Appendix E.2 Pile Driving Acoustic Analysis

Acoustic Effects Analysis from Pile Driving during Port Damage Repair Training Activities

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APPENDIX E.2 Pile Driving Acoustic Analysis

E.2.1 Introduction

The Navy performed a quantitative analysis outside of Navy's Acoustic Effects Model to estimate the number of times that marine mammals and sea turtles could be affected by pile driving and extraction used during proposed training activities. This document summarizes the activity parameters for Port Damage Repair training, and the methodology and assumptions used in the acoustic impact analysis. Although much of the information described here is also provided in various sections and appendices of the Hawaii-California Training and Testing (HCTT) EIS/OEIS, as well as the technical report titled *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing* (U.S. Department of the Navy, 2024), the information is compiled here for easy reference and to support the conclusions made in the Navy's analysis.

The analysis considered details of the activity, sound exposure criteria, and the number and distribution of marine mammals and sea turtles. This information was then used in an 'area*density' model where the areas within each footprint (i.e., zone of influence [ZOI]) that encompass a potential effect are calculated for a given day's activities. The effects analyzed include behavioral response, TTS, and AINJ for marine mammals and sea turtles. Then, for marine mammals and sea turtles, these areas were multiplied by the density of each marine species within the nearshore environment to estimate the number of effects. Uniform density values were derived from survey data specific to the activity location. Since the same animal can be 'taken' only once every day (i.e., 24-hour reset time), the number of predicted effects from a given day were multiplied by the number of days for that activity. This generated a total estimated number of effects over the entire activity, which was then multiplied by the maximum number of times per year this activity could happen, resulting in estimated effects per species and stock in a year.

E.2.2 Activity Description

Port Damage Repair training activities are conducted by Naval Construction Groups and would involve intermittent impact and vibratory pile driving over multiple days, several times per year. Crews could work 24 hours a day for each event. Port Damage Repair training activities are made up of multiple events, each which could occur up to 12 times per year. Each training event is comprised of up to seven separate modules, each which could occur up to three iterations during a single event (for a maximum of 21 modules). Training events would last a total of 30 days, of which pile driving is only anticipated to occur for a maximum of 14 days. When training events are complete, all piles and sheets are removed via vibratory extraction or dead pull methods. The pile driving method and total number of piles to be driven are presented in
Table E.2-1.

Impact and vibratory pile driving, and removal could occur during Port Damage Repair training activities at one of three locations (Wharf Delta, Wharf 4 East or Wharf 4 South, as shown in Figure E.2-1) within the shallow waters of Port Hueneme, California. For purposes of this analysis, all acoustic modeling was conducted from a single source location approximately 50 meters from at the southeast corner of Wharf 4 East (see Figure E.2-2). This location was selected as it would result in the widest zone of influence from sound produced by in-water pile driving. Note, some training modules are only anticipated to occur at Wharf Delta, which would result in an overestimation of potential impacts by modeling at Wharf 4 East. Furthermore, acoustic modeling was limited to the footprint of the harbor as most activities would occur along the quay wall at Wharf 4 or in the enclosed area at Wharf Delta, reducing the potential for sound from pile driving to travel outside the mouth of the harbor. Although some coastal species passing near the entrance of the port (e.g., coastal bottlenose dolphins or gray whales) may detect sound from pile driving activities, behavioral responses from these exposures are not expected to rise to the level of take under military readiness.

Table E.2-1: Total Number and Type of Piles Quantitatively Analyzed under Port Damage Repair Training Activities

Pile Size and Type	Number of Piles per Module	Number of Piles per Training Event[1]	Alternative 1		Alternative 2	
			Annual[2]	7-Year	Annual[2]	7-Year
Impact (install only)						
12 to 20-inch Timber Round Piles	10 (up to 10 install, 0 remove)	30	360	2,520	360	2,520
12 to 20-inch Steel H-Piles	4 (up to 4 install, 0 remove)	12	144	1,008	144	1,008
12 to 20-inch Steel, Timber, or Composite Round Piles	10 (up to 10 install, 0 remove)	30	360	2,520	360	2,520
		Totals	***864***	***6,048***	***864***	***6,048***
Vibratory (install and/or remove)						
12 to 20-inch Timber Round Piles	10 (0 install, 10 remove)	30	360	2,520	360	2,520
12 to 20-inch Steel H-Piles	4 (0 install, 4 remove)	12	144	1,008	144	1,008
12 to 20-inch Steel, Timber or Composite Round Piles[3]	40 (15 install, 25 remove)	120	1,440	10,080	1440	10,080
27.5 or 18-inch Steel or FRP Z-shape	64 (32 install, 32 remove)	192	2,304	16,128	2,304	16,128
		Totals	***4,248***	***29,736***	***4,248***	***29,736***

