Hydroacoustic Monitoring Plan

Test Pile Project

At

NAVAL BASE KITSAP Bremerton, Washington

Navy Region Northwest

Silverdale, WA

March 2023

Naval Facilities Engineering Command Northwest

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1 INTRODUCTION

The U.S. Department of the Navy (Navy) proposes to conduct the Test Pile Project to test pile and coffer dam installation and removal methods at Naval Base Kitsap (NBK) Bremerton. NBK Bremerton is located in the Puget Sound region of Washington State and the specific installation and removal location addressed in this plan is within the area of the Puget Sound Naval Shipyard (PSNS) & Intermediate Maintenance Facility (IMF).

The purpose of the project is to test the installation and removal of temporary steel pipe piles and steel sheet piles. The project will install 45 36-inch-diameter steel pipe piles and 30 14-inch steel sheet piles. Vibratory installation shall be used to the extent practicable to drive steel pipe piles and steel sheet piles to minimize high sound pressure levels associated with impact pile driving. Impact pile driving will be required to “proof” piles or when vibratory installation fails to fully drive a pile to the proper depth. A bubble curtain or other noise attenuation device shall be employed during impact installation of steel pipe piles where water depths are greater than 0.67 meters (2 feet). All piles installed as part of the Test Pile Project will be removed using either a vibratory hammer, direct pull, or by cutting the piles off at the mudline at the end of the project,

During construction, impact installation of steel piles will produce underwater sound pressure levels that may injure fish protected under the Endangered Species Act (ESA). Pile driving will also result in underwater sound pressure levels that may exceed harassment (Level B) and injury (Level A) thresholds for marine mammals. The Navy has received take from the National Marine Fisheries Service (NMFS) for fish listed under the ESA and for protected marine mammals under the MMPA. In order to comply with the above federal laws and prevent unauthorized take, the Navy must perform hydroacoustic monitoring during a subset of steel pile installations that use an impact hammer. The monitoring data will be used to validate the accuracy of the assumptions made in the calculation of ESA and MMPA takes. This plan provides the protocol for performing the acoustic monitoring required to valid the assumptions.

