TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

APPENDIX M – FISH AND SEA TURTLE NOISE MODELING INFORMATION

NORTHEAST SUPPLY ENHANCEMENT PROJECT

January 2020

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

ATTACHMENT M-1

FISH-TURTLE NOISE MODELING MEMORANDUM

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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ecology and environment, inc.

Memorandum

To: Steven MacLeod

From: Katie Guttenplan

CC: Sara Mochrie

Date: 9 July 2018

Re: Potential Noise Impacts of Pile Installation Activities on Fish and Sea Turtles (Northeast Supply Enhancement Project)

Transcontinental Gas Pipe Line Company, LLC (Transco), a subsidiary of Williams Partners L.P. (Williams), is proposing to expand its existing interstate natural gas pipeline system in Pennsylvania and New Jersey and its existing offshore natural gas pipeline system in New Jersey and New York waters. Transco has proposed distinct in-water construction activities with sound-producing elements in order to install and remove 163 steel pipe piles: vibratory pile driving, impact pile driving, and clamshell dredging. The in-water portion of the Project would occur in areas that support several fish and sea turtle species. To examine the potential impacts of sound associated with in-water construction activities, particularly pile installation and removal, sound propagation modeling was conducted to determine potential to injure or behaviorally disturb fish or sea turtles. NOAA Fisheries GARFO (2017) has implemented criteria including: 206 dB peak (peak injury), 187 dB SEL_{cum} (cumulative injury for fish > 2 grams), 183 dB SEL_{cum} (cumulative injury for fish < 2 grams), and a 150 dB RMS (behavioral) sound level thresholds for fish and 180 dB RMS (injury) and 166 dB RMS (behavioral) sound level thresholds for sea turtles (**Table 1**).

Table 1.
Behavioral and Injury Thresholds for ESA-Listed Species in NMFS' Greater Atlantic Region

Species	**Thresholds**	**Units**
Sturgeon/Salmon Behavioral	150	dB RMS re 1 µPA
Sturgeon/Salmon Injury	206	dB peak re 1 µPA
Sturgeon/Salmon Injury (>2g)	187	dB SEL_{cum} re $\mu PA^2 s$
Sturgeon/Salmon Injury (<2g)	183	dB SEL_{cum} re $\mu PA^2 s$
Sea Turtle Behavioral	166	dB RMS re 1 µPA
Sea Turtle Injury	180	dB RMS re 1 µPA

To estimate the sound propagation for installation and removal of the proposed piles in the Project area, Transco identified source levels for each pile size using the compendium compiled by Caltrans (2015) and applied the practical spreading loss model.

<u>Practical Spreading Loss Model:</u>

$$TL = 15 \log (R_1/R_0)$$

where:

TL = Source Level – sound Threshold Level

R_1 = Range distance the sound criteria extends away from the source (in meters)

R_0 = Reference range (i.e., @ 1 meter, @ 10 meters, etc.) (in meters)

The practical spreading loss model was used to determine the approximate straight-line distance (isopleth) from the sound source where the NOAA Fisheries Service injury and behavioral threshold criteria were estimated to be reached while driving or removing each specific pile size (Table 2).

Table 2.
Isopleths for Injury from Peak Sound and for Behavioral Disturbance.

Pile Size and Hammer Type	**Peak Source Level (dB Peak)**[1]	**RMS Source Level (dB RMS)**	**Isopleth 206 dB Peak**[1] (Fish -Injury) **(meters)**	**Isopleth 150 dB RMS** (Fish - Behavioral) **(meters)**	**Isopleth 180 dB RMS**[2] (Sea Turtle- Injury) **(meters)**	**Isopleth 166 dB RMS**[2] (Sea Turtle- Behavioral) **(meters)**
10 in steel piles (vibratory)	NA	150	NA	10	NA	NA
24 in steel piles (vibratory)	NA	165	NA	100	NA	NA
36 in steel piles (impact)[3]	210	193	18	7,356	74	631
36 in steel piles (vibratory)[3]	NA	175	NA	464	NA	40
48 in steel piles (vibratory)	NA	178	NA	736	NA	63
60 in steel piles (impact)	210	195	18	10,000	100	858
60 in steel piles (vibratory)	NA	180	NA	1,000	10	86

