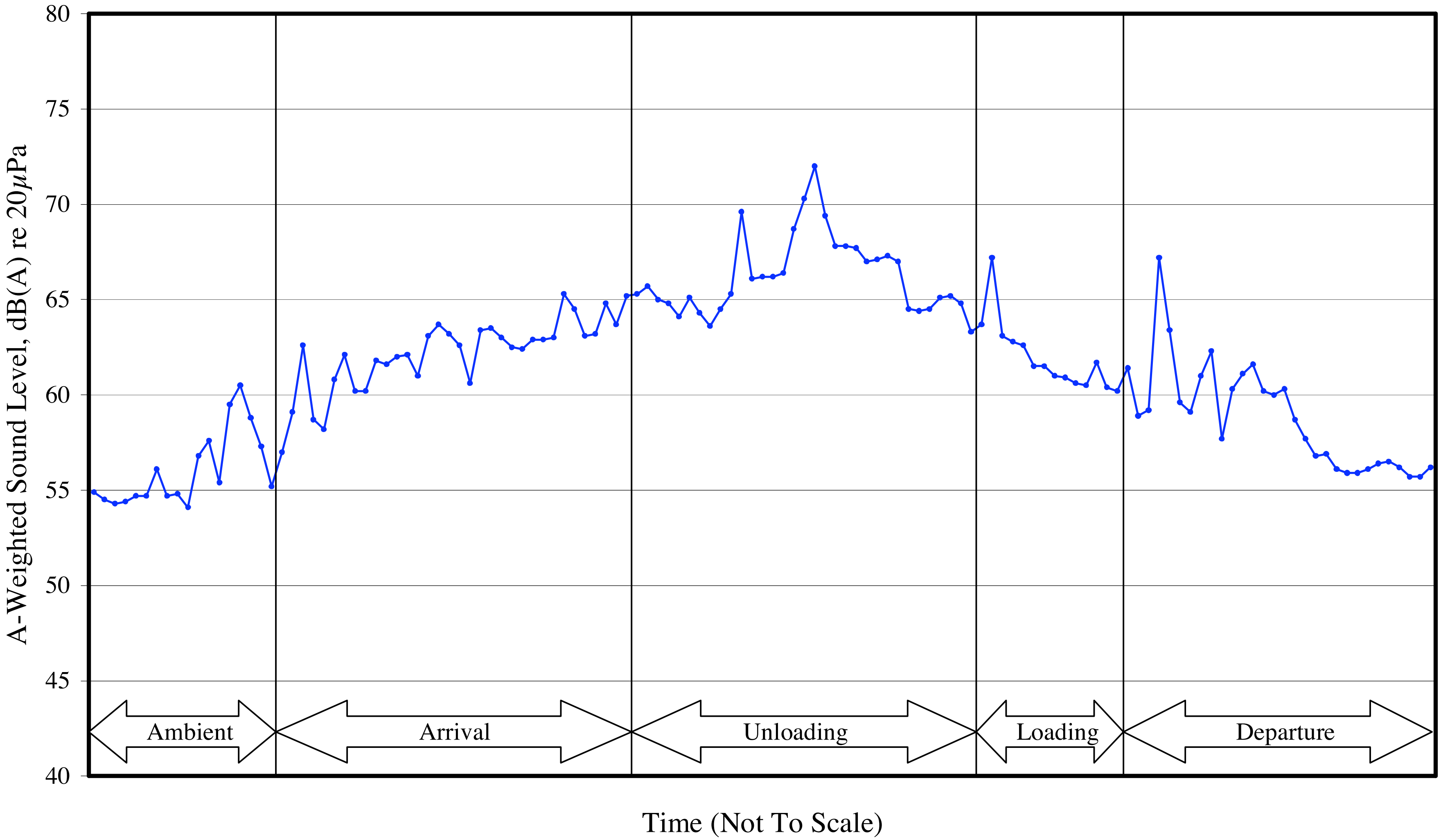


Figure 19 – HYAK – Seattle Terminal – Airborne Noise

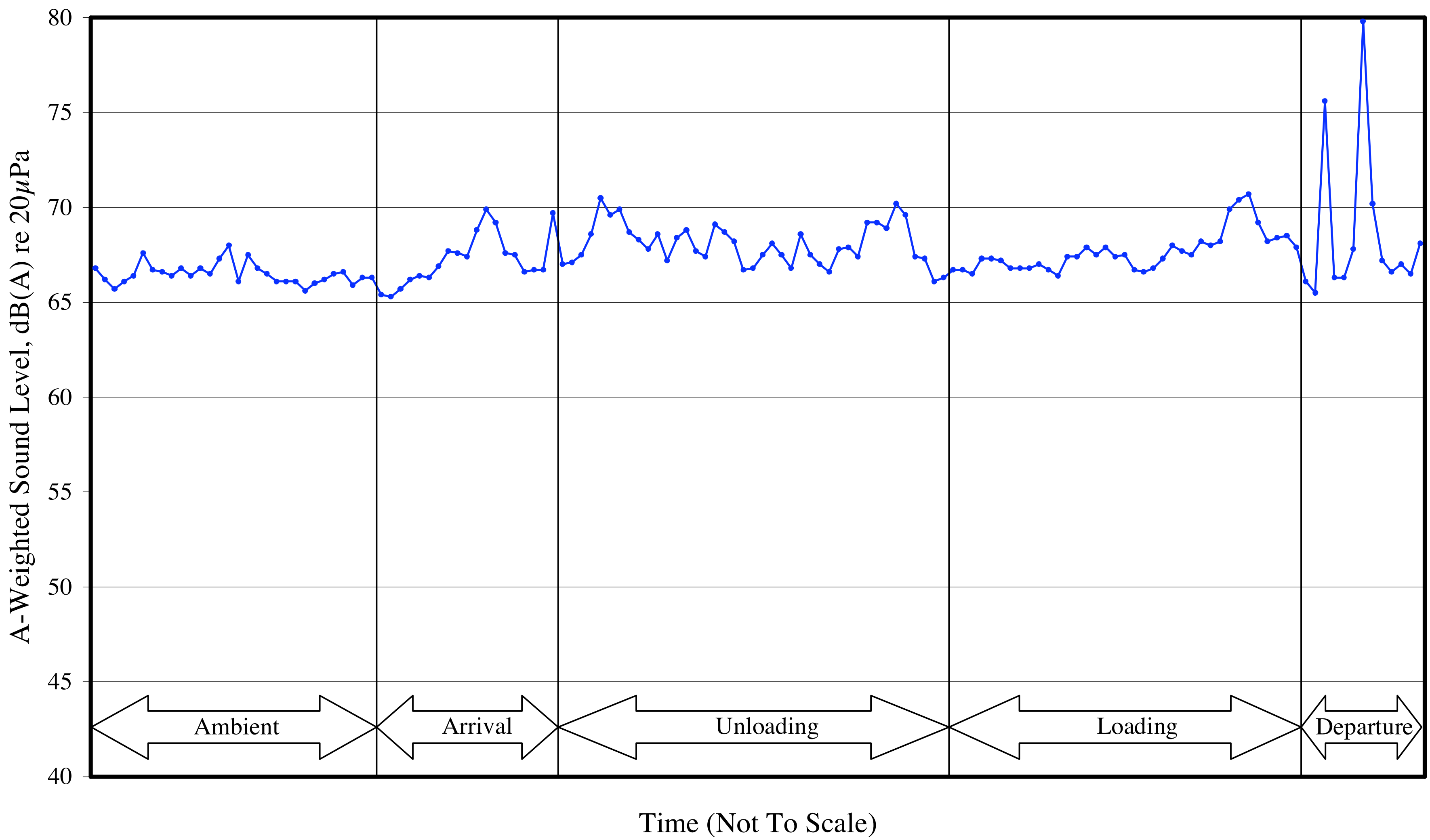


Figure 20 – EVERGREEN STATE – Friday Harbor Terminal – Airborne Noise

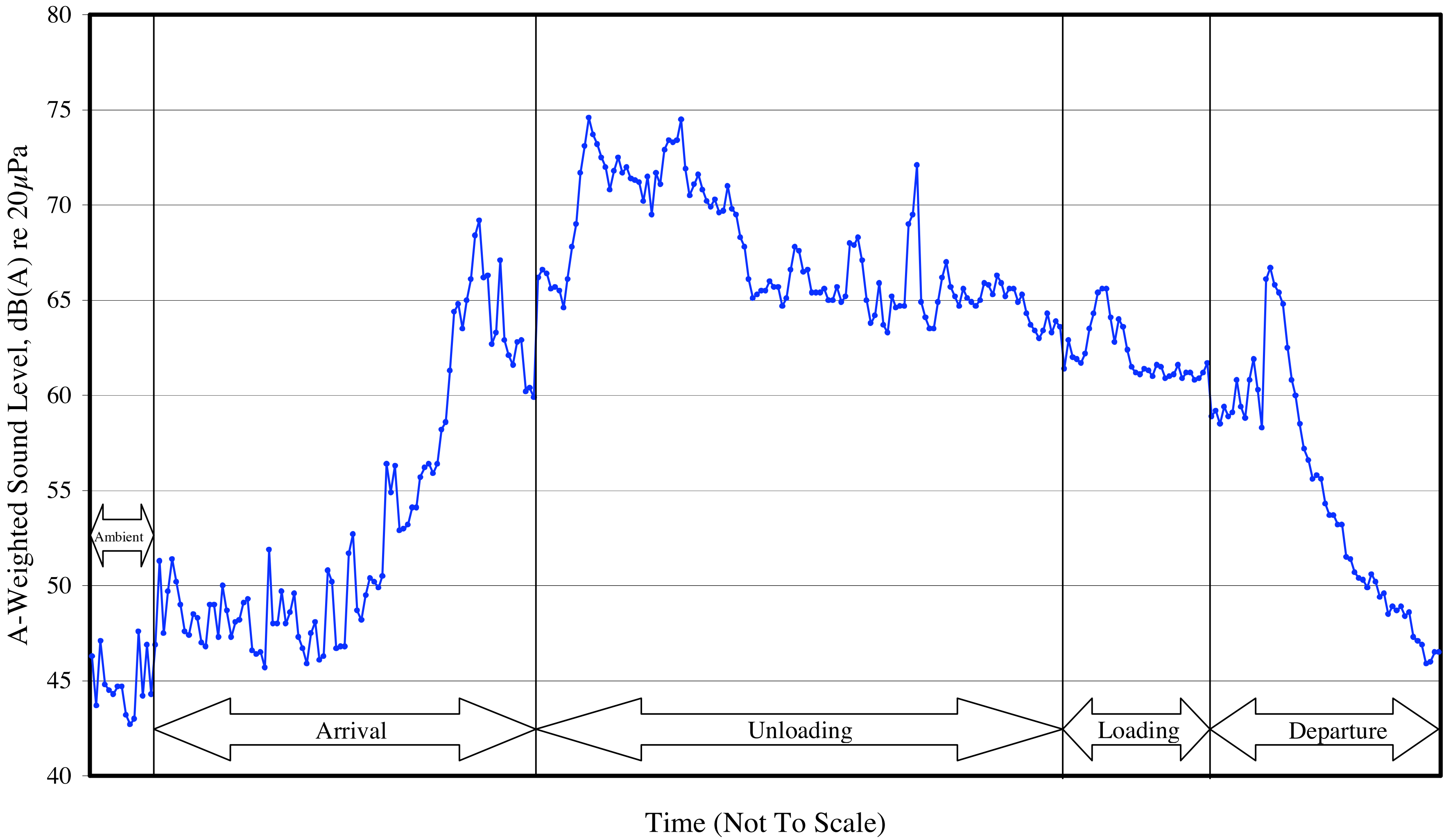
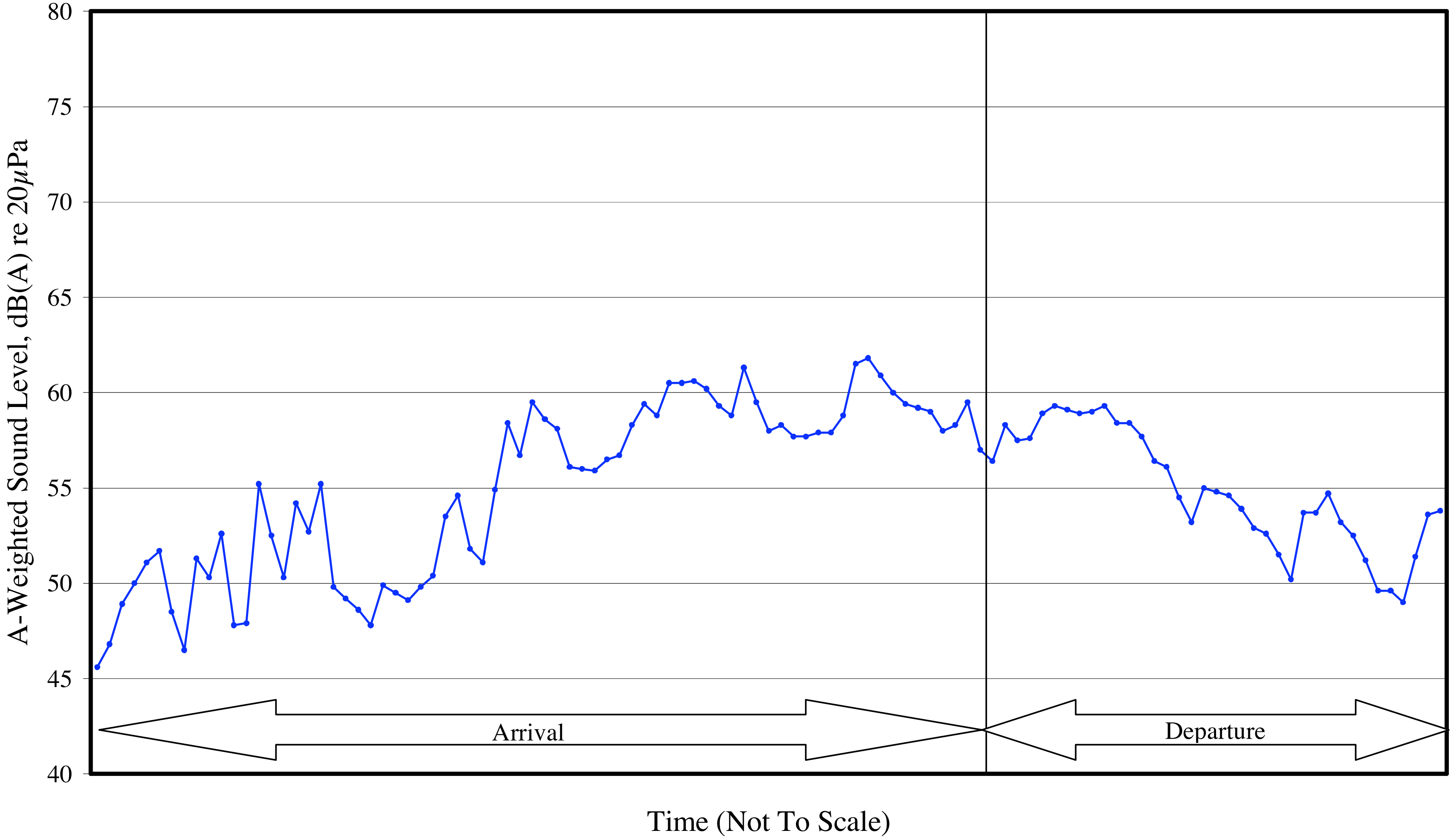


Figure 21 – EVERGREEN STATE – Shaw Island Terminal – Airborne Noise



Appendix A – Test Plan

This section presents the plan for measurement of airborne and underwater noise levels of representative vessels in the WSF fleet.

Measurements will begin 17 January 2005 and are intended to complete by 27 January 2005.

Airborne Noise Measurement

Ferry Terminal Noise Measurement

This section considers near-terminal airborne noise. This is noise perceived by a listener who isn't aboard the ferry. Rather, the listener may be a resident near a terminal or along the shoreline of a route, or a user of a shoreline park, or other similar receptor-site occupant.

The purpose of these measurements is to identify and quantify the noise contributed by the ferry. From this WSF can determine whether the noise is significant enough to investigate *en route* noise impacts at a later date.

JJMA personnel will measure the noise due to ferry operation at the following WSF Ferry terminals:

- Bremerton
- Seattle
- Friday Harbor
- Shaw Island

Arrangements

The measurements will be conducted within the period 17 – 27 January 2005. Detailed selection of test dates at each terminal will depend upon weather conditions. We will communicate our plans to WSF each day. Each day in the early afternoon we will e-mail Captain Greg Sugden our planned location for the next day. This will permit Captain Sugden to send any necessary messages to that location, shortly in advance of our arrival. Note that many decisions will be weather driven, and therefore we need to reserve the ability to change the details of the measurement schedule at any time.