[1] The Number of Piles using Impact or Vibratory Methods X 3 (to represent 3 iterations of each module within a given training event).
[2] The Number of Piles per Activity X 12 (to represent 12 events per year).

[3] Includes 12 H-beam piles (6 install, 6 remove) modeled using same surrogate acoustic data as round piles composed of any material.

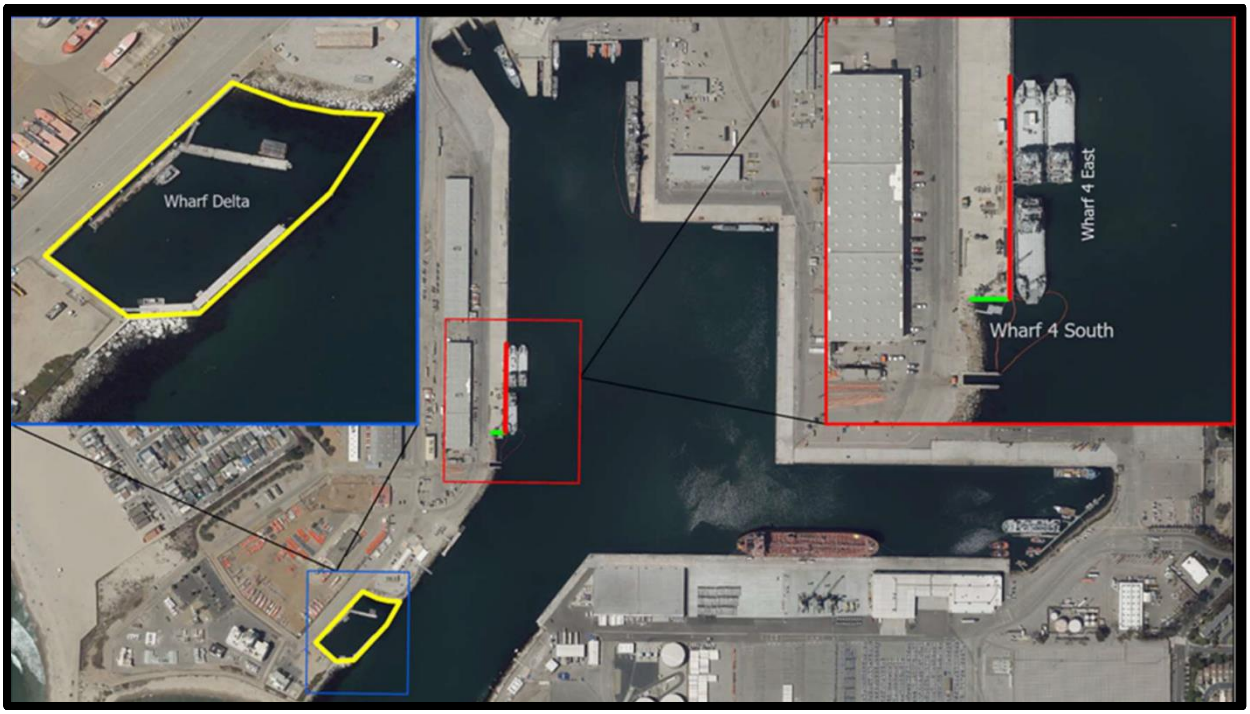

Figure E.2-1: Pile Installation/Removal Locations in Port Hueneme

