Appendix J. Overview of Acoustic Modeling Report

J.1. Introduction and Short Project Description

This appendix is focused on providing an overview of the methods, assumptions, and results of the technical acoustic modeling report prepared for the Project (COP Volume III, Appendix R-2; Ocean Wind 2022a). Readers who may be less familiar with acoustic terminology are recommended to refer to the glossary (COP Volume III, Appendix R-2, Appendix A; Ocean Wind 2022a).

The Project would consist of up to 98 WTGs, up to three OSS, and interconnection and export cables. The Project would be on the OCS offshore New Jersey in BOEM Lease Area OCS-A 0498. The major underwater noise-producing activities of this Project would include impact pile driving during construction. The piles to be driven would include large (11-meter-diameter at the mudline) monopiles and 2.44-meter-diameter pin piles. This appendix summary focuses on the quantitative modeling of the impact pile driving. Qualitative assessments of lower noise level activities were also provided in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2022a).

For the quantitative modeling assessment, predicted sound fields were generated for one representative deep-water location for the monopiles and for one shallow-water location for the jacket foundation with pin piles (COP Volume III, Appendix R-2, Figure 2 and Table 3; Ocean Wind 2022a). Sound field predictions were made for both summertime and wintertime conditions. To predict sound fields, the sound produced at the pile as the hammer strikes it must be characterized. The propagation of the hammer-strike sound through the water column and the sediment is then predicted. The result is a set of predicted broadband sound fields, which are used to predict the ranges to U.S. regulatory isopleths as well as the number of marine animals that could be exposed to sound levels that exceed regulatory thresholds. Finally, the effects of sound source mitigation (e.g., bubble curtains) on impact pile-driving effects were explored.

A separate report (Hannay and Zykov 2021) explored the predicted effects of UXO removal by detonation at several locations. In this report, the ranges were calculated to a variety of regulatory thresholds for peak pressure, impulse, and SEL metrics. The modeling of acoustic fields generated by UXO detonations was performed using a combination of semi-empirical and physics-based computational models.

J.2. Acoustic Models and Assumptions

The acoustic assessment of Project pile driving relies upon a variety of models to predict the potential effect of Project activities on marine animals. The models used in the quantitative analysis include:

1. GRLWEAP Model: to model the force applied to the pile by the hammer
2. Finite Difference Model: to compute pile vibrations after the hammer strikes the pile
3. Full Waveform Range-dependent Acoustic Model (FWRAM): to calculate the time-dependent sound field and PK sound levels
4. Marine Operation Noise Model (MONM): a parabolic equation model to calculate SEL values for both impulse pile driving and UXO detonations
5. JASMINE Model: the JASCO Applied Sciences animat[1] movement and exposure model

[1] Animat = simulated animal

6. UXO Semi-empirical Models: to predict the shock pulse source waveform, the impulse amplitude, and their attenuation with range
7. NMFS User Spreadsheet Tool (NMFS 2020): this tool, supplied by NMFS, is used to calculate distances to regulatory thresholds when more sophisticated modeling is not available or is not warranted; this tool was used for HRG modeling and assumes spherical spreading.

Both FWRAM and MONM predict the propagation of the source signal through the physical environment. As such, these models require accurate descriptions of the ocean bathymetry, seafloor sediment properties, water column sound velocity profile, and ocean surface roughness. The assumptions of these models and their inputs are critical to the accuracy of the model output.

J.2.1 Physical Environment

The bathymetry information used in the modeling was extracted from the General Bathymetric Chart of the Oceans (GEBCO Bathymetric Compilation Group 2020). A simplified model of the sediment properties (i.e., the Geoacoustic Model) was developed based on measurements made within the Project area. The water column properties (i.e., sound velocity profile) were extracted from the U.S. Navy's Generalized Digital Environmental Model (Naval Oceanographic Office 2003). The water column properties change seasonally, and an average of all the summer months was used to represent the Project area for the times in which pile driving was expected to occur. Additional analyses using winter conditions were prepared in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2022a) but were not used for exposure analysis because the proposed activities are intended to take place outside of the NARW seasonal closures.

J.2.2 Pile Sound Source Details

Required inputs for the modeling are the assumed size and properties of the piles, as well as the hammer energy used to drive them into the sediment (Table J-1).