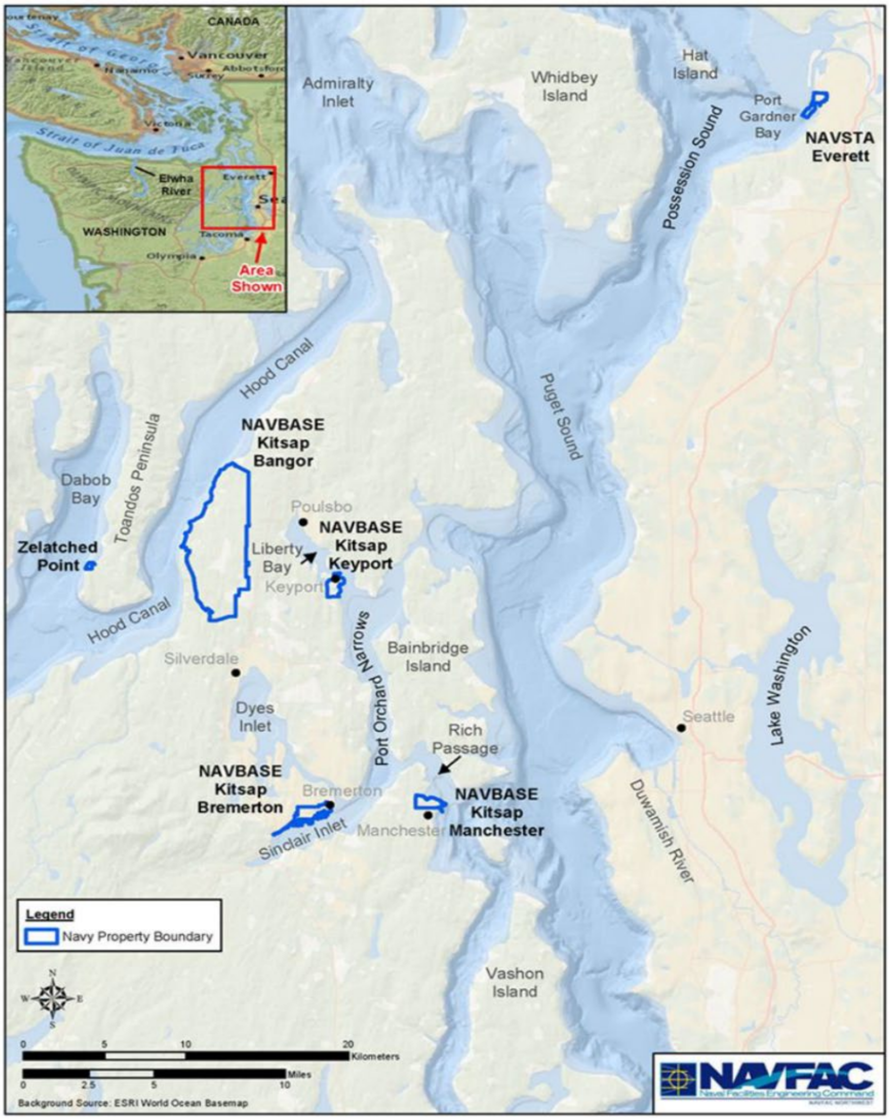

Figure 1. Site Location Map for Naval Base Kitsap Bremerton

2 OBJECTIVES

The primary objective of acoustic monitoring during the Test Pile Project is to validate the distances to thresholds calculated during the ESA and MMPA analyses and ensure.

2.1 ESA Thresholds for Fish

In the NMFS Biological Opinion (NMFS 2018a), the distance to the 187 dB (fish ≥ 2) and 183 dB (fish < 2 g) cumulative SEL fish thresholds were calculated to be 159 meters and 295 meters, respectively. These distances were calculated using source level data for single strike sound pressure at 10 meters for impact driving 36-inch steel piles in a marine environment. These source level values are 211 dB peak, 194 dB RMS, 181 dB SEL. Applying an 8 dB reduction in sound pressure assumed with the mandatory use of a bubble curtain, the anticipated sound levels were reduced to 203 dB peak, 186 dB RMS, and 173 dB single strike SEL. The source level values and expected attenuation value were derived from the Navy's document titled *Proxy source sound levels and potential bubble curtain attenuation for acoustic modeling of nearshore marine pile driving at Navy installations in Puget Sound* (Navy 2015).

In the Incidental Take Statement (NMFS 2018a) and associated Errata (NMFS 2018b), NMFS concluded that ESA take would be exceeded if:

1. Sound exceeds cumulative SEL of 205 dB at 10 meters.
2. Duration of pile driving exceeds 160 days.
3. Duration of impact pile driving exceeds 45 minutes per day.

Therefore, the first objective of hydroacoustic monitoring is to ensure that cumulative SEL of 205 dB at 10 meters is not exceeded.

2.2 MMPA Thresholds for Marine Mammals

The second objective of hydroacoustic monitoring during the Test Pile Project is to validate the MMPA Level A and Level B Zone of Influence (ZOI) based on acoustic data collected during previous monitoring efforts within at NBK Bremerton and within the Puget Sound region. Acoustic thresholds established by NMFS defined the ZOIs, and each zone encompasses the area within the underwater threshold isopleths. NMFS (2018c) acoustic thresholds for the onset of Permanent Threshold Shifts (PTS) for functional hearing groups of cetaceans and pinnipeds (Table 1) were used to calculate Level A ZOIs. The NMFS thresholds for behavioral harassment that has the potential to result in disruption of behavioral patterns of cetaceans and pinnipeds was used to calculate the distance to the Level B ZOI (Table 1). Source level values described above for ESA listed fish were also used to calculate the distance to the thresholds.

The Navy has committed to a shutdown of pile driving when any marine mammal is present within the defined Level A ZOIs, and when any cetacean is detected within the Level B ZOI (NMFS 2018d). The calculated distances of these ZOIs for impact installation of 36-inch piles during the Test Pile Projet project are shown in Table 2.