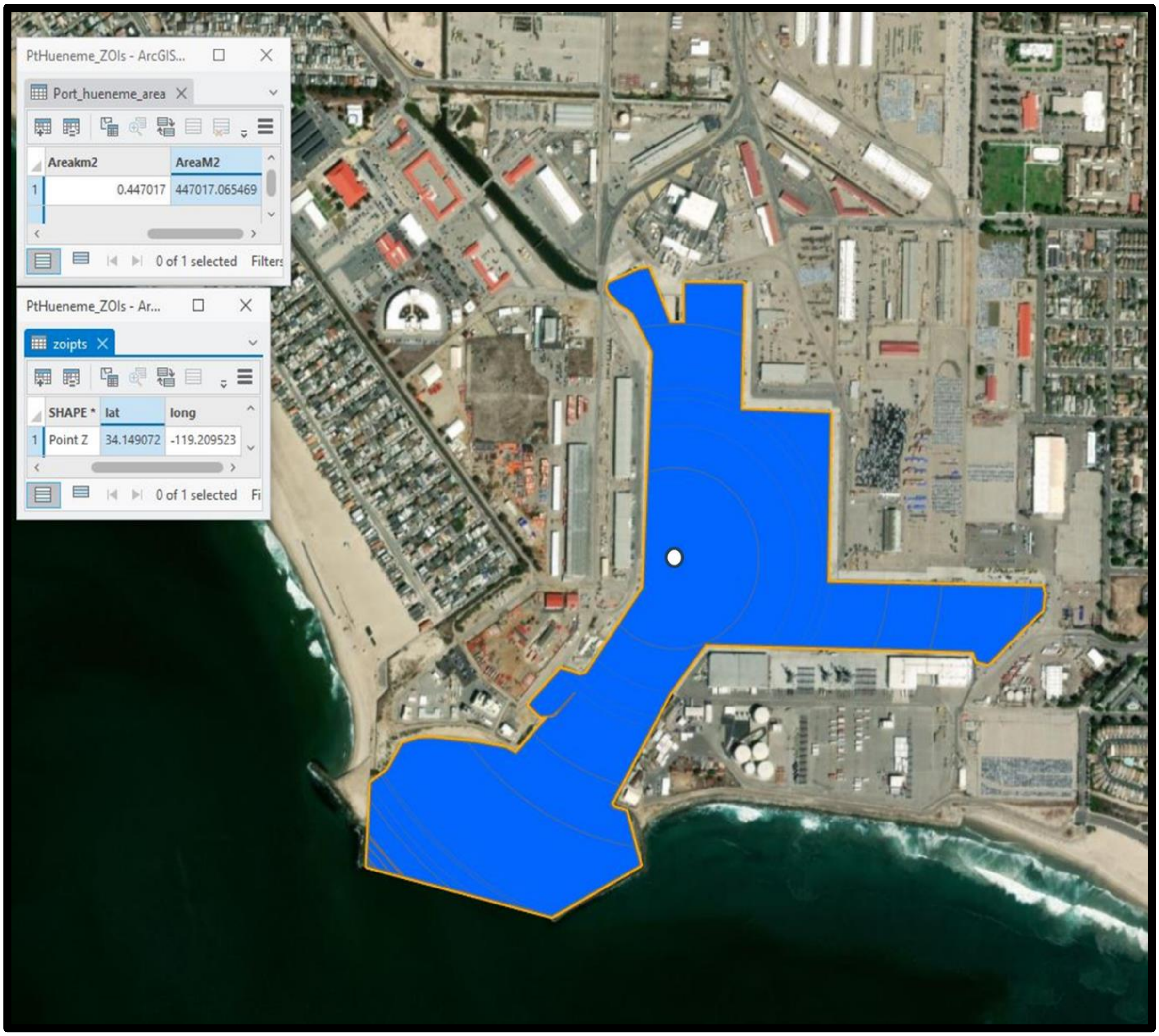

Figure E.2-2: Square Footage and Source Location for Acoustic Modeling within Port Hueneme

E.2.3 Criteria and Thresholds

A comprehensive discussion on how the criteria and thresholds for AINJ and TTS in marine mammals and sea turtles were derived is available in the Criteria and Thresholds TR. Additionally, this report includes detailed information on frequency weighting and hearing groups.