We recommend that all locations should be apprised of the test program and the two week test window, and we have provided to Captain Sugden a draft of a letter from himself to cognizant persons at those locations, for his use in such communication – See Section 9.3

Procedures

Since the goal is to determine whether the ferry noise will disturb the nearest sensitive receptors, we will begin by selecting representative noise measurement sites at the terminal, near to neighboring property. Examples of such sites include the Bremerton Marina gate, Friday Harbor neighboring business property, and Seattle Alaskan Way property.

We will collect and present A-weighted, C-weighted, and one-third octave band noise at the terminals during commute and non-commute hours.

Measurements will include background noise at the terminals during the Off-Commute Period, as well as the total airborne noise during vessel arrival and departure. We will also take still photographs of selected areas at the terminals.

We will use portable test equipment powered by self contained batteries. We will use laptop computers and may seek AC power to run them, depending upon availability. All test equipment will be provided by JJMA.

Personnel

Noise measurements will be performed by JJMA personnel Mr. Chris McKesson and Mr. William Daube.

Ferry On-Board Noise Measurement

On board noise measurements will be taken to determine what the likely sources of far-field noise are. The following vessels will be measured:

- M/V KITSAP – Bremerton to Seattle service
- M/V HYAK – Bremerton to Seattle service and/or M/V ELWHA – Friday Harbor service
- M/V ILLAHEE – Friday Harbor service

Arrangements

The above measurements will be conducted within a two-week period from 17 to 27 January 2005 during ferryborne transits between terminal locations. Each day we will communicate our tentative ferry passages for the next day to Captain Sugden, in the early afternoon, so that he may pass this information to necessary persons. Note that many decisions will be weather driven, and therefore we need to reserve the ability to change the details of the measurement schedule at any time.

We may need the assistance of a ferry Deckhand to permit access to certain areas of the ship. We have provided to Captain Sugden a draft of a letter from himself to cognizant persons at those locations, for his use in such communication – See Section 9.3

Procedures

The time available on a given ferry transit does not permit extensive data gathering. We will make on-board A-weighted, C-weighted, and octave band measurements in the near field of the diesel exhaust, diesel intake, HVAC inlets, and at other potential ferry noise sources to determine the sources of the dominant noise heard at the terminal. We will also take still photographs of selected areas on the ferry.

Personnel

Noise measurements will be performed by JJMA personnel Mr. Chris McKesson and Mr. William Daube.

Underwater Noise Measurement

Arrangements

Scheduling of the Underwater Noise Measurements is the most weather-critical portion of the test program. We will monitor weather forecasts and will attempt to select the most appropriate conditions for the measurements.

Due to the unpredictable nature of the weather we can't at this time state on which days we will make the underwater noise measurements. We will communicate our test plans as early as possible to Captain Greg Sugden, so that he can keep all necessary other personnel apprised. Each day in the early afternoon we will e-mail Captain Sugden with our planned location for the next day. This will permit Captain Sugden to send any necessary messages to that location, shortly in advance of our arrival.

We recommend that all locations be apprised of the test program and the two week test window, and we have provided to Captain Sugden a draft of a letter from himself to cognizant persons at those locations, for his use in such communication – See Section 9.3

Procedures

Underwater Noise Measurements will be performed using a hydrophone lowered from an anchored support vessel. JJMA personnel will be aboard the support vessel.

The support vessel will be the recreational sailing yacht ASAGI. This is a 36-foot sailboat, blue hull with white deckhouse. Persons on board will be as described below.

ASAGI will supply

- 175W inverter
- Heat (kerosene heater)
- Cooking and toilet facilities
- Ground Tackle
- VHF radio
- Depthsounder
- Required navigation lights & safety equipment

JJMA will supply

- Binoculars
- Rangefinder
- Handheld VHF
- Anemometer
- Noise measurement instrumentation
- 3 PFDs
- Portable Generator
- 500W inverter
- Anchor ball

The measurements will be performed on the Friday Harbor and Seattle-Bremerton routes with the yacht anchored at a location along the ferry's track. Our initial planned anchoring locations are depicted below. Our intent is to anchor the yacht such that the ferry passes approximately 400 yards from the yacht.

We will measure the ferry's distance using a laser rangefinder provided by JJMA. We will measure the ferry's underwater noise level using a hydrophone and acoustic equipment provided by JJMA.

We will record the position of the yacht (latitude and longitude) as well as the depth and temperature of the water at the yacht's location, and the depth of the hydrophone.
We intend to measure the ferry vessels KITSAP, HYAK, ILLAHEE, and either ELWHA or YAKIMA.

At some times ferries of the WSF fleet are escorted by USCG security vessels. These escort craft produce significant underwater noise which would ruin the ferry underwater noise measurement. If such escort vessels are present on the day of testing, JJMA personnel will communicate with the ferry Masters by VHF radio, and will ask them to request the USCG craft to secure their engines for the critical minutes of the testing.