Table 1. NMFS Injury and Disturbance Threshold Criteria for Underwater and Airborne Noise

	Airborne Noise (impact and vibratory pile driving) (re 20 µPa)[1]	***Underwater Vibratory Pile Driving Noise (non-impulsive sounds) (re 1 μPa^2s)***		***Underwater Impact Pile Driving Noise (impulsive sounds) (re 1 μPa^2s)***	
Marine Mammals	***Disturbance Guideline (haulout)[2]***	***Weighted PTS Onset (Level A) Threshold[6]***	***Level B Disturbance Threshold (Unweighted)***	***Weighted PTS Onset (Level A) Threshold[3, 6]***	***Level B Disturbance Threshold (Unweighted)***
Low-Frequency Cetaceans	Not applicable	199 dB SEL_{CUM}[4]	120 dB RMS (applies to both cetaceans and pinnipeds)	219 dB Peak[5] 183 dB SEL_{CUM}[4]	160 dB RMS (applies to both cetaceans and pinnipeds)
Mid-Frequency Cetaceans	Not applicable	198 dB SEL_{CUM}[4]		230 dB Peak[5] 185 dB SEL_{CUM}[4]	
High-Frequency Cetaceans	Not applicable	173 dB SEL_{CUM}[4]		202 dB Peak[5] 155 dB SEL_{CUM}[4]	
Otariidae (sea lions)	100 dB RMS (unweighted)	219 dB SEL_{CUM}[4]		232 dB Peak[5] 203 dB SEL_{CUM}[4]	
Phocidae (harbor seal)	90 dB RMS (unweighted)	201 dB SEL_{CUM}[4]		218 dB Peak[5] 185 dB SEL_{CUM}[4]	

Key: µPa = micropascal; dB = decibel; PTS = permanent threshold shift; re = referenced; RMS = root mean square; SELCUM = cumulative sound exposure level

Notes: 1. Airborne disturbance thresholds not specific to pile driver type. 2. Sound level at which pinniped haulout disturbance has been documented. This is not considered an official threshold, but is used as a guideline. 3. Dual metric acoustic thresholds for impulsive sounds: Whichever results in the largest isopleth for calculating PTS onset is used in the analysis. 4. Cumulative sound exposure level over 24 hours. 5. Flat weighted or unweighted peak sound pressure within the generalized hearing range. 6. Values being presented as the threshold are only the values for the species group's best hearing sensitivity because it is frequency weighted. These are frequency weighted thresholds determined from the minimum value of the exposure function and the weighting function at its peak (i.e., area of best sensitivity; equivalent to K+C).

Table 2. Calculated Distances to Level A and Level B Thresholds during Impact driving 36-inch Steel Piles at the Test Pile Project

Marine Mammal Group	*Behavior Threshold Level B*	*Injury Threshold Level A*
High frequency cetaceans	464 meters	900 meters
Mid-frequency cetaceans	464 meters	500 meters
Low-frequency cetaceans	464 meters	750 meters
Phocid Pinnipeds: Harbor Seal	464 meters	400 meters
Otariid Pinnipeds: Sea Lions	464 meters	50 meters

Notes: Assumes a maximum of 6,000 strikes per day. Distance calculated using source level values from Navy 2015 and 8 dB of attenuation from bubble curtain.

3 METHODS

3.1 Pile Installation

The location of the Test Pile Project is shown below in Figure 2. During construction of the project, 45 temporary 36-inch steel pipe piles and 30 temporary 14-inch steel sheet piles will be installed. Because impact driving of steel piles can produce underwater noise levels that have been known to be harmful to fish, marine mammals and marine birds, vibratory methods will be used to drive steel pipe piles except when geotechnical conditions require use of an impact hammer. A small number of piles will also require “proofing” with an impact hammer to verify their load bearing capacity. Hydroacoustic monitoring will be conducted during proofing of three 36-inch piles (Figure 3 and Figure 4). The piles chosen to be monitored will be installed in water depths that are representative of midchannel or typical water depths at the project location where piles will be driven.

