# Appendix A

# Planned Pile Replacement and Contingency Pile Estimates

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**Table A-1. Planned Pile Replacement and Contingency Pile Estimates**

| Project | Piles by Construction Year[1] | | | | | Pile Extraction | | | | Pile Installation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Pile Type | Size (in) | Qty | Method | Pile Type | Size (in) | Qty | Method |
| **NBK Bangor** | | | | | | | | | | | | | |
| Contingency | 75 | | | | | Steel<br>Timber<br>Concrete | Up to 36 | 75 | Vibratory or cut at mudline | Steel<br>Concrete | Up to 36 | 75 | Impact or vibratory |
| EHW-1 | 12 | 8 | 8 | 8 | 8 | Steel<br>Timber<br>Concrete | Up to 36 | 44 | Vibratory or cut at mudline | Steel<br>Concrete | Up to 36 | 44 | Impact or vibratory |
| **Zelatched Point** | | | | | | | | | | | | | |
| Contingency | 20 | | | | | Timber | 12 | 20 | Vibratory or cut at mudline | Steel<br>Timber<br>Concrete | Up to 36 | 20 | Impact or vibratory |
| **NBK Bremerton** | | | | | | | | | | | | | |
| Contingency | 75 | | | | | Steel<br>Timber | Up to 24<br>Up to 14 | 75 | Vibratory/ choke & pull | Concrete | Up to 24 | 75 | Impact |
| RM021-05 Replace Fender Pile Pier 5 | - | 360 | - | - | - | Timber | Up to 14 | 360 | Vibratory/ choke & pull | Concrete | Up to 24 | 360 | Impact |
| RM1114785 Piers 5, 6, 7, Mooring A & Dry Dock 5 – Concrete Repairs | - | - | - | - | 20 | Timber | Various | 20 | Vibratory/ choke & pull | Sheet steel | Various | 20 | Vibratory |
| Pier 4, Replace Fender Piles | - | 80 | - | - | - | Timber | Up to 14 | 80 | Vibratory/ choke & pull | Steel | Up to 14 | 80 | Vibratory |

[1] Pile construction is anticipated in these years but potentially could be moved to a different year.

**Table A-1. Planned Pile Replacement and Contingency Pile Estimates**

| Project | Piles by Construction Year[1] | | | | | Pile Extraction | | | | Pile Installation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | Pile Type | Size (in) | Qty | Method | Pile Type | Size (in) | Qty | Method |
| **NBK Keyport** | | | | | | | | | | | | | |
| Contingency | 4 | 4 | 4 | 4 | 4 | Concrete<br>Steel | Up to 18 | 20 | Vibratory | Steel | Up to 36 | 20 | Impact or vibratory |
| **NBK Manchester** | | | | | | | | | | | | | |
| Contingency | 50 | | | | | Timber<br>Plastic | Up to 18 | 50 | Vibratory/ choke & pull | Timber<br>Plastic<br>Concrete | Up to 18<br>Up to 24 | 50 | Impact |
| **NAVSTA Everett** | | | | | | | | | | | | | |
| Contingency | 76 | | | | | Steel<br>Timber | Various | 1<br>75 | Vibratory/ choke & pull | Steel<br>Concrete<br>Timber | 36<br>Up to 24 | 1<br>75 | Impact or vibratory |
| RM10-7403 North Wharf Repairs | - | - | 2 | - | - | Concrete | - | 2 | TBD | Concrete | - | 2 | Impact |

[1] Pile construction is anticipated in these years but potentially could be moved to a different year.

# Appendix B

# Proxy Source Sound Levels and Potential Bubble Curtain Attenuation for Acoustic Modeling of Nearshore Marine Pile Driving at Navy Installations in Puget Sound

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# Proxy Source Sound Levels and Potential Bubble Curtain Attenuation for Acoustic Modeling of Nearshore Marine Pile Driving at Navy Installations in Puget Sound

**Revised**
**January 2015**

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## 1.0 BACKGROUND

The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) issue incidental take for Endangered Species Act (ESA)-listed species potentially adversely affected by the Navy's activities. This includes sound pressure levels (SPLs) produced from pile driving. Incidental take statements (ITS) are an outcome of Section 7 consultations and addressed in the Biological Opinions. The NMFS also issues authorizations for noninjurious take (Level B) for marine mammals for noise produced by pile driving. Such take provisions are authorized by the Marine Mammal Protection Act.[1]

ITS often authorize incidental take by the area encompassed within zones above noise thresholds for ESA-listed fish. ITS for other animals such as marbled murrelets and marine mammals are based upon the number of animals anticipated to occur in the zones above the noise thresholds. For example, the peak SPL for the onset of injury threshold for fish is 206 dB referenced to 1 micropascal (µPa)[2]. If actual project noise exceeds the extent of the modeled authorized area, the project would exceed authorized incidental take allotted in the ITS. Consequently, the project would be required to reinitiate consultation under Section 7 of the ESA and a shut-down of impact pile driving would occur until a new ITS is issued. For marbled murrelets and marine mammals, injurious incidental take is avoided by monitoring areas exceeding the injury thresholds. If an animal enters this area, pile driving is shut down until it leaves. In addition, there can be provisions in an ITS or MMPA authorization allocating incidental take for potential behavioral disturbance. In this case, monitoring is required within the behavioral disturbance zones. Therefore, accurate establishment of the extent of the area exceeding established thresholds is essential to complying with the terms of an ITS or MMPA authorization.

When possible data obtained for a given site are used to predict expected source levels. However, for most project sites, prior measurements of the extent of pile driving noise have not been made. For these sites the extents of the areas where noise exceeds threshold values are modeled with an equation for sound propagation using proxy values for the source pile driving levels. Proxy source values are therefore either from prior measurements obtained on-site by installing the same type and size of piles or, when site specific information is lacking, obtained from the same or most similar type and size pile at locations with a similar sound environment. Other important factors include the type of equipment used to install the pile, substrate type, and water depth, all of which result in variations in pile driving noise levels. Detailed analyses of these factors are beyond the scope of this source document. The following section considers the rationale we used when reviewing proxy impact and vibratory pile driving source values for

[1] New NMFS criteria using frequency weighted (filtered) responses are in development, with new standards anticipated. The current revision of this document does not include frequency weighted results; such results will be promulgated in a revised edition.
[2] All peak and root-mean-square (RMS) sound pressure levels in this document are referenced to 1 µPa. All sound exposure levels (SEL) in this document are referenced to 1 $\mu Pa^2$-second. All peak SPLs in this document refer to absolute peak overpressures or under pressures.

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noise threshold metrics. We first discuss the available data included in the review. Second, we discuss the values for each threshold metric (peak SPL, root-mean-square [RMS], and sound exposure level [SEL]) that will result in a high likelihood of encompassing the extent of actual project noise levels. Last, we review relevant data available for various types and sizes of piles typically used for pile driving and recommend proxy source values for Navy installations in Puget Sound.

Section 2 of this document is a review of attenuation levels reported for various impact pile driving projects.

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# 2.0 PROXY SOURCE SOUND LEVELS FOR ACOUSTIC MODELING OF NEARSHORE MARINE PILE DRIVING AT NAVY INSTALLATIONS IN PUGET SOUND

## 2.1 UNDERWATER PILE DRIVING SOURCE LEVELS

### 2.1.1 Data Sources

Differences in underwater source levels for a given pile size and type will vary because of differences in geologic conditions, water depths where piles are installed, and pile driver type. In other words, the same size pile and type may generate different noise characteristics when installed in dissimilar environments. To obtain source values and model distances to the USFWS and NMFS thresholds for nearshore marine environments at Navy installations in Puget Sound, we reviewed available values from multiple nearshore marine projects obtained from the California Department of Transportation (CALTRANS), Washington State Department of Transportation (WSDOT), and Navy pile driving acoustic reports. Projects were located in California, Oregon, and Washington. Non-marine projects were excluded because of differences in substrate and/or acoustic conditions, and are not relevant herein due to the dissimilar nature from typical work performed at Navy marine facilities in Puget Sound. For example, a project located in Lake Washington and a freshwater bay (SR 520 Test Pile Project) was excluded due to very different substrate conditions present at those sites. Projects located in rivers were excluded because substrate characteristics, such as presence of bedrock, were not typical of Puget Sound. River projects also had different bathymetric profiles as well as increased current velocities. Of the projects reviewed, only measurements from unattenuated piles (e.g. a noise attenuation device was not operating[3]) were evaluated. Attachments 1 through 5 in Appendix A list the projects considered in this review.

All projects considered in the review had similar nearshore project depths from less than 5 m to approximately 15 m with the exception of Test Pile Program at Naval Base (NAVBASE) Kitsap Bangor where depths ranged from approximately 13 to 27 m. Impact pile driver type is listed in the attachments. Impact pile drivers can be drop, pneumatic, hydraulic, or diesel powered. With some exceptions at the Friday Harbor Ferry Terminal, all impact driven piles were installed with diesel powered drivers. Vibratory drivers vary only by size (energy) and type (variable moment/non-variable moment), but because of the limited data set, no attempt was made to distinguish between driver energies when reviewing noise levels produced from different impact or vibratory drivers.

Proxy values in similar marine sound environments can be challenging to obtain for pile driving because of variations in geologic conditions between projects and variability within project sites. Substrate types were not reported for most projects included in the review.

[3] Pile caps are routinely placed on top of piles prior to driving to cushion equipment. While they are recognized as providing some sound attenuation, they are not considered in this analysis because they are part of baseline sound measurement presented in many reports.

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Substrate types typical of Puget Sounds are sand/silt to sand/silt/cobbles overlying glacial till or hard clay layers. Therefore, projects located in the marine waters of Puget Sound, including the San Juan Islands, were considered more heavily because they would be more likely to share the same substrate characteristics than projects located in the San Francisco Bay area, the mouth of the Columbia River, or coastal bays. However, it should be noted that within Puget Sound a considerable variability in substrate conditions can exist between projects and within projects due to harder glacial layers and unforeseen encounters with glacial erratics (e.g. erratic rocks). Depending on the substrate type, piles may easily be advanced or, because of glacial till or submarine boulders, piles may require much more energy to drive. Piles driven to different tip elevations could also experience different driving conditions. For example, fender piles generally are not driven to the same depth as structural piles and may not encounter the same resistance during driving. Therefore, considerable variation in values is expected when looking from project to project or pile to pile within a project. To ensure proxy values are protective of species, conservative values were chosen to encompass regional and pile to pile variation. The following section considers the rationale we used when reviewing values for various sound metrics.

### 2.1.2 Other Considerations in Evaluation of Pile Driving Source Values

Proxy values need to be conservative. This ensures the area modeled above the injury thresholds is correctly assessed and remains within an ITS for fish. This approach will also preclude incidental take considered injurious based on the established injury criteria of marbled murrelets and marine mammals. In addition, proxy values are used to model the areas above the marbled murrelet and marine mammal behavioral thresholds or guidance values. Sound levels from pile driving are reported on either a per pile basis within a project, or per project summary basis. Summary data reported in acoustic reports varies, but can include one or more of the following:

- Per pile averages
- Ranges
- Minimum and maximum values
- Per project average
- Typical values
- Average range
- Minimum, maximum, average minimum
- Average maximum value
- Standard deviation.

Thus, interpretation of the reported levels may depend on the analytical methodology selected, which in turn can affect the proxy source level selected for modeling analysis. For

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example, one approach to choosing a source value is to pick the mean value from a number of projects reviewed. The results from the model utilizing this mean value will adequately characterize the estimated average extent of noise from pile driving. However, depending on the pile to pile variability it would only characterize the area for individual piles if the pile to pile variability in the source data were low. If the data were highly variable, the extent of the area above the threshold would be smaller or larger than described by the model on a per pile basis. Therefore, on-site monitoring of pile driving noise could exceed the modeled values on a significant portion of the piles. Another, but more conservative approach is to select the proxy source value from the highest value of all values reported. This method would ensure that most, if not all, measured values on a pile by pile basis would be below the selected value, but could significantly overestimate the area or extent of biological impact.

In the section below we outline the rationale we used for selecting proxy values from the available data for each threshold metric. Values were chosen to ensure that a reasonable worst case scenario is modeled to estimate the extent of noise from pile driving.

#### 2.1.2.1 ROOT MEAN SQUARE

The root-mean-square (RMS) value is the metric used to define the behavioral zones for fish, marbled murrelets, and marine mammals. For piles that are impact driven, RMS values are generally reported for individual piles over the duration of the driving of a given pile; often the number of strikes is also reported on a per-pile basis. Thus, in order to best characterize a broad-base proxy SPL, average RMS pressures were computed from the reported SPL (dB) values, and then weighted by the number of pile strikes for a given pile. This weighting methodology estimates proxy values across multiple projects with differing numbers of piles or strike counts, and the effect of using weighting values ensures that a single project or pile does not overtly bias the result high or low. This proxy value represents the most likely value expected for individual pile strikes for a typical project.

For piles that are vibratory driven, RMS values are typically computed over 10-second or 30-second averaging periods, and represent the most probable typical value over a long event. Thus, recommended proxy RMS values for vibratory and impact pile driving are computed using different techniques. For vibratory piles, reported values were selected on a pile-by-pile basis for a given pile type and size. An average value was computed by converting selected SPL values (dB) into pressure values, summing them together in linear space, dividing by the total number, n, of selected piles, and converting the result back to SPL (dB). In following this approach, the proxy value represents the arithmetic average value for each pile type and size from applicable projects. Thus, for vibratory driven piles averaged RMS values were used from all applicable projects as a representative average level of long-term pile driving events.

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Weighted SPL averages are computed by first converting all SPL values to linear space, weighting pressure values by the number of events (for example, by number of strikes, *n*), normalizing by dividing by the number of events, and then converting back to SPL. Using *k* as an index counter for all piles, 1 = pile #1, 2 = pile #2, etc.:

$$Weighted\ SPL = 10\log_{10}[\frac{1}{n_{total}}\sum_{k=1}^{n_{total}}(n_k P_k)]$$

where

$$n_{total} = n_1 + n_2 + n_3 \ldots$$

Charts depicting the behavior of the measured data used to prepare proxy values within this document are presented in Appendix B. Two types of charts are provided. First, for all data types, a sorted chart showing amplitude for all piles included, recommended proxy value, and when available, minimum and maximum levels observed. Next, the cumulative probability distribution function charts are provided for all pile sizes, with the recommended proxy value annotated on each chart.

#### 2.1.2.2 PEAK SOUND PRESSURE LEVEL

The peak sound pressure level (SPL) metric is used to evaluate the potential for injurious effects to fish. The barotrauma injury to fish due to peak over or under pressurization could result in instantaneous injury with a single strike. Average peak impact SPL values were selected from applicable projects, from which a weighted probability distribution function (PDF) was computed based on the number of pile strikes for each pile. To ensure a conservative proxy value, a value representing the ninetieth percentile of the PDF was selected, meaning that for a typical impact pile driving project, 90% of all pile strikes would typically occur below this proxy value. Use of this value ensures potentially injurious effects to fish would have a high likelihood of being within the area exempted for incidental take.

#### 2.1.2.3 SOUND EXPOSURE LEVEL

The sound exposure level (SEL) metric for impact driving is used to calculate the area of cumulative exposure potentially resulting in injury to fish or marbled murrelets over a daylong pile driving event (the accumulation of energy received from all pile strikes). To compute the cumulative SEL all single strike SEL energy in a workday is summed to calculate the overall SEL. However, modeling for the SEL "dosage" generally involves estimation of a typical single pile value logarithmically added to sum the expected energy over the day. While some strikes may be lower and some higher than the mean SEL value, use of the mean value would result in the best overall estimate of expected cumulative energy over the work day. In practice, the SEL value will vary on any given workday due to variability in the levels measured for each individual strike. The acoustic reports reviewed typically provided the mean single strike SEL per pile. Therefore, the most representative estimate of the single strike SEL for a proxy value is

to use a mean SEL value from data from all piles in applicable projects. Furthermore, to avoid biasing the data high or low from a single pile or project, a weighted average was computed using the number of pile strikes, *n*, in the same manner as was followed for computation of impact RMS values. This approach ensures that a single project or pile does not bias the result high or low. This proxy value represents the most likely value expected for individual pile strikes for a typical project.

### 2.1.3 Impact Driving Source Values

Table 2-1 summarizes projects from Attachment 1 in Appendix A that were considered in the final analysis and highlights proxy values. Theses highlighted proxy source values are reasonably conservative for modeling future Navy pile driving projects in Puget Sound. Detailed discussions of the projects considered and the values obtained for each pile type and size are provided below.

**Table 2-1. Summary of Unattenuated Impact Pile Driving Levels Considered. Recommended Proxy Source SPLs at 10 m Bolded.**

| Pile Size | Number of Projects Considered[1] | Range of Average RMS (n-weighted pile average) dB re 1µPa | Range of Average Peak (90% PDF value) dB re 1µPa | Range of Average SEL (n-weighted pile average) dB re 1µPa |
|---|---|---|---|---|
| **Steel** | | | | |
| 24-inch | 2 | 181-198 (**193**) | 196-213 (**210**) | 176-185 (**181**) |
| 30-inch | 3 | 192-196 (**195**) | 203-217 (**216**) | 182-187 (**186**) |
| 36-inch (all projects) | 3 | 185-196 (**192**) | 202-211 (**211**) | 173-186 (**184**) |
| 36-inch (Bangor only) | 1 | 185-196 (**194**) | Not reported[3] | 173-183 (**181**) |
| All 24/30/36-inch | 7 | 181-198 (**193**) | 196-217 (**211**) | 173-193 (**184**) |
| **Concrete** | | | | |
| ≤18-inch | 3 | 158-173 (**170**)[2] | 172-188 (**184**)[2] | 147-163 (**159**)[2] |
| 24-inch | 7 | 167-179 (**174**)[2] | 180-191 (**188**)[2] | 158-167 (**164**)[2] |

**[1]See Appendix A, Attachment 1 and 2 for projects reviewed.**
**[2]Number of pile strikes, *n*, was not available for any concrete projects; all piles were equally weighted.**
**[3]Although absolute peak values were collected for TPP testing, average peak values were not reported; unattenuated data from EHW-2 was not collected.**

#### 2.1.3.1 24-INCH STEEL PILE IMPACT DRIVING SOURCE VALUES

Attachment 1 in Appendix A lists six marine nearshore projects reviewed for possible inclusion in the analysis. Data for one 24-inch pile installed with an impact hammer in the Test Pile Project at NBK Bangor are listed in Attachment 1. However, only 7 pile strikes were reported and measurements from this pile are lower than all of the other five projects reviewed. Therefore, these data were not considered in the selection of the most conservative value. Of the remaining five projects reviewed, the Bainbridge Island Ferry Terminal Preservation Project and the Friday Harbor Restoration Ferry Terminal project were considered as the most representative

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of typical glacial till and erratics encountered in Puget Sound and were carried forward in the analysis. We based this on the assumption that substrate conditions are more similar than those found in San Francisco Bay or the mouth of the Columbia River.

For the two ferry terminal sites, five piles were driven at Bainbridge Island in substrate that consisted of a mix of sand and fist-sized rocks with occasional rocks one-foot in diameter. At Friday Harbor six piles were driven into a silty sand substrate approximately 9 meters thick and underlain by a hard clay lens. Three of the piles at this site encountered a large rock ledge approximately 10.7 meters below the mudline. One of the six piles in the project had the high end of the data clipped[4] and therefore invalid, so this pile was excluded from the analysis. This project used different hammer types, but because the report noted little variation in the data, all five remaining piles were included in our review. Data from the two ferry projects only included values without a bubble curtain attenuator operating, i.e. no attenuation.

Source levels for each metric reviewed are discussed below. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 1 for the two ferry terminal projects.

**RMS SPL**

Weighted average proxy RMS source values for the two Puget Sound ferry terminal projects were 189 dB (range 181 dB to 193 dB) and 195 dB (range 193 dB to 198 dB) (Attachment 1), representing 1007 pile strikes. Therefore, actual RMS values would be expected to fall between 181 dB and 198 dB. The weighted average RMS value of 193 dB was chosen as a conservative value that likely encompasses the average extent of the area exceeding the injury thresholds for marine mammals and the behavioral thresholds for marine mammals, fish and marbled murrelets.

**Peak SPL**

Average peak SPLs reported for individual piles at the Bainbridge Island and Friday Harbor projects were 202 dB to 209 dB and 196 dB to 213 dB, with an average weighted value of 207 dB. Of the applicable projects, the 90% probability from the weighted cumulative distribution density function value of 210 dB was chosen as a conservative proxy value that likely encompasses the modeled extent of the area over the onset of injury threshold for fish. Table 2-1 summarizes the values from the two projects considered likely to be most representative.

**SEL**

Mean weighted SEL values for the two Puget Sound projects reviewed are each 181 dB for all piles. The mean SEL per any one pile for both projects ranged from 176 and 185 dB. These

[4] Clipping occurs when a signal exceeds the linear limits of an electronics system in essence the extreme levels of the signal are truncated or "clipped" off. For pile driving measurements, clipped data can produce results that are lower than the actual signal of interest, thus producing invalid results.

values are higher than the values reported for the other three projects reviewed (project SEL means that ranged from 168 to 177 dB). Therefore, the Washington projects were considered the most conservative and a mean weighted SEL of 181 dB was chosen as a reasonable proxy value of the overall SEL for 24-inch piles.

#### 2.1.3.2 30-INCH STEEL PILE IMPACT DRIVING SOURCE VALUES

Data for 30-inch steel pipe piles were available from three marine pile driving projects in Puget Sound, Washington and one project from San Francisco Bay, California. No projects from Bangor were available for analysis, and data from the California project provided only typical data, and did not provide per-pile SPL or number of strikes for each pile (see Attachment 1 in Appendix A). All available data in Attachment 1 were reviewed. However, as with the 24-inch pile source values, values from the Puget Sound projects were considered the most representative of source values because of similar substrate characteristics and are the only values considered in the Table 2-1 summary. Note that data from the Vashon Island project were acquired from 7m to 16m from the pile, and were normalized using a $15 \cdot \log_{10}(\text{range}/10\text{m})$ relationship.

**RMS SPL**

Average RMS source values for three Puget Sound projects ranged from 192 dB to 196 dB. The minimum average value reported for any one pile is 192 dB (Eagle Harbor Ferry Terminal) and a maximum average reported of 196 dB (Vashon Island Ferry Terminal, two piles). The RMS values from three Puget Sound projects were moderately higher than values measured from the California project considered, which reported a typical RMS value 190 dB. A conservative proxy RMS value is the weighted average value of 195 dB from the three projects in Puget Sound representing 263 pile strikes. This value would be a reasonable worst case ensuring that noise levels modeled would have a high likelihood of not exceeding this value.

**Peak SPL**

Average peak SPLs reported from the Puget Sound projects with available data ranged from 203 dB to 217 dB (n=3 projects) on a per-pile basis, with a computed weighted average of 214 dB. Levels from three piles at Eagle Harbor Ferry Terminal range from 7 to 11 dB quieter than those measured at two other Puget Sound sites, indicating a significant variability between sites. The typical peak SPL reported for the single California project was 205 dB, which was noted to be on the lower end of the range of data reported from Puget Sound, although the number of pile strikes was not reported, thus this data were not included in the weighted average for 30” peak values. The 90% weighted cumulative probability value of 216 dB was chosen as a reasonable and conservative proxy value.

**SEL**

Average per-pile SEL values were reported for the two Puget Sound Projects representing 214 pile strikes; the Eagle Harbor project did not report single strike SEL levels, and a California

project did not report any SEL levels. SEL values from the two applicable projects ranged from 182 dB to 187 dB with an overall weighted average of 186 dB. Thus, a reasonable conservative SEL source value for future projects in Puget Sound is 186 dB derived from the weighted value of reported Puget Sound levels.