Figure 22 – Planned Underwater Noise Measurement Location - Bremerton – Seattle Route

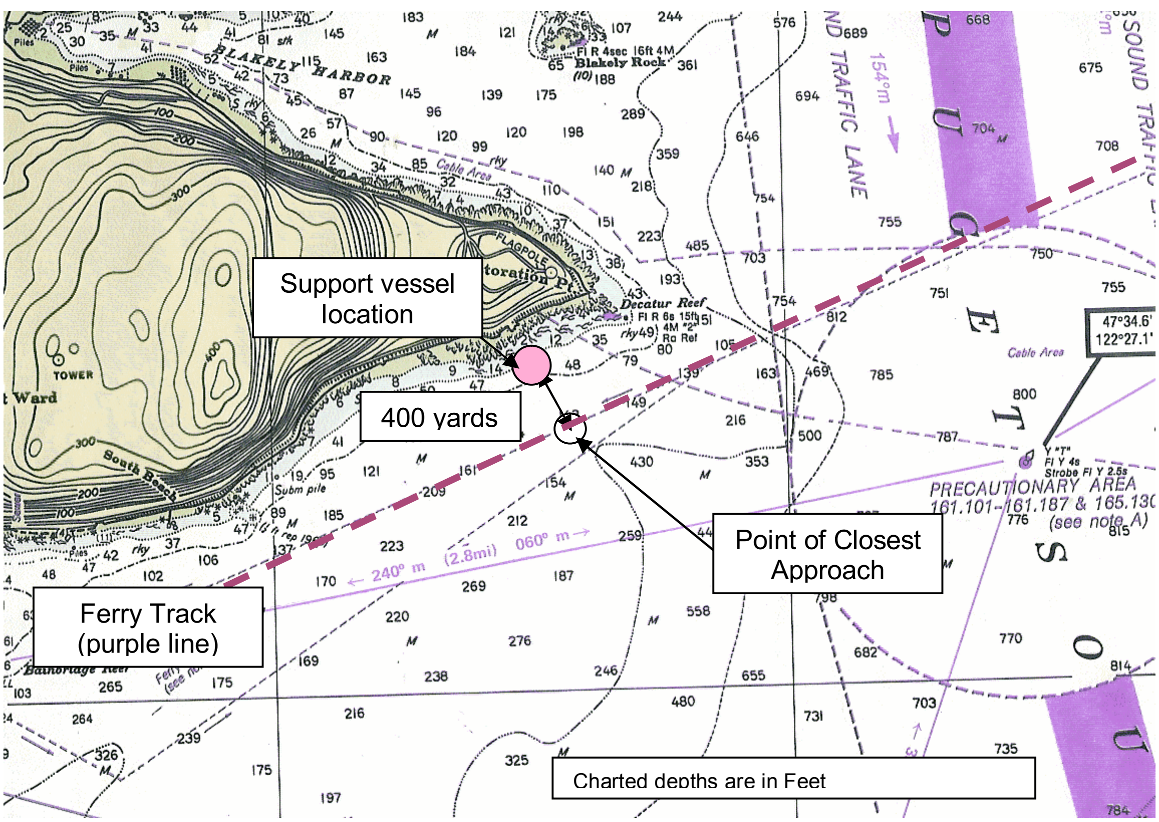
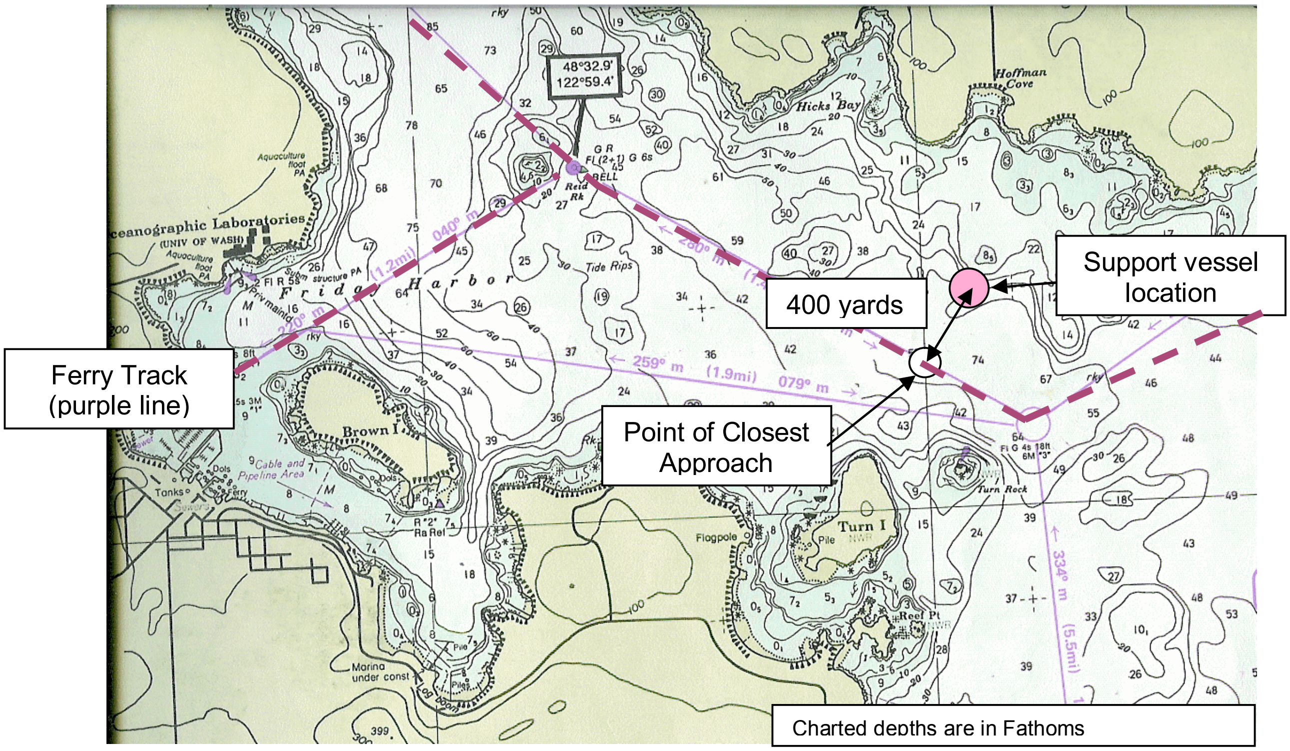


Figure 23 – Planned Underwater Noise Measurement Location - Friday Harbor Route



Personnel

Noise measurements will be performed by JJMA personnel Mr. Chris McKesson and Mr. William Daube.