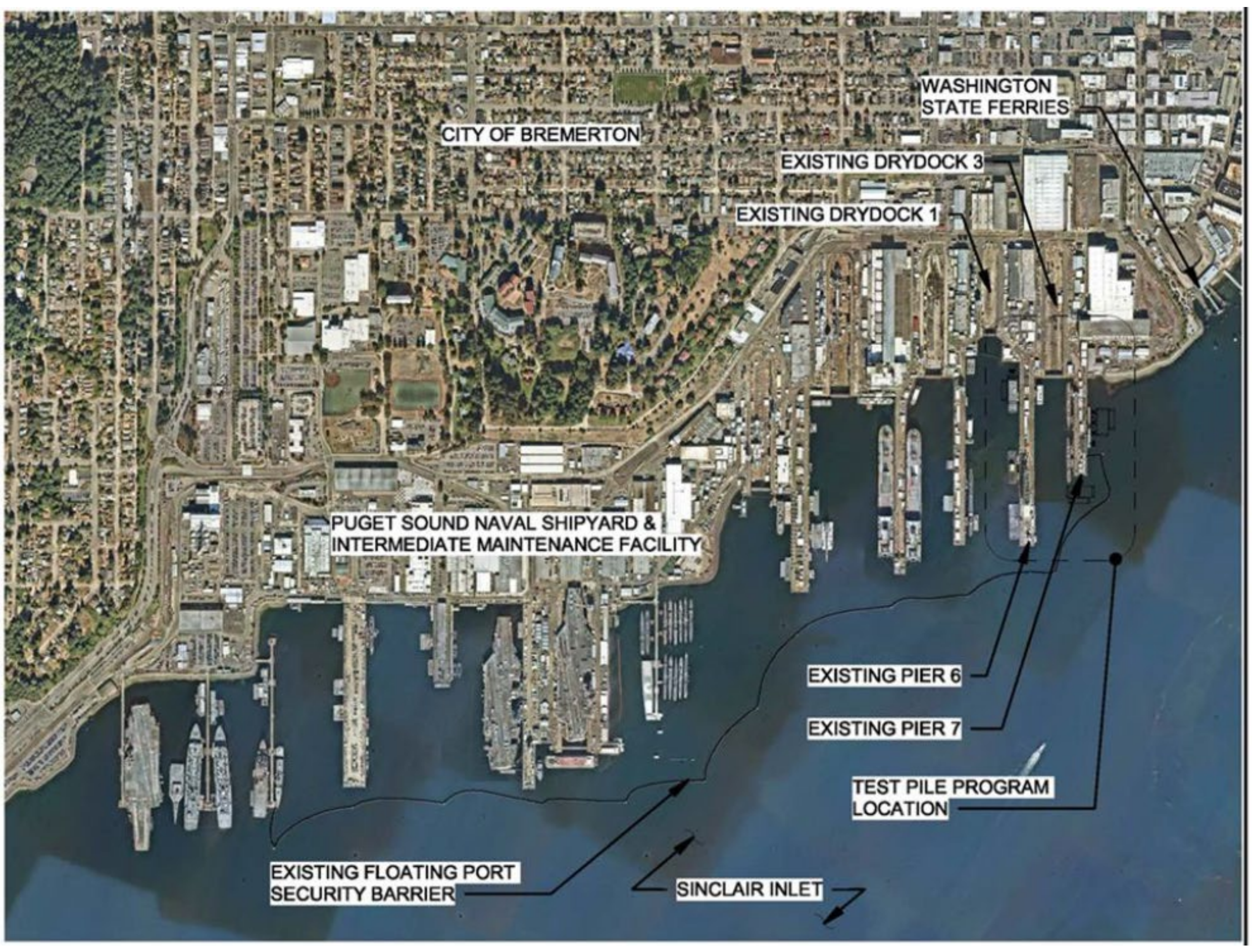

Figure 2. Overview of Test Pile Project Action Area (Black dotted line)

Figure 3. Detailed Locations of Piles

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3.2 Qualifications and Requirements

The contractor shall submit a detailed description of their qualifications, which must include a minimum of a bachelor's degree in a related field and 3 years' experience in noise monitoring and analysis. A list of the contractor's proposed sound level monitoring equipment shall be included along with specifications and a description of the purpose. The measurement range in terms of amplitude (in dB referenced to one micropascal (re: 1 uPa)), sensitivity and frequency shall be stated. A minimum frequency range of 20 Hz to 20 kHz and a minimum sampling rate of 48,000 Hz shall be used when monitoring. Sampling rates higher than 48 kHz are preferred. Section 3.3 below lists the minimum requirements of the equipment to be used. In addition to the equipment selection, quality control/quality assurance procedures should be described (e.g., how will system responses be verified and how will data be managed). To facilitate further analysis of data full bandwidth, time-series underwater signal shall be recorded as a text file (.txt) or wave file (.wav) or similar format. Recorded data shall not use data compression algorithms or technologies (e.g. MP3, compressed .wav, etc.).