#### 2.1.3.3 36-INCH STEEL PILE IMPACT DRIVING SOURCE VALUES

Data for 36-inch steel pipe piles were available from three marine pile driving projects in Puget Sound, Washington and one project from Humboldt Bay along the California coast (Attachment 1 in Appendix A). All projects installed piles with a diesel hammer. The Humboldt Bay project did not report number of pile-strikes, and furthermore, this pile was only measured by re-striking a pile that had already been driven. Therefore, this project was excluded from the 36-inch average value computations. Data from two piles measured during the NBK Bangor Test Pile Program were at 11m and 20m from the pile, and were normalized using a $15 \cdot \log_{10}(\text{range}/10\text{m})$ relationship.

**RMS SPL**

Average RMS source values for the three Puget Sound projects ranged from 185 dB to 196 dB, representing 662 pile strikes, the full range of which were observed during the Test Pile Program at NBK Bangor project. The weighted average value for these projects was 192 dB, and represents a reasonable proxy RMS value for impact driven 36-inch piles. The average RMS value of 193 dB reported for the 36-inch pile from the Humboldt Bay Bridge project in California fell within the range of values for the three Washington 36-inch pile projects reviewed, although as previously discussed, this value was not included in the averaging calculations. Considering just the Test Pile Program at Bangor, 121 pile strikes produced a set of measurements ranging from 185 to 196 dB, with a weighted average value of 194 dB.

**Peak SPL**

Average peak SPLs reported from two Puget Sound projects ranged from 202 dB to 211 dB on a per-pile basis, representing 541 pile strikes. Average peak values were not reported for the NBK Bangor project. A proxy peak value of 211 dB was chosen representing the 90% cumulative probability SPL.

**SEL**

Average SEL values were reported for three Puget Sound projects, with 662 pile strikes measured. SEL values ranged from 173 dB to 186 dB with an overall weighted average of 184 dB, the recommended proxy value for piles driven in Puget Sound. Only one value was reported for the Humboldt Bay project, 183 dB, which was within the range of values reported in Puget Sound. A reasonable conservative SEL source value for future projects in Puget Sound is 184 dB derived from the weighted average of three Puget Sound projects. Analyzing data from

just the NBK Bangor project resulted in a weighted average value of 181 dB, with a data range of 173 to 183 dB.

#### 2.1.3.4 COMBINED STEEL PIPE IMPACT DRIVING SOURCE VALUES

Review of RMS, average peak, and SEL values for steel pipe piles of 24, 30, and 36-inches shows that often only slight differences are noted across the three sizes (see Table 2-1). In some cases, weighted average values for smaller piles are higher than for larger piles, even if by only one or two decibels. For this reason a combined analysis was done for each of the metrics to investigate the potential value of preparing overall average values over multiple sizes of steel pipe piles. Each of the metrics is discussed in the following paragraphs.

**RMS SPL**

Average RMS values over 24, 30, and 36-inch piles ranged from 181 dB to 198 dB, although weighted averages were very close, 193, 195, and 192 dB, respectively, with an overall weighted average value of 193 dB. 30-inch piles (three projects located in Puget Sound, not including any NBK Bangor projects) produced average RMS levels of 195 dB, higher than both 24-inch and 36-inch average values. Even though few piles and a lower number of pile strikes were measured with 30-inch piles, the scatter in the points measured only ranged from 192 to 196 dB, without a large deviation. 24-inch and 36-inch piles have larger data sets, but nonetheless, the recommended proxy value for each of these sizes is only a few decibels different. Figure B-4 in Appendix B graphically shows how the scatter for each pile size compares with other pile sizes. While it is reasonable to assert that RMS impact values for steel pipe piles can be represented by a single, composite value of 193 dB, additional data is recommended to be collected to increase the size of the analysis sample set.

**Peak SPL**

Peak SPL values varied over a broader range than RMS values, although 24- and 36-inch 90% cumulative probability results were within 1 dB, representing 1,669 pile strikes. 30-inch results were measurably higher than either 24- or 36-inch data, represented by fewer piles, and fewer strikes (263 strikes). Furthermore, 30-inch pile data is somewhat bi-modal in behavior, with three values near 203 to 204 dB, and four in the 211 to 217 dB range, and nothing in between. Figure B-11 in Appendix B graphically shows the distribution of levels by pile size. Three piles represented in the 211 to 217 dB range were measured from distances other than the standard 10 meter de facto measurement range, which were corrected using the traditional practical spreading model. Although not necessarily incorrect, this serves to increase the uncertainty of those measurements. Since none of the 30-inch (nor 24-inch measurements) represent data acquired directly from NBK projects, it makes sense to prepare a broader analysis to consider different pile sizes for the purpose of increasing confidence in the estimated peak values. The 90% cumulative distribution value for all 24-, 30-, and 36-inch applicable projects is 211 dB, represented by 1,932 pile strikes, and is the recommended proxy value for NBK Bangor

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projects, especially those using 24-inch and 30-inch steel pipe piles, until such time that Bangor-specific data can be acquired using these pile sizes.

**SEL**

Weighted average SEL values for 24-, 30-, and 36-inch piles also resulted in somewhat anomalous data with 30-inch steel pipe piles, with both 24-inch and 36-inch data producing lower values. As described above, the 30-inch data set includes range corrected values, and furthermore, only represented 4 piles, since single strike SEL values were not reported for one of the Puget Sound projects (Eagle Harbor Ferry Terminal). Figure B-16 in Appendix B shows the data grouping by pile size. This gives rise to increased uncertainty in the 30-inch average vales.

There is some evidence that SEL values for 36-inch piles at NBK Bangor (182 dB, weighted average) is lower than a proxy value including Puget Sound projects (184 dB). This conclusion is drawn from a modest sample size (4 piles, 121 strikes) of NBK Bangor measurements. Similar analyses could not be done with 24- and 30-inch piles, since these data did not exist for NBK Bangor projects.

Taken in summary, there is motivation to compute a single proxy value for all 24-, 30-, and 36-inch steel pipe piles, but this approach is not recommended at this time due to the uncertainty in the data scatter, and different results among RMS, SEL, and peak metrics. Additional data should be collected before using combined analyses.

#### 2.1.3.5 18-INCH CONCRETE PILE IMPACT DRIVING SOURCE VALUES

Attachment 2 in Appendix A lists three marine nearshore projects that monitored sound levels during installation of 18-inch or similar (16-inch) concrete piles, none of which were conducted in Puget Sound. Two projects were conducted at the Berkeley Marina in San Francisco Bay, California, one in 2007 and one in 2009 using 18-inch concrete piles. Acoustic measurements were only collected for four piles total for both projects. Water depth was fairly shallow ranging from 3 to 4 meters. Source levels for each metric reviewed are discussed below. Another project located near Concord, CA at the Naval Weapons Station (NWS) drove five 16-inch concrete piles, with water depth of 10 meters. Source values for this project were similar to those for the Berkeley Marina projects, and thus data from the Concord NWS were included in the analysis. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 2 and highlights recommended proxy source values. Since the number of pile strikes for all concrete projects were not reported, pile averages were computed.

**RMS SPLs**

Average RMS values for three projects using 16 or 18-inch concrete piles ranged from of 158-173 dB (Table 2-1), with an average RMS value of 170 dB over 9 piles, selected as a conservative value likely to encompass the maximum extent of the area exceeding the behavioral thresholds and guidance for marine mammals, fish and marbled murrelets. No concrete pile

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levels exceed the RMS injury thresholds established for marine mammals (180 dB RMS for cetaceans and 190 dB RMS for pinnipeds).

**Peak SPLs**

Average peak SPLs reported for all piles at the Berkeley Marina projects ranged from 172 dB to 188 dB. Because only three projects with relatively small samples sizes were available for review, a per-pile average value of 184 dB was chosen as the recommended SPL proxy value for all piles. This value is below the threshold for the onset of injury in fish (206 dB). Table 2-1 summarizes the values from these projects.

**SEL**

Two average SEL values of 155 and 159 dB were reported for the two Berkeley marina projects, both with very small sample sets ranging from 147 dB to 163 dB. SEL data were not acquired for the Concord NWS project. The per-pile average value of 159 dB SEL was selected as the most conservative proxy value available for 18-inch concrete piles until additional data are obtained.

#### 2.1.3.6 24-INCH CONCRETE PILE IMPACT DRIVING SOURCE VALUES

Only one value from a single 24-inch concrete pile was available for the Mukilteo Ferry Terminal in Puget Sound. Therefore, we reviewed seven additional marine projects: six in San Francisco Bay, California, and one in Humboldt Bay, California (Attachment 2 in Appendix A). Note that some of the San Francisco Bay projects included data from the same site in two different time periods. Two projects (Humboldt State Floating Dock and Pier 40 Marina) included piles that were driven using a jetting technique, often in combination with a reduced level of fuel to minimize driving energy. Piles driven under these circumstances were not included in the calculation of piles averages. Table 2-1 summarizes unattenuated impact pile driving source data from Attachment 2 and highlights recommended proxy source values.

**RMS SPLs**

The one pile in Puget Sound reported a maximum RMS value of 170 dB, with average values reported for the California projects ranging from 167 dB RMS to 179 dB RMS. The recommended proxy source value was chosen from the highest average pile value over all projects, 174 dB RMS (Table 2-1). No concrete pile noise levels exceed the RMS injury threshold established for pinnipeds (190 dB RMS), nor the RMS injury threshold for cetaceans (180 dB RMS).

**Peak SPLs**

Average Peak SPLs reported for projects ranged from approximately 180 dB to 191 dB. The per-pile 90% cumulative probability value of 188 dB was chosen as the recommended proxy peak SPL value. This value is below the peak threshold for the onset of injury in fish (206 dB). Table 2-1 summarizes the values from the two projects.

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**SEL**

Sound exposure levels were only reported for six of the eight projects reviewed, with per-pile values ranging from 158 dB to 167 dB (Table 2-1). The pile SEL average over all projects of 164 dB was considered representative of a conservative average SEL source value for 24-inch piles.

### 2.1.4 Vibratory Pile Driving Source Values

NMFS has established non-impulsive injury thresholds (180 dB RMS for cetaceans, 190 dB RMS for pinnipeds) and a disturbance threshold (120 dB RMS) for marine mammals. Vibratory driving is considered a non-impulsive sound source. Attachment 3 in Appendix A contains a list of vibratory projects and derived proxy source values we reviewed in order to calculate how far sound from vibratory driving exceeds the thresholds discussed in Section 1.2.1. Table 2-2 presents the summary of vibratory pile driving data from the projects reviewed. Due to the similarity in levels across multiple projects, 16-inch and 24-inch piles were considered together, and 30-inch and 36-inch piles were considered together.

**Table 2-2. Vibratory Pile Driving SPLs.***
**Recommended Proxy Source SPLs at 10 m Bolded.**

| Pile Size and Type | Number of Projects Considered[1] | Range of Average RMS dB re 1µPa @ 10 meters | Reasonable Source Level dB re 1µPa dB @ 10 meters |
|---|---|---|---|
| **Timber** | | | |
| 12-inch | 1 | 152-155[2] | **153[2]** |
| **Steel Pipe** | | | |
| 16-inch and 24-inch | 4 | Bangor 153-162<br>All projects 159-162 | **161** |
| 30-inch and 36-inch | 7 | Bangor 166<br>All projects 159-172 | **NBK Bangor 166**<br>**Other Puget Sound Locations 167** |
| **Steel Sheet** | | | |
| 24-inch | 3 | 160-163** | **163** |

**[1]See Attachment 3 for projects reviewed.**
**[2]Data reported at 16m, converted to equivalent range of 10m using $15Log_{10}[16/10]$ range correction factor.**
* Recommended values for 10 meters unless otherwise indicated.
**Highest value for pile; value includes some averages from only top or bottom depth measurements and one from top and bottom averaged.

#### 2.1.4.1 TIMBER PILE VIBRATORY DRIVING SOURCE VALUES

Only one timber pile study is available and only for noise measurements taken during extraction of one 12-inch diameter pile (see Attachment 3 in Appendix A). The highest RMS value was 152 dB measured at 16 meters (Table 2-2), with an average value of 150 dB reported at 16 meters.

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#### 2.1.4.2 24-INCH DIAMETER STEEL PIPE PILE VIBRATORY DRIVING SOURCE VALUES

Two projects in Washington and one in California were reviewed for 24-inch diameter steel pipe piles. The Washington marine projects at the Friday Harbor Terminal and NBK, Bangor waterfront, only measured one pile each, but reported similar sound levels of 162 dB RMS and 159 dB RMS (range 157 dB to 160 dB), respectively (see Attachment 3 in Appendix A). Because only two piles were measured in Washington, the California project was also included in the analysis. The California project was located in a coastal bay and reported a "typical" value of 160 dB RMS with a range 158 to 178 dB RMS for two piles where vibratory levels were measured. Caltrans summarized the project's RMS level as 170 dB RMS (Table I.2-3 in Caltrans 2012), although most levels observed were nominally 160 dB. A fourth project at NBK, Bangor drove 16-inch hollow steel piles, and measured levels similar to those for the 24-inch piles; therefore these data were included in the 24-inch analyses. Although the data set is limited to these four projects, close agreement of the levels (average project values from 159 to 162 dB at 10 meters) indicate similar vibratory conditions at NBK, Bangor. The highest project average of 162 dB was selected as the most reasonable proxy for 24-inch steel pipe piles. This number is higher than the data from the Bangor Test Pile Program and is therefore conservative.

#### 2.1.4.3 30-INCH AND 36-INCH DIAMETER STEEL PIPE PILE VIBRATORY DRIVING SOURCE VALUES

Five projects were reviewed for 30-inch diameter piles and four projects were reviewed for 36-inch diameter piles, with a total sample set of seven projects since some projects used both 30-inch and 36-inch piles. All projects were located in Puget Sound. Because the 30-inch diameter pile average RMS measurements overlap (164 dB, 168 dB, 170 dB, and 171 dB) the measurements reported for 36-inch diameter piles at the Bangor waterfront, the Edmonds and Anacortes ferry terminals range (159 dB, 162.5 dB, 169 dB, respectively), the 30-inch and 36-inch pile data were combined for the review.

We reviewed data from Bangor waterfront projects for 30 and 36-inch piles, which were based on a large sample size relative to other projects (n~68 piles, Attachment 3). RMS vibratory average levels were consistently lower at Bangor than other Puget Sound locations. We recommend using the site-specific data average RMS level for modeling vibratory pile driving at NBK, Bangor, that is, the recommended RMS vibratory installation proxy source value 30-inch to 36-inch diameter piles is 166 dB. Because site specific data is unavailable for all other Navy installations in Puget Sound, we recommend the more conservative proxy value of 167 dB for other Puget Sound Navy sites, which represents the average level for all Puget Sound locations excluding NBK, Bangor for both 30-inch and 36-inch piles.

Table 2-2 summarizes the ranges for the combined size category. Table 2-2 presents reasonable proxy values expected from reviewing values taken from the highest average project SPL for all projects reviewed.

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#### 2.1.4.4 24-INCH STEEL SHEET PILE VIBRATORY DRIVING SOURCE VALUES

Sound levels for vibratory sheet pile driving were reported for three Caltrans projects at the Port of Oakland in San Francisco Bay (see Attachment 3in Appendix A). No data were found for sheet pile driving in Puget Sound. RMS values were only available for one pile at one project and this had an average RMS value of 163 dB. The second project reported 1 sec SEL levels at 10 m for 5 vibratory driven sheet piles. The average per pile SEL ranged from 157 to 160 dB based on the average top and bottom depth measurements. Caltrans also reported 162 dB RMS as the highest average for a single depth for the same project. The third project reported 163 dB RMS (Table I.2-3 in Caltrans 2012). Caltrans reported 160 dB RMS as the typical sheet pile value for all three projects (Table I.2-2 in Caltrans 2012). Based on the levels from the three projects, 163 dB RMS value was used as a conservative proxy value.

## 2.2 AIRBORNE PILE DRIVING SOURCE VALUES

NMFS has established an in-air noise disturbance threshold of 90 dB RMS re 20µPa (unweighted) for harbor seals, and 100 dB RMS re 20µPa (unweighted) for all other pinnipeds. Attachment 4 and Attachment 5 in Appendix A list the impact and vibratory pile driving projects, respectively, that were reviewed. Most projects report A-weighted levels. For this review, however, only unweighted data were considered. Two airborne noise values are presented for most projects: $L_{max}$ and $L_{eq}$, The $L_{max}$ is the instantaneous highest sound level measured during a specified period, or maximum noise level. It typically represents a short duration average, usually 35 milliseconds. Because impact pile driving is an impulsive sound with short durations, the signal is most appropriately characterized by the $L_{max}$ value. Proxy values for impact driving are found in Attachment 4.

The $L_{eq}$ is the equivalent steady-state noise level in a stated period of time. It contains the same acoustic energy as the time-varying noise level during the same period. $L_{eq}$ is primarily used for a steadier, non-impulsive noise. The $L_{eq}$, which averages the source over a period of time, is a better descriptor for non-impulsive sound like vibratory pile driving. These values are listed in Attachment 5 for vibratory pile driving and Table 2-3 summarizes $L_{max}$ and $L_{eq}$ data.

Review of the available literature provided two unweighted $L_{max}$ levels, both from the NBK Bangor Test Pile Program. A maximum level of 112 dB re 20 µPa was measured for 36-inch piles (n=9 piles), at the de facto measurement distance of 50 feet, and was therefore chosen as a conservative proxy value for piles 30 and 36-inches. A maximum level of 110 dB was measured for a single 24-inch pile, and was selected as the most representative value for modeling analysis.

Unweighted RMS $L_{eq}$ values of 88 dB were obtained from vibratory pile driving 18-inch steel pipe piles. A single 30-second measurement was made for 24-inch piles during the Test Pile Program at NBK, Bangor. These data fit the overall trend of smaller and larger pile sizes. The limited data set for 24-inch steel pipe, supports a reasonable representative proxy value of 92 dB.

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Limited data were available for 30 and 36-inch piles. One 30-inch pile measured at the Keystone ferry terminal fell within the range of 36-inch piles measured at Bangor., although the average value for this was 2 dB above the average value measured at Bangor. Levels measured at Vashon Island ferry terminal were made using A-weighted filters, and adjusted for range and filter type. Even after corrections were made observed levels were significantly lower than other sites, thus these data were not considered for further analysis. We therefore selected 95 dB (unweighted) as the representative $L_{eq}$ average proxy value for 30-inch and 36-inch piles. Based on the limited data available, the RMS $L_{eq}$ value for 18-inch steel pipe piles was chosen as the proxy source value for vibratory installation or removal of piles less than 24-inch regardless of pile type. The RMS $L_{eq}$ value for 24-inch steel pipe piles was chosen as the best estimate for 24-inch sheet piles.

**Table 2-3. Summary of Airborne Source Levels.**
**Recommended Proxy Source Values Bolded.[1]**

| Pile Type | Size (diameter in inches) | Installation Method | |
|---|---|---|---|
| | | Impact RMS $L_{max}$ (Unweighted) Impact | Vibratory RMS $L_{eq}$ (Unweighted) Vibratory |
| **Timber** | 12-inch | --- | --- |
| **Steel Pipe** | 18-inch | --- | **88** |
| | 24-inch | **110**[2] | **92**[2] |
| | 30-inch | --- | **95** |
| | 36-inch | **112** | **95** |
| **Steel Sheet** | 24-inch | --- | --- |

Notes: All values relative to 20µPa and at 15 m (50 ft) from pile.
[1]See Attachments 4 and 5 in Appendix A for projects reviewed.
[2] Limited data set.

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## 3.0 EVALUATION OF POTENTIAL BUBBLE CURTAIN SOUND ATTENUATION

To reduce noise produced from impact pile driving, bubble curtains are used around the pile as it is driven and can be confined or unconfined. Confined bubble curtains place a fabric shroud or rigid sleeve around the pile to hold air bubbles near the pile, ensuring they are not washed away by currents or tidal action. They are recommended when water velocities are 0.6 meters (1.6 feet per second) or greater (NMFS 2008).

None of the project locations at Naval Base Kitsap, Naval Magazine Indian Island, Naval Station Everett, Naval Air Station Whidbey Island Seaplane Base, Manchester Fuel Depot are in high current areas; therefore, this discussion focuses on unconfined bubble curtains. Unconfined bubble curtains involve use of pressurized air injected from an air compressor on the pile driving barge through small holes in aluminum or PVC pipe around the driven pile. Noise reduction results from unconfined bubble curtains were reported from several projects. There was a wide range of effectiveness from very little measurable attenuation in some cases to high attenuation in others (Illingworth and Rodkin 2001; WSDOT 2013). Caltrans (2009) summarized the application of unconfined bubble curtain systems in various California projects and reported from 1 to 5 dB of attenuation in high current situations and 5 to 15 dB of attenuation in low current situations. Application of a multiple-ring system in a deep water, strong current setting (Benicia-Martinez Bridge) achieved 15 to more than 30 dB attenuation when driving 8-foot diameter piles. Because some sound pressure waves also propagate from the pile through the substrate and reenter the water column, not all sound pressure waves will be attenuated by a bubble curtain (Reinhall and Dahl 2011). Variability in bubble curtain performance when measured at various distances out from the pile is likely explained by the sound propagation properties of various substrates, the localized bathymetry, as well as variances in embedment depths of piles.

### 3.1 NOISE ATTENUATION ASSUMPTIONS FOR ACOUSTIC MODELING

The Navy conducted a Test Pile Program at Naval Base Kitsap, Bangor where attenuation of an unconfined bubble curtain was measured when driving 24-inch, 36-inch, and 48-inch steel pipe piles.[5] It should be noted that attenuation measurements were not conducted at EHW-2, and are therefore excluded from calculations herein.[6] Calculations for attenuation were made by calculating the amplitude ratio reduction of the pressure metric with the bubble curtain on compared to the bubble curtain off measurements, and then converting the ratio into a decibel

[5] Illingworth and Rodkin, 2012
[6] Attenuated measurements from pile installation at EHW-2 in 2012 were similar to nonattenuated measurements from test piles installed in 2011 at the project site, indicating a nonfunctional bubble curtain. Most commonly observed problems reported for non-functional bubble curtains reflect inadequate air-flow or poor seating of the bottom of the curtain at the water-sediment boundary resulting in a non-attenuated sound path.

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value. Weighted values are computed for each metric based on the number of strikes measured. All measurements were taken from the nominal 10 meter de facto distance from the pile.

The sole 24-inch pile in this project was struck a total of 3 times with the bubble curtain turned on. Therefore, the results are unlikely to be indicative of values that would be obtained on this site with more extensive measurements and are not considered further in this review. Piles for which fewer than 10 strikes were measured were also excluded. It is recommended to acquire a larger 24-inch data set to obtain a better synopsis for these results.

For 36-inch piles the weighted average peak, RMS, and SEL reduction with use of the bubble curtain was 10 dB, where the averages of all bubble-on and bubble-off data were compared (see Table 3-1 below). This data set represents 2 piles, for a total of 165 strikes. For 48-inch piles, the weighted average pressure reduction for RMS, peak, and SEL with use of a bubble curtain was 8 dB, representing 138 strikes. Across all piles (36" and 48") and all metrics (RMS, peak, SEL), the weighted average attenuation was 9 dB.

**Table 3-1. Reduction (dB) in Weighted Average Noise Values for Impact Pile Driving of Steel Piles with a Bubble Curtain. Measured at 10 Meters Averaging Mid-Depth and Deep-Depth Data. Measurements Obtained during Bangor Naval Base Test Pile Program.**

| Pile Size | Attenuation Level (RMS) | | Attenuation Level (Peak) | | Attenuation Level (SEL) | | Weighted Average (all metrics) |
|---|---|---|---|---|---|---|---|
| | Weighted | Unweighted | Weighted | Unweighted | Weighted | Unweighted | |
| 36-inch | 9 | 9 | 11 | 11 | 10 | 10 | 10 |
| 48-inch | 7 | 7 | 9 | 9 | 7 | 7 | 8 |
| Overall weighted average | | | | | | | 9 |
| Source: Illingworth & Rodkin 2012 | | | | | | | |

We also reviewed unconfined bubble curtain attenuation rates from available reports from projects in Washington, California, and Oregon that impact drove steel pipe piles up to 48-inches in diameter. Table 3-2 contains a summary of the attenuation levels reported. Several studies were reviewed, but not included in the summary because they were not considered representative. Excluded studies were:

- Willamette River Bridge Project (Caltrans 2012). Bubble curtain was poorly designed and deployed in a river with a high current. No RMS SPLs reported.
- South Umpqua River (Caltrans 2012). Current conditions resulted in little coverage of piles by bubble curtain. No RMS SPLs reported.
- Ten Mile River Bridge Project (Caltrans 2012). 30-inch piles driven with bubble curtain, but inside of cofferdam.