Table J-1 Key Assumptions About the Piles Used in the Underwater Acoustic Modeling

Foundation type	Modeled maximum impact hammer energy (kJ)	Number of Strikes	Strike Rate (min-1)	Pile diameter (m)	Pile wall thickness (mm)	Seabed penetra-tion (m)	Piles per day
Monopile	4,000	10,846	50	8 to 11	80	50	2
Jacket	1,500	13,191	50	2.44	75	70	2–3

kJ = kilojoule; m = meter; mm = millimeter

To estimate the number of marine animals likely to be exposed above the regulatory thresholds, a conservative construction schedule that maximized activity during the highest-density months for each species was assumed. Sixty WTG monopiles (two per day for 30 days) were assumed to be installed in the highest-density month of each species and an additional 38 WTG monopiles (two per day for 19 days) were assumed to be installed during the month with the second highest animal density. Two options are being considered for OSS foundations: either three monopiles (two per day for 1 day and one on a third day) or 48 pin piles (three per day for 16 days) in the highest-density month. Both options were modeled and evaluated.

Monopile installation was expected to begin with 500-kilojoule (kJ) hammer strikes that would be scaled up to 4,000 kJ at the end of the pile progression. A total of 10,846 strikes are expected per pile, and the strike rate was estimated at 50 strikes per minute. Pin piles are expected to scale from 500 kJ to 1,500 kJ hammer strike energies during the piling progression. A total of 13,191 strikes are predicted for each pin pile, with a strike rate of 50 strikes per minute. Details of the pile progression are presented in the technical acoustic modeling report (COP Volume III, Appendix R-2, Tables 1 and 2; Ocean Wind 2022a). No simultaneous pile driving was included in the modeling assumptions.

J.2.3 Vibratory Driving Source Details

The sound level of the vibratory pile driver was assumed to be 165 dB re 1 µPa squared (μPa^2) at 10 meters range. The NMFS (2020) practical spherical spreading model was used to estimate the range to regulatory thresholds. This modeling assumed that the installation and removal of cofferdams would each require 18 hours to complete over 2 days, with vibratory driving taking place for no longer than 12 hours each day.

J.2.4 UXO Sound Source Details

Five different charge sizes (Table J-2) were modeled at the four modeling sites with depths ranging from 12 meters to 45 meters in depth. The net explosive weights listed in Table J-2 include both the donor charge and UXO weights. Predictions for the range to thresholds were made with and without 10 dB of bubble curtain mitigation.

Table J-2 UXO Charge Sizes Used for Underwater Acoustic Modeling

Navy Bin	Maximum net equivalent weight TNT	
	kilograms	pounds
E4	2.3	5
E6	9.1	20
E8	45.5	100
E10	227	500
E12	454	1,000

TNT = trinitrotoluene

J.2.5 HRG Sound Source Details

Both non-impulsive and impulsive HRG sources were considered (Table J-3).

Table J-3 HRG Equipment Used for Underwater Acoustic Assessment

Equipment	Operating frequency (kHz)	SL_{rms} (dB re 1 µPa m)	$SL_{0\text{-}pk}$ (dB re 1 µPa m)	Pulse duration (width) (mse)	Repetition rate (Hz)	Beam-width (degrees)	CF (2016) or MAN
Non-parametric shallow penetration SBPs (non-impulsive)							
ET 216 (2000DS or 3200 top unit)	2–16	195	--	20	6	24	MAN
	2–8	--	--	--	--	--	--
ET 424	4–24	176	--	3.4	2	71	CF
ET 512	0.7–12	179	--	9	8	80	CF
GeoPulse 5430A	2–17	196	--	50	10	55	MAN
Teledyne Benthos Chirp III - TTV 170	2–7	197	--	60	15	100	MAN

Equipment	Operating frequency (kHz)	SL_{rms} (dB re 1 μPa m)	$SL_{0\text{-}pk}$ (dB re 1 μPa m)	Pulse duration (width) (mse)	Repeti-tion rate (Hz)	Beam-width (degrees)	CF (2016) or MAN
Medium penetration SBPs (impulsive)							
AA, Dura-spark UHD (400 tips, 500 J)	0.3–1.2	203	211	1.1	4	Omni	CF
AA, triple plate S-Boom (700–1,000 J)	0.1–5	205	211	0.6	4	80	CF

CF = Crocker and Fratantonio; dB re 1 μPa = decibel referenced to 1 microPascal; kHz = kilohertz; m = meter; MAN = manufacturer; $SL_{0\text{-}pk}$ = zero to peak source level; SL_{rms} = root-mean-square source level; SBP = sub-bottom profilers

J.3. Details of Attenuation (Bubble Curtain) Method

As described in Ocean Wind's Application for MMPA Rulemaking and Letter of Authorization, Ocean Wind is proposing use of a dual noise mitigation system (e.g., bubble curtain system and an additional system) to achieve broadband noise attenuation during impact pile installation (Ocean Wind 2022b). The same or a different noise mitigation system would be used during UXO detonations.