3.3 Equipment

- Vessel equipped with a depth finder, measuring tape, navigational plotting equipment, and both fixed and hand-held GPS units.
- One (1) autonomous floating raft.
- Hydrophone Receiving Sensitivity- 211dB re 1V/µPa
- Hydrophone Receiving Sensitivity - 200dB re 1/µPa
- Signal Conditioning Amplifiers (4-channel) with Amplifier Gain- 0.1 mV/pC to 10 V/pC transducer Sensitivity Range- 10-12 to 103 C/MU
- One (1) Calibrator (pistonphone-type)
- One (1) Portable Dynamic Signal Analyzer (4-channel) Sampling Rate 48kHz or greater
- (one) Microphone (free field type) Range- 30 – 120 dBA Sensitivity- -29 dB ± 3 dB (0 dB = 1 V/Pa)
- Flow shield (If water velocity ~> 1m/s)- Open cell foam cover or functional equivalent
- Laptop computer or Digital Audio Recorder compatible with digital signal analyzer
- Real Time and Post-analysis software

3.4 Data Collection and Analysis

3.4.1 Methodology

Underwater background sound level measurements will follow NMFS (2012). Hydroacoustic monitoring will be conducted for four piles struck with an impact hammer. Piles chosen to be monitored are driven in water depths that are representative of mid-channel or typical water depths at the project location where piles will be driven.

Underwater noise levels during impact pile driving and the effectiveness of the noise attenuation device shall be monitored by placing one hydrophone at a distance of 10 meters from the pile to be monitored. This hydrophone can be tethered to a barge or other structure but shall be located approximately midwater depth. A second hydrophone shall be located from an autonomous floating raft at a distance of three times the depth of the pile to be monitored. There should be a direct line of sight between the pile and the hydrophone(s) in all cases.

There should be a direct line of sight between the pile and the hydrophone(s) in all cases. If water velocity is 1 meter/second or greater, 1-3 meters off the bottom may be recommended for near field hydrophones and greater than 5 meters from the surface may be recommended for any far field hydrophones. A weighted tape measure will be used to determine the depth of the water. The hydrophone(s) will be attached to a nylon cord, a steel chain, or other proven anti-strum features if the current is swift enough to cause strumming of the line. The nylon cord or chain will be attached to an anchor that will keep the line the appropriate distance from each pile. The nylon cord or chain will be attached to a float or tied to a static line at the surface. The distances will be measured by a tape measure, where possible, or a range-finder. The acoustic path (line of sight) between the pile and the hydrophone*(s)* should be unobstructed in all cases.

The hydrophone calibration will be checked at the beginning of each day of monitoring activity. NIST traceable calibration forms shall be provided for all relevant monitoring equipment. Prior to the initiation of pile driving, the hydrophone will be placed at the appropriate distance and depth as described above.

The onsite inspector/contractor will inform the acoustics specialist when pile driving is about to start to ensure that the monitoring equipment is operational. Underwater sound levels will be continuously monitored during the entire duration of each pile being driven with a minimum one-third octave band frequency resolution. The wideband instantaneous absolute peak pressure and Sound Exposure Level (SEL) values of each strike, and daily cumulative SEL, should be monitored in real time during construction to ensure that the project does not exceed its authorized take level. Peak and rms pressures will be reported in dB (re:1 µPa). SEL will be reported in dB (re: 1 $\mu Pa^2 \cdot sec$). Wideband time series recording is strongly recommended during all impact pile driving.

Prior to, and during, the pile driving activity, environmental data will be gathered, such as water depth and tidal level, wave height, and other factors that could contribute to influencing the underwater sound levels (e.g., aircraft, boats, etc.). Start and stop time of each pile driving event and the time at which the bubble curtain or functional equivalent[1] is turned on and off will be logged.

The contractor or agency will provide the following information, in writing, to the contractor conducting the hydroacoustic monitoring for inclusion in the final monitoring report: a description of the substrate composition, approximate depth of significant substrate layers, hammer model and size, pile cap or cushion type, hammer energy settings and any changes to those settings during the piles being monitored, depth pile driven, blows per foot for the piles monitored, and total number of strikes to drive each pile that is monitored.