Of the remaining studies reviewed, significant variability in attenuation occurred; however, an average of at least 8 dB of peak SPL attenuation was achieved on ten of the twelve projects

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(Table 3-2). Some of the lower attenuation levels reported were attributed to the bottom ring not seated on the substrate, poor airflow, or currents that resulted in an uneven distribution of bubbles (WSDOT 2005a, WSDOT 2005b, Caltrans 2012).

In summary, bubble curtain performance is highly variable. Effectiveness depends on the system design and on-site conditions such as water depth, water current velocity, substrate and underlying geology. Installation and how well the curtain is seated on the substrate at the bottom are also important factors. To avoid loss of attenuation from design and implementation errors, our project has specific bubble curtain design specifications, including testing requirements for air pressure and flow prior to initial impact hammer use, and a requirement for placement on the substrate.

While bubble curtain performance is variable, we believe that, based on information from the Bangor Naval Base Test Pile Program, an average peak SPL[7] reduction of 8 dB to 10 dB at 10 meters would be an achievable level of attenuation for steel pipe piles of 36- and 48-inches in diameter. However, to be more conservative for 48 inch piles, use of 7 dB for both RMS and SEL metrics is justified.

[7] For most of the studies reviewed, Peak SPLs were the only metric reported.

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## Table 3-2. Summary of Attenuation Levels Reported with Unconfined Bubble Curtains During Impact Driving of Steel Pipe Piles up to 40-Inches Diameter.

| Project/Location | Steel Pipe Pile Diameter | Range (dB) | Mean Peak dB re 1µPa @ 10 m | Standard Deviation (dB) |
|---|---|---|---|---|
| Friday Harbor Ferry Terminal Restoration/ San Juan Island marine waters, WA[1] | 24-inch<br>30-inch | 0-5 | 2 | 2.2 |
| Bainbridge Island Ferry Terminal Preservation/ Puget Sound marine waters, WA[1] | 24-inch | 3-14 | 7 | 4.7 |
| Cape Disappointment Boat Launch Facility, Wave Barrier Project/ Columbia River, Illwaco, WA[1] | 12-inch<br>(n=5*) | 6-17 | 11 | 4.9 |
| Mukilteo Ferry Terminal Test Pile/Puget Sound marine waters, WA[1] | 36-inch<br>(n=2) | 7-22 | 15 | 10.6 |
| Anacortes Ferry Terminal Dolphin Replacement/Puget Sound marine waters, WA[1] | 36-inch<br>(n=7) | 3-11 | 8 | 3.1 |
| SR 520 Test Pile Project/Lake Washington/Portage Bay (freshwater), WA[1, 2] | 24-inch (n=4)<br>30-inch (n=2) | 3-32 | 20 | 11.1 |
| Columbia River Crossing Test Pile Program/Columbia River, WA/OR[3] | 24-inch<br>(n=1) | --- | 10 | --- |
| Tesoro's Amorco Wharf/San Francisco Bay, Martinez, CA[2] | 24-inch<br>(n=8 battered and n=8 vertical) | --- | ~10 dB (not well seated, stated capable of up to 15 dB and strong currents present at times and poor positioning on some piles)* | --- |
| Deep Water-tongue Point Facility Pier Repairs/ Columbia River, Astoria, OR[2] | 24-inch<br>(n=10) | 5-22 | 14 | --- |
| Portland-Milwaukie Light Rail Project/Willamette River, Portland, OR[2] | 24-inch<br>(n=5) | 8-27 | --- | --- |
| Bay Ship and Yacht Dock/San Francisco Bay, Almeda, CA[2] | 40-inch<br>(n=2) | --- | ~10-15 (Not installed at the substrate at start of drive. Performance from part of drive when bubble curtain properly situated).* | --- |
| Richmond-San Rafael Bridge Project/San Francisco Bay, CA[2] | 30-inch<br>(n=2) | --- | 9 | --- |

Sources: [1]WSDOT 2013, Also, see individual report references for WSDOT; [2]Caltrans 2012; [3]CRC 2011.
*As reported by Illingworth and Rodkin in Caltrans 2012.

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## 4.0 REFERENCES

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13) WSDOT. 2006. Underwater sound levels associated with pile driving at the Cape Disappointment boat launch facility, wave barrier project. March 2006. Available at http://www.wsdot.wa.gov/environment/air/piledrivingreports.htm.

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# APPENDIX A

# STUDIES REVIEWED FOR EVALUATION OF UNDERWATER PILE DRIVING SOUND

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# Appendix A: Studies Reviewed for Evaluation of Underwater Pile Driving Sound

## Attachment 1. Impact Pile Driving SPLs from Studies Utilizing Steel Pipe/CISS Piles. Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Hammer Type | Water Depth (m) | Distance (m) | RMS (dB re 1 µPa) | Peak (dB re 1 µPa) | SEL (dB re 1 µPa$^2$s) |
|---|---|---|---|---|---|---|---|---|
| **24-inch Steel Pipe** | | | | | | | | |
| **Bainbridge Island Ferry Terminal[1]** | **Bainbridge Island, WA** | **n=5** | **Diesel** | **2.1-3.4** | **10** | **Weighted Ave 195 Ave range 193-198** | **Weighted Ave 206 Ave range 202-209** | **Weighted Ave 181 Ave range 177-184** |
| **Friday Harbor Ferry Terminal[2]** | **Friday Harbor, WA** | **n=5** | **Diesel, pneumatic, hydraulic** | **10-14.3*, ** ** | **10** | **Weighted Ave 189 Ave range 181-193** | **Weighted Ave 207 Ave range 196-213** | **Weighted Ave 181 Ave range 176-185** |
| Bangor Test Pile Program[3] | Bangor Naval Base, WA | † n=1 | Impact | 4.6 | 10 | Max 180 | Max 193 | Ave 167 |
| Conoco/Phillips Dock [4] | Rodeo, San Francisco Bay, CA | n=2 | Diesel | >5 | 10 | Range 188-189 | 203 (unclear if this is average or ave max) | Typical 177 Range 177-178 |
| Tesoro's Amorco Wharf- all values were attenuated- values reported are mostly unattenuated – strong currents present[4] | San Francisco Bay; Martinez, CA | (1st pile with poor attenuation) | Diesel | 10-15 | 10 | 189 | Max 209 | 174 |
| Deep Water-Tongue Point Facility Pier Repairs[4] | Mouth of Columbia River; Astoria, OR | n=10 | Diesel | unknown | 10 | Ave 182 Ave range 178-189 | Ave max 198 Range 193-206 Max 207 | Ave 168 Ave range 160-175 |
| **30-inch Steel Pipe** | | | | | | | | |
| Richmond-San Rafael Bridge, CALTRANS[4] | San Rafael, CA | n=4 | Diesel | 4-5 | 10 | Typical 190 (max=192) | 210 max (typical 205) | --- |
| **Eagle Harbor Maintenance Facility[5]** | **Bainbridge Island, WA** | **n=3** | **Diesel** | **10** | **10 (n=2) 16 (n=1)** | **Weighted Ave 192 Ave range 192-193** | **Weighted Ave 204 Ave range 203-204** | **---*** ** |
| **Friday Harbor Ferry Terminal #8[2]** | **Friday Harbor, WA** | **n=1** | **Diesel** | **10.4*** | **10** | **196** | **211** | **187** |
| **Vashon Ferry Terminal[6,#]** | **Vashon Island, WA** | **n=3** | **Diesel** | **11-12** | **10** | **Weighted Ave 195 Ave range 192-196** | **Weighted Ave 215 Ave range 212-217** | **Weighted Ave 186 Ave range 182-187** |

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## Attachment 1. Impact Pile Driving SPLs from Studies Utilizing Steel Pipe/CISS Piles (continued). Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Hammer Type | Water Depth (m) | Distance (m) | RMS (dB re 1 µPa) | Peak (dB re 1 µPa) | SEL (dB re 1 µPa$^2$s) |
|---|---|---|---|---|---|---|---|---|
| **36-inch Steel Pipe****** | | | | | | | | |
| Humboldt Bay Bridge[4] | Humboldt Bay – Eureka, CA | CISS n=1, restrikes | Diesel | 10 | 10- | 193 (max) | 210 (max) | 183 (max) |
| **Mukilteo Test Piles[7]** | **Mukilteo, WA** | **n=2** | **Diesel** | **7.3** | **10** | **Weighted Ave 190 Ave range 187-191** | **Weighted Ave 205 Ave range 202-207** | **Weighted Ave 183 Ave range 180-184** |
| **Anacortes Ferry[8]** | **Anacortes, WA** | **n=7** | **Impact** | **12.8** | **10** | **Weighted Ave 192 Ave range 189-193** | **Weighted Ave 209 Ave range 205-211** | **Weighted Ave 185 Ave range 183-186** |
| **Bangor Test Pile Program[3,#]** | **Bangor Naval Base, WA** | **n=4** | **Diesel** | **13.7-26.8** | **10** | **Weighted Ave 194 Ave range 185-196** | **---^** | **Weighted Ave 181 Ave range 173-183** |

Notes: Ave = Average.
***** Substrate was sandy silt/clay.
****** Substrate was sandy silt/rock.
*** Single strike SEL not reported.
****EHW-2 project at Bangor waterfront measured 24- and 36-inch piles; however, all piles were attenuated so they are not included in the table. 24-inch (n = 41) averages were: average peak = 199 (s.d. 9.58), average RMS = 179 (s.d. = 24.10), SEL = 170 dB (s.d. = 7.48). 36-inch pile (n = 26): average peak = 205 (s.d. = 4.33), average RMS = 188 (s.d. = 5.01), average SEL = 175 (s.d. = 5.11) (Navy 2013).
† 24-inch piles were not hit very hard, so these are not representative of the levels that may occur in the future or elsewhere.
# distance to pile ranged above and below 10m. Data normalized to 10m using $15\log_{10}$ (range/10m) relationship.
^ Average peak values not reported.

### Sources:

[1] WSDOT 2005a
[2] WSDOT 2005b
[3] Navy 2012
[4] Caltrans 2012
[5] JASCO Research. 2005, WSDOT 2008
[6] WSDOT 2010b
[7] WSDOT 2007a
[8] WSDOT 2007b

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## Attachment 2. Impact Pile Driving SPLs from Studies Utilizing Concrete Piles. Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Hammer Type | Water Depth (m) | Distance (m) | RMS (dB re 1 µPa) | Peak (dB re 1 µPa) | SEL (dB re 1 µPa$^2$s) |
|---|---|---|---|---|---|---|---|---|
| **16-inch and 18-inch Piles** | | | | | | | | |
| Pier 2 Concord NWS[1] (16-inch square) | Concord, CA | n=5 | Drop Steam Powered | 7 | 10 | Ave 171<br>Ave range 167-173 | Ave max 183<br>Ave max range 182-184<br>Max 184 | N/A |
| Berkeley Marina (2007) [1] (18-inch octagonal) | Berkeley, CA | n=1 | Diesel | 2-3 | 10 | Ave 159<br>Ave range 155-167 | Ave max 172<br>Ave range 172-181<br>Max 181 | Ave 155 |
| Berkeley Marina (2009) [1] (18-inch octagonal) | Berkeley, CA | n=3 | Diesel | 2-3 | 10 | Ave 169<br>Ave range 165-178 | Ave max 189<br>Ave max range 184-192<br>Max 192 | Ave 159 |
| **24-inch Piles** | | | | | | | | |
| Mukilteo Ferry Terminal[2] (octagonal) | Mukilteo, WA | n=1 | Diesel | 7-8 | 10 | Ave 170<br>(single pile) | Ave max 184<br>Single pile | Ave 159 dB<br>Range 159-170 |
| Amports Pier 95[1] (octagonal) | Benicia, CA | Not provided | Diesel | 3-7 | 10 | Ave 170<br>Range 168-172 | Ave max 184<br>Range 180-192<br>Max 192 | N/A |
| Pier 40 Marina[1] (square) | San Francisco, CA | n=7 | Diesel | 3-4 | 10 | Ave 171*<br>Ave range 167-174* | Ave max 184*<br>Ave range 180-186*<br>Max 186** | N/A |
| Berth 22 Port of Oakland (December 2004)[1] (octagonal) | Oakland, CA | Several | Diesel | 0-15 (dependent on row) | 10 (mostly) | Ave 176***<br>Ave range***<br>171-179<br>Max 181 | Ave max 188***<br>Ave max range***<br>183-191<br>Max 193 | Ave 165***<br>Ave range**<br>162-167 |
| Berth 22 Port of Oakland (August 2004)[1] (octagonal) | Oakland, CA | n=4 | Diesel | 10-13 | 10 | Ave 175<br>Ave range during loudest part of drive<br>174-176<br>Max 178 | Ave max 187<br>Ave max range during loudest part of drive<br>186-188<br>Max 190 | Ave 165<br>Ave range during loudest part of drive<br>164-166<br>Max 168 |

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## Attachment 2. Impact Pile Driving SPLs from Studies Utilizing Concrete Piles (continued). Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Hammer Type | Water Depth (m) | Distance (m) | RMS (dB re 1 µPa) | Peak (dB re 1 µPa) | SEL (dB re 1 µPa$^2$s) |
|---|---|---|---|---|---|---|---|---|
| **Berth 32 Port of Oakland (2005)[1] (octagonal)** | **Oakland, CA** | **n=2** | **Diesel** | **3-7** | **10** | **Ave 174<br>Ave range 172-176** | **Ave max 186<br>Ave max range 185-187<br>Max 187** | **Ave 163<br>Ave range 158-165** |
| **Berth 32 Port of Oakland (2004)[1] (octagonal)** | **Oakland, CA** | **n=5** | **Diesel** | **>10** | **10** | **Ave 173<br>Ave range 173-174** | **Ave max 185<br>Ave max range 184-185<br>Max 185** | **Ave 162<br>Ave range 161-163** |
| Humboldt State University Floating Dock****[1] **(octagonal)** | Humboldt Bay, Eureka, CA | n=3 | Diesel | 3-4 | 10 | Ave 157<br>Ave range 156-158 | Ave max 179<br>Ave max range 176-179<br>Max 179 | Ave 148<br>Ave range 142-151 |

Notes: Ave = Average.
* For piles with fuel setting on high, no jetting.
**Pile with fuel setting on low, no jetting.
*** Average for row, not pile. Sound levels varied by depth. Only in-water sound levels reported in table (unattenuated values from Row A-D in Table 1.5-4 in Caltrans 2013).
****Piles jetted, so project data is not included in analysis.

**Sources:**
[1] Caltrans 2012
[2] WSDOT 2007a

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## Attachment 3. Vibratory Pile Driving SPLs from Marine Projects. Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Water Depth (meters) | Distance (meters) | Mean RMS* dB re 1 µPa |
|---|---|---|---|---|---|
| **12-inch Timber** | | | | | |
| **Port Townsend Dolphin Timber Pile Removal[1]** | **Port Townsend, WA** | **n=1** | **---** | **16** | **Average 150<br>Range 149-152** |
| **13-inch Steel Pipe** | | | | | |
| Mad River Slough Pipeline Construction[2] | Mad River Slough, Arcata, CA | n=3 | 4.5-5.5 | 10 | 155 |
| **16-inch Steel Pipe** | | | | | |
| **EHW-1[3]** | **Bangor, WA** | **n=8** | **9-12** | **10** | **162<br>Ave range 153-168** |
| **24-inch Steel Pipe** | | | | | |
| **Friday Harbor[4]** | **Friday Harbor, WA** | **n=1** | **2.6** | **10** | **162** |
| **Trinidad Pier Reconstruction[2]** | **Trinidad Bay, Humbolt County, CA** | **n=2** | **15.2** | **10** | **Typical 160<br>range 158-178** |
| **Bangor Test Pile Program[5]** | **Bangor Naval Base, WA** | **n=2 (1 pile vibed in and out)** | **4.6** | **10** | **160<br>Ave range 157-160**** |
| **30-inch Steel Pipe** | | | | | |
| **Edmonds[6]** | **Edmonds, WA** | **n=2** | **6.4** | **10** | **165-166** |
| **Keystone Ferry Terminal[7]** | **Coupeville, WA** | **n=4** | **~9.4** | **10<br>11<br>6<br>11** | **Per pile values due to different distances<br>(165<br>176<br>176<br>165)<br>Ave 173<br>Ave range 165-176** |
| **Vashon Ferry Terminal[8]** | **Vashon Island, WA** | **n=4** | **<6** | **11-16** | **167<br>Ave range 160 - 169** |
| **Port Townsend Test Pile Project[9, 10]** | **Port Townsend, WA** | **n=1** | **8.8** | **10** | **170<br>Ave range 164-174** |
| **EHW-1[3]** | **Bangor, WA** | **n=35** | **9-12** | **10** | **168<br>Ave range 155-174** |
| **36-inch Steel Pipe** | | | | | |
| **Edmonds Ferry Terminal[6]** | **Edmonds, WA** | **n=2** | **5.8** | **11** | **Ave range 162-163** |
| **Anacortes Ferry Terminal[11]** | **Anacortes, WA** | **n=2** | **12.7** | **11** | **Ave range 168-170** |
| **Port Townsend Test Pile Project[9, 10]** | **Port Townsend, WA** | **n=1** | **9.5** | **10** | **172<br>159-177** |
| **Bangor Test Pile Program[5]** | **Bangor Naval Base, WA** | **n=~33** | **13.7-26.8** | **10** | **164 **<br>Ave range 154-169** |

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## Attachment 3. Vibratory Pile Driving SPLs from Marine Projects (continued). Bolded values were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Water Depth (meters) | Distance (meters) | Mean RMS* dB re 1 µPa |
|---|---|---|---|---|---|
| **24-inch AZ25 Steel Sheet** | | | | | |
| **Berth 23, Port of Oakland[2]** | **Oakland, CA** | **n=1** | **~12-14** | **10** | **163*** ** |
| **Berth 30, Port of Oakland[2]** | **Oakland, CA** | **n=5** | **~12** | **10** | 1-sec SEL**** = **159** **Ave range 157-160** **(162 highest ave from bottom depth)** |
| **Berth 35/37, Port of Oakland[2]** | **Oakland, CA** | **---** | **15** | **10** | **163** |

Notes: Ave = Average.
*WSDOT typically reports average of 30-second RMS values calculated over the duration of a drive.
** Average of all pile driving events.
***Involved only stabbing. Average reported by Caltrans Table I-1.2-3.
****RMS SPLs were not reported, but would be similar to SEL for 1 second. Average top and bottom depths.

**Sources:**
[1] WSDOT 2011a
[2]Caltrans 2012
[3]Miner 2012
[4]WSDOT 2010a
[5] Navy 2012
[6] WSDOT 2011b
[7]WSDOT 2010c
[8]WSDOT 2010d
[9] WSDOT 2010e
[10] Laughlin 2010
[11] WSDOT 2012

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## Attachment 4. Impact Pile Driving Lmax Airborne SPL Studies. Bolded projects were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Distance (meters/feet) | $L_{max}$ dB re 20 µPa |
|---|---|---|---|---|
| 12-inch Steel Pipe | | | | |
| Cape Disappointment Boat Launch Facility, Wave Barrier Project[1] | Columbia River, Astoria, OR | 1 at 50 m | 50 m/164 ft | 89 A-weighted |
| 24-inch Steel Pipe | | | | |
| **Bangor Test Pile Program** | **Bangor Naval Base, WA** | **1** | **15.2 m/50 ft<br>121.9 m/400 ft** | **110 dB (109dBA)<br>95 dB (93 dBA)** |
| SR 520 Bridge Replacement Test Pile[2] | Portage Bay, Seattle, WA | 2 | 11-15 m/36-49 ft | 95-100 dBA |
| 30-inch Steel Pipe | | | | |
| Friday Harbor Ferry Terminal Restoration[3] | San Juan Island Area, Friday Harbor, WA | 1 | 49 m/160 ft | --- |
| SR 520 Bridge Replacement Test Pile[2] | Union Bay, Lake Washington, Seattle, WA | 4 | 11-15 m/36-49 ft | 103-106 dBA |
| 36-inch Steel Pipe | | | | |
| **Bangor Test Pile Program[4]** | **Bangor Naval Base, WA** | **---** | **15 m/50 ft** | **109 dB (s.d.=2.58)<br>Range 106-112 dB** |

Notes: All values unweighted unless indicated. Only unweighted values were considered for proxy values.

**Sources:**
[1] WSDOT 2006
[2] WSDOT 2010f
[3] WSDOT 2005b
[4] Navy 2012

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## Attachment 5. Vibratory Pile Driving $L_{eq}$ Airborne SPL Studies. Bolded projects were considered for proxy source levels.

| Project | Location | Number of Piles Measured | Distance (meters/feet) | Average RMS $L_{eq}$ dB re 20 µPa* | Average RMS $L_{eq}$ dBA re 20 µPa* |
|---|---|---|---|---|---|
| 18-inch Steel Pipe | | | | | |
| **Wahkiakum Ferry Terminal [1]** | **Columbia River, WA** | **1** | **15.2 m/50 ft*** | **87.5** | |
| 24-inch Steel Pipe | | | | | |
| Bangor Test Pile Program | Bangor Naval Base, WA | 1 | 15.2 m/50 ft<br>121.9 m/400 ft | 92<br>78 dB | 85<br>72 |
| SR 520 Bridge Replacement Test Pile[2] | Portage Bay, Seattle, WA | 1 | 11 m/36 ft | 88 dBA | --- |
| 30-inch Steel Pipe | | | | | |
| **Keystone Ferry Terminal[1]** | **Puget Sound, WA** | **1** | **15.2 m/50 ft*** | **95<br>Range 93-96** | |
| Vashon Ferry Terminal Test Pile Project[1,3] | Puget Sound, Vashon Island, WA | 2 | 15.2 m/50 ft* | ~83-85** | ~77-80 dBA* |
| 36-inch Steel Pipe | | | | | |
| **Bangor Test Pile Program[4]** | **Bangor Naval Base, WA** | **---** | **15 m/50 ft** | **93 (s.d. =3.08)<br>Range 89-102** | |

Notes: All values unweighted unless indicated.
* Sound pressure levels standardized to 50 ft range. Measurements made at 11 meters.
**Converted to C-weighted from A-weighted measurements to approximate unweighted sound level, reported at a distance of 26 to 36 feet.

**Sources:**
[1] WSDOT 2010g
[2] WSDOT 2010f
[3] WSDOT 2010d
[4] Navy 2012

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5) Minor, R. 2012. Hydroacoustic Monitoring Production Piles: PP30”X0.50” steel pipe piles, APE 200-6 vibratory driver/extractor; Falsework piles: PP16”, APE 200-6 vibratory driver/extractor; Explosives Handling Wharf No. 1, October 7-27, 2011, Naval Base Kitsap, Bangor Washington. Report to Jayme Newbigging, P.E. Manson Construction and Engineering Company from Robert Miner Dynamic Testing, Inc. March 3, 2012.