No specific sound source attenuation method was specified in the modeling report. However, the effect of sound source attenuation at 0, 6, 10, 15, and 20 dB for winter and summer conditions was presented in the report for the marine mammal regulatory SEL isopleths (COP Volume III, Appendix R-2, Tables H-45 and H-46; Ocean Wind 2022a). These sound source attenuation effects are summarized for LFC (Figure J-1) to provide an illustration of the general effectiveness of different levels of sound source attenuation. An attenuation of 10 dB produces about a 50-percent reduction in the ranges to injury thresholds or isopleths. All the predicted exposures and ranges to thresholds were calculated using 10 dB of sound source attenuation.

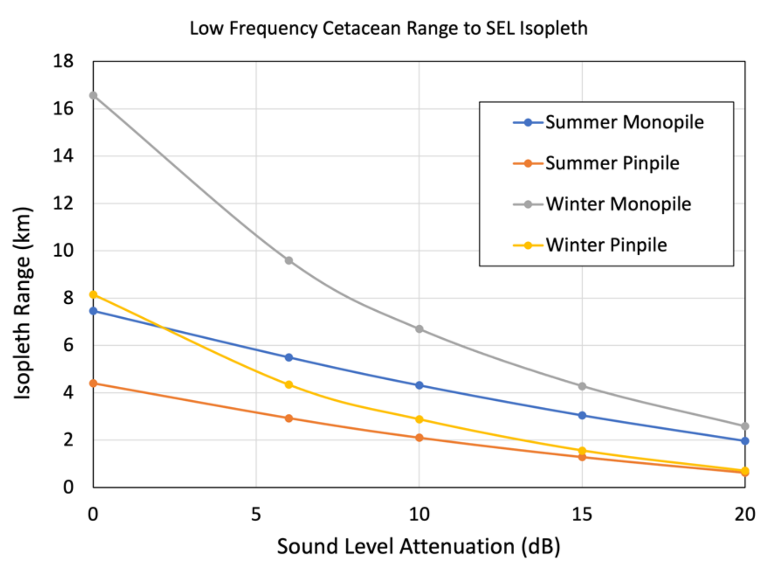

Figure J-1 Effect of Sound Source-Attenuation Levels on Ranges to SEL Isopleths for LFC in Summer and Winter Conditions

The effects of the five levels of sound attenuation on the distances to fish regulatory isopleths for the large monopoles were presented in the technical acoustic modeling report (COP Volume III, Appendix R-2; Ocean Wind 2022a), Tables H-47 to H-54, with pin pile values presented in Tables H-55 to H-62.

J.4. Propagation Modeling Methods

To model the sound from the pile driving, the force of the pile-driving hammers was computed using the GRLWEAP 2010 wave equation model (Pile Dynamics 2010). The forcing functions from GRLWEAP were used as inputs to the Finite Difference model to compute the resulting pile vibrations. The sound radiating from the pile is simulated using a vertical array of discrete point sources. Their amplitudes were derived using an inverse technique, such that their collective particle velocity, calculated using a near-field wave-number integration model, matched the particle velocity in the water at the pile wall.

J.4.1 SEL Modeling

MONM was used to compute received SEL (L_E) for impact pile driving and UXO detonations. MONM uses a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model that has been modified to account for a solid seabed (Zhang and Tindle 1995). Like all parabolic equation models, MONM requires environmental inputs such as bathymetry, the water sound speed profile, and seabed properties.

J.4.2 PK and SPL Modeling for Impact Pile Driving

Time-domain predictions of the pressure waves generated in the water are required for calculating SPL and PK pressure levels for impulsive sounds from impact pile driving. Furthermore, the pile must be represented as a distributed source to accurately characterize vertical directivity effects in the near-field zone. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments (Figure J-2), and it requires the same environmental inputs as MONM. Synthetic pressure waveforms were modeled over the frequency range 10 to 2,048 Hz, inside a 0.5-second window. The synthetic pressure waveforms were post-processed, after applying a travel time correction, to calculate standard SPL and SEL metrics versus range and depth from the source.