Additional vessel operation personnel may be present, including but not limited to Mrs. Debra McKesson, and Fred & Gloria Wiedenhoeft (friends of McKesson).

One WSF representative may also be on board.

Appendix B - Procedure for Calculating the Ferry Underwater Noise at the Propeller from Remote Hydrophone Measurements

This section explains the procedure used to measure and determine the underwater sound pressure level (in decibels) of each at ferry at 1 meter from the ferry's propeller. In this way, we can compare the underwater noise level of each ferry even though the distance from the hydrophone to the ferry was different for each ferry underwater noise measurement. Although the ferry noise is generated by various sources on the ferry, for the purpose of this calculation, the ferry is considered to be a point noise source located at the propeller. Consequently, the ferry underwater sound pressure level (FLp) is defined as:

$$FLp\ (dB) = 10 \log_{10} (P/Po)^2$$

where:

FLp = underwater sound level of ferry at 1 meter from the ferry, dB re 1 μPa

P = rms sound pressure at one meter from the noise source

Po = reference pressure = 1 μPa (where Pa = Pascal)

In order to determine the ferry underwater noise, the underwater sound pressure level was measured with a hydrophone lowered a known distance into the water. The distance to the aft end of the ferry was measured with a laser rangefinder. The major instrumentation consisted of a hydrophone (Wilcoxon model H507B), signal conditioner (PCB model 483B07) and sound level meter (Larson Davis model 824). The following steps explain this procedure in detail.

1. The oscillatory sound pressure in the water due to the ferry generates a root-mean-square (rms) voltage output from the hydrophone, V_H. V_H is amplified or attenuated by the signal conditioner, depending upon its attenuator setting. The measured display on the sound level meter, MLp (in decibels), or its output (stored in its internal memory) is related to V_H as follows:

$$MLp = 10 \log_{10} (S_A V_H/V_O)^2\ dB$$

where:

MLp = measured value from sound level meter, dB

S_A = attenuator setting on signal conditioner

V_H = hydrophone output voltage, μvolt

V_O = sound level meter reference voltage = 1 μvolt

The voltage input to the sound level meter, $S_A V_H$, is therefore calculated from the sound level meter display, MLp, as follows:

$S_A V_H = 10^{MLp/20}$ μvolt

Hydrophone output voltage is determined from the sound level meter as:

$V_H = [10^{MLp/20}/S_A]$ μvolt.

2. The hydrophone's measured voltage sensitivity is approximately -178.3 dB re 1V/1μPa. By decibel arithmetic, this is equivalent to 1.216 x 10^{-9} volt/μPa (or 1216 μV/Pa) or 822.37 Pa/V. Therefore, using the hydrophone output voltage, V_H, determined in the previous step, the sound pressure at the hydrophone, and the sound pressure level at the hydrophone HLp) are:

$P_H = 822.37 V_H$ Pa
$HLp = 10 \log_{10} (P_H/Po)^2$ dB
where:
HLp = sound pressure level at the hydrophone, dB
P_H = sound pressure at the hydrophone, μPa
Po = reference pressure = 1 μPa

After further decibel arithmetic and substitution, the sound pressure level at the hydrophone, HLp, is calculated as follows:

$HLp = MLp - 20 \log_{10} S_A + 58.3$ dB
where:
MLp = reading (or output) from the sound level meter, dB
S_A = amplification or attenuation from signal conditioner (S_A = 10.0, 1.0, or 0.1)

During pre-test instrumentation checkout and calibration, the sound level meter output from a known voltage signal simulating the hydrophone output was measured. It was determined that the sound level meter output was 1.5 dB too high because the internal sound level meter gain had been pre-adjusted for the microphone. Normally, this would be compensated for by adjusting the internal gain of the sound level meter. In this case however, we did not want re-adjust the gain on site because we would be quickly changing from airborne noise measurements to underwater noise measurements. Therefore, it was decided to compensate for this 1.5 dB mathematically during the data processing. The correct sound pressure level at the hydrophone is therefore

$HLp = MLp - 20 \log_{10} S_A + (58.3 - 1.5)$ dB, or

$HLp = MLp - 20 \log_{10} S_A + 56.8$ dB

3. In order to estimate the underwater sound pressure level at 1 meter from the ferry (FLp), it was assumed that the measured sound radiates from the ferry by a combination of spherical and cylindrical spreading. A range correction (RC) is added to the sound level at the hydrophone, HLp, to account for this spreading, the horizontal distance from the ferry to the hydrophone, and the effective channel depth.

   $FLp\ (dB) = HLp + RC\ \ dB$
   $RC = 10\log_{10}(R/Ro) + 10\log_{10}(H/Ho)\ \ dB$
   where:
   R = horizontal distance from ferry to hydrophone, meters
   Ro = reference distance = 1 meter
   H = effective channel depth, meters
   Ho = reference distance = 1 meter

4. The sound pressure level at one meter from the ferry is computed as follows:

   $FLp\ (dB) = MLp - 20\log_{10} S_A + 56.8 + 10\log_{10}(R/Ro) + 10\log_{10}(H/Ho)$
   where:
   FLp = underwater sound level of ferry at 1 meter from the ferry propeller, dB re 1 μPa
   MLp = measured result from sound level meter output file, dB
   S_A = amplification or attenuation from signal conditioner (S_A = 10.0, 1.0, or 0.1)
   R = horizontal distance from ferry to hydrophone, meters
   Ro = reference distance = 1 meter
   H = effective channel depth, meters
   Ho = reference distance = 1 meter