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*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

# APPENDIX B

# DATA CHARTS FOR MEASURED DATA AND CUMULATIVE PROBABILITY DISTRIBUTION FUNCTIONS

***Proxy Source Sound Levels and Bubble Curtain Attenuation***
***Revised January 2015***

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*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

# Appendix B: Data Charts for Measured Data and Cumulative Probability Distribution Functions

## Impact RMS

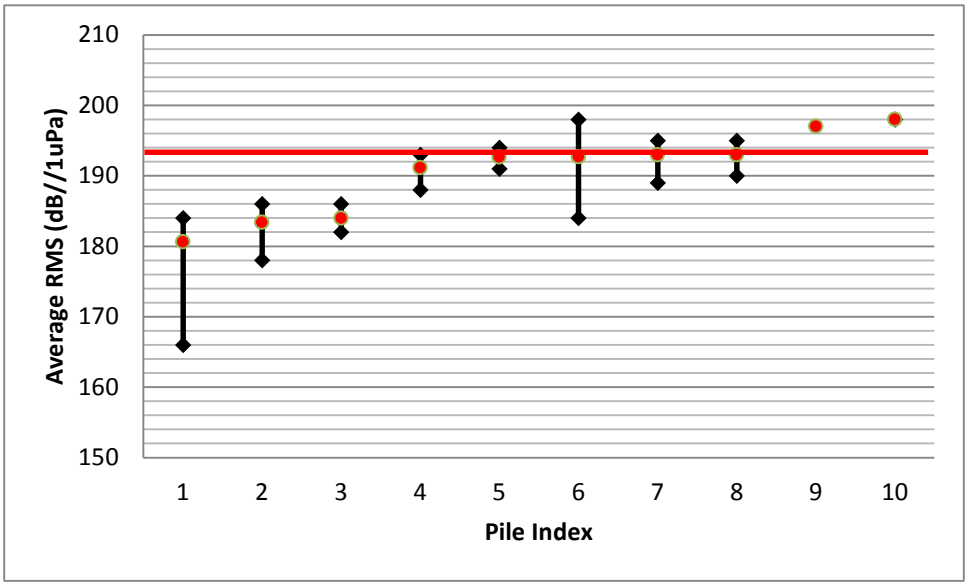


**Figure B-1. 24-inch RMS Measurements**

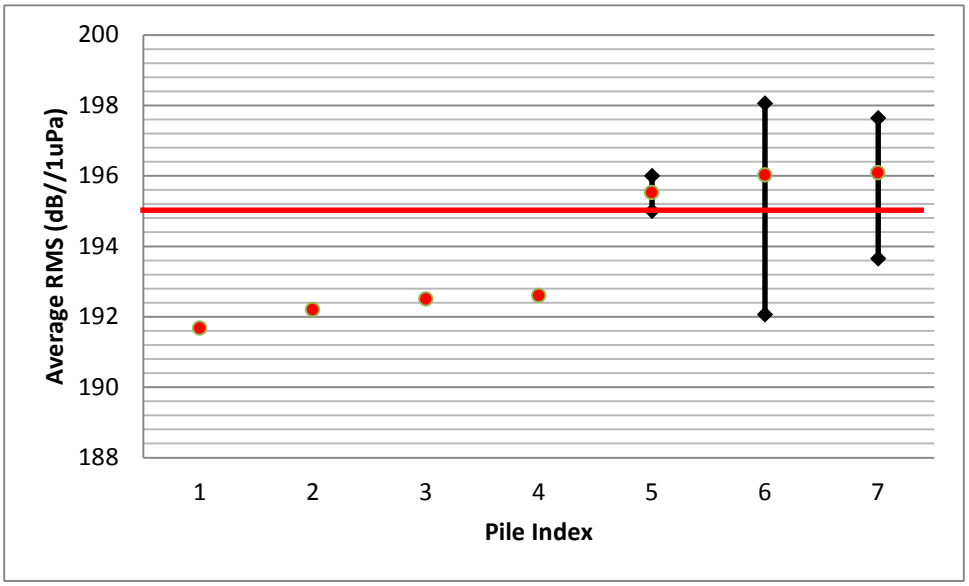


**Figure B-2. 30-inch RMS Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

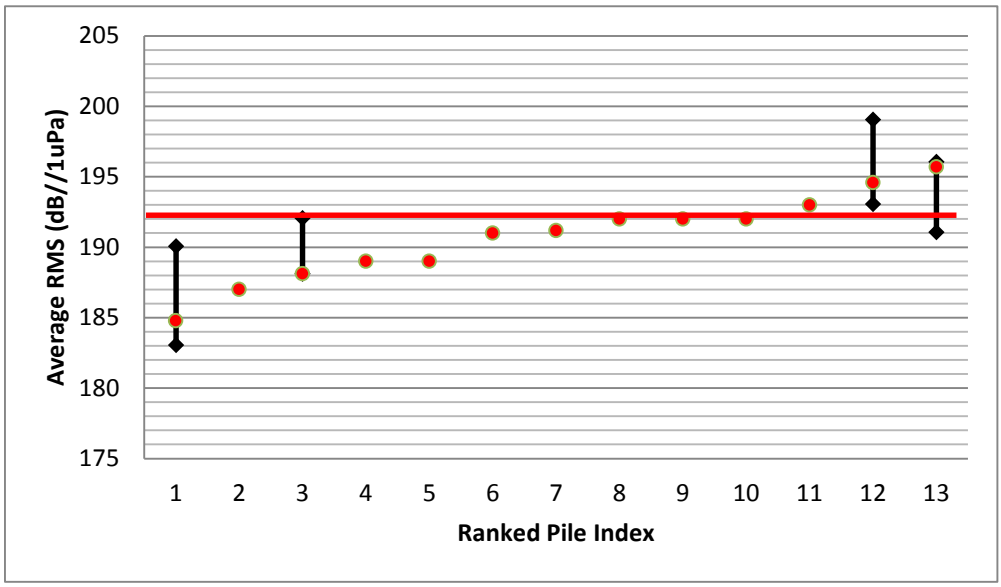


**Figure B-3. 36-inch RMS Measurements**

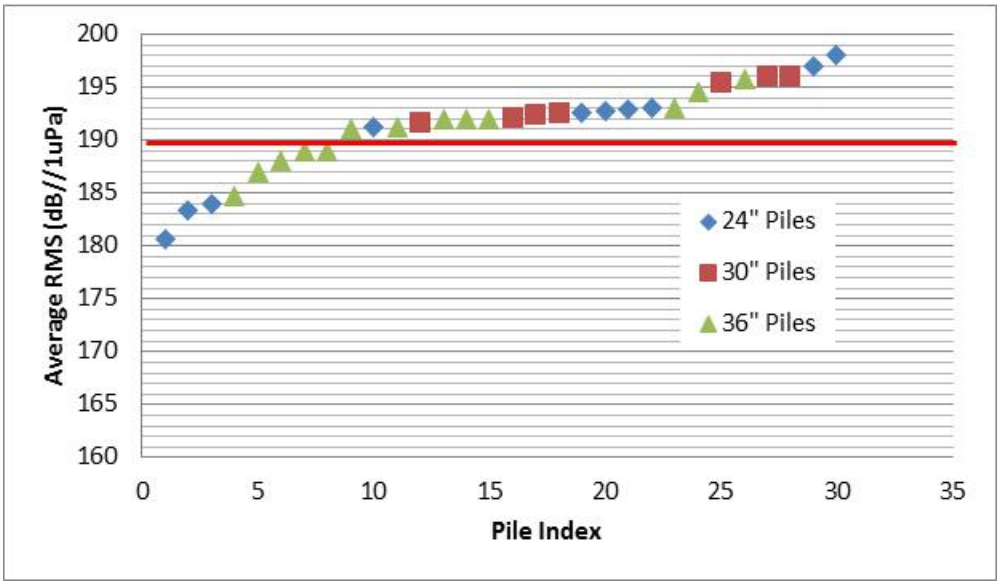


**Figure B-4. Combined Analysis: 24, 30, 36-inch RMS Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

## Impact Average Peak

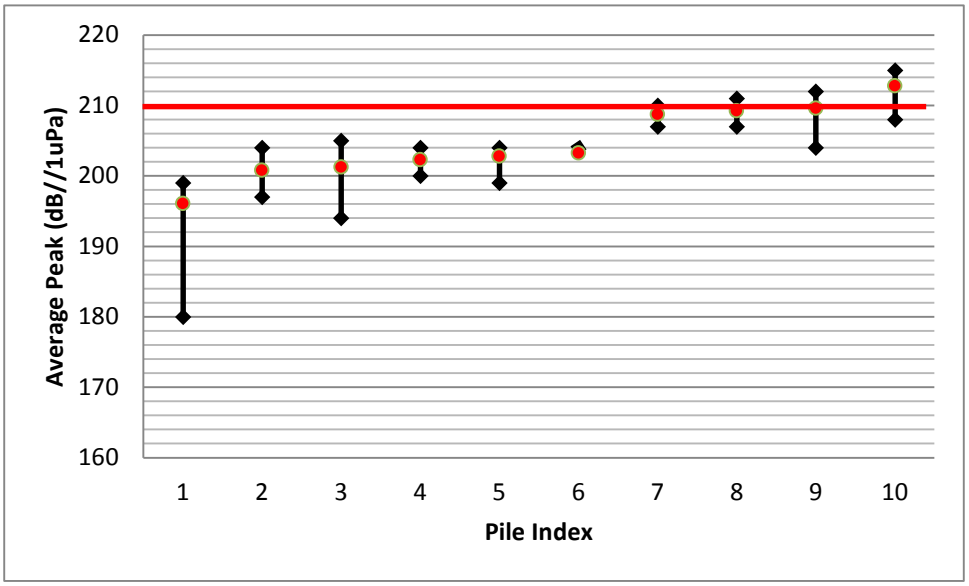


**Figure B-5. 24-inch Average Peak Measurements**

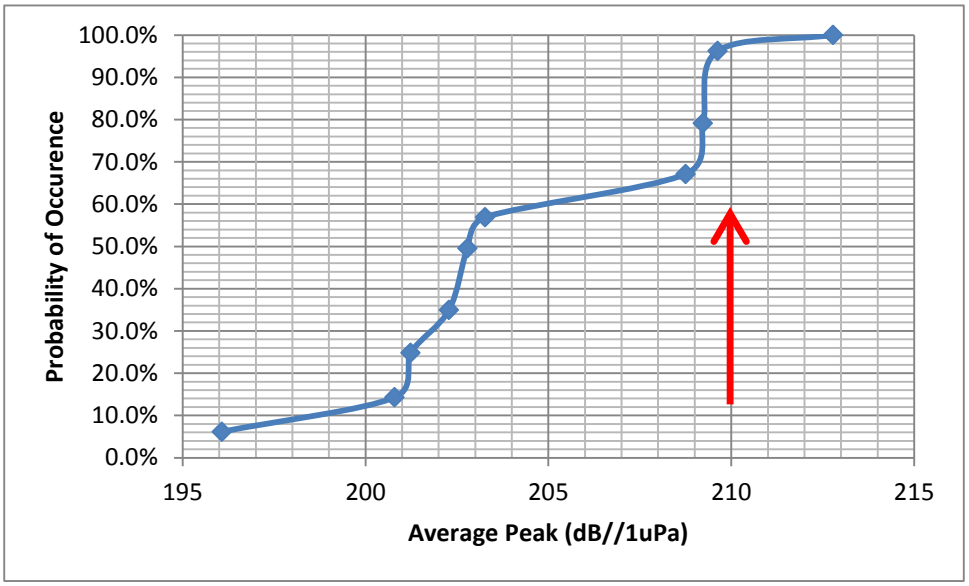


**Figure B-6. 24-inch Average Peak Cumulative Distribution Function**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

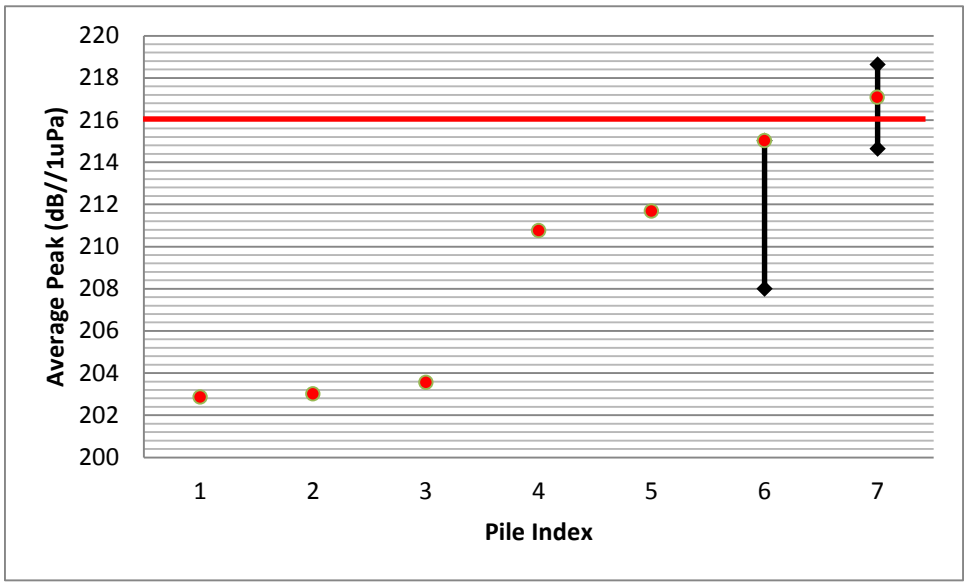


**Figure B-7. 30-inch Average Peak Measurements**

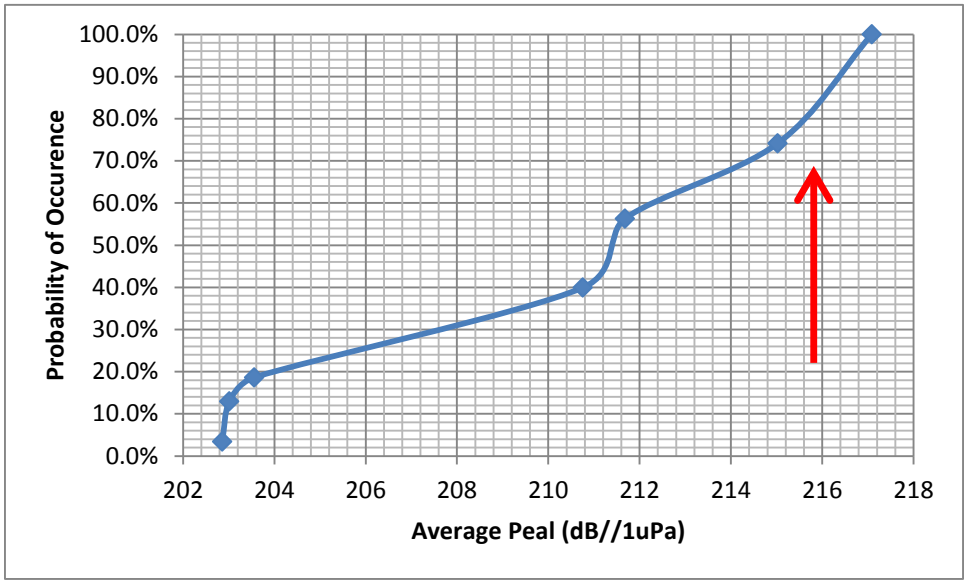


**Figure B-8. 30-inch Average Peak Cumulative Distribution Function**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

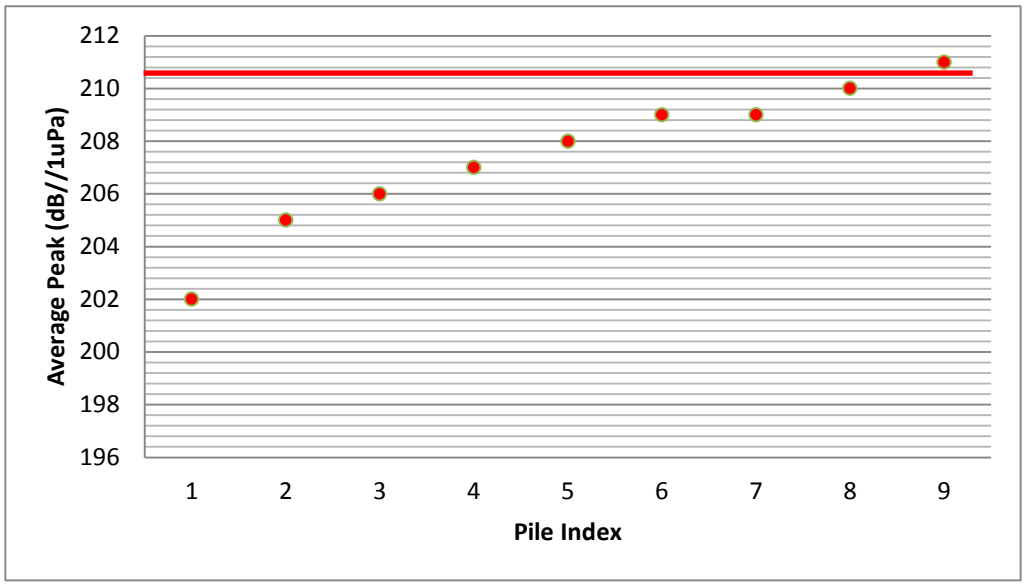


**Figure B-9. 36-inch Average Peak Measurements**

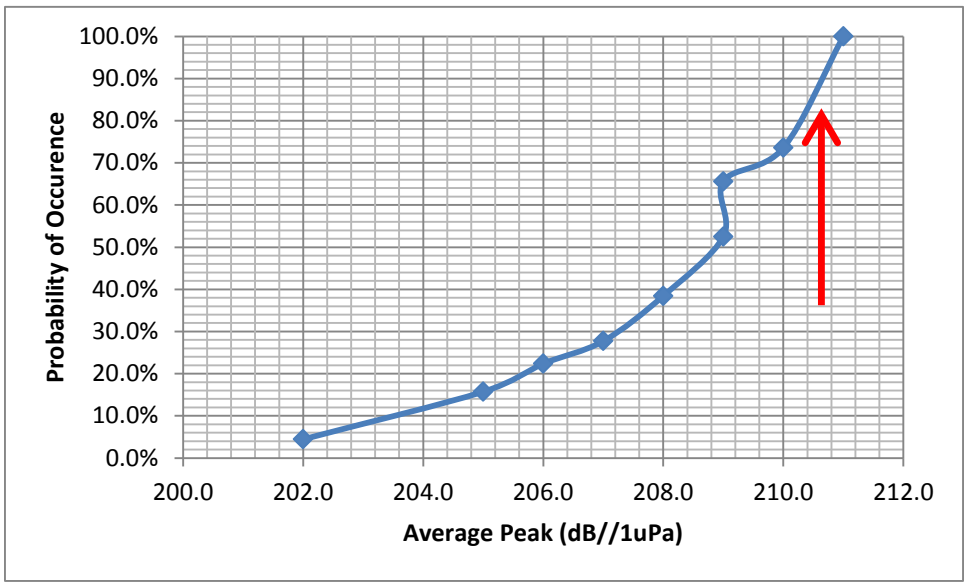


**Figure B-10. 36-inch Average Peak Cumulative Distribution Function**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

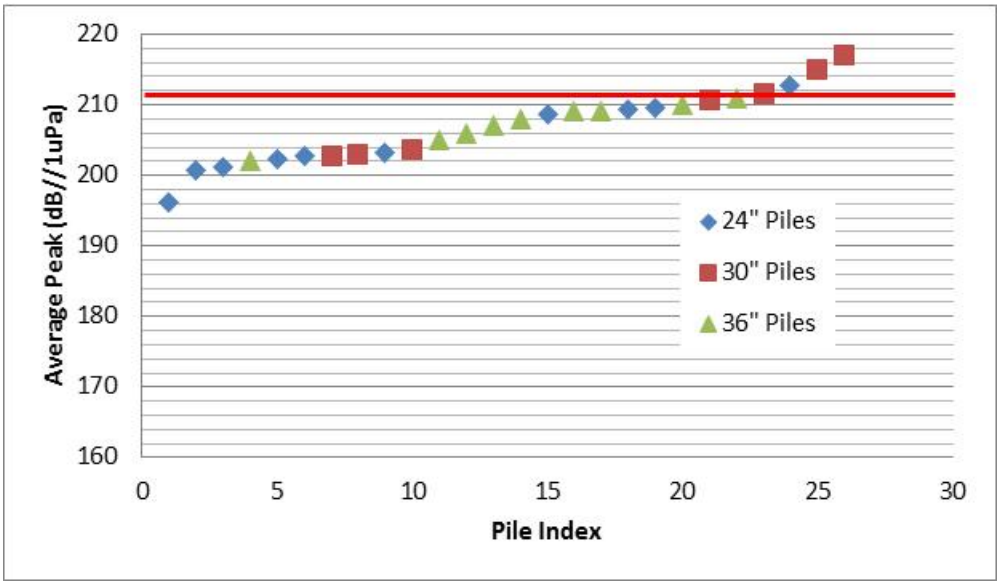


**Figure B-11. Combined Analysis: 24, 30, 36-inch Average Peak Measurements**

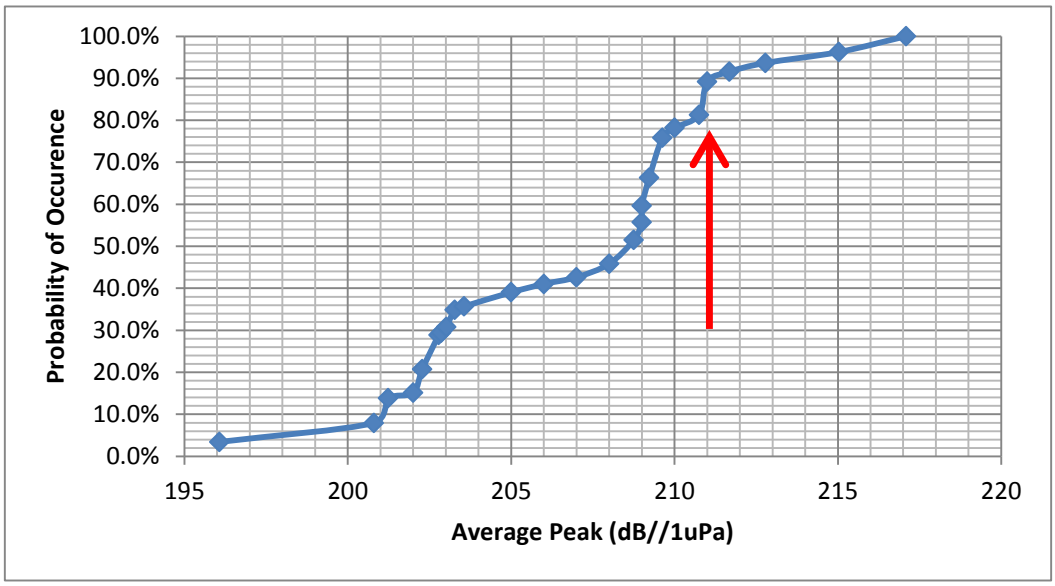


**Figure B-12. Combined Analysis: 24, 30, 36-inch Average Peak Cumulative Distribution Function**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