3.4.2 Signal Processing

Post-analysis of the underwater pile driving sounds will include:

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[1] A functional equivalent must function as well as or better than the attenuation device that was proposed during consultation or required by the ESA consultation or applicable permits. It must achieve the same or better sound level reductions that were used in the calculations during ESA consultation or the permitting process.

- Number of pile strikes per pile and per day.
- For each recorded strike (or each strike from a subset), determine the following:
  - The peak pressure, defined as the maximum absolute value of the instantaneous pressure (overpressure or underpressure).
  - The root mean squared sound pressure across 90% of the strikes energy ($RMS_{90\%}$).
  - Sound exposure level, measured across 100% of the accumulated sound energy ($SEL_{100\%}$). Calculation methodology is provided in Appendix A.
- Maximum, mean, median, and range of the peak pressure with and, if applicable, without attenuation.
- Maximum, mean, median, range, and Cumulative Distribution Function (CDF) of the $RMS_{90\%}$, both with and, if applicable, without attenuation where the CDF is used to report the percentage of $RMS_{90\%}$ values above the thresholds.
- Maximum, mean, median and range of the $SEL_{90\%}$, both with and, if applicable, without attenuation.
- Cumulative SEL (cSEL) across all of the pile strikes. If SEL was calculated for all strikes, cSEL is estimated as indicated in Appendix A. If SEL was calculated for a subset of strikes, cSEL is estimated as follows: cSEL = SEL_{mean} + 10*log(total #strikes).
- Where surrogate piles are monitored to represent a larger project, an estimate of the cSEL during a typical day of construction driving must be reported by summing the SEL over the expected number of pile strikes in a typical day for the larger project: cSEL = SEL_{mean} + 10*log(#strikes). The SEL_{mean} used in this calculation must correspond with the actual sound attenuation measures that will be used during construction of the larger project.
- A frequency spectrum both with and, if applicable, without attenuation, between a minimum of 20 and 20 kHz for up to eight successive strikes with similar sound levels.

3.4.3 Analysis

Analysis of the data from the San Francisco-Oakland Bay Bridge Pile Installation Demonstration project (PIDP) indicated that 90% of the acoustic energy for most pile driving impulses occurred over a 50 to 100 millisecond period with most of the energy concentrated in the first 30 to 50 milliseconds (Illingworth and Rodkin, 2001). The RMS values computed for this project will be computed over the duration between where 5% and 95% of the energy of the pulse occurs. The SEL energy plot will assist in interpretation of the single strike waveform. The single strike SEL from the entire duration of the pile driving sequence along with the total number of strikes per pile and per day will be used to calculate the cumulative SEL for each pile and each 24-hour period. In addition, a waveform analysis of the individual absolute peak pile strikes will be performed to determine any changes to the waveform with the bubble curtain. A comparison of the frequency content with and without noise attenuation will be conducted. Units of underwater sound pressure levels will be dB (re:1 µPa) and units of SEL will be re:1 μPa^2 sec.

4 REPORTING

Preliminary results for the daily monitoring activities, if required, will be submitted/reported to Navy who will correspond with the primary points of contact[2] at NMFS. In addition, a final draft report including data collected and summarized from all monitoring locations will be submitted to the Navy, who will then submit the report to the Services within 90 days of the completion of hydroacoustic monitoring.

The results will be summarized in graphical form and include summary statistics and time histories of impact sound values for each pile. A final report will be prepared and submitted to the Services within 30 days following receipt of comments on the draft report from the Services. The report shall include:

1. Size and type of piles.
2. A detailed description of the bubble curtain, including design specifications.
3. The impact hammer energy rating used to drive the piles, make and model of the hammer.
4. A description of the sound monitoring equipment.
5. The distance between hydrophone(s) or microphone(s) and pile.
6. The depth of the hydrophones and depth of water at hydrophone locations.
7. The distance from the pile to the water’s edge.
8. The depth of water in which the pile was driven.
9. The depth into the substrate that the pile was driven.
10. The physical characteristics of the bottom substrate into which the piles were driven.
11. The total number of strikes to drive each pile and for all piles driven during a 24- hour period.
12. The median, mean, max, min of SELss, SPLrms, SPLpk, and pulse duration that is used for 90% energy window for SPLrms, as well as cSEL of each pile driven.
13. The results of the hydroacoustic monitoring, as described under Signal Processing. An example table is provided in Appendix C for reporting the results of the monitoring.
14. The distance at which peak, cSEL, and rms values exceed the respective threshold values.
15. A description of any observable fish, marine mammal, or bird behavior in the immediate area and, if possible, correlation to underwater sound levels occurring at that time.