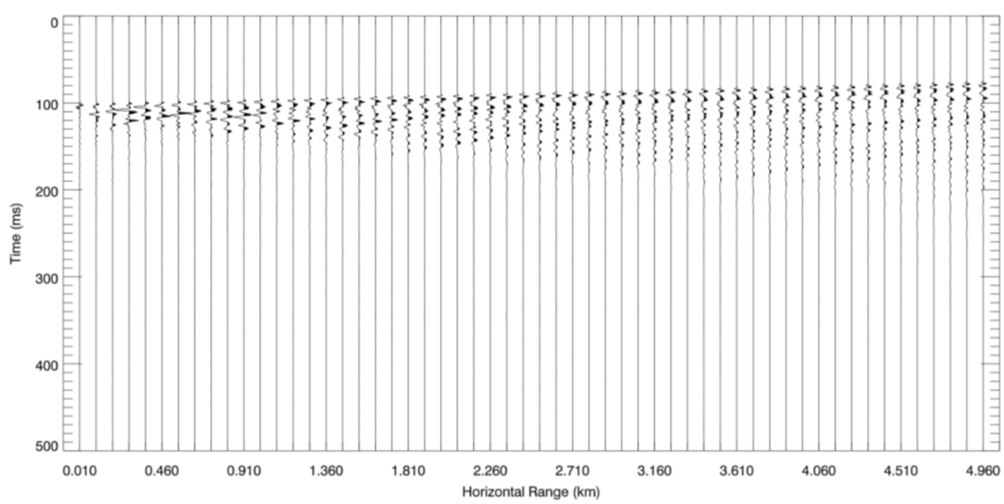

Figure J-2 Example of Synthetic Pressure Waveforms Computed by FWRAM at Multiple Range Offsets

J.4.3 Vibratory Pile Driving Modeling

Vibratory driving hammers are assumed to have a sound level of 165 dB re 1 μPa^2 at 10 meters range. Because the source level is so low, the simple NMFS (2020) practical spherical spreading model was used to predict the ranges to regulatory thresholds, which is a reasonable approach.

J.4.4 Peak Pressure and Impulse Modeling for UXO Detonations

The waveform of UXO detonations was predicted using the methodology of Arons and Yennie (1948, 1949). The shock wave peak pressure as a function of range was predicted using weak shock theory (Rogers 1977). These are both well-established prediction methods that have been validated.

J.4.5 HRG Acoustic Propagation Methods

Ranges to level A regulatory isopleths for the HRG sources were calculated using the NMFS (2020) User Spreadsheet Tool. This tool accounts for the source level, the speed of the vessel, the repetition rate of the source, the pulse duration, and frequency weighting for each source/animal hearing group combination. Ranges to behavioral thresholds were calculated using the NMFS (2020) practical spherical spreading model. Finally, isopleth distances for HRG sources with beamwidths less than 180° were calculated following NMFS Office of Protected Resources interim guidance (NMFS 2019).

J.5. Animal Movement Model Methodology

The combination of the predicted sound fields and animal movements was used to derive the animal exposures. Movement predictions are typically created using an animat-based model (Dean 1998; Frankel et al. 2002). Such modeling is typically conducted for individual species, when sufficient data are available, or representative species groups. Animat models require the input of a variety of behavioral parameter values that reproduce the "behavioral envelope" of each species or group. Examples include the range of swimming speeds, dive depths, and course changes. The output can be thought of as a table of latitude, longitude, depth, and time values that represent the four-dimensional movements of the animat; the input values were not included in the report.

The JASMINE animat modeling program was used to simulate animal movement through the predicted sound fields. JASMINE simulates full four-dimensional movement (space and time). The direction of animats was predicted using either a random walk, correlated random walk, or correlated random walk with directional bias (used for migratory animals). The underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2; Ocean Wind 2022a) did not specify which directional model was used in the simulations they conducted.

Animat tracks begin with an initial position. The animal's direction is based on the input behavioral parameters, which, along with its speed and diving behavioral values, are used to create an individual movement leg (i.e., the course between two three-dimensional locations). The model then repeats the individual movement leg process to build a full track for the duration of the simulation.

Within each modeled species or species group, JASMINE can simulate different behavioral states (e.g., foraging, resting, or directed travel). A set of transition probabilities is used to control when or if an individual animat will switch behavioral states. However, the details of which behavioral states and the transition probabilities used in the animat modeling were not provided in the report.

JASMINE can include behavioral aversion to sound sources as a behavioral state. Aversion is used to explore how the predicted exposures of animals may differ between simulations where aversion to sound sources is included or not. The underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2; Ocean Wind 2022a