# Impact SEL

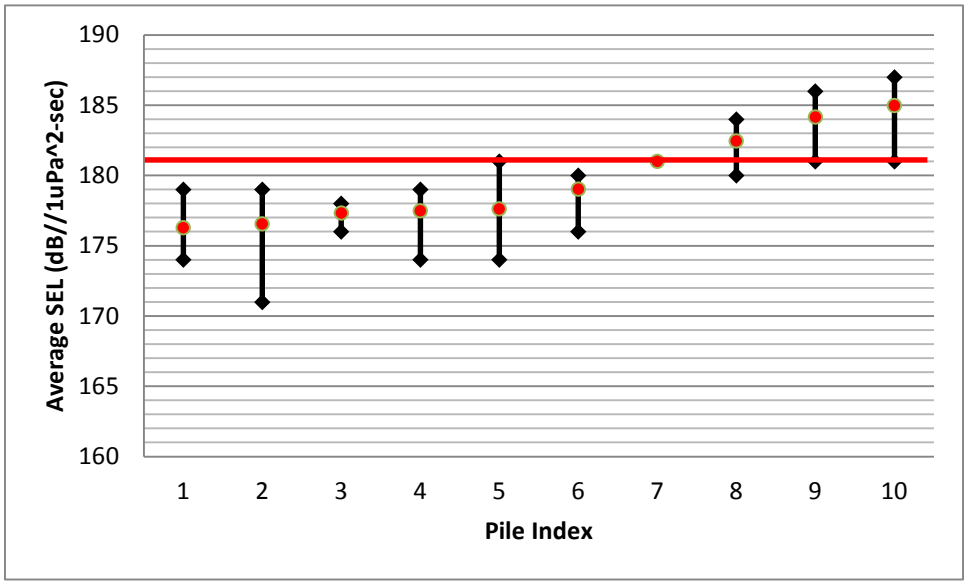


**Figure B-13. 24-inch SEL Measurements**

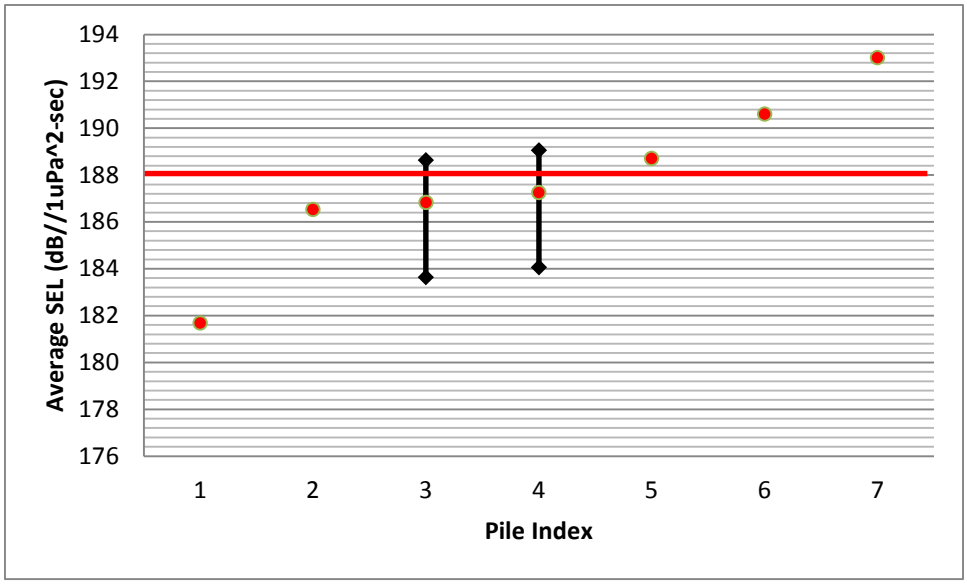


**Figure B-14. 30-inch SEL Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

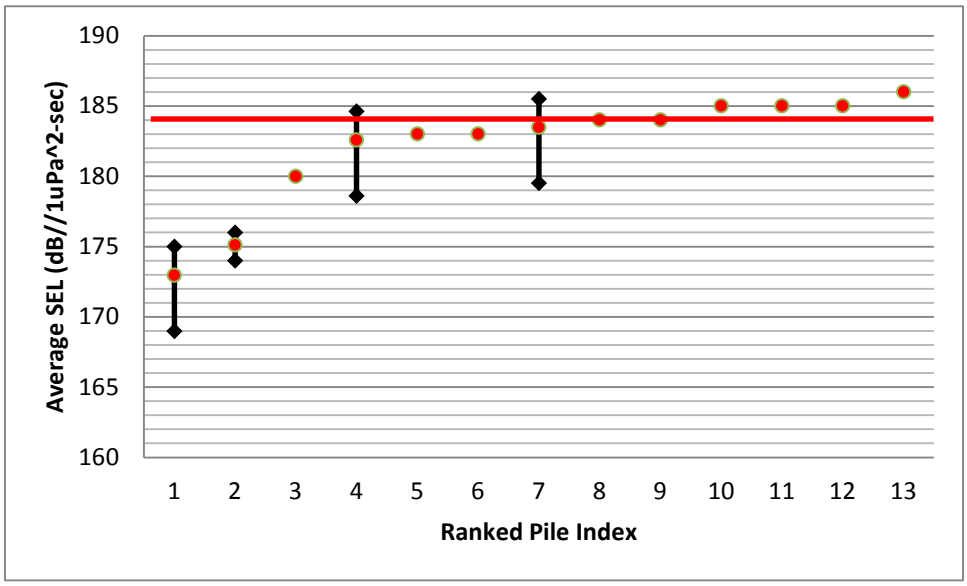


**Figure B-15. 36-inch SEL Measurements**

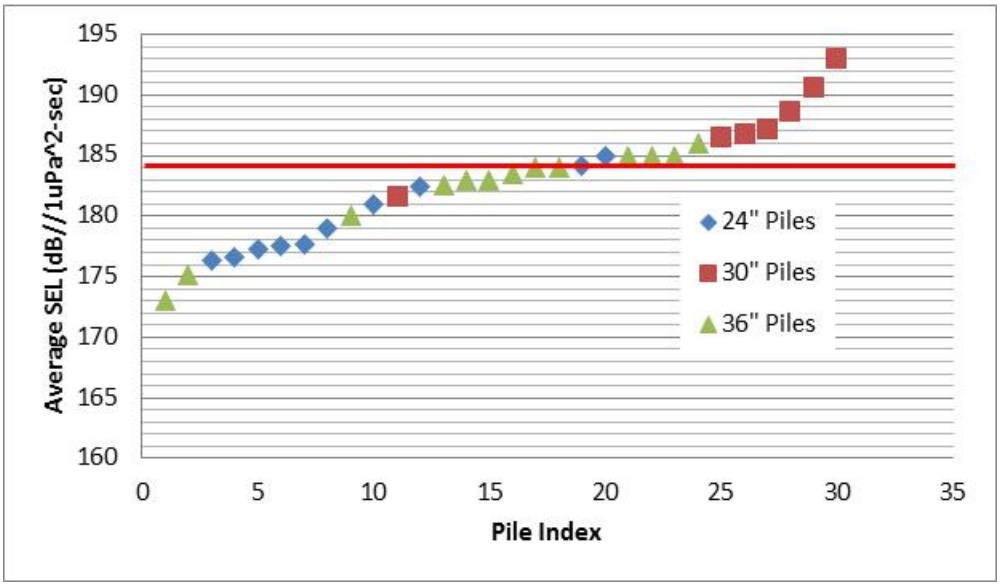


**Figure B-16. Combined Analysis: 24, 30, 36-inch SEL Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

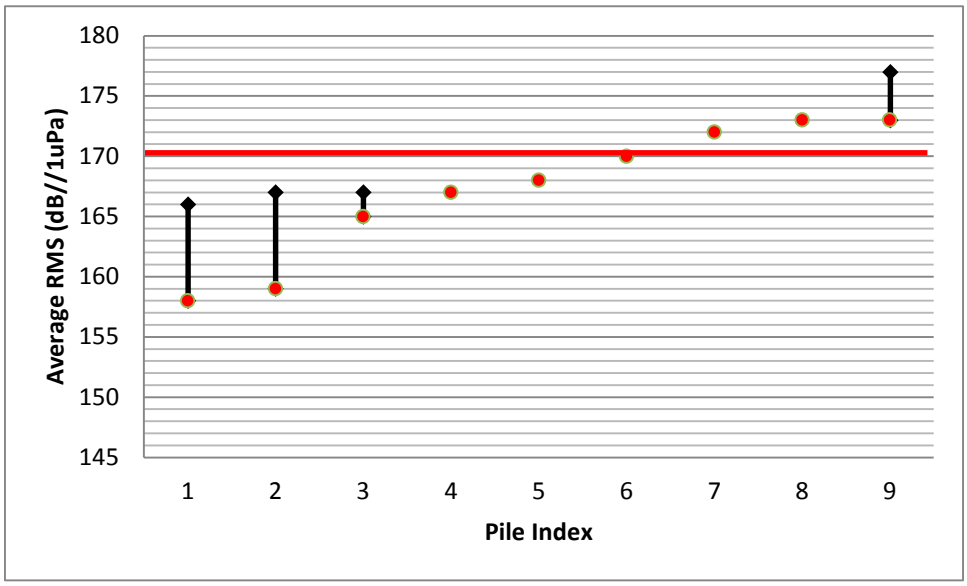


**Figure B-17. Concrete 16, 18-inch RMS Measurements**

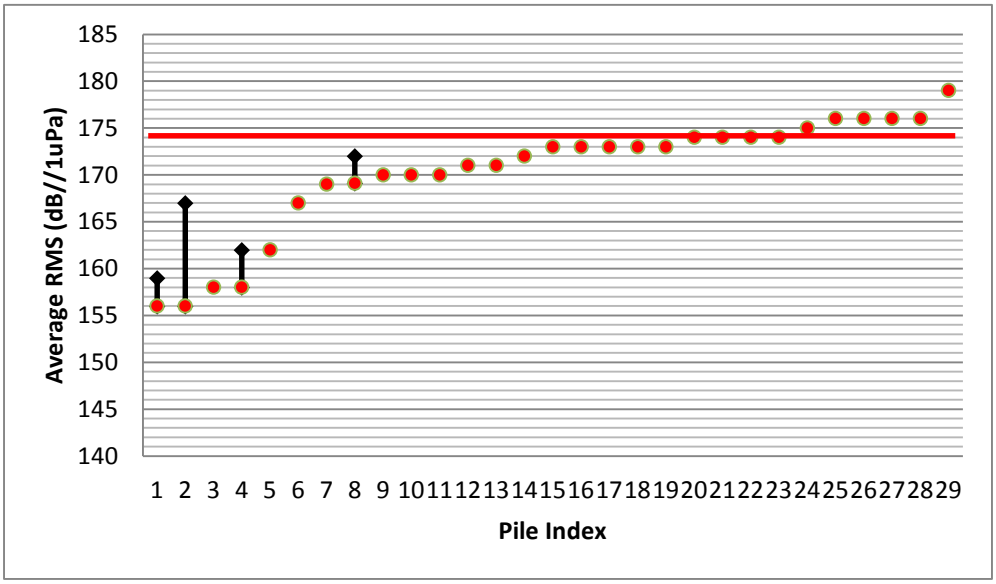


**Figure B-18. Concrete 24-inch RMS Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

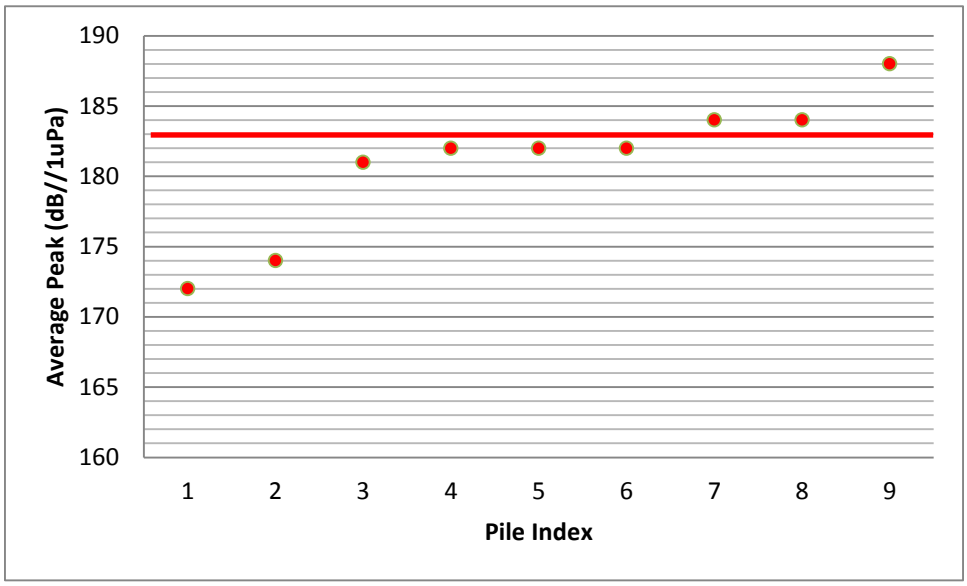


**Figure B-19. Concrete 16, 18-inch Average Peak Measurements**

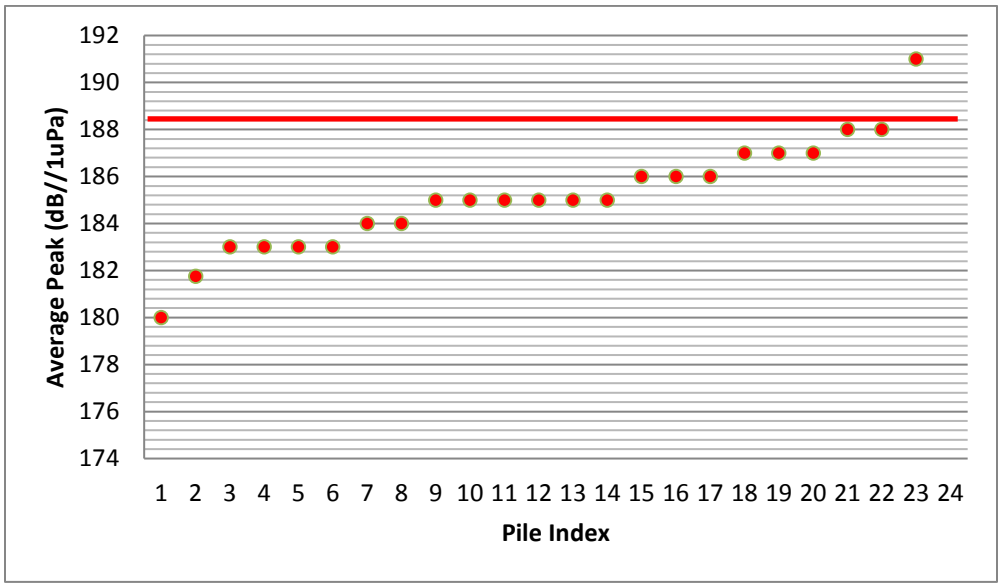


**Figure B-20. Concrete 24-inch Average Peak Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

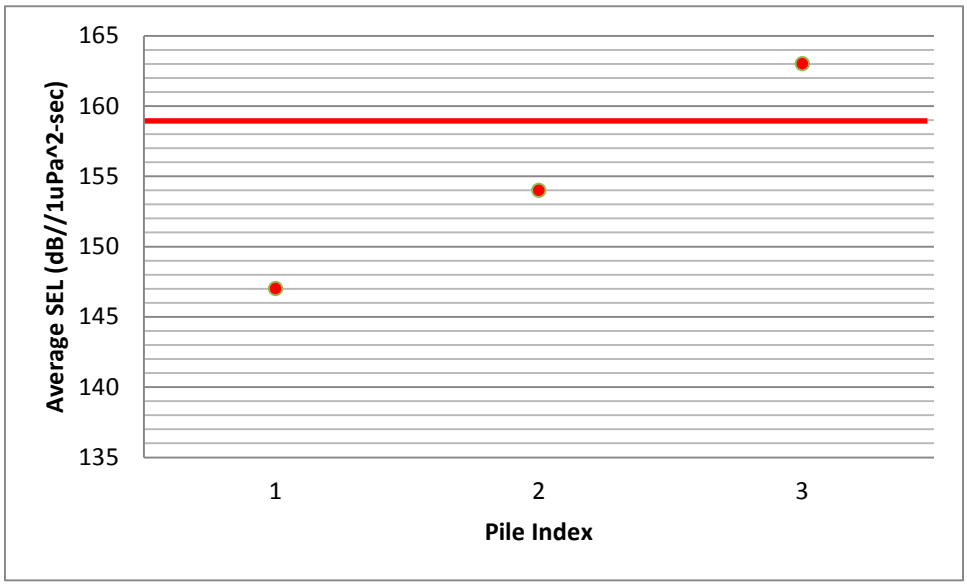


**Figure B-21. Concrete 16, 18-inch SEL Measurements**

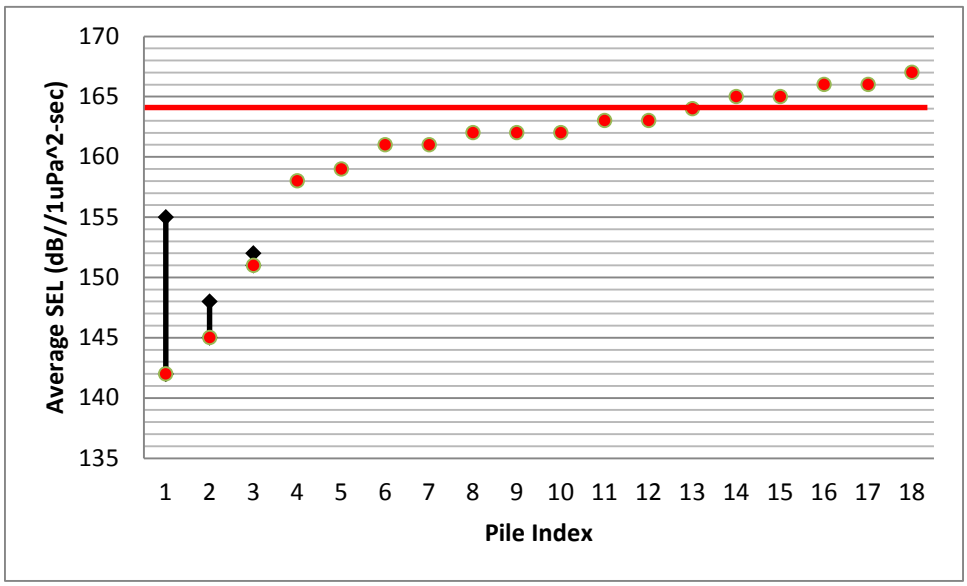


**Figure B-22. Concrete 24-inch SEL Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

## Vibratory RMS

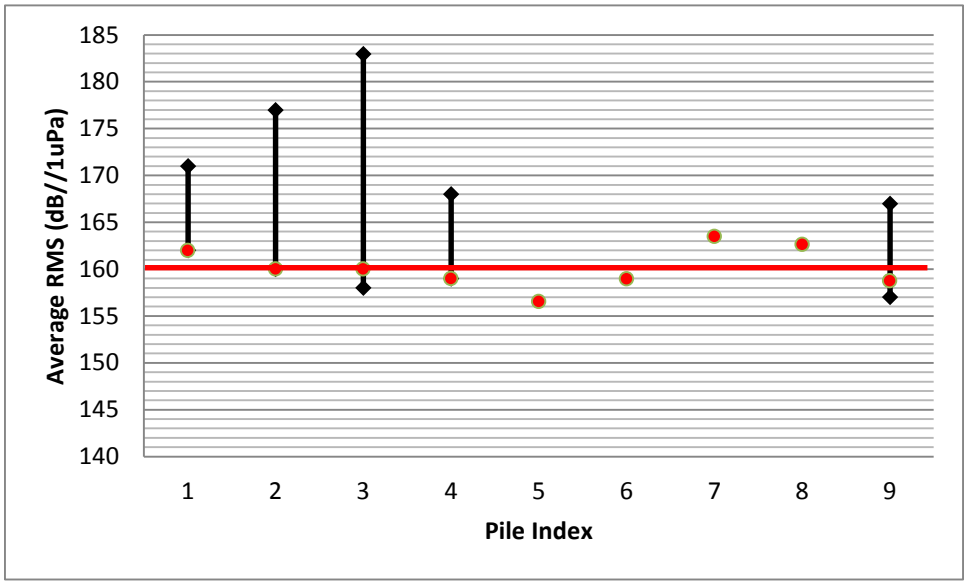


**Figure B-23. 24-inch RMS Vibratory Measurements**

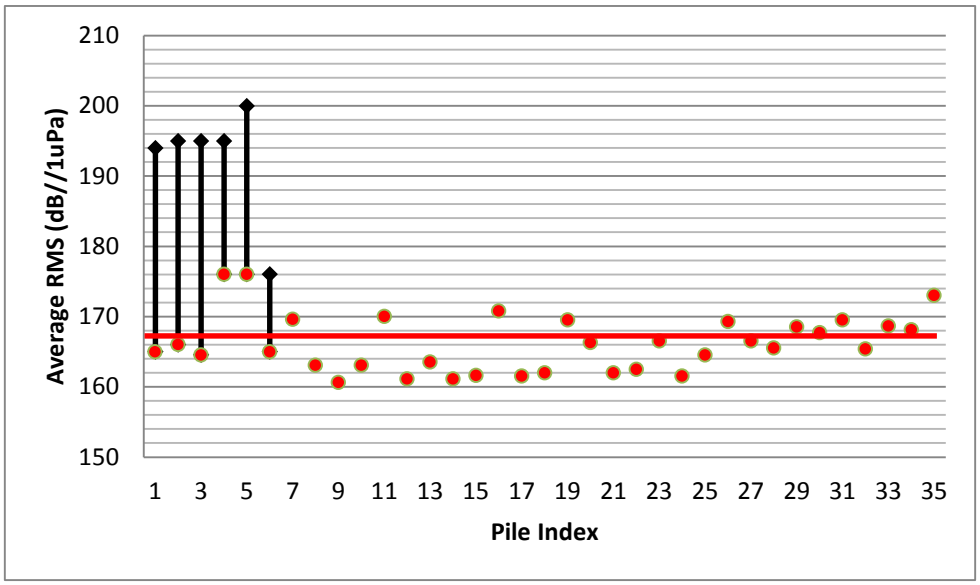


**Figure B-24. 30-inch RMS Vibratory Measurements**

*Proxy Source Sound Levels and Bubble Curtain Attenuation*
*Revised January 2015*

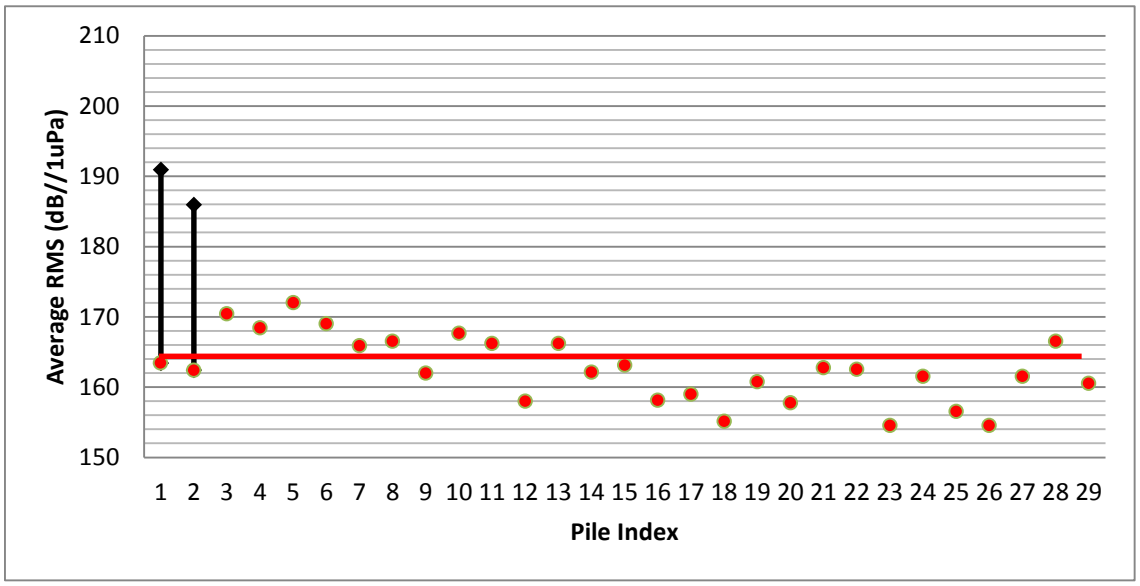


**Figure B-25. 36-inch RMS Vibratory Measurement**

***Proxy Source Sound Levels and Bubble Curtain Attenuation***
***Revised January 2015***

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# Appendix C

# Marine Mammal Surveys and Density and Abundance Determinations at Installations Included in the Marine Structure Maintenance and Pile Replacement Program

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# Appendix C
# Marine Mammal Surveys and Density and Abundance Determinations

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# 1 INTRODUCTION

The Navy performs quantitative analyses to estimate the number of marine mammals that could be affected by at-sea training and testing activities. A key element of this quantitative impact analysis is knowledge of the abundance and concentration (density) of the species in specific areas where those activities will occur. The Navy's Marine Species Density Database (NMSDD) (Navy, 2015) reviews historical temporal and spatial distribution records and group size of marine mammals in Navy's Pacific 3rd and 7th Fleet's Area of Responsibility, which includes Puget Sound. This report includes a description of the currently available density data used in the quantitative impact analysis for marine species that may be impacted by the Navy's projects. The unit of metric for this type of analysis is density or the number of animals present per unit area.