Appendix C - Ferry Underwater and Airborne Noise Measurements vs. Log Number

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
1	Underwater Noise	KITSAP	1/18/05	Bainbridge Reef	Westbound	In Transit
2	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	In Transit
3	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	Ambient
4	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	In Transit
5	Underwater Noise	HYAK & KITSAP	1/18/05	Bainbridge Reef	East &West	In Transit
6	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Westbound	In Transit
7	Underwater Noise	HYAK & KITSAP	1/18/05	Bainbridge Reef	East &West	In Transit
8	Underwater Noise	KITSAP	1/18/05	Bainbridge Reef	Westbound	Ambient
9	Underwater Noise	KITSAP	1/18/05	Bainbridge Reef	Eastbound	In Transit
10	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	Ambient
11	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Westbound	In Transit
12	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Westbound	Ambient
13	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Westbound	Ambient
14	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Westbound	In Transit
15	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	Ambient
16	Underwater Noise	HYAK	1/18/05	Bainbridge Reef	Eastbound	In Transit
17	Underwater Noise	KITSAP	1/19/05	Bainbridge Reef	Westbound	In Transit
18	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Departure
19	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient
20	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Arrival
21	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Departure
22	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Arrival
23	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Departure

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
24	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient
25	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient
26	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Arrival
27	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Idling
28	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Idling
29	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Departure
30	Underwater Noise	HYAK	1/19/05	Bremerton	Terminal	Ambient
31	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Arrival
32	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Idling
33	Underwater Noise	KITSAP	1/19/05	Bremerton	Terminal	Departure
34	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Ambient
35	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Arrival
36	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Unloading
37	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Idling
38	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Ambient w/bus
39	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Ambient
40	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Idling
41	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Idling
42	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Loading
43	Airborne Noise	HYAK	1/19/05	Bremerton	Terminal	Departure
44	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient
45	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient
46	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient w/bus
47	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Arrival
48	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Unloading
49	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Idling
50	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Ambient w/bus

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
51	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Loading
52	Airborne Noise	KITSAP	1/19/05	Bremerton	Terminal	Departure
53	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
54	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
55	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
56	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
57	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
58	Airborne Noise	WENATCHEE	1/20/05	On-board		In Transit
59	Underwater Noise	KITSAP	1/20/05	Seattle	Terminal	Arrival
60	Underwater Noise	TACOMA	1/20/05	Seattle	Terminal	Arrival
61	Underwater Noise	TACOMA & KITSAP	1/20/05	Seattle	Terminal	Idling
62	Underwater Noise	TACOMA & KITSAP	1/20/05	Seattle	Terminal	Departure
63	Underwater Noise	KITSAP	1/20/05	Seattle	Terminal	Ambient
64	Underwater Noise	TACOMA	1/20/05	Seattle	Terminal	Ambient
65	Underwater Noise	WENATCHEE	1/20/05	Seattle	Terminal	Arrival
66	Underwater Noise	WENATCHEE	1/20/05	Seattle	Terminal	Ambient
67	Underwater Noise	WENATCHEE	1/20/05	Seattle	Terminal	Departure
68	Underwater Noise	HYAK	1/20/05	Seattle	Terminal	Arrival
69	Underwater Noise	HYAK	1/20/05	Seattle	Terminal	Arrival
70	Underwater Noise	HYAK	1/20/05	Seattle	Terminal	Unloading
71	Underwater Noise	TACOMA & HYAK	1/20/05	Seattle	Terminal	Arrival/Idling
72	Underwater Noise	TACOMA	1/20/05	Seattle	Terminal	Departure
73	Underwater Noise	WENATCHEE	1/20/05	Seattle	Terminal	Arrival
74	Underwater Noise	KITSAP & WENATCHEE	1/20/05	Seattle	Terminal	Arrival/Idling
75	Underwater Noise	KITSAP	1/20/05	Seattle	Terminal	Departure
76	Underwater Noise	KITSAP	1/20/05	Seattle	Terminal	Ambient
77	Underwater Noise	KITSAP	1/20/05	Seattle	Terminal	Ambient