[1]Note that calculating isopleths for potential injury based on peak dB is only appropriate for impulsive sources, i.e. impact pile driving, and so these peak source levels and isopleth calculations are not provided for vibratory pile driving.
[2]Note that in cases where the source level was below the threshold, no isopleth was calculated.
[3]Note that during modeling 34-inch piles were treated as 36-inch piles due to lack of data for 34-inch piles.
4 Note that all dB are re 1 µPA in this table

Furthermore, the NOAA Fisheries (nd) Pile Driving calculator spreadsheet tool for impact pile driving was used to verify the calculated values above and to determine if sound from impact pile diving of the 36- and 60-inch piles would surpass SEL_{cum} dB thresholds for fish > 2 grams and fish < 2 gram (Table 3). Note that in order for a fish to experience take from cumulative sound, an individual would have to remain within the ensonifed area above the threshold (a radius equivalent to the isopleth) throughout the duration of the pile driving event.

Table 3.
Isopleths for Injury from Cumulative Sound

Pile Size	**Isopleth Fish > 2 grams SEL_{cum} dB (fish-injury) (meters)**	**Isopleth Fish < 2 grams SEL_{cum} dB (fish-injury) (meters)**
36 inch steel piles	997	1,585
60 inch steel piles	1,657	2,154
[1] Note that all dB are re μPA^2s in this table		

Project-related sound for certain activities is anticipated to exceed the threshold criteria for fish and sea turtles (Tables 3 and 4). During impact pile driving, peak source levels for 36-inch and 60-inch piles were measured at 210 dB re 1µPa (California Department of Transportation 2015), which exceeds the injurious thresholds. The modeled isopleths for injury from peak source levels is small, 18 meters, and thus injury from peak source levels is unlikely. Modeled isopleths for injury to fish from cumulative sound ranged from 997 meters to 2,154 meters. Modeled injury isopleths for turtles were small and thus injury to sea turtles would be unlikely. The modeled isopleths for potential behavioral disturbance to fish ranged from 10 meters to 10,000 meters from the sound source. The modeled isopleths for potential behavioral disturbance to sea turtle ranged from 40 meters to 858 meters except for 10- and 20-inch piles, which had sources levels below the behavioral disturbance threshold. Note that for some piles at certain locations sound will encounter land and thus be truncated before reaching the full modeled propagation distances listed above. Thus, the actual isopleths might differ from the modeled isopleths.

Modeling using the methodology described above was also conducted for clamshell dredging. The source level associated with clamshell dredging (156.6 dB re 1 µPA) is below the injury thresholds for fish and sea turtles. Modeling for this activity did not result in a cumulative ensonifed area for fish (for either fish < or > 2 grams). The modeled isopleth for potential behavioral disturbance of fish was 2.8 meters. The modeled isopleth for potential behavioral disturbance of sea turtles was not conducted as the source level was below the threshold.

Transco conservatively estimates a total of 42.5 days (70.25 hours) for pile installation beginning June 6th, 2019 through August 9th, 2019, and a total of 23 days (46.25 hours) for pile removal beginning July 25th, 2019 through August 27th, 2019, to complete the in-water construction activities for 163 steel piles (Table).