Because impact pile driving produces impulsive noise, impulsive criteria were used to assess the onset of TTS and AINJ for these sources. Vibratory pile driving and removal produces continuous, non-impulsive noise. Therefore, the non-impulsive criteria were used to assess the onset of TTS and AINJ.

Table E.2-2 shows the weighting factors that were used in this analysis for both impact and vibratory pile driving. Weighting factors were derived from the marine mammal and sea turtle weighting functions using the NMFS default frequencies based on the type of pile driving. These standard values are:

- kHz for marine mammals exposed to impact pile driving
- 2.5 kHz for marine mammals exposed to vibratory pile driving

- 0.16 kHz for sea turtles exposed to impact or vibratory pile driving

Table E.2-2: Weighting Factors Applied to Each Hearing Group for Impact and Vibratory Pile Driving (Applies to TTS and INJ Effects Only)

Marine Species Hearing Groups	Weighting Factor for Vibratory Pile Driving (cSEL)	Weighting Factor for Impact Pile Driving (cSEL)
Very Low-Frequency Cetaceans	-0.09	-0.03
Low-Frequency Cetaceans	-0.01	-0.05
High-Frequency Cetaceans	-2.32	-3.45
Very High-Frequency Cetaceans	-17.41	-21.19
Otariids (In-Water)	-3.54	-5.23
Phocids (In-Water)	-0.45	-0.80
Sirenians	-10.08	-12.86
Sea Turtles	-5.86	-5.86

cSEL: cumulative sound exposure level.

National Marine Fisheries Service (NMFS) risk criteria were applied to estimate behavioral effects from impact and vibratory pile driving. Frequency weighting was not used for behavioral response criteria for impact or vibratory pile driving and extraction.

E.2.4 Acoustic Parameters

Sound from in-water pile driving could be transmitted on direct paths through the water, be reflected at the water surface or bottom, or travel through bottom substrate. Soft substrates such as sand bottom would absorb or attenuate the sound more readily than hard substrates (rock), which may reflect the acoustic wave.

Impact pile driving would involve the use of an impact hammer with both it and the pile held in place by a crane. When the pile driving starts, the hammer part of the mechanism is raised up and allowed to fall, transferring energy to the top of the pile. The pile is thereby driven into the sediment by a repeated series of these hammer blows. Each blow results in an impulsive sound emanating from the length of the pile into the water column as well as from the bottom of the pile through the sediment. Broadband impulsive signals are produced by impact pile driving methods, with most of the acoustic energy concentrated below 1,000 hertz (Hz) (Hildebrand, 2009b).

Vibratory installation and extraction would involve the use of a vibratory hammer suspended from the crane and attached to the top of a pile. The pile is then vibrated by hydraulic motors rotating eccentric weights in the mechanism, causing a rapid vibration of the pile. The vibration and the weight of the hammer applying downward force drives the pile into the sediment. During removal, the vibration causes the sediment particles in contact with the pile to lose frictional grip on the pile. The crane slowly lifts the vibratory extraction hammer and pile until the pile is free of the sediment. In some cases, the crane may be able to lift the pile without the aid of an extraction hammer (i.e., dead pull), in which case no noise would be introduced into the water. Vibratory driving and removal create broadband, non-impulsive noise at low source levels, for a short duration with most of the energy dominated by lower frequencies (Hildebrand, 2009a).

Regardless of pile type, impact pile driving would incorporate a soft start procedure which may "warn" nearby marine species and reduce the initial noise exposure. The soft start procedure incorporates the use of three sets of three blows of the hammer at a reduced energy, with at least 30 seconds of separation between the sets. Table E.2-3 provides a summary of the sound levels selected for use in the acoustic analysis for each pile size and type to be used during Port Damage Repair activities.