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
78	Underwater Noise	TACOMA	1/20/05	Seattle	Terminal	Arrival
79	Underwater Noise	HYAK	1/20/05	Seattle	Terminal	Arrival
80	Underwater Noise	HYAK & WENATCHEE	1/20/05	Seattle	Terminal	Departure/Arriving
81	Airborne Noise	KITSAP	1/20/05	Seattle	Terminal	Arrival
82	Airborne Noise	KITSAP	1/20/05	Seattle	Terminal	Unloading
83	Airborne Noise	TACOMA	1/20/05	Seattle	Terminal	Arrival
84	Airborne Noise	TACOMA	1/20/05	Seattle	Terminal	Unloading
85	Airborne Noise	TACOMA	1/20/05	Seattle	Terminal	Loading
86	Airborne Noise	TACOMA	1/20/05	Seattle	Terminal	Departure
87	Airborne Noise	WENATCHEE	1/20/05	Seattle	Terminal	Arrival
88	Airborne Noise	WENATCHEE	1/20/05	Seattle	Terminal	Unloading
89	Airborne Noise	KITSAP & WENATCHEE	1/20/05	Seattle	Terminal	Loading
90	Airborne Noise	KITSAP	1/20/05	Seattle	Terminal	Departure
91	Airborne Noise	WENATCHEE	1/20/05	Seattle	Terminal	Departure
92	Airborne Noise	WENATCHEE	1/20/05	Seattle	Terminal	Ambient
93	Airborne Noise	WENATCHEE	1/20/05	Seattle	Terminal	Ambient
94	Airborne Noise	HYAK	1/20/05	Seattle	Terminal	Arrival
95	Airborne Noise	HYAK	1/20/05	Seattle	Terminal	Unloading
96	Airborne Noise	HYAK	1/20/05	Seattle	Terminal	Loading
97	Airborne Noise	HYAK	1/20/05	Seattle	Terminal	Departure
98	Airborne Noise	YAKIMA	1/21/05	Calibration		
99	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
100	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
101	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
102	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
103	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
104	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
105	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
106	Airborne Noise	YAKIMA	1/21/05	On-board		In Transit
107	Underwater Noise	EVERGREEN STATE	1/22/05	South of Shaw Island	Westbound	In Transit
108	Underwater Noise	EVERGREEN STATE	1/22/05	South of Shaw Island		Ambient
109	Underwater Noise	EVERGREEN STATE	1/22/05	South of Shaw Island		Ambient
110	Underwater Noise	EVERGREEN STATE	1/22/05	South of Shaw Island	Eastbound	In Transit
111	Underwater Noise	ELWHA	1/22/05	Flat Point		Ambient
112	Underwater Noise	ELWHA	1/22/05	Flat Point		Ambient
113	Underwater Noise	ELWHA	1/22/05	Flat Point		Ambient
114	Underwater Noise	ELWHA	1/22/05	Flat Point	Eastbound	In Transit
115	Underwater Noise	EVERGREEN STATE	1/22/05	Flat Point	Westbound	In Transit
116	Underwater Noise	EVERGREEN STATE	1/22/05	Flat Point		Ambient
117	Underwater Noise	EVERGREEN STATE	1/22/05	Flat Point		Ambient
118	Underwater Noise	EVERGREEN STATE	1/22/05	Flat Point	Eastbound	In Transit
119	Underwater Noise	YAKIMA	1/22/05	Flat Point	Westbound	In Transit
120	Underwater Noise	YAKIMA	1/22/05	Flat Point	Eastbound	In Transit
121	Underwater Noise	YAKIMA	1/22/05	Flat Point		Ambient
122	Underwater Noise	YAKIMA	1/22/05	Flat Point		Ambient
123	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Ambient
124	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Arrival
125	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Unloading
126	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Idling
127	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Loading
128	Airborne Noise	EVERGREEN STATE	1/22/05	Friday Harbor	Terminal	Departure
129	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Ambient

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
130	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Ambient
131	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Arrival
132	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Unloading
133	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Idling
134	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Loading
135	Airborne Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Departure
136	Underwater Noise	ELWHA	1/23/05	Friday Harbor	Terminal	Ambient
137	Underwater Noise	ELWHA	1/23/05	Friday Harbor	Terminal	Ambient
138	Underwater Noise	ELWHA	1/23/05	Friday Harbor	Terminal	Arrival
139	Underwater Noise	ELWHA	1/23/05	Friday Harbor	Terminal	Idling
140	Underwater Noise	ELWHA	1/23/05	Friday Harbor	Terminal	Departure
141	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Arrival
142	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Idling
143	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Departure
144	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Ambient
145	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Ambient
146	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Arrival
147	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Unloading
148	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Idling
149	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Loading
150	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Horn Blast
151	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Departure
152	Airborne Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Ambient
153	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Arrival
154	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Idling
155	Underwater Noise	EVERGREEN STATE	1/23/05	Friday Harbor	Terminal	Departure
156	Underwater Noise	YAKIMA	1/23/05	Friday Harbor	Terminal	Arrival

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
157	Airborne Noise	EVERGREEN STATE	1/24/05	Friday Harbor	Terminal	Ambient
158	Airborne Noise	EVERGREEN STATE	1/24/05	Friday Harbor	Terminal	Ambient
159	Airborne Noise	EVERGREEN STATE	1/24/05	Friday Harbor	Terminal	Arrival
160	Airborne Noise	EVERGREEN STATE	1/24/05	Friday Harbor	Terminal	Arrival
161	Airborne Noise	EVERGREEN STATE	1/24/05	Friday Harbor	Terminal	Unloading
162	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
163	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
164	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
165	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
166	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
167	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
168	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
169	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
170	Airborne Noise	ILLAHEE	1/24/05	On-board		In Transit
171	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Arrival
172	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Unloading
173	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Departure
174	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Ambient
175	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Ambient
176	Airborne Noise	EVERGREEN STATE	1/24/05	Shaw Island	Terminal	Arrival
177	Airborne Noise	EVERGREEN STATE	1/24/05	Shaw Island	Terminal	Departure
178	Airborne Noise	EVERGREEN STATE	1/24/05	Shaw Island	Terminal	Departure
179	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Ambient
180	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Ambient
181	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Arrival
182	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Idling
183	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Departure

Log no.	Measurement type	Ferry	Date	Location	Route	Operation
184	Underwater Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Departure
185	Airborne Noise	EVERGREEN STATE	1/24/05	Shaw Island	Terminal	Unloading
186	Airborne Noise	EVERGREEN STATE	1/24/05	Shaw Island	Terminal	Departure
187	Airborne Noise	ELWHA	1/24/05	Shaw Island	Terminal	Arrival
188	Airborne Noise	ELWHA	1/24/05	Shaw Island	Terminal	Unloading
189	Airborne Noise	ELWHA	1/24/05	Shaw Island	Terminal	Idling
190	Airborne Noise	ELWHA	1/24/05	Shaw Island	Terminal	Departure
191	Airborne Noise	ELWHA	1/24/05	Shaw Island	Terminal	Departure
192	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Arrival
193	Airborne Noise	ILLAHEE	1/24/05	Shaw Island	Terminal	Departure