Table 4.
Estimated Durations for Pile Installation and Removal by Pile Diameter and Site Location

Site	Pile Diameter (inches)	Total Quantity (ea.)	Method	Driving Time Per Pile (min)	Start Date	End Date	Estimated Total Number of Days	Estimated Time Required to Install all Piles (hours)
Installation								
HDD Morgan Offshore (MP 12.59)[1]	36	22	Vibratory	15	6/9/2019	6/19/2019	6.5	5.5
			Impact	52-62				22
	36-48	8	Vibratory	15	6/15/2019	6/17/2019	2	1
	24	10	Vibratory	15	6/13/2019	6/15/2019	3	2.5
Neptune Power Cable Crossing (MP 13.84)	10	8	Vibratory	15	6/20/2019	6/22/2019	2	2
MP 14.5 to MP 16.5	24	22	Vibratory	15	6/19/2019	6/24/2019	5	5.5
MP 28.0 to MP 29.36	34	12	Vibratory	15	7/18/2019	7/21/2019	3	3
HDD Ambrose West Side (MP 29.4)	36	3	Vibratory	15	6/29/2019	7/1/2019	1.5	0.75
	36-60	8	Vibratory	15	6/28/2019	7/2/2019	4	2
			Impact	38				5
	36-48	8	Vibratory	15	6/29/2019	7/1/2019	1.5	2
	24	12	Vibratory	15	6/28/2019	6/29/2019	1.5	3
HDD Ambrose East Side (MP 30.48)	24	22	Vibratory	15	7/18/2019	7/23/2019	5	5.5
	36	3	Vibratory	15	6/26/2019	6/27/2019	0.5	0.75
	36-48	8	Vibratory	15			1	2
	36-48		Vibratory	15				
	24	10	Vibratory	15	6/24/2019	6/26/2019	1.5	2.5
	60	1	Vibratory	15	8/8/2019	8/9/2019	0.5	0.25
MP 34.5 to MP 35.04	34	4	Vibratory	15	7/18/2019	7/21/2019	3	1
			Impact	52				3.5
Neptune Power Cable Crossing (MP 35.04)	10	2	Vibratory	15	6/28/2019	6/29/2019	1	0.5
Removal								
HDD Morgan Offshore (MP 12.59)[1]	36	22	vibratory	30	8/10/2019	8/13/2019	3	11
	36-48	8	vibratory	15				2
	24	10	vibratory	5	7/27/2019	7/30/2019	3	1
Neptune Power Cable Crossing (MP13.84)	10	8	vibratory	15	8/8/2019	8/11/2019	1.5	2
MP 14.5 to MP 16.5	24	22	vibratory	15	8/8/2019	8/11/2019	1.5	5.5

Site	Pile Diameter (inches)	Total Quantity (ea.)	Method	Driving Time Per Pile (min)	Start Date	End Date	Estimated Total Number of Days	Estimated Time Required to Install all Piles (hours)
MP 28.0 to MP 29.36	34	12	vibratory	30	8/24/2019	8/27/2019	2	6
HDD Ambrose West Side (MP 29.4)	36	3	vibratory	15	8/4/2019	8/8/2019	0.5	0.75
	36-60	8	vibratory	30			0.5	4
	36-48	8	vibratory	15			1	2
	24	12	vibratory	5	7/31/2019	8/2/2019	2	1
HDD Ambrose East Side (MP 30.48)	24	10	vibratory	5	7/25/2019	7/27/2019	2	1
	24	22	vibratory	15	8/4/2019	8/8/2019	0.5	5.5
	36	3	vibratory	15			0.5	0.75
	36-48	8	vibratory	15			1	2
	60	1	vibratory	15	8/24/2019	8/27/2019	1	0.25
MP 34.5 to MP 35.04	34	4	vibratory	15	8/24/2019	8/27/2019	2	1
Neptune Power Cable Crossing (MP 35.04)	10	2	vibratory	15	8/24/2019	8/27/2019	1	0.5
[1]Note that Morgan Shoreline is at mile post (MP) 12.16.								

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NOAA. nd. Pile Driving Tool Excel Spreadsheet. Sent via email from John Stadler, Essential Fish Habitat Coordinator for the NOAA Fisheries West Coast Region, to David Trimm, Ecology and Environment.

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

ATTACHMENT M-2

CLUPEID HEARING MEMO

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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ecology and environment, inc.