[2] The primary point of contact is the biologist that conducted the Section 7 consultation and MMPA consultation for NMFS. In the event that the consulting biologist is not available, communication regarding monitoring results and reports should be addressed to the manager of the consultation branch or division with a reference to the consultation title.

5 REFERENCES

Illingworth and Rodkin, Inc. 2001. Noise and Vibration Measurements Associated with the Pile Installation Demonstration Project for the San Francisco-Oakland Bay Bridge East Span, Final Data Report, Task Order 2, Contract No. 43A0063.

NMFS, 2012. Guidance Document: Data Collection Methods to Characterize Underwater Background Sound Relevant to Marine Mammals in Coastal Nearshore Waters and Rivers of Washington and Oregon. Memorandum: NMFS Northwest Fisheries Science Center – Conservation Biology Division and Northwest Regional Office – Protected Resources Division, January 31, 2012.

NMFS, 2018. Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. NOAA Technical Memorandum NMFS-OPR-59. April 2018.

United States Navy, 2015. Proxy source sound levels and potential bubble curtain attenuation for acoustic modeling of nearshore marine pile driving at Navy installations in Puget Sound. Prepared by Michael Slater, Naval Surface Warfare Center, Carderock Division, and Sharon Rainsberry, Naval Facilities Engineering Command Northwest. Revised January 2015.

APPENDIX A Calculation of Cumulative SEL

An estimation of individual SEL values can be calculated for each pile strike by calculating the following integral, where T is T90, the period containing 90% of the cumulative energy of the pulse (eq. 1).

$$SEL = 10 \log \left(\int_0^T \frac{p^2(t)}{p_0^2} dt \right) \quad dB \qquad \text{(eq. 1)}$$

Calculating a cumulative SEL from individual SEL values cannot be accomplished simply by adding each SEL decibel level arithmetically. Because these values are logarithms, they must first be converted to antilogs and then accumulated. Note, first, that if the single strike SEL is very close to a constant value (within 1 dB), then cumulative SEL = single strike SEL + 10 times log base 10 of the number of strikes N, i.e, 10Log10(N). However if the single strike SEL varies over the sequence of strikes, then a linear sum of the energies for all the different strikes needs to be computed. This is done as follows: divide each SEL decibel level by 10 and then take the antilog. This will convert the decibels to linear units (or uPa^2s). Next, compute the sum of the linear units and convert this sum back into dB by taking 10Log10 of the value. This will be the cumulative SEL for all of the pile strikes.

APPENDIX B Calculation of a Cumulative Distribution Function and Plot for Background Sound Level Analysis

Data from three full 24-hour underwater measurement cycles (minimum) are used to calculate a 30 second Root Mean Square (RMS) value for each 30-second period for the entire dataset. The RMS should be calculated for both the full frequency range recorded as well as a separate dataset, which has been passed through a high pass filter thus eliminating those frequencies below 1000 Hz. These datasets are then grouped into 24-hour periods. To determine if the data is approximately log-normal in distribution, each 24-hour period is plotted as a Probability Density Function (PDF). Each 24-hour period can be plotted on the same PDF plot. The plots should be approximately log normal in distribution and thus can be used in the further analysis. Each day of data should have an approximately Gaussian sigmoid shape, the differences between them and the ideal might be hard to spot, but the sigmoid from day to day will show noticeable variation. Data which does not approximate a log normal distribution should be excluded from further analysis.

The Cumulative Distribution Function (CDF) plot is obtained by plotting the normalized cumulative sum vs. the bin location. You can also get the PDF from plotting the normalized bin count vs. the bin location. The normalized bin count is obtained by dividing the count column by (number of data points multiplied by the space between 2 consecutive bins). This provides the integral of the PDF equal to 1. For instructions on creating a histogram in Microsoft Excel, see:
http://www.vertex42.com/ExcelArticles/mc/Histogram.html