However, some marine mammal species occur infrequently in the vicinity of shoreline construction projects such as the Marine Structure and Pile Replacement Program (MPR) installations, and using a density based analysis for species that occur intermittently does not adequately account for their unique temporal and spatial distributions. For intermittently occurring species, the historical likelihood of encounter at a MPR installation was used to develop a realistic estimate of potential exposure. These species include humpback whale, minke whale, gray whale, transient killer whale, Southern Resident killer whale, Dalls' porpoise, and harbor porpoise (in Hood Canal only). The likelihood of exposure of individuals of these species to project impacts is discussed in Section 6.10 of this application.

Application of the density values in the NMSDD is appropriate for other species that occur regularly in the vicinity of MPR installations, in cases where there are no more comprehensive site-specific survey data. These species include harbor porpoise, Dall's porpoise, Steller sea lion, California sea lion, and harbor seal.

In locations where marine mammals congregate, density-based analyses tend to under-estimate impacts because density values assume even distribution of individuals over the region. To remedy this, the Navy has conducted site-specific haulout surveys to help estimate abundances, as opposed to density, of pinnipeds that haul out at or near several MPR installations. Available surveys include the following:

- Steller sea lion – NAVBASE (Naval Base) Kitsap Bangor and Manchester
- California sea lion – NAVBASE Kitsap Bangor, Bremerton, Manchester, and NAVSTA Everett
- Harbor seal – NAVBASE Kitsap Bangor and NAVSTA Everett

The analysis of project impacts at these installations does not use density data because site-specific survey data are considered a better predictor of marine mammal exposures than density data. The following sections provide summaries of the Navy's survey and monitoring efforts at MPR installations, and discuss the reasoning behind determination of species abundances used in the analysis of MPR project impacts.

# 2 SURVEY AND MONITORING EFFORTS

## 2.1 Survey and Monitoring Efforts in the Vicinity of NAVBASE Kitsap Bangor

Available data on marine mammal populations in Hood Canal are from surveys of harbor seal haulouts (Jeffries et al., 2000) and recent surveys and monitoring efforts on NAVBASE Kitsap Bangor (Agness and Tannenbaum, 2009; Tannenbaum et al., 2009, 2011; HDR, 2012; Hart Crowser, 2013; Navy, 2014, 2016), some of which covered a very limited area.

### 2.1.1 Baseline Surveys of Hauled Out Pinnipeds

Since April 2008 Navy personnel have recorded sightings of marine mammals (California sea lion, Steller sea lion, and harbor seal) at known haulouts along the Bangor waterfront, including submarines and the nearshore pontoons of the floating security fence. Sightings of marine mammals within the waters adjoining these locations were also recorded. Sightings were attempted during a typical work week (i.e., Monday through Friday), but inclement weather, holidays, or security constraints often precluded surveys. Through 2012, these sightings took place frequently (average 14 per month) and only included haulouts. Surveys were minimal in 2013 due to budget reductions. Surveys since 2013 have been conducted weekly (approximately four per month). During the surveys, staff visited each of the above mentioned locations and recorded observations of marine mammals on data collection forms, noting date, time, location, number, and species of marine mammals (by location), and other relevant notes. Surveys were conducted using binoculars and the naked eye from shoreline locations or the piers/wharves themselves. Data were compiled for the period from April 2008 through June 2016 for analysis in this Incidental Harassment Authorization (Navy, 2014, 2016). Additional incidental observations of harbor seals were reported by Naval Facilities Engineering Command biologists in September and October 2016.

### 2.1.2 Vessel-Surveys of Bangor Shoreline

Boat-based opportunistic sightings along portions of the Bangor waterfront during the course of beach seine fish surveys during the spring/summer of 2007 detected two marine mammal species (harbor seal and California sea lion) (Agness and Tannenbaum, 2009). In these surveys, seals and sea lions were noted in a field notebook, as well as date, time, location, number of individuals, species, and other relevant notes.

Boat-based protocol marine wildlife surveys conducted during July through September 2008 (12 surveys) and November through May 2009/2010 (12 surveys) (Tannenbaum et al., 2009, 2011) detected four marine mammal species (harbor seal, California sea lion, harbor porpoise, and Dall's porpoise). These protocol surveys operated along pre-determined transects parallel to the shoreline from the nearshore out to approximately 1,800 feet from shoreline, at a spacing of 100 yards, and covered the entire Bangor waterfront (approximately 1.5 square miles) at a speed of 5 knots or less. Two observers recorded sightings of marine mammals both in the water and hauled out, including date, time, species, number of individuals, age (juvenile, adult), behavior (swimming, diving, hauled out, avoidance dive), and haulout location. Positions of marine mammals were obtained by recording distance and bearing to the animal with a rangefinder and compass, noting the concurrent location of the boat with Global Positioning System (GPS), and, subsequently, analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected.

### 2.1.3 Surveys in Hood Canal and Dabob Bay

The Navy conducted vessel-based line transect surveys in Hood Canal and Dabob Bay to collect density data for species present in Hood Canal. The primary impetus for the Hood Canal/Dabob Bay surveys was that observational data during pile driving monitoring (HDR, 2012) indicated an unexpected abundance of harbor porpoise within Hood Canal. The surveys in Hood Canal were conducted in September and October and detected three marine mammal species (harbor seal, California sea lion, and harbor porpoise). Transects generally covered the area from Hazel Point on the south end of the Toandos Peninsula to Thorndyke Bay. The surveys operated along pre-determined transects that followed a double saw-tooth pattern to achieve uniform coverage of the entire Bangor waterfront. The vessel traveled at a speed of approximately 5 knots when transiting along the transect lines. Two observers recorded sightings of marine mammals both in the water and hauled out, including the date, time, species, number of individuals, and behavior (swimming, diving, etc.). Positions of marine mammals were obtained by recording the distance and bearing to the animal(s), noting the concurrent location of the boat with GPS, and subsequently analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected. Distance sampling methodologies were used to estimate densities of animals.

Surveys in adjacent Dabob Bay represented a different pattern and generally followed the shoreline while completing a circular route through the bay. A large exclusion zone surrounding a Navy ship moored temporarily in Dabob Bay made it difficult to perform zigzag transects across the bay; therefore, early attempts at surveys in Dabob did not follow a zigzag pattern, and switching to this survey pattern later in the project would have made density information collected during early “loop pattern” surveys incompatible with later data. Therefore, the loop pattern was followed during all subsequent baseline surveys in the bay.

### 2.1.4 Monitoring During Test Pile Program and EHW-2 Construction

Marine mammal monitoring was conducted in the EHW-2 project area in late 2011 during a test pile program as mitigation for pile driving noise (HDR, 2012).

Marine mammal monitoring was conducted during in-water construction periods on the EHW-2 from late September 2012 to mid-January 2015 (Hart Crowser, 2013, 2014, 2015). Monitoring was conducted in several areas: (1) Primary Surveys within the behavioral monitoring and shutdown zones in the waterfront restricted area (WRA) (464-meter radius of the driven pile), (2) In the first construction year, Outside Boat Surveys within the larger Level B behavioral harassment zone due to vibratory pile driving but outside of the WRA, and (3) Delta Pier Surveys of marine mammals hauled out on submarines at Delta Pier and, in Year 2, Marginal Wharf. Monitoring of the first two areas was conducted in accordance with an approved Marine Mammal Monitoring Plan for the EHW-2 project and consisted of placing marine mammal observers on construction barges, the construction pier, and vessels located in near-field (within the behavioral monitoring zone in the WRA) and, in the first year of construction, far-field (outside the WRA but within the Level B harassment zone) locations. Marine mammal observers reported occurrences of marine mammals during actual construction (i.e., pile driving activity) and non-construction periods. The survey effort continued for the third and final construction year (mid-July 2014 through mid-January 2015) within the behavioral monitoring and shutdown zones in the WRA with similar monitoring protocols.

### 2.2 Survey Efforts in the Vicinity of NAVBASE Kitsap Bremerton

Surveys at NAVBASE Kitsap Bremerton are conducted by Navy personnel from a vessel that runs along the port security barrier, or by visual surveys conducted from Pier 6. Floats on the port security barrier are used as haulouts by sea lions. Surveys began in September 2010, and data was collected at least once per month (Navy, 2014). Sightings of marine mammals within the waters adjoining these locations were also recorded. Aerial surveys were conducted by the Washington Department of Fish and Wildlife from spring 2013 through spring 2014; however, a final report is not available for this analysis (Robert Uyeyama, 2016, personal communication).

### 2.3 Survey Efforts in the Vicinity of the NAVBASE Kitsap Manchester

Floating platforms located approximately 0.5 miles offshore from the NAVBASE Kitsap Manchester's finger pier in Clam Bay and surrounding waters are surveyed for marine mammals. The Navy began surveying the floats incidentally to other surveys in November 2012 (Navy, 2014, 2016).

Surveys were typically conducted several times per month with the exception of September 2013 through November 2013 when no surveys were conducted (Navy, 2014). Surveys were conducted using binoculars and the naked eye from shoreline locations. Data collected used the same process as presented above for NAVBASE Kitsap Bremerton. Aerial surveys were conducted by the Washington Department of Fish and Wildlife from spring 2013 through spring 2014; however, a final report is not available for this analysis (Balla-Holden, 2014, personal communication).

### 2.4 Survey Efforts in the Vicinity of NAVSTA Everett

NAVSTA Everett piers, Port Security Barrier, log rafts adjacent to NAVSTA Everett, and surrounding waters were surveyed for marine mammals. Data was recorded once in March 2012 and then several times per month from June 2012 onward (Navy, 2014). Surveys were conducted from shoreline locations using binoculars and the naked eye. Data collected used the same process as presented above for NAVBASE Kitsap Bremerton. Aerial surveys were conducted by the Washington Department of Fish and Wildlife from spring 2013 through spring 2014; however, a final report is not available for this analysis (Balla-Holden, 2014, personal communication).

## 3 ABUNDANCE DETERMINATIONS BY SPECIES

Pinniped abundance at installations at or near MPR installations was determined by evaluating ground-based on-site counts of animals at haulouts using data compiled by the Navy (2014) for NAVBASE Kitsap Bangor, Bremerton, Manchester, and NAVSTA Everett and supplemented with 2015 data for NAVBASE Kitsap Bangor and Manchester (Navy, 2016). Abundance was based on the highest average monthly maximum counts. Surveys at NAVBASE Kitsap Bangor were initiated in 2008 and a noticeable upward trend in the numbers of Steller sea lions and California sea lions has become apparent since mid-2012. Therefore, at Bangor abundance was calculated based on average monthly maximum counts during the in-water work window starting in mid-2012. This trend may be occurring at other installations as well but the surveys have not been conducted for enough years to confirm it. At other installations all survey data were considered in calculating average monthly maximum counts. As described in Section 6.10 of this application, the monthly average maximum counts that occurred during the in-water work window at each installation were evaluated to estimate marine mammal exposures to pile driving noise. This average is considered the abundance of that species at that installation during pile driving activity.

## 3.1 NAVBASE Kitsap Bangor

| *Maximum Number of Steller Sea Lions Observed in Single Survey at NAVBASE Kitsap Bangor* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Month*** | ***2008–2009*** | ***2009–2010*** | ***2010–2011*** | ***2011–2012*** | ***2012–2013*** | ***2013–2014*** | ***2014 – 2015*** | ***2015 – 2016*** | ***2012–2016 Average*** |
| July | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| September | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 |
| October | 0 | 0 | 4 | 3 | 6 | 9 | 3 | 6 | 6 |
| November | 4 | 6 | 4 | 5 | 4 | 11 | 13 | 9 | 9 |
| December | 0 | 3 | 2 | 4 | 4 | N/A | 7 | 5 | 5 |
| January | 0 | 2 | 1 | 3 | N/A | 1 | 6 | 0 | 2 |
| February | 1 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 1 |
| March | 0 | 2 | 2 | 3 | N/A | 1 | 1 | 1 | 1 |
| April | 0 | 4 | 6 | 4 | 0 | 2 | 1 | 0 | 1 |
| May | 0 | 0 | 6 | 3 | 0 | 2 | 0 | 0 | 1 |
| June | 0 | 0 | 0 | 0 | N/A | 0 | 0 | 0 | 0 |

| *Maximum Number of California Sea Lions Observed in a Single Survey at NAVBASE Kitsap Bangor* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Month*** | ***2008–2009*** | ***2009–2010*** | ***2010–2011*** | ***2011–2012*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***2012–2016 Average*** |
| July | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 1 |
| August | 0 | 1 | 3 | 4 | 5 | 0 | 15 | 3 | 6 |
| September | 12 | 32 | 33 | 14 | 11 | 35 | 44 | 30 | 30 |
| October | 47 | 44 | 42 | 56 | 70 | 88 | 84 | 113 | 89 |
| November | 50 | 58 | 42 | 81 | 70 | 122 | 93 | 102 | 97 |
| December | 27 | 38 | 50 | 64 | 69 | N/A | 63 | 118 | 83 |
| January | 4 | 44 | 33 | 43 | N/A | 48 | 43 | 16 | 36 |
| February | 28 | 34 | 42 | 48 | 44 | 42 | 32 | 56 | 44 |
| March | 37 | 40 | 54 | 82 | N/A | 65 | 55 | 104 | 75 |
| April | 46 | 51 | 66 | 52 | 32 | 49 | 48 | 106 | 59 |
| May | 33 | 17 | 54 | 18 | N/A | 20 | 12 | 54 | 29 |
| June | 3 | 12 | 17 | 4 | N/A | 8 | 8 | 17 | 11 |

Incidental observations (N = 6 surveys) in September – October 2016 recorded as many as 26 harbor seals hauled out or in the water near Marginal Wharf at NAVBASE Kitsap Bangor.

## 3.2 NAVBASE Kitsap Bremerton

| *Maximum Number of California Sea Lions Observed in a Single Survey at NAVBASE Kitsap Bremerton* | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Month*** | ***2010–2011*** | ***2011–2012*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***MAX Average 2010–2016*** |
| July | N/A | 1 | 0 | 0 | 0 | 1 | 0 |
| August | N/A | 18 | 41 | 27 | 37 | 9 | 26 |
| September | N/A | 72 | 50 | 94 | 109 | 120 | 75 |
| October | N/A | 111 | 144 | 219 | 133 | 162 | 154 |
| November | 84 | 144 | 62 | 162 | 116 | 314 | 147 |
| December | 126 | 125 | N/A | 89 | 55 | 115 | 102 |
| January | 44 | 17 | 2 | 16 | 24 | 2 | 18 |
| February | N/A | 34 | 40 | 51 | 15 | 5 | 29 |
| March | 29 | 9 | 41 | 39 | 4 | 28 | 23 |
| April | 14 | 3 | 38 | 20 | 2 | 29 | 18 |
| May | 12 | 18 | 11 | 2 | 3 | 11 | 10 |
| June | 0 | 2 | 0 | 7 | 3 | 9 | 4 |

## 3.3 NAVBASE Kitsap Manchester

| *Maximum Number of Steller Sea Lions Observed in a Single Survey at NAVBASE Kitsap Manchester* | | | | | |
|---|---|---|---|---|---|
| ***Month*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***MAX Average 2012–2016*** |
| July | N/A | 0 | 0 | 0 | 0 |
| August | N/A | 0 | 0 | 0 | 0 |
| September | N/A | N/A | 0 | 2 | 1 |
| October | N/A | N/A | 13 | 29 | 21 |
| November | 4 | N/A | 42 | 35 | 27 |
| December | N/A | 4 | 34 | 21 | 20 |
| January | N/A | 9 | 20 | 3 | 11 |
| February | 0 | 0 | 4 | 2 | 2 |
| March | N/A | 0 | 2 | 1 | 11 |
| April | 0 | 2 | 4 | 0 | 2 |
| May | 1 | 3 | 2 | 0 | 2 |
| June | 0 | 0 | 0 | 0 | 0 |

| *Maximum Number of California Sea Lions Observed in a Single Survey at NAVBASE Kitsap Manchester* | | | | | |
|---|---|---|---|---|---|
| ***Month*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***MAX Average 2012–2016*** |
| July | N/A | 0 | 0 | 2 | 1 |
| August | N/A | 0 | 2 | 2 | 1 |
| September | N/A | N/A | 3 | 47 | 25 |
| October | N/A | N/A | 130 | 32 | 81 |
| November | 88 | N/A | 128 | 41 | 86 |
| December | N/A | 3 | 117 | 75 | 65 |
| January | N/A | 110 | 60 | 46 | 72 |
| February | 0 | 0 | 27 | 30 | 14 |
| March | N/A | 30 | 46 | 29 | 35 |
| April | 3 | 43 | 38 | 19 | 26 |
| May | 5 | 40 | 34 | 12 | 23 |
| June | 1 | 2 | 13 | 1 | 4 |

## 3.4 NAVSTA Everett

| *Maximum Number of California Sea Lions Observed in a Single Survey at NAVSTA Everett* | | | | | |
|---|---|---|---|---|---|
| ***Month*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***MAX Average 2012–2016*** |
| July | 3 | 2 | 17 | 4 | 7 |
| August | 39 | 20 | 20 | 38 | 29 |
| September | 45 | 55 | 77 | 131 | 77 |
| October | 95 | 110 | 132 | 132 | 117 |
| November | 123 | 130 | 128 | 104 | 121 |
| December | 92 | 70 | 62 | 57 | 70 |
| January | 41 | 64 | 36 | 29 | 43 |
| February | 71 | 70 | 49 | 49 | 60 |
| March | 102 | 86 | 56 | 113 | 89 |
| April | 97 | 65 | 65 | 215 | 111 |
| May | 41 | 43 | 75 | 135 | 74 |
| June | 20 | 8 | 18 | 25 | 18 |

| *Maximum Number of Harbor Seals Observed in a Single Survey at NAVSTA Everett* | | | | | |
|---|---|---|---|---|---|
| ***Month*** | ***2012–2013*** | ***2013–2014*** | ***2014–2015*** | ***2015–2016*** | ***MAX Average 2012–2016*** |
| July | 186 | 132 | 60 | 314 | 173 |
| August | 198 | 178 | 57 | 387 | 205 |
| September | 254 | 379 | 172 | 491 | 324 |
| October | 343 | 250 | 354 | 242 | 343 |
| November | 338 | 149 | 162 | 150 | 200 |
| December | 158 | 82 | 193 | 326 | 190 |
| January | 140 | 168 | 107 | 132 | 137 |
| February | 131 | 150 | 53 | 147 | 120 |
| March | 104 | 289 | 226 | 204 | 206 |
| April | 153 | 241 | 219 | 143 | 189 |
| May | 125 | 136 | 144 | 91 | 124 |
| June | 145 | 104 | 230 | 110 | 147 |

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# Appendix D

# Marine Mammal Monitoring Plan Template

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# Marine Structure Maintenance and Pile Replacement Program

## Marine Mammal Monitoring Plan Template

## *Installation/Project Name*

**Navy Region Northwest**

**Silverdale, WA**

***Date***

**Naval Facilities Engineering Command Northwest**

**1101 Tautog Circle**

**Silverdale, WA 98315**

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# 1 INTRODUCTION

***(This section will be installation and project-specific. Monitoring plans will be prepared by Navy biologists based on the current NMFS monitoring plan template and the specific project/location.)***

The U.S. Department of the Navy (Navy) proposes to conduct maintenance and repair activities at marine waterfront structures over a 5-year period at six installations within Navy Region Northwest (Region). These installations, which are located in the Puget Sound region of Washington State, include: Naval Base (NAVBASE) Kitsap Bangor, NAVBASE Kitsap Bremerton, NAVBASE Kitsap Keyport, NAVBASE Kitsap Manchester, Zelatched Point, and Naval Station (NAVSTA) Everett. ***State which installation/project(s) are covered by this monitoring plan.***

The purpose of this plan is to provide a protocol for marine mammal monitoring that will occur during in-water construction scheduled to occur between ***Insert dates for the project(s) covered by this monitoring plan***. Visual marine mammal monitoring will be conducted before, during, and after pile driving activities where noise levels may behaviorally disturb marine mammals. Noise levels from pile driving were determined to exceed the behavioral and injury thresholds for marine mammals, and a zone surrounding piles being installed will be visually monitored and pile driving will be shut-down if marine mammals are in the injury zone. This measure will preclude physical harm to marine mammals. This monitoring plan was developed to ensure compliance with the Letter of Authorization issued for this project by the National Marine Fisheries Service.

# 2 METHODS

## 2.1 Observer Qualifications

Monitoring will be conducted by qualified, trained marine mammal observers (hereafter, “observer”). An observer is a biologist with prior training and experience in conducting marine mammal monitoring or surveys, and who has the ability to identify marine mammal species and describe relevant behaviors that may occur in proximity to in-water construction activities. A trained observer will be placed at the best vantage point(s) practicable (e.g., from a small boat, the pile driving barge, on shore, or any other suitable location) to monitor for marine mammals and implement shutdown/delay procedures when applicable by calling for the shutdown to the hammer operator. The observers will have no other construction related tasks while conducting monitoring.

A dedicated monitoring coordinator will be on-site during all construction days. The monitoring coordinator will oversee marine mammal observers. The monitoring coordinator will serve as the liaison between the marine mammal monitoring staff and the construction contractor to assist in the distribution of information.

## 2.2 Data Collection

Observers will use a National Marine Fisheries Service (NMFS)-approved Marine Mammal Observation Record Form (Appendix A) which will be completed by each observer for each survey day.

- Date and time that pile driving begins or ends
- Construction activities occurring during each sighting

- Weather parameters (e.g., percent cover, percent glare, visibility)
- Water conditions (e.g., tidal state [incoming (flood), slack (neither direction), or outgoing (ebb)], and sea state). The Beaufort Sea State Scale (Appendix B) will be used to determine sea-state.
- Species, numbers, and if possible, sex and age class of marine mammals
- Marine mammal behavior patterns observed, including bearing from observer and direction of travel. If possible, include the correlation to sound pressure levels for context.
- Distance from pile driving activities to marine mammals and distance from the marine mammal to the observation point
- Locations of all marine mammal observations
- Other human activity in the area. Record the hull numbers of fishing vessels if possible.

The monitoring coordinator will complete a Marine Mammal Observation Record Form (Appendix A) for each day of monitoring. The summary form compiles information collected on the individual sighting forms and provides additional details about construction activities during marine mammal monitoring. The summary form will be provided to the Navy each day following monitoring.