Memo

To: Sara Mochrie

From: Katie Guttenplan

CC: Steve MacLeod, Megan Eakin, Lyndie Hice-Dunton

Date: 24 May 2018

Re: Potential Impacts on High-Frequency Clupeid Fish from Low Frequency Pile Driving

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Clupeid Hearing and Response

Clupeids are considered fish that develop a swim bladder and inner ear structures to help them detect sound. The swim bladder is used to detect sound primarily by pressure detection (Mohr et al. 2017). Their unique structure of the inner ear allows the fish to move in response to the sound stimulus (Popper et al. 2004). A number of species of Clupeid fish, including blueback herring, American shad, and gulf menhaden, can detect and respond to ultrasonic sounds up to at least 180 kHz, whereas other Clupeids, including bay anchovies and Spanish sardines, do not appear to detect sounds above about 4 kHz (Popper et al. 2004). Studies performed to test Clupeid hearing have found two areas of sensitivity for some species: a low frequency band from 0.2 to 0.8 kHz and another at 25 to 150 kHz and seem particularly sensitive to pulsed tones (Nester et al. 1992; Mann et al. 1997; Mann et al. 1998; Mann et al. 2001; Reine and Dicerson 2014).

Not all Clupeids have high-frequency hearing. Behavioral studies of the responses of American shad to ultrasound demonstrate that they show a graded series of responses depending on the sound level and, to a lesser degree, on the frequency of the stimulus. The responses typically consisted of short-term avoidance. Low-intensity stimuli elicit a non-directional movement of the fish, whereas somewhat higher sound levels elicit a directional movement away from the sound source (Popper et al. 2004). Still higher level sounds produce a ‘‘wild’’ chaotic movement of the fish. Scientists speculate that the response of the American shad (and, presumably, other Clupeids that can detect ultrasound) to ultrasound evolved to help these species detect and avoid major predators, such as echolocating cetaceans. As dolphins echolocate, the fish are able to hear the sound at over 100 m. If the dolphins detect the fish and come closer, the nature of the behavioral response of the fish changes in order to exploit different avoidance strategies and lower the chance of being eaten by the predators (Popper at al. 2004).

Pile Driving Noise

Both vibratory and impact pile driving noise are considered low frequency noise sources (Blackwell 2005; Reinhall and Dahl 2011; Dahl et al. 2015). Generally, the larger the piles the more the spectral energy predominates in the lower frequencies.

According the NOAA Fisheries 2016 Acoustic Guidance, the weighting factor adjustments (WFAs) can be conceptualize as the 95% frequency contour percentile, or the upper frequency below which 95% of the total cumulative energy is contained (Charif et al 2010). In other words, in setting the WFAs at 2 kHz for impact pile driving and 2.5 kHz for vibratory pile driving, the NOAA guidance is assuming that only 5% of the energy occurs above those frequencies for each of the respective activities (Table 1).

Table 1: Suggested (Default*) Weighting Factor Adjustments (WFA) from the NOAA Fisheries 2016 Acoustic Guidance:

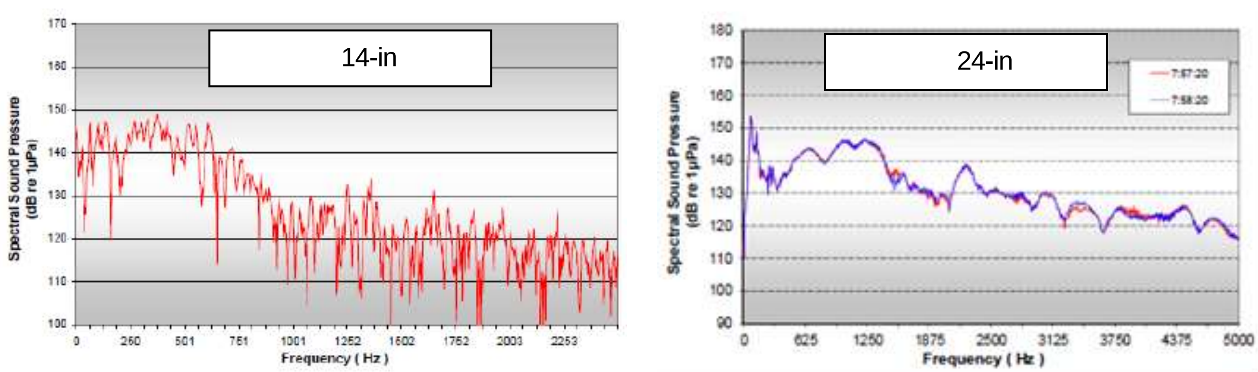
Source	WFA	Example Supporting Sources
Seismic	1 kHz	Breitzke et al. 2008; Tashmukhambetov et al. 2008; Tolstoy et al. 2009
Impact pile driving	2 kHz	Blackwell 2005; Reinhall and Dahl 2011
Vibratory pile driving	2.5 kHz	Blackwell 2005; Dahl et al. 2015
Drilling	2 kHz	Greene 1987; Blackwell et al. 2004; Blackwell and Greene 2006

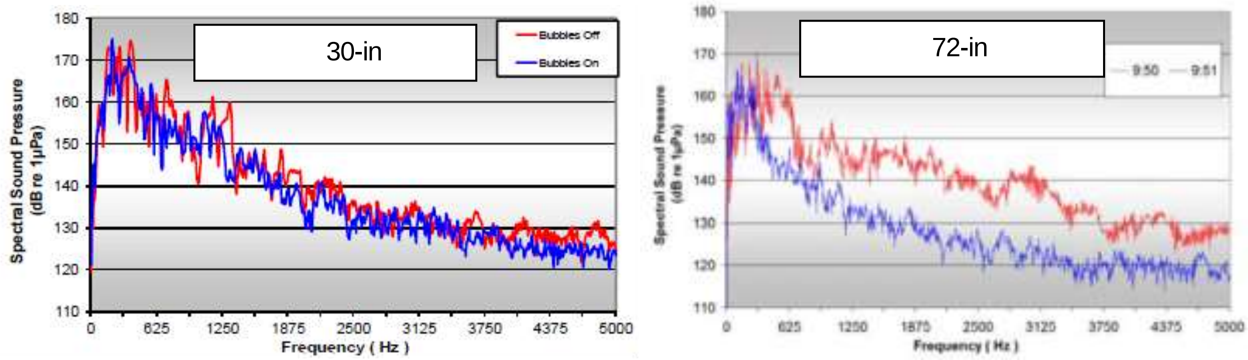
* NOAA Fisheries acknowledges default WFAs are likely conservative

¥ Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

This is supported by the measured data that corresponds to impact and vibratory pile driving of various sizes of piles (ICF Jones & Stokes et al. 2009). Several example spectral sound pressure levels, or the sound pressure levels as a function of frequency, of this measure data are included to demonstrate the distribution of the bulk of the sound energy at the lower frequencies (Figure 1). Unfortunately, most of these graphs cut off at much lower frequencies than those that overlap with the high-frequency hearing range of Clupeid fish, and so sound spectral sound pressure levels are not available at those frequencies. However, the sound pressure likely continues to decrease as frequency increases.

Figure 1. Spectral Sound Pressure for Impact and Vibratory Pile Driving for Various Pile Sizes





For most of these examples, the spectral sound pressure level at frequencies between 2 and 5 kHz is below the 150 db re 1 µPa root-mean-square (RMS) threshold at which Clupeid fish might be affected. It is reasonable to assume that the spectral sound pressure level for vibratory and impact pile driving at the higher frequencies where Clupeids have sensitivity are below the threshold at which the noise might disturb the fish.

Considering the types of anticipated pile types, numbers, and installation methods for the Northeast Supply Enhancement Project, the standard practical spreading model can be used to determine isopleths based on the criteria for sturgeon (Table 2). This model is better suited for propagation at the low frequencies associated with pile driving noise.