Table E.2-3: Underwater Sound Levels Used in the Analysis of Pile Driving Activities

Pile Descriptions	Unattenuated Single Strike Level (dB)			Unattenuated SPL (dB rms)
	Peak SPL	RMS	SEL	
Impact (install only)				
12 to 20-inch Timber Round Piles[1]	180	170	160	-
12 to 20-inch Steel H-Piles[2]	195	180	170	-
12 to 20-inch Steel, Timber or Composite Round Piles[3]	203	189	178	-
Vibratory (install and/or remove)				
18 or 27.5-inch steel or FRP Z-piles[4]	-	-	-	159
12 to 20-inch Steel, Timber or Composite Round or H-Piles[5]	-	-	-	166

REFERENCES: (1) 14-inch round timber piles (Caltrans, 2020); (2) 14-inch steel H-beam piles (Caltrans, 2020); (3) 24-inch steel pipe piles (Illingworth and Rodkin Inc., 2007); (4) 25-inch steel sheet piles (Naval Facilities Engineering Systems Command Southwest, 2020); (5) 24-inch steel piles (Washington State Department of Transportation, 2010).

In addition to underwater noise, the installation and removal of piles would also result in airborne noise in the environment. Impact pile driving creates in-air impulsive sound up to a maximum of 114 dB re 20 μPa (unweighted) at a range of 15 meters (m) for 24-inch and 36-inch steel piles (Illingworth and Rodkin, 2017; Illingworth and Rodkin, 2015; Illingworth and Rodkin Inc., 2013). Reported sound levels for vibratory driving or extraction would be lower than that produced during impact driving (e.g., 94 dB re 20 μPa within a range of 10–15 m).

Consistent with recommendations from NMFS, transmission loss (TL) was assumed to be TL = 15 * Log10 (range). As this standard value does not account for absorption or attenuation, predicted ranges to effects and resulting ZOIs may overestimate the actual footprint of the ensonified area and therefore may overestimate the number of potential effects.

E.2.5 Ranges to Effects

Ranges to potential effects (e.g., behavioral response, TTS, and AINJ) were calculated based on the TL reported above. The functional threshold for a given effect was subtracted from the source level of a given pile (specific to the size, type, and method) to find the TL needed to reach that threshold. For TTS and AINJ the functional threshold was found by adding the weighting factor to the species-specific hearing group TTS or AINJ weighted threshold. The thresholds that were used for the behavioral response criteria were not weighted. The metric used to estimate TTS and AINJ effects was cumulative sound exposure level (cSEL), which increases with signal duration based on the number of strikes for impact pile driving (Equation 6-1) or the number of seconds for vibratory pile driving or extraction (Equation 6-2).

$$cSEL = single\ strike\ SEL + 10 * Log_{10}(\#\ strikes) \quad (6\text{-}1)$$

$$cSEL = one\ second\ SEL + 10 * Log_{10}(\#\ seconds) \quad (6\text{-}2)$$

Based on best available science regarding animal reactions to sound, selecting a reasonable accumulation period is necessary to accurately reflect the period an animal would likely be exposed to the sound. A representative duration of five minutes (300 s) was used for this accumulation period, with 60 strikes per minute per pile for piles driven using the impact method (see the AFTT and HCTT EIS/OIESs for details). Five minutes was chosen because most marine mammals and sea turtles should be able to easily move away from the expanding ZOI of TTS/AINJ within this time frame, especially considering the Navy's soft start procedures which may "warn" marine species and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Alternatively, animals could avoid the zone altogether if they are outside of the immediate area upon startup. This should reduce their exposure to higher levels of individual pile strikes thereby reducing their cumulative SEL.

Once the difference between the source level and the appropriate criteria was found, the range to this TL was solved for AINJ and TTS effects using Equation 6-3 and for behavioral effects using Equation 6-4.

$$10 * 10\ \hat{}\ \left(\frac{Source\ Level\ [cSEL] - Functional\ Threshold}{spreading\ coefficient}\right) \quad (6\text{-}3)$$

$$10 * 10\ \hat{}\ \left(\frac{Source\ Level\ [dB\ RMS] - Functional\ Threshold}{spreading\ coefficient}\right) \quad (6\text{-}4)$$

This provided the single-pile range to effect for each effect category and each marine species hearing group. The ranges to effects are shown in the AFTT and HCTT EIS/OEISs.

As mentioned above, in-air noise is also produced during pile driving activities. Using a maximum source level of 114 dB re 20 µPa (unweighted) at a range of 15 meters (m) for impact pile driving, the calculated in-air ranges to all effects (AINJ, TTS and behavioral) are shorter than those estimated from in-water transmission. Because areas affected by airborne noise are smaller than the underwater impact zones, a separate in-air analysis was not conducted.