## 2.3 Equipment

The following equipment will be required to conduct marine mammal monitoring:

- ***If boat-based monitors are used, add the following text.*** A survey boat will include the following minimum equipment: a means to keep electrical equipment dry, a fixed marine radio for the Captain to communicate on marine channels independent of observers communicating on a dedicated channel, depth finder, measuring tape, and GPS units that track the constant movement of the vessel. Vessels will comply with all Coast Guard regulations and be able to pass a Coast Guard safety inspection. ***Other equipment may need to be added to the list depending on the extent and timing of the project need, such as a flying bridge for elevated observation, depth finder, and navigation plotting equipment.***
- Hearing protection for biologists and boat operators working near heavy construction equipment
- At a minimum, portable marine radios with extra batteries and headsets for the observers to communicate with the monitoring coordinator, construction contractor, and other observer(s). Red and green flags can be added as back-up or in addition to the radios.
- Cellular phones that do not have a camera (depending on installation restrictions) and the contact information for the other observer(s), monitoring coordinator, and Navy point of contact.
- Nautical charts
- Daily tide tables for the project area
- Watch or Chronometer
- Binoculars (quality 7 x 50 or better, can have built-in rangefinders or reticles) and/or rangefinders
- Monitoring plan, IHA permit, and/or other relevant permit requirement specifications in sealed clear plastic cover
- Notebook with pre-standardized monitoring Marine Mammal Observation Record forms on non-bleeding paper (e.g., Rite-in-the-Rain)
- Marine mammal identification guides on waterproof paper

- Clipboard
- Pen/Pencil

## 2.4 Pile Driving Visual Monitoring and Shutdown Zones

***Visual monitoring and shutdown zones will be determined in consultation with NMFS and will be stated in the LOA and ESA Incidental Take Statement and/or Terms and Conditions sections of the Biological Opinion. Monitoring and shutdown distances may vary depending on the installation and project specifications, such as pile size and pile type. In the following sections, state the visual monitoring distance and shutdown zone distance that are required for the project(s) covered by this monitoring plan.***

During all pile driving, the Navy will visually monitor Injury and Behavioral Disturbance Zones as follows:

- An **xx** meter **Injury Monitoring Zone** shall be established and monitored to prevent injury to marine mammals from noise due to impact pile driving steel and physical interaction with construction equipment. Injury Zones for impacting non-steel piles have a minimum Shutdown Zone of 10 meters to prevent injury to marine mammals from interaction with construction equipment. There are no regulatory criteria regarding injury thresholds during vibratory pile installation.
- During pile driving, a **Behavioral Disturbance Monitoring Zone** will be established that will encompass as much of the Behavioral Disturbance Zone (i.e., for impact driving, the zone where impact pile driving levels are estimated to be at or above 160 dB re 1 µPa and for vibratory driving, the zone where vibratory pile driving noise levels are estimated to be at or above 120 dB RMS) that can be practicably monitored from observer positions described in Section 2.5.

During all pile driving, the Navy will establish Shutdown Zones as follows:

- A **Shutdown Zone for cetaceans** will include the Injury Zone and the portion of the Behavioral Disturbance Zone that can be practicably monitored from observer positions described in Section 2.5. If a cetacean approaches or enters the Shutdown Zone, pile driving will cease. See Figure D-1.
- A **Shutdown Zone for pinnipeds** will include the Injury Zone. If a pinniped enters the Shutdown Zone, pile driving will cease, but if it enters only the Behavioral Disturbance Zone, a take would be recorded and behaviors documented. That pile would be completed without cessation, unless the animal approaches or enters the Shutdown Zone, at which point all pile driving activities will be halted. See Figure D-2.
- If marine mammals are seen outside the Behavioral Disturbance Zone, these animals will also be recorded (not as a take) and their location identified.
- Distances for all monitoring zones are provided in Table D-1 below.

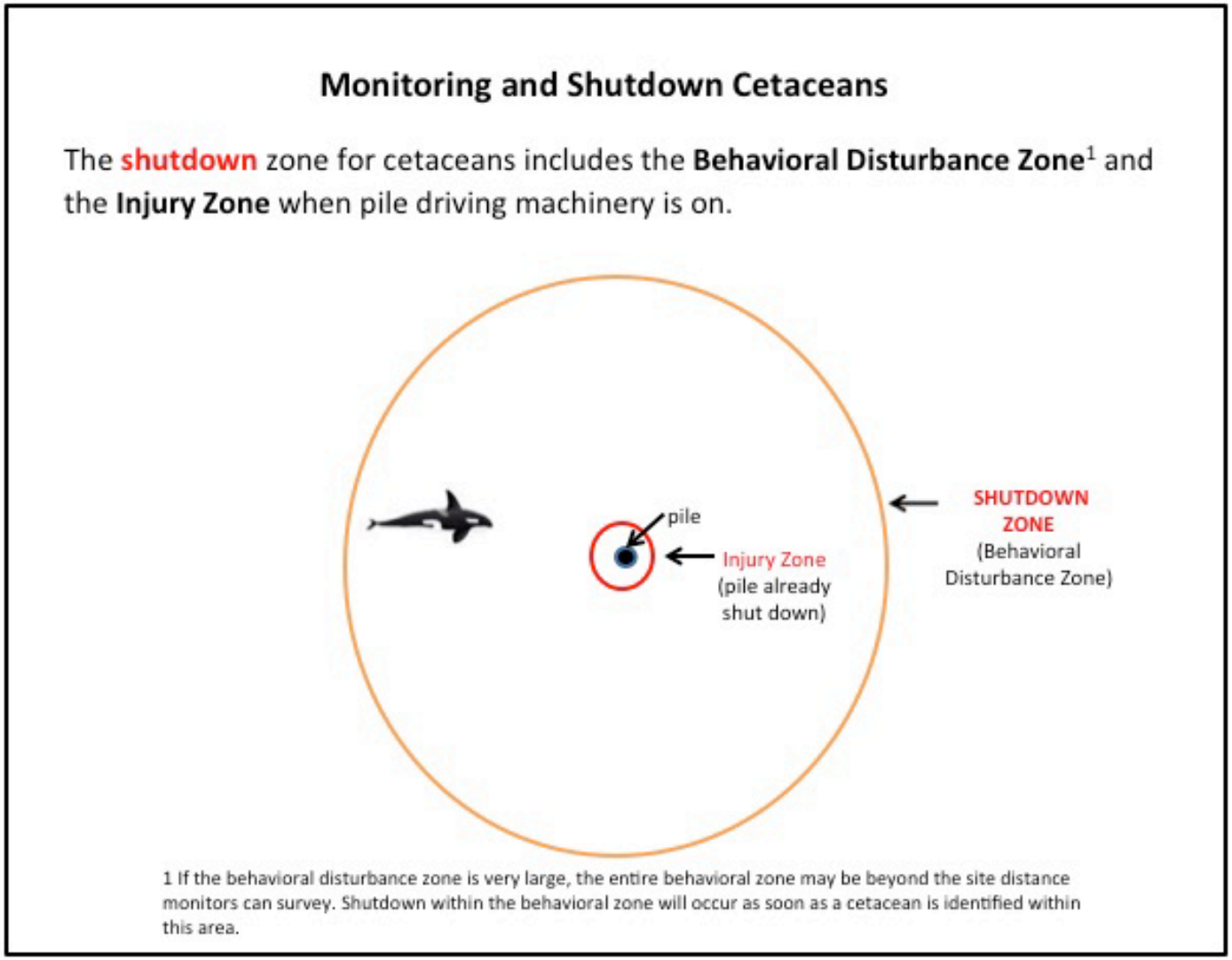


**Figure D-1. Monitoring and Shutdown for Cetaceans**

## Monitoring and Shutdown Pinnipeds

The **shutdown** zone for pinnipeds is the **Injury Zone** for pile driving. Shutdown will also occur within the behavioral zone if the pinniped is swimming toward the pile driving equipment that is turned on/in use, to avoid potential injury to a pinniped swimming toward the Injury Zone. If the pinniped is within the Behavioral Disturbance Zone, construction will be allowed to continue, and marine mammal monitors will **document behavior and location and will track** animal to ensure that it does not enter the shutdown zone.

1 If the behavioral disturbance zone is very large, the entire behavioral zone may be beyond the site distance monitors can survey. Shutdown within the behavioral zone will occur as soon as a cetacean is identified within this area.

**Figure D-2. Monitoring and Shutdown for Pinnipeds**

**Table D-1. Monitoring Zone Distances**

| Marine Mammal Group | Monitoring Zones | | | | | |
|---|---|---|---|---|---|---|
| | Vibratory | | | Impact | | |
| | Behavioral Disturbance | Injury | Shutdown | Behavioral Disturbance | Injury | Shutdown |
| **Cetaceans** | Approximately **XX** meters | n/a | Approximately **XX** meters | **XX** meters | **XX** meters | **XX** meters |
| **Pinnipeds** | Approximately **XX** meters | n/a | 10 meters | **XX** meters | **XX** meters | **XX** meters |

## 2.5 Observer Monitoring Locations

**[The number of marine mammal observers will be determined based on the effectiveness of monitoring the Injury and Disturbance Zones at each project site.]** In order to effectively monitor the Injury and Behavioral Disturbance Zones, a marine mammal observer will be positioned at the best practicable vantage points, taking into consideration security, safety, and space limitations at the waterfront. The observer will be stationed on the pier, or on the pile driving barge in a location that will provide adequate visual coverage for the **xx** meter Injury Zones. If required, a second observer will be stationed in a small vessel, on the pier, or on the pile driving barge to maximize observation of the **Behavioral Disturbance Zone**. Each monitoring location will have a minimum of one dedicated marine mammal observer (not including boat operators) (see Figure D-3).

## 2.6 Monitoring Techniques

The Navy will collect sighting data and behaviors of marine mammal species observed pre-, during, and post-driving period. The efficacy of visual detection depends on several factors including the observer's ability to detect the animal, the environmental conditions (visibility and sea state), and monitoring platforms. The following survey methodology will be implemented for all monitoring activities:

- Observers will survey the Injury and Behavioral Disturbance Zones. Monitoring will take place 15 minutes prior to initiation through 30 minutes post-completion of pile driving to ensure there are no marine mammals present.
- In case of reduced visibility due to weather or sea state, the observers must be able to see the Shutdown Zones or pile driving will not be initiated until visibility in these zones improves to acceptable levels.
- The Injury and Behavioral Disturbance Monitoring Zones will be monitored throughout the time required to install a pile.
- Marine Mammal Observation Record forms (Appendix A) will be used to document observations.
  ***[Obtain most recent version of sighting form prior to use.]***
- Any survey boats engaged in marine mammal monitoring will maintain speeds equal to or less than 10 knots.

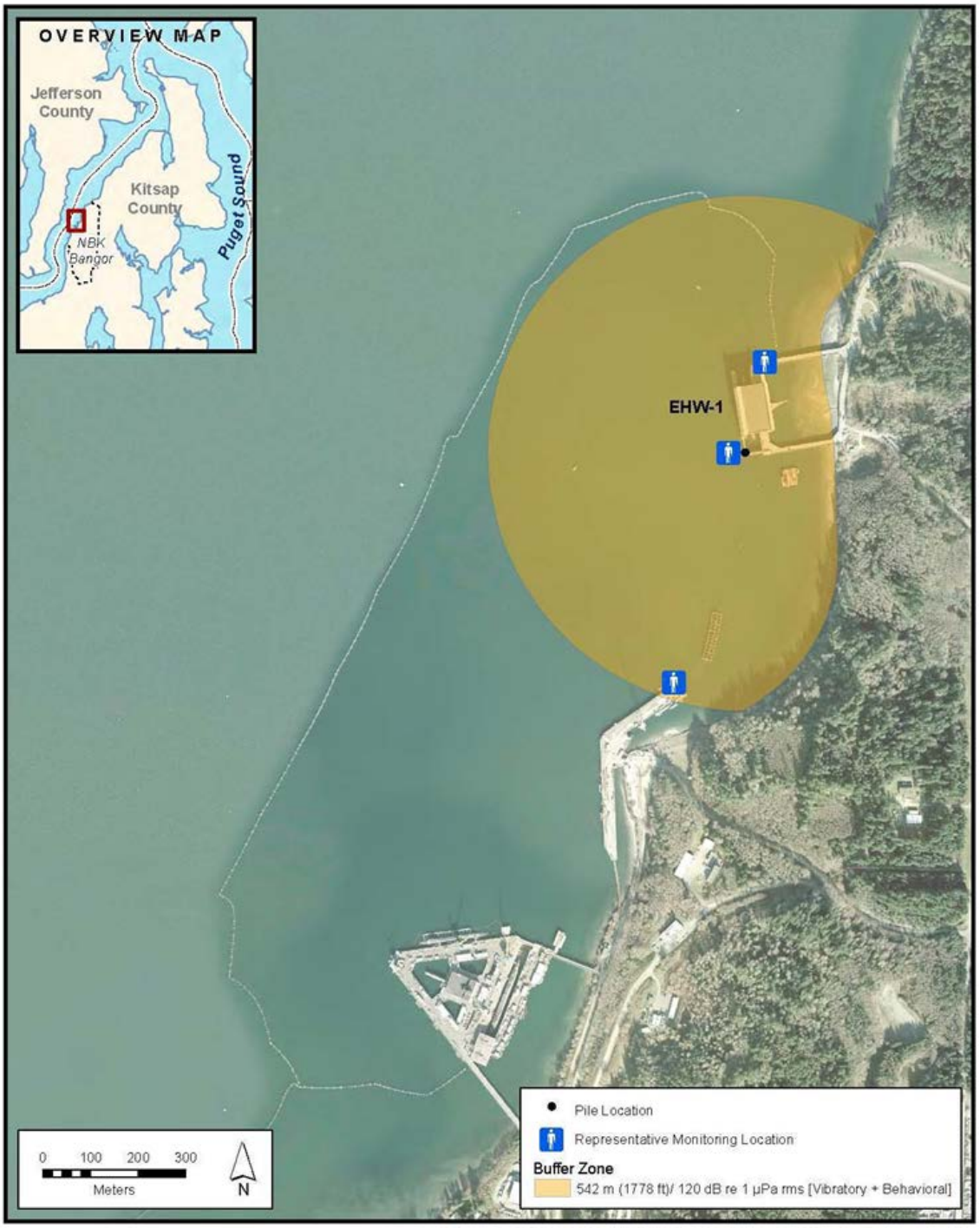


**Figure D-3. Example of Marine Mammal Visual Monitoring Zone with Representative Monitoring Locations Indicated**

***(Replace this figure with figure(s) depicting the project and installation covered by this plan.)***

- Observers will be trained and experienced marine mammal observers in order to accurately verify species sighted.
- Observers will use binoculars and the naked eye to search continuously for marine mammals.

### 2.6.1 Visual Survey Protocol – Pre-Activity Monitoring

The following survey methodology will be implemented prior to commencing pile driving:

- Visual surveys of the Injury and Behavioral Zone will occur for at least 15 minutes prior to the start of construction.
- If marine mammal(s) are present within or approaching a Shutdown Zone prior to pile driving, the start of these activities will be delayed until the animal(s) leave the Shutdown Zone voluntarily and have been visually confirmed beyond the Shutdown Zone, or 15 minutes has elapsed without re-detection of the animal.
- If marine mammal(s) are not detected within a Shutdown Zone (i.e., the zone is deemed clear of marine mammals), the observers will inform the monitoring coordinator/construction contractor that pile driving can commence.
- If a marine mammal approaches or enters the Shutdown Zone, pile driving will be delayed until the animal(s) leave the zone. If pinnipeds (s) are present within the Behavioral Disturbance Monitoring Zone, pile driving would not need to be delayed, but observers would monitor and document, to the extent practical, the behavior of marine mammals that remain in the zone.

### 2.6.2 Visual Survey Protocol – During Activity Monitoring

The Injury and Behavioral Disturbance Monitoring Zones will be monitored throughout pile driving. The following survey methodology will be implemented during pile driving:

- If a cetacean approaches or enters the Shutdown Zone for cetaceans, pile driving will cease until the animal(s) leave the zone. If a pinniped enters the Shutdown Zone for pinnipeds, pile driving will cease until the animal(s) leave the zone. If a pinniped is observed within or entering the Behavioral Disturbance Zone during pile driving, a take would be recorded, behaviors documented, and the Shutdown Zone monitor alerted to the position of the animal. However, that pile segment would be completed without cessation, unless the animal approaches or enters the Shutdown Zone for pinnipeds, at which point all pile driving activities will be halted. The observers shall immediately radio to alert the monitoring coordinator/construction contractor. This action will require an immediate “all-stop” on pile operations.
- Once a shutdown has been initiated, pile driving and other in-water construction activities will be delayed until the animal has voluntarily left the Shutdown Zone and has been visually confirmed beyond the Shutdown Zone, or 15 minutes have passed without re-detection of the animal (i.e., the zone is deemed clear of marine mammals). The monitoring coordinator will inform the construction contractor that activities can re-commence.
- If shutdown and clearance procedures would result in an imminent concern for human safety, as determined by the construction contractor, the Navy Point of Contact will be notified prior. The Navy POC will notify NMFS within 24 hours.

### 2.6.3 Visual Survey Protocol – Post-Activity Monitoring

Monitoring of the Shutdown Zones will continue for 30 minutes following completion of pile driving. These surveys will record marine mammal observations, and will focus on observing and reporting unusual or abnormal behavior of marine mammals. During these surveys, if any injured, sick, or dead marine mammals are observed, procedures outlined below in Section 3.0 should be followed.

# 3 INTERAGENCY NOTIFICATION

In the event that the Navy needs to modify terms of this monitoring plan, the NMFS representative will be promptly contacted for discussion of the requested modification. In the unanticipated event that the specified activity clearly causes the take of a marine mammal in a manner prohibited by this IHA, such as an injury (Level A harassment), serious injury, or mortality, Navy shall immediately cease the specified activities and report the incident to the Chief of the Permits and Conservation Division (301-427-8425), Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator (206-526-6550), NMFS. The report must include the following information:

- Time and date of the incident
- Description of the incident
- Environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility)
- Description of all marine mammal observations in the 24 hours preceding the incident
- Species identification or description of the animal(s) involved
- Fate of the animal(s) and
- Photographs or video footage of the animal(s)

Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS will work with Navy to determine what measures are necessary to minimize the likelihood of further prohibited take and ensure Marine Mammal Protection Act compliance. Navy may not resume their activities until notified by NMFS.

In the event that Navy discovers an injured or dead marine mammal, and the lead observer determines that the cause of the injury or death is unknown and the death is relatively recent (e.g., in less than a moderate state of decomposition), Navy shall immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator, NMFS. The report will include the same information as listed above. Activities may continue while NMFS reviews the circumstances of the incident. The Navy will work with NMFS to determine whether additional mitigation measures or modifications to the activities are appropriate.

In the event that Navy discovers an injured or dead marine mammal, and the lead observer determines that the injury or death is not associated with or related to the activities authorized in the IHA (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), the Navy shall report the incident to the Chief of Permits and Conservation Division, Office of Protected Resources, NMFS, and the Northwest Regional Stranding Coordinator, NMFS, within 24 hours of the discovery. Navy shall provide photographs or video footage or other documentation of the stranded animal sighting to NMFS.

Care should be taken in handling dead specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In preservation of biological materials from a dead animal, the finder (i.e., marine mammal observer) has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. The Navy will prepare a Chain of Custody Record (Appendix C) to document handling of specimens.

Primary points of contact for the Navy are: **[*Update contacts as needed*]**

1. Tyler Yasenak – (360) 315-2452
2. Greg Leicht – (360) 315-5411

The Navy primary point of contact will contact NMFS. The primary points of contact at NMFS are:

1. Modification to protocol – (360) 753-5835
2. Chief of the Permits and Conservation Division – (301-427-8425)
3. Northwest Regional Stranding Coordinator – (206-526-6550)

# 4 MONITORING REPORTS

A draft report will be submitted to NMFS within 90 work days of the completion of marine mammal monitoring. A final report will be prepared and submitted to the NMFS within 30 days following receipt of comments on the draft report from the NMFS. At a minimum, the report shall include:

- General data:
  - Date and time of activities
  - Water conditions (e.g., sea-state, tidal state)
  - Weather conditions (e.g., percent cover, visibility)
- Specific pile data:
  - Description of the pile driving activities including the size and type of pile
  - The installation methods used for each pile and the duration each method was used per pile
  - Impact or vibratory hammer force used to drive/extract piles
  - Detailed description of the sound attenuation system, including the design specifications
  - Depth of water in which the pile was driven
  - Depth into the substrate that the pile was driven
- Specific pile removal data:
  - Description of the pile removal activities being conducted
    - Size and type of piles
    - The machinery used for removal
    - Duration each pile removal method was used
  - The vibratory driver force
- Pre-activity observational survey-specific data:
  - Dates and time survey is initiated and terminated

  - Description of any observable marine mammal behavior in the immediate area during monitoring
  - If possible, the correlation to underwater sound levels occurring at the time of the observable behavior
  - Actions performed to minimize impacts to marine mammals.
- During-activity observational survey-specific data:
  - Description of any observable marine mammal behavior within monitoring zones or in the immediate area surrounding monitoring zones including the following:
    - Distance from animal to source
    - Reason why/why not shutdown implemented
    - If a shutdown was implemented, behavioral reactions noted and if they occurred before or after implementation of the shutdown
    - If a shutdown is implemented, the distance from animal to source at the time of the shutdown
    - Behavioral reactions noted during soft starts[1] and if they occurred before or after implementation of the soft start
    - Distance to the animal from the source during soft start
  - Actions performed to minimize impacts to marine mammals
  - Times when pile driving is stopped due to presence of marine mammals within the Shutdown Zones and time when pile driving resumes
- Post-activity observational survey-specific data:
  - Results, which include the detections of marine mammals, species and numbers observed, sighting rates and distances, behavioral reactions within and outside of monitoring zones
  - A refined take estimate based on the number of marine mammals observed during the course of construction

[1] The objective of a soft-start is to provide a warning and/or give animals in close proximity to pile driving a chance to leave the area prior to a vibratory or impact driver operating at full capacity thereby, exposing fewer animals to loud underwater and airborne sounds.

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# Appendix A

# Marine Mammal Observation Record Form

*[Obtain most recent version of sighting form prior to use.]*

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# APPENDIX A
# MARINE MAMMAL OBSERVATION RECORD FORM

Project Name: _____

Monitoring Location_____
(Pier Location, Vessel based, Land Location, other)

Page _____ of _____

Date: _____

Vessel Name: _____

Time Effort Initiated:_____

Time Effort Completed:_____

## Sighting Data

| Event Code | Sighting Number (1 or 1.1 if resight) | Time/Duration watching sighting (Start/End time if continuous) | WP # (every time a sighting is made) | Observer | Sighting cue | Species | Dist/ Dir to Animal (from Observer) | Dist to Pile (btwn animal & pile) | # of Animals Group Size (min/max/best )# of Calves | Relative Motion/and Behavior Code (see code sheet) | Const Type During Sighting | Miti gation used during sighting? | Miti gation Type? | Visibility | % Glare | Weath Cond | Sea State and Wave Ht | Swell Dir | Behavior Change/ Response to Activity/Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | Light Mod Heavy | N or S W or E | |
| | | : : : : | | | | | m or km ° | m or km | / / ___ calves | opening closing parallel none | PRE POST SSV SSI V I PC DP ST NONE | Y N | DE SD | B P M G E | | | | N or S W or E | |

Sighting #=chronological number of sightings, If resight of same animal, then 1.1, 1.2, etc. WP (Waypoint)=GPS recording of lat/long, time/date stamp. Critical for vessel observers.