Table 2: Anticipated Pile Sizes, Numbers, and Installation Methods

Diameter Inches	Quantity	Installation Method	Isopleth to 150 dB re 1 µPa RMS (meters)
10	10	Vibratory Hammer	No zone- source level below threshold
24	76	Vibratory Hammer	100
34	12	Vibratory Hammer	464
34	4	Vibratory & Diesel Impact Hammer	Vibratory: 464 Impact: 7356
36	22	Vibratory & Diesel Impact Hammer	Vibratory: 464 Impact: 7356
36-48	24	Vibratory Hammer	736
36-60	8	Vibratory & Diesel Impact Hammer	Vibratory: 1000 Impact: 10000
60	1	Vibratory Hammer	1000

Accelerated Attenuation of High Frequency Sound

In addition, not only does a tiny percentage of the energy of the activities occur at the high frequencies at which Clupeid have hearing sensitivity, but the attenuation rate of sound is much greater at those frequencies. Models that incorporate frequency-dependent attenuation indicate that the attenuation rate at 160 kHz would result in smaller ensonifed areas than at lower frequencies, even assuming all other variables remain constant (which they do not as indicated above [Kusel 2016].

Modeling Clupeid Acoustic Zones

Based on the information regarding hearing sensitivity of Clupeids, spectral sound pressure levels of pile driving noise, and the accelerated attenuation rate for high frequency sound, it is unlikely that pile driving noise would have sufficient energy at the frequencies at which Clupeids have high-frequency hearing sensitivity to cause disturbance to the fish. Any acoustic propagation models would need to use the spectral sound pressure, which is lower at the noise source than the thresholds of disturbance. In addition, the already lower energy sound would attenuate more quickly at these frequencies. Therefore, modeling of the lower frequency noise levels (e.g., in the range audible to sturgeon), which is already underway, should be sufficient to determine the potential effect on Clupeids since the model is better suited for the low-frequencies of the pile-driving noise and the radius of disturbance from lower frequency noise is expected to be larger than for higher frequencies.

References

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TRANSCONTINENTAL GAS PIPE LINE COMPANY, LLC

ATTACHMENT M-3

SOUND PROPAGATION MODELING

NORTHEAST SUPPLY ENHANCEMENT PROJECT

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ecology and environment, inc.

Memorandum

To: Sara Mochrie

From: Katie Guttenplan

Date: 30 May 2019

Re: Latest Noise Modeling on Fish and Sea Turtles – May 2019
(Northeast Supply Enhancement Project)

In June 2018, Transcontinental Gas Pipe Line Company, LLC (Transco), a subsidiary of Williams Partners L.P. (Williams), performed sound propagation modeling to determine the potential for sound associated with in-water construction activities (pile installation and removal) to injure or behaviorally disturb fish and sea turtles. Transco used criteria that the National Oceanic and Atmospheric Administration (NOAA) Greater Atlantic Regional Fisheries Office (NOAA Fisheries GARFO) (2018) has developed to determine potential injury and behavioral impacts for Endangered Species Act (ESA)-listed fish and sea turtles (Table 1). Transco's 2018 modeling was updated in May 2019 in response to a request by NOAA Fisheries GARFO to incorporate criteria used by the Navy for sea turtles, which now include criteria for permanent and temporary threshold shifts that can result from impulsive activities.

Table 1.
Behavioral and Injury Thresholds for ESA-Listed Species in NOAA Fisheries Greater Atlantic Region