Table E.2-4 shows the predicted ranges to AINJ, TTS, and behavioral response for each marine mammal hearing group exposed to impact and vibratory pile driving.

Table E.2-4: Marine Mammal Ranges to Effects for Pile Driving

FHG	Pile Type/Size and Method	BEH	TTS	AINJ
OCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	43 m	4 m
	20" Steel H Piles using Impact Methods	215 m	201 m	20 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	685 m	69 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	3,981 m	12 m	1 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	3,981 m	36 m	2 m
PCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	116 m	12 m
	20" Steel H Piles using Impact Methods	215 m	538 m	54 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	1,839 m	184 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	11,659 m	35 m	2 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	11,659 m	105 m	5 m

Note: AINJ = auditory injury, TTS = temporary threshold shift, BEH = behavior, OCW = otariids in water, PCW = phocids in water

E.2.6 Calculating the Number of Effects per Species and Stock

The ZOI for an effect is the area that encompasses the sound levels at or above a threshold for that given effect to the threshold for the next higher-order effect. For example, the ZOI for TTS is the area where sound levels meet or exceed the TTS threshold but are still below the AINJ threshold. The number of times marine mammals or sea turtles could be affected was found by multiplying these ZOIs by the density of marine species in the area.

To calculate the total area of the ZOI, one of two methods were used depending on the Study Area. For AFTT, first the single pile ZOI was needed. Since Port Damage Repair pile driving activities occur in the nearshore environment and animals would generally be seaward of this, the area of a circle (for ZOIs that do not overlap major land features) or a half-circle (for ZOIs that overlap land features) was calculated with a range (i.e., radius) to each effect category for impact and vibratory pile driving. The single pile 'ring-shaped' or 'c-shaped' ZOI for each effect was then found by subtracting the next smaller effect area (i.e., higher order effect; TTS ZOI = TTS Area - AINJ Area). For HCTT, a multi ring buffer analysis tool in GIS was used to estimate the expanding ZOI by 1-meter increments limited to the boundaries of the harbor where Port Damage Repair activities would occur. This tool created a lookup table which was then used to pull the appropriate ZOI based on the available range to effects.

As mentioned above, marine mammals and sea turtles would likely leave the immediate area of pile driving and extraction activities and may be less likely to return as activities persist. However, some 'naïve' animals may enter the area during the short period of time when pile driving and extraction equipment is being re-positioned between piles. Therefore, an animal "refresh rate" of 10% was selected. This means that 10% of the single pile ZOI was added for each consecutive pile within a given

24-hour period to generate the daily ZOI per effect category. These daily ZOIs were then multiplied by the number of days of pile driving and pile extraction and then summed to generate a total ZOI per effect category (i.e., behavioral response, TTS, AINJ). These total ZOIs were then multiplied by the density of marine species to produce estimates of the number of times animals of each species could be affected.

E.2.7 PORT HUENEME SPECIES DENSITY

The species most likely to occur where Port Damage Repair activities would occur are California sea lions and harbor seals. Species specific densities are required to estimate potential effects but were not available from the NMSDD for the specific activity location. As such, survey data collected at Port Hueneme from 2020-2024 of hauled-out pinnipeds were analyzed to provide an estimated abundance estimates for each species (T. McConchie, personal communication, June 26, 2024). Sighting data suggest an average daily abundance of:

- 25.89 for California sea lions, and
- 1.52 for harbor seals

These abundances were then divided by the total area of the harbor (~0.4470 sq.km), which resulted in the following density estimates:

- 57.92 California sea lions per km^2, and
- 3.40 harbor seals per km^2.

As stated, these densities were based on counts of hauled-out pinnipeds and therefore may overestimate the total number of individuals in the water at any given time. Nevertheless, within the analysis, all individuals are assumed to remain in the water where they could be taken by in-water sound from pile driving activities. While in-air exposures are possible based on the proximity of haulout locations to pile driving training activities, this analysis assumed that any animal that would be hauled out would also enter the water at some point during pile driving. Considering that the in-water exposure area is larger than the in-air exposure area, it was not necessary to conduct a separate in-air effects analysis.

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