# Sighting Codes
# (Sighting Cue & Behavior Codes)

**Behavior codes**

| Code | Behavior | Definition |
|---|---|---|
| BR | Breaching | Leaps clear of water |
| CD | Change Direction | Suddenly changes direction of travel |
| CH | Chuff | Makes loud, forceful exhalation of air at surface |
| DI | Dive | Forward dives below surface |
| DE | Dead | Shows decomposition or is confirmed as dead by investigation |
| DS | Disorientation | An individual displaying multiple behaviors that have no clear direction or purpose |
| FI | Fight | Agonistic interactions between two or more individuals |
| FO | Foraging | Confirmed by food seen in mouth |
| MI | Milling | Moving slowly at surface, changing direction often, not moving in any particular direction |
| PL | Play | Behavior that does not seem to be directed towards a particular goal; may involve one, two or more individuals |
| PO | Porpoising | Moving rapidly with body breaking surface of water |
| SL | Slap | Vigorously slaps surface of water with body, flippers, tail etc. |
| SP | Spyhopping | Rises vertically in the water to "look" above the water |
| SW | Swimming | General progress in a direction. Note general direction of travel when last seen [Example: "SW (N)" for swimming north] |
| TR | Traveling | Traveling in an obvious direction. Note direction of travel when last seen [Example: "TR (N)" for traveling north] |
| UN | Unknown | Behavior of animal undetermined, does not fit into another behavior |
| **Pinniped only** | | |
| EW | Enter Water (from haul out ) | Enters water from a haul-out for no obvious reason |
| FL | Flush (from haul out ) | Enters water in response to disturbance |
| HO | Haul out (from water) | Hauls out on land |
| RE | Resting | Resting onshore or on surface of water |
| LO | Look | Is upright in water "looking" in several directions or at a single focus |
| SI | Sink | Sinks out of sight below surface without obvious effort (usually from an upright position) |
| VO | Vocalizing | Animal emits barks, squeals, etc. |
| **Cetacean only** | | |
| LG | Logging | Resting on surface of water with no obvious signs of movement |

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## Sighting Codes (continued)

**Marine Mammal Species**

| Code | Marine Mammal Species |
|---|---|
| CASL | California Sea Lion |
| HSEA | Harbor Seal |
| STSL | Steller Sea Lion |
| HPOR | Harbor Porpoise |
| DPOR | Dall's Porpoise |
| ORCA | Killer Whale |
| HUMP | Humpback Whale |
| UNLW | Unknown Large Whale |
| RIVO | River Otter (not a marmam) |
| OTHR | Other |
| UNKW | Unknown |

**Event**

| Code | Activity Type |
|---|---|
| E ON | Effort On |
| E OFF | Effort Off |
| PRE | Pre Watch |
| POST | Post Watch |
| SSV | Soft start-vibratory |
| SSI | Soft start-impact |
| WC | Weather Condition/Change |
| S | Sighting |
| M-DE | Mitigation Delay |
| M-SD | Mitigation Shutdown |

**Construction Type**

| Code | Activity Type |
|---|---|
| SSV | Soft Start (Vibratory) |
| SSI | Soft Start (Impact) |
| V | Vibratory Pile Driving (installation and extraction) |
| I | Impact Pile Driving |
| PC | Pneumatic Chipping |
| DP | Dead pull |
| ST | Stabbing |
| NONE | No Pile Driving |

**Mitigation Codes**

| Code | Activity Type |
|---|---|
| DE | Delay onset of Pile Driving |
| SD | Shut down Pile Driving |

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# Sighting Codes (continued)

**Visibility**

| Code | Distance Visible |
|---|---|
| B | Bad (<0.5km) |
| P | Poor (0.5 – 1.5km) |
| M | Moderate (1.5 – 10km) |
| G | Good (10 - 15km) |
| E | Excellent (<15km) |

**Glare**

Percent glare should be total glare of observers' area of responsibility. Are they covering 90 degrees or 180 degrees? Total glare for that area and write that area down on the datasheet so we know later what percentage of the field of view was poor due to glare.

**Weather Conditions**

| Code | Weather Condition |
|---|---|
| S | Sunny |
| PC | Partly Cloudy |
| L | Light Rain |
| R | Steady Rain |
| F | Fog |
| OC | Overcast |

**Sea State and Wave Height**

Use Beaufort Sea State Scale for Sea State Code. This refers to the surface layer and whether it is glassy in appearance or full of white caps. In the open ocean, it also takes into account the wave height, but in inland waters the wave heights (swells) may never reach the levels that correspond to the correct surface white cap number. Therefore, include wave height for clarity.

| Code | Wave Height |
|---|---|
| Light | 0 – 3 ft |
| Moderate | 4 – 6 ft |
| Heavy | >6 ft |

**Swell Direction**

Swell direction should be where the swell is coming from (S for coming from the south). If possible, record direction relative to fixed location (pier). Choose this location at beginning of monitoring project.

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# Appendix B

# Beaufort Sea State Scale

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# APPENDIX B
# BEAUFORT SEA STATE SCALE

**US Navy and Beaufort Sea State Codes** (http://ioc.unesco.org and http://www.wrh.noaa.gov/pqr/info/beaufort.php)

| Beaufort Sea State | Wind Speed (knots) | Wind Description | Wave Height (ft) Beaufort | Sea State – Beaufort | Notes Specific to On-water Seabird Observations | Photos Indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 0 | <1 | Calm | 0 | Calm; like a mirror | Excellent conditions, no wind, small or very smooth swell. You have the impression you could see anything. | |
| 1 | 1-3 | Light air | ¼ < ½ | Ripples with appearance of scales; no foam crests | Very good conditions, surface could be glassy (Beaufort 0), but with some lumpy swell or reflection from forests, glare, etc. | |

## APPENDIX B
## BEAUFORT SEA STATE SCALE (continued)

| Beaufort Sea State | Wind Speed (knots) | Wind Description | Wave Height (ft) Beaufort | Sea State – Beaufort | Notes Specific to On-water Seabird Observations | Photos Indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 2 | 4-6 | Light breeze | ½ – 1 (max 1) | Small wavelets; crests with glassy appearance, not breaking | Good conditions, no whitecaps; texture/lighting contrast of water make murrelets hard to see. Surface could also be glassy or have small ripples, but with a short, lumpy swell, thick fog, etc. | |
| 3 | 7-10 | Gentle breeze | 2 – 3 (max 3) | Large wavelets; crests begin to break; scattered whitecaps | Fair conditions, scattered whitecaps, detection of murrelets definitely compromised; a hit-or-miss chance of seeing them owing to water choppiness and high contrast. This could also occur at lesser wind with a very short wavelength, choppy swell. | |

## APPENDIX B
## BEAUFORT SEA STATE SCALE (continued)

| Beaufort Sea State | Wind Speed (knots) | Wind Description | Wave Height (ft) Beaufort | Sea State – Beaufort | Notes Specific to On-water Seabird Observations | Photos Indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 4 | 11-16 | Moderate breeze | 3 ½ – 5 (max 5) | Small waves becoming longer, numerous whitecaps | Whitecaps abundant, sea chop bouncing the boat around, etc. | |
| 5 | 17-20 | Fresh breeze | 6 – 8 (max 8) | Moderate waves, taking longer form; many whitecaps; some spray | | |

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# Appendix C

# Chain Of Custody Record

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## Chain of Custody Record

| Date and Time of Collection: | Duty Station: | Collection By: |
|---|---|---|

| Source of Specimen (Person and/or Location):<br><br>Found At: | Project Name: |
|---|---|

| Item No: | Description of Specimen (Include Species and Tag Number): | | | |
|---|---|---|---|---|
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |

## Chain of Custody Record

| | | | | |
|---|---|---|---|---|
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |

# Appendix E

# Weighted Frequency Analysis for Auditory Effects of Underwater Construction Noise

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# Weighted Frequency Analysis for Auditory Effects of Underwater Construction Noise

December 8, 2016

D. Grebner, NUWC Keyport Division, Code 214
M. Renken, NUWC Keyport Division, Code 234
M. Slater, NSWC Carderock Division, Code 7300

The intent of this short analysis is to determine whether the application of the auditory weighting function for a marine mammal species across the entire one-second SEL spectrum is a closer estimate than applying the weighting function at a single frequency as suggested in the National Marine Fisheries Service (NMFS) Spreadsheet. The ultimate goal of both analyses is to predict the potential range to effect for auditory effects (Permanent Threshold Shift and Temporary Threshold Shift). The NMFS Spreadsheet (2016) was implemented as an optional tool to help evaluate the effects of a proposed action on marine mammal hearing and provides suggestions for estimated effect distances (i.e., isopleths) where the cumulative sound exposure level (SELcum) PTS onset thresholds may be exceeded (required by NOAA regulatory statutes). The NMFS Spreadsheet determines the Weighting Function (W(f)) from only a single frequency and is considered to be a conservative method that typically results in higher estimates of the PTS onset distance from the pile driving activity. The analysis focused on the data provided from the Naval Kitsap Bangor Test Pile Program and the Puget Sound Naval Shipyard Intermediate Maintenance Facility Pier 6 Fender Pile Replacement Project.

The overall purpose of the Naval Kitsap Bangor Test Pile Program (TPP) was to collect geotechnical and propagation information. Such data would be used to validate design concepts, construction methods, and environmental analyses to be used for future projects at Naval Base Kitsap at Bangor waterfront, as well as Explosives Handling Wharf Pile Replacement (EHW-1) Project. In addition to acoustic monitoring during pile driving events, biological monitoring of marine species in Hood Canal was also performed. Further information and procedures on impact pile driving for steel piles can be found in the Naval Base Kitsap Bangor Test Pile Program: Acoustic Monitoring Report,

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December 8, 2016
Other requests for this document shall be referred to:
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Bethesda, MD 20817-5700
Attn: Michael A. Slater, Phone: 301-227-6088

Bangor, WA 2012 by Illingsworth & Rodkin, Inc. Sound levels during impact pile driving of concrete piles were examined in another report (Puget Sound Naval Shipyard Intermediate Maintenance Facility Pier 6 Fender Pile Replacement Project: Acoustic Monitoring Results 2016) with the intent of assessing more accurate sound exposure levels (SEL).

In this analysis, sound level data over one second were collected off 1/3 octave band frequency graphs for two steel and one concrete impact pile driving events. For both the 36" and 24" steel piles, sound levels were obtained from averaged one-second SEL spectral dataset measured on 1 September 2011. The W(f) was applied to the entire spectrum (from 8 Hz to 20 kHz) of a single strike from the impact pile driving recording collected on a 36" and 24" steel pile with hammer size D-80. Hydrophones were positioned at mid-water column depth approximately 10-11 meters (m) from the steel pile. For the 24" concrete pile, one-second SEL spectral data were extracted from a figure in the Pier 6 Report during the time period of 10-17 September 2015. The W(f) was applied to the entire spectrum (from 20 Hz to 50 kHz) on a single strike from an impact pile driving recording collected on a 24" concrete pile using a Delmag D-36 driving device. Hydrophones were located approximately 10 m from the concrete pile. Since harbor seals are the most prevalent species in this area, most of this analysis focused on Phocid pinniped hearing sensitivities. Weighting factor parameters were obtained from NOAA's Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset Permanent and Temporary Threshold Shifts 2016, Table ES2. Parameters for Phocids are: a=1.0, b=2, $_{f1}$ = 1.9 kHz, $f_2$ = 30 kHz, and C = 0.75 dB (Table 1). Range to effect distances were calculated for all five hearing groups (low-frequency, mid-frequency, and high-frequency cetaceans, along with Phocid and Otariid pinnipeds).

**Table 1:** Parameters for each hearing group used to determine Weighting Functions, W(f)

| Weighting Function W(f) Parameters | Low-Frequency Cetaceans | Mid-Frequency Cetaceans | High-Frequency Cetaceans | Phocid Pinnipeds | Otariid Pinnipeds |
|---|---|---|---|---|---|
| **a** | 1 | 1.6 | 1.8 | 1 | 2 |
| **b** | 2 | 2 | 2 | 2 | 2 |
| **$f_1$** | 0.2 | 8.8 | 12 | 1.9 | 0.94 |
| **$f_2$** | 19 | 110 | 140 | 30 | 25 |
| **C** | 0.13 | 1.2 | 1.36 | 0.75 | 0.64 |

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

Note: 'f' in the NOAA Spreadsheet is a single frequency, in this analysis it is multiple frequencies along the pile spectra; $f_1$ is low frequency cutoff, $f_2$ is high frequency cutoff; a and b are the low and high frequency exponents, respectively, specific to each functional hearing group; C is a constant (gain, dB) specific to each group

W(f)s at specific frequencies along the spectrums for this analysis were compared to those used in the NOAA Spreadsheet to validate the W(f) calculations and determine a methodology for determining the SELs. For instance, for the 36" steel pile, the W(f) for the unweighted SEL was -15.0 dB at a peak frequency of 315 Hz; the corresponding W(f) in the NOAA Spreadsheet at input of 315 Hz was also -15.0

dB (as expected). The NOAA User Spreadsheet however, suggests that people use a Weighting Function Adjustment (WFA) input frequency of 2 kHz for impact pile driving. The NOAA WFA would be equivalent to our W(f) results at only 2 kHz with all other frequencies differing in W(f)s. A comparison of W(f)s for Phocids between this analysis and the NOAA Spreadsheet are highlighted in Table 2 along with overall decibel (dB) differences for each pile type. The peak frequency for the impact pile driving on a steel pile was 315 Hz. The overall W(f) in this analysis was -8.0 dB for an unweighted SEL 36" steel pile (with no bubble curtain), which is more than three times reduction in sound level (in dB) than NOAA's W(f) at 2 kHz. This is significant because an adjustment of 6 dB (SEL re 1 uPa^2 s) would change the range to effect up to a factor of four. In other words, the NMFS recommendation could be four times larger than it should be to produce a conservative margin.

**Table 2:** Comparison of analysis Weighting Functions to NOAA Spreadsheet using weighting factor parameters for Phocids

| | | | | | | | Overall SEL Adjustment (dB) | | |
|---|---|---|---|---|---|---|---|---|---|
| Frequency (kHz) | 0.315 | 1 | 2 | 4 | 8 | 16 | 36" Steel Pile | 24" Steel Pile | 24" Concrete Pile |
| Analysis Weighting Function W(f) (dB)[§] | -15.0 | -5.9 | -2.08 | -0.29 | -0.08 | -1.49 | -8.0 | -10.0 | -14.0 |
| NOAA Spreadsheet Weighting Function W(f) (dB)* | -2.08 | -2.08 | -2.08 | -2.08 | -2.08 | -2.08 | -2.08 | -2.08 | -2.08 |
| Differences | -12.92 | -3.82 | 0 | 1.79 | 2.00 | 0.59 | -5.92 | -7.92 | -11.92 |

[§]Analysis adjustments to be applied to impact pile driving noise SELs; weighing applied to multiple frequencies

*NOAA Spreadsheet WFA is set to a single frequency (2 kHz) for impact pile driving, so the W(f) is equivalent to the W(f) for this analysis at 2 kHz. NOAA Spreadsheet does not differentiate between pile types.

Data collection included sound levels without and with the application of a bubble curtain (BC off, BC on), which were implemented to dampen the impact pile driving source levels. Center frequencies were determined for the 1/3 octave band frequencies while spectrum levels were extracted from the graphs. For the steel piles, sound levels were summed over one second for both unweighted and weighted sound levels with and without a bubble curtain application. The resultant steel pile associated SELs as a function of frequency (dB re 1 $uPa^2s$) are shown in Table 3. For a 36" steel pile, the largest SEL was the unweighted level without a bubble curtain of 191 dB, while the lowest was the weighted level with a bubble curtain at 173 dB (a -18 dB difference). All weighted values in Table 3 used the W(f) parameters for Phocid pinnipeds only (Table 1). Application of the W(f) for the 36" steel pile alone reduced the unweighted SEL by -8 dB (Tables 2 & 3), while the addition of the bubble curtain further reduced levels in the unweighted and weighted levels by -8 dB and -10 dB, respectively (Table 3). The pile for this particular 24" steel pile example was not hit very hard, so while the spectral shape is characteristic for this pile type, the levels shown are lower than would be anticipated (Tables 2 & 3).

For the concrete pile data, no bubble curtain was applied, so results are for unweighted and weighted SELs only. The same methodology of applying the W(f) over the entire one-second spectrum with respect to frequency was applied to a spectral average for multiple strikes of a single 24" concrete pile.[1] The averaged unweighted data was 171 dB while the weighted data (for Phocids) had a single strike SEL of 157 dB; this is an overall spectrum level reduction of -14 dB (Table 2 & 3). The NOAA Spreadsheet does not specify between pile types, so the recommended WFA for impact pile driving remained 2 kHz with a W(f) of -2.08 dB (Table 2). Since the analysis is still focusing on Phocids, the W(f) at specific frequencies (e.g., 1 kHz, 2 kHz) are the same for impact pile driving for both steel and concrete piles (Table 3). For the concrete pile, the conservatism is even more extreme, resulting in ranges predicted by the NOAA Spreadsheet that are much larger than needed, because the spectral content of the concrete pile driving strike is even lower in frequency than for a steel pile.

**Table 3:** Analysis results of unweighted and weighted SELs with bubble curtains off and on using weighting factor parameters for Phocids

| Pile Type | Unweighted SEL (dB) | | Weighted SEL (dB) | |
|---|---|---|---|---|
| | BC off | BC On | BC off | BC On |
| 36" Steel Pile | 191 | 183 | 183 | 173 |
| 24" Steel Pile* | 179 | 173 | 169 | 161 |
| 24" Concrete Pile | 171 | - | 157 | - |

'BC' indicates Bubble Curtain; '-' indicates bubble curtain was not applied

*24" steel pile hit less hard, spectral shape characteristic for pile type, but levels lower

In this analysis, to show that spectral shape matters, range to effect distances were calculated for the weighted SELs for all five hearing groups and for all three pile types without and with a bubble curtain (Table 4a-c). As shown, the W(f) parameters vary between the five hearing groups (Table 1) as well as SELcum thresholds (Table 4a-c); this alters the ranges to effects between hearing groups. Since the number of needed impact pile driving strikes also may vary, two realistic yet different examples are shown (e.g., 4000 and 1000 strikes per day) for all three pile types (36" steel pile (Table 4a), 24" steel pile (Table 4b), and 24" concrete pile (Table 4c)).

[1] SEL spectra were not directly measured during the Pier 6 project, only powersum values were made using the USLM analyzer. In place of this, the RMS averaged spectrum for a series of pile strikes were used as a proxy to estimate the spectral shape of a single strike on a 24" concrete pile.

**Table 4a:** 36" Steel pile range to effect distances using weighted SELs (bubble curtain off and on) for each hearing group

| | | | | Range to Effect (m)[§] | | | |
|---|---|---|---|---|---|---|---|
| | | Weighted SEL (dB re 1uPa$^2$s) | | w/ 4000 strikes/pile | | w/ 1000 strikes/pile | |
| | SELcum Threshold | BC off | BC on | BC off | BC on | BC off | BC on |
| Low-Frequency Cetaceans | 183 | 189 | 181 | 6330 | 1854 | 2512 | 736 |
| Mid-Frequency Cetaceans | 185 | 167 | 155 | 159 | 25 | 63 | 10 |
| High-Frequency Cetaceans | 155 | 161 | 151 | 6330 | 1364 | 2512 | 541 |
| Phocid Pinnipeds | 185 | 183 | 173 | 1854 | 399 | 736 | 158 |
| Otariid Pinnipeds | 203 | 183 | 172 | 117 | 22 | 46 | 9 |

[§] Input parameters for range to effect calculations: weighted SEL (for BC off & on), 1 pile/day, propagation: 15log10(R), distance to strike SEL: 10 m, number of strikes/pile was 4000 m or 1000 m; 'BC' indicates Bubble Curtain; '-' indicates bubble curtain was not applied; SELcum is cumulateive SEL

**Table 4b:** 24" Steel pile range to effect distances using weighted SELs (bubble curtain off and on) for each hearing group

| | | | | Range to Effect (m)[§] | | | |
|---|---|---|---|---|---|---|---|
| | | Weighted SEL (dB re 1uPa$^2$s) | | w/ 4000 strikes/pile | | w/ 1000 strikes/pile | |
| | SELcum Threshold | BC off | BC on | BC off | BC on | BC off | BC on |
| Low-Frequency Cetaceans | 183 | 171 | 170 | 399.4 | 342.5 | 158.5 | 135.9 |
| Mid-Frequency Cetaceans | 185 | 152 | 148 | 15.9 | 8.6 | 6.3 | 3.4 |
| High-Frequency Cetaceans | 155 | 148 | 144 | 860.4 | 465.6 | 341.5 | 184.8 |
| Phocid Pinnipeds | 185 | 169 | 161 | 216.1 | 63.3 | 85.8 | 25.1 |
| Otariid Pinnipeds | 203 | 168 | 160 | 11.7 | 3.4 | 4.6 | 1.4 |

[§] Input parameters for range to effect calculations: weighted SEL (for BC off & on), 1 pile/day, propagation: 15log10(R), distance to strike SEL: 10 m, number of strikes/pile was 4000 m or 1000 m; 'BC' indicates Bubble Curtain; '-' indicates bubble curtain was not applied; SELcum is cumulateive SEL

**Table 4c:** 24" Concrete pile range to effect distances using weighted SELs (bubble curtain off and on) for each hearing group

| | | | | Range to Effect (m)[§] | | | |
|---|---|---|---|---|---|---|---|
| | | Weighted SEL (dB re 1uPa$^2$s) | | w/ 4000 strikes/pile | | w/ 1000 strikes/pile | |
| | SELcum Threshold | BC off | BC on | BC off | BC on | BC off | BC on |
| Low-Frequency Cetaceans | 183 | 167 | - | 216.1 | - | 85.8 | - |
| Mid-Frequency Cetaceans | 185 | 140 | - | 2.5 | - | 1.0 | - |
| High-Frequency Cetaceans | 155 | 136 | - | 136.4 | - | 54.1 | - |
| Phocid Pinnipeds | 185 | 157 | - | 34.3 | - | 13.6 | - |
| Otariid Pinnipeds | 203 | 156 | - | 1.9 | - | 0.7 | - |

[§] Input parameters for range to effect calculations: weighted SEL (for BC off & on), 1 pile/day, propagation: 15log10(R), distance to strike SEL: 10 m, number of strikes/pile was 4000 m or 1000 m; 'BC' indicates Bubble Curtain; '-' indicates bubble curtain was not applied; SELcum is cumulateive SEL

Range to effect distances were reduced for all species using the full weighted frequency spectrum approach in this analysis versus the NOAA single frequency approach, due simply to the SEL spectral shape coupled with the weighting function (Table 5). As mentioned, the suggested input WFA in the NOAA Spreadsheet for impact pile driving is 2 kHz (this is the sole input 'f' in the W(f) calculation (Table 1 equation). In Table 5, the input parameters to calculate each range to effect distance (in meters) included: 4000 strikes/pile, 1 pile/day, a propagation of 15 (i.e., 15log(R)) and distance to strike of 10 m. Both examples represent the extreme SELs for the unweighted, no bubble curtain scenarios from Table 3. For the 36" steel pile (191 dB), the ranges computed using the NOAA Spreadsheet were 1.4 -2.9 times greater than those seen for this analysis (see 'Ratio' column for both pile types) (Table 5). For the 24" concrete pile (171 dB), the ratio was 1.8 – 8.4 times greater in distance (NOAA range to effect distances compared to those for this analysis).

**Table 5:** Range to effect calculation differences between NOAA Spreadsheet and This Analysis using two representative pile driving scenarios

| | | 36" Steel Pile with unweighted SEL (191 dB) | | | 24" Concrete Pile with unweighted SEL (171 dB) | | |
|---|---|---|---|---|---|---|---|
| | | Range to Effect (m)[§] BC off | | | Range to Effect (m)[§] BC off | | |
| | SELcum Threshold | NOAA | This Analsis | **Ratio** | NOAA | This Analsis | **Ratio** |
| Low-Frequency Cetaceans | 183 | 8592.3 | 6330 | 1.4 | 398.8 | 216 | 1.8 |
| Mid-Frequency Cetaceans | 185 | 305.6 | 159 | 1.9 | 14.2 | 2.5 | 5.6 |
| High-Frequency Cetaceans | 155 | 10234.8 | 6330 | 1.6 | 475.1 | 136.4 | 3.5 |
| Phocid Pinnipeds | 185 | 4598.2 | 1854 | 2.5 | 213.4 | 34.3 | 6.2 |
| Otariid Pinnipeds | 203 | 334.8 | 117 | 2.9 | 15.5 | 1.9 | 8.4 |

[§] Input parameters for range to effect calculations: unweighted SELs (for BC off), 1 pile/day, propagation: 15log10(R), distance to strike SEL: 10 m, number of strikes/pile was 4000 m; 'BC' indicates Bubble Curtain; Ranges to Effects results from NOAA Spreadsheet, this analysis, and the differences are shown

'Ratio' is the ratio of distances for NOAA divided by this analysis; ratios for both pile types are presented

This analysis suggests that computing the sound level over the entire one-second spectrum as a function of frequency is a more accurate estimate of the unweighted SEL since the spectral shape of the auditory weighting function is applied to the spectral shape of the pile driving strikes across the relevant spectrum. As stated above, using the NMFS single frequency recommended approach may be too conservative in the eventual estimation of the range to effect for PTS. This conservatism is even larger for concrete pile driving. Comparison of the impact pile driving SELs for the 36” steel pile versus the 24” concrete pile, indicate that unweighted (no bubble curtain) source levels for the concrete pile were approximately 20 dB less than that for the steel impact pile strike.

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