Species	Thresholds	Units
Sturgeon/Salmon Behavioral[a]	150	dB RMS re 1 µPa
Sturgeon/Salmon Injury[a]	206	dB peak re 1 µPa
Sturgeon/Salmon Injury (>2g)[a]	187	dB SEL_{cum} re µPa^2s
Sturgeon/Salmon Injury (< 2g)[a]	183	dB SEL_{cum} re µPa^2s
Sea Turtle Behavioral[a]	166	dB RMS re 1 µPa
Sea Turtle Injury[a]	180	dB RMS re 1 µPa
Sea Turtle Permanent Threshold Shift (PTS) Onset cumulative[b]	204	dB SEL_{cum} re µPa^2s
Sea Turtle Permanent Threshold Shift (PTS) Onset peak[b]	232	dB peak re 1 µPa
Sea Turtle Temporary Threshold Shift (TTS) Onset cumulative[b]	189	dB SEL_{cum} re µPa^2s
Sea Turtle Temporary Threshold Shift (PTS) Onset peak[b]	226	dB peak re 1 µPa

[a] NOAA Fisheries GARFO 2018 Guidance
[b] NOAA Fisheries GARFO 2019 Request

Transco identified source levels for each pile size using the compendium compiled by Caltrans (2015) and applied the practical spreading loss model to calculate isopleths. Table 2 shows the sound source levels used during the modeling.

Table 2.
Sound Source Levels Used in Propagation Modeling:
Steel Pile Installation and Removal (near source [10 meters], unattenuated)

Pile Diameter	**Activity**[a]	**Source Levels dB RMS**[b]	**Source Level dB SEL**[b]	**Source Level dB Peak**[b]
10 inches	Vibratory	150	-	-
24 inches	Vibratory	160	-	-
36 inches	Diesel Impact	193	183	210
36 inches	Vibratory	168	-	-
48 inches	Vibratory	170	-	-
60 inches	Diesel Impact	195	185	210
60 inches	Vibratory	170	-	-

[a] Note that acoustic propagation modeling for vibratory activities only uses dB RMS, while modeling for impact pile driving uses dB RMS, SEL, and Peak, depending on the model. Therefore, only dB RMS are provided for vibratory activities.

[b]All sound levels are expressed as decibels (dB) re 1 μPa.

Isopleth modeling was conducted using the source levels in Table 2 for both injury and behavioral thresholds for fish and sea turtles (see Tables 3 and 4, respectively). For a fish or sea turtle to experience take from cumulative sound, an individual would have to remain within the ensonifed area above the threshold (a radius equivalent to the isopleths noted in Tables 3 and 4) throughout the duration of the pile-driving event. Potential injury and behavioral disturbance from peak and root-mean-square (RMS) thresholds are instantaneous and do not require the individual to remain in the ensonifed area throughout the duration of the pile-driving activity.

Calculating isopleths for potential cumulative and peak injury is appropriate only for impulsive sources (e.g., impact pile driving); therefore, isopleths are not provided for vibratory pile driving. Also note that cumulative calculations proceed even if the source level is below the threshold, as the cumulative noise might surpass the threshold. However, when the received sound exposure level (SEL) from an individual pile strike is below a certain level, then the accumulated energy (SEL_{cum}) from multiple strikes would not contribute to injury, regardless of how many pile strikes occur. This SEL is referred to as "effective quiet", and is assumed to be 150 dB re 1μPa

SEL for fish (per the NOAA Fisheries GARFO 2018 guidance) and 166 dB re 1µPa SEL for sea turtles. Effective quiet establishes a limit on the maximum distance from the pile where injury to fish and sea turtles is expected—the distance at which the single-strike SEL attenuates to the effective quiet. Beyond this distance, no physical injury is expected, regardless of the number of pile strikes. However, within the zone subject to SEL above these thresholds, the severity of the injury can increase as the number of strikes increases.

Table 3.
Isopleths for Peak and Cumulative Injury and for Behavioral Disturbance for Fish[a]

Steel Pile Size and Hammer Type	Isopleth 150 dB RMS (Behavioral) (meters)	Isopleth 206 dB Peak (Peak Injury)[b] (meters)	Isopleth Fish ≥ 2 grams 187 dB SEL_{cum} (Cumulative Injury)[b] (meters)	Isopleth Fish < 2 grams 183 dB SEL_{cum} (Cumulative Injury)[b] (meters)
10 inches (vibratory)	10.0	-	-	-
24 inches (vibratory)	46.4	-	-	-
36 inches (impact)[c]	7,356.4	18.5	996.8	1,584.9
36 inches (vibratory)[c]	158.5	-	-	-
48 inches (vibratory)	215.4	-	-	-
60 inches (impact)	10,000.0	18.5	1,657.5	2,154.4
60 inches (vibratory)	215.4	-	-	-

[a] In this table, all dB RMS and Peak are re 1 µPa and all dB SEL_{cum} are re $\mu Pa^2 s$.
[b] Calculating isopleths for potential cumulative and peak injury is appropriate only for impulsive sources (i.e., impact pile driving); therefore, isopleths are not provided for vibratory pile driving and instead are listed as "-".
[c] During modeling, 34-inch-diameter piles were treated as 36-inch-diameter piles due to lack of data for 34-inch-diameter piles.

Lastly, for RMS- and Peak-based thresholds, if the source level is below the threshold, then it is not appropriate to calculate an isopleth. For sea turtles, there were cases where the source level was below the relevant RMS- or Peak-based threshold. In these cases, "NA" is listed in Table 4.

Table 4.
Isopleths for Peak and Cumulative Injury and for Behavioral Disturbance for Sea Turtles[a]

Steel Pile Size and Hammer Type[a]	Isopleth[b] 166 dB RMS (Behavioral) (meters)	Isopleth[b] 180 dB RMS (Injury) (meters)	Isopleth 204 dB SEL_{cum} (Cumulative PTS)[c] (meters)	Isopleth[b] 232 dB Peak (Peak PTS)[c] (meters)	Isopleth 189 dB SEL_{cum} (Cumulative TTS)[c] (meters)	Isopleth[b] 226 dB Peak (Peak TTS)[c] (meters)
10 inches (vibratory)	NA	NA	-	-	-	-
24 inches (vibratory)	NA	NA	-	-	-	-
36 inches (impact)[d]	631.0	73.6	73.3	NA	135.9	NA

Table 4.
Isopleths for Peak and Cumulative Injury and for Behavioral Disturbance for Sea Turtles[a]

Steel Pile Size and Hammer Type[a]	Isopleth[b] 166 dB RMS (Behavioral) (meters)	Isopleth[b] 180 dB RMS (Injury) (meters)	Isopleth 204 dB SEL_{cum} (Cumulative PTS)[c] (meters)	Isopleth[b] 232 dB Peak (Peak PTS)[c] (meters)	Isopleth 189 dB SEL_{cum} (Cumulative TTS)[c] (meters)	Isopleth[b] 226 dB Peak (Peak TTS)[c] (meters)
36 inches (vibratory)[d]	13.6	NA	-	-	-	-
48 inches (vibratory)	18.5	NA	-	-	-	-
60 inches (impact)	857.7	100.0	121.9	NA	184.8	NA
60 inches (vibratory)	18.5	NA	-	-	-	-

[a] In this table, all dB RMS and Peak are re 1 μPa and all dB SEL_{cum} are re $\mu Pa^2 s$.
[b] In cases where the source level was below the threshold, no isopleth was calculated and is listed as "NA".
[c] Calculating isopleths for potential cumulative and peak PTS and TTS is appropriate only for impulsive sources (i.e., impact pile driving); therefore, isopleths are not provided for vibratory pile driving and instead are listed as "-".
[d] During modeling, 34-inch-diameter piles were treated as 36-inch-diameter piles due to lack of data for 34-inch-diameter piles.

<u>References</u>

California Department of Transportation (Caltrans). 2015. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Report #CTHWANP-RT-15-306.01.01. Sacramento California. 532 pp.

NOAA Fisheries GARFO. 2018. GARFO Acoustics Tool: Analyzing the effects of pile driving on ESA-listed species in the Greater Atlantic Region. Updated 7/09/2018. Available at: http://www.greateratlantic.fisheries.noaa.gov/protected/section7/guidance/consultation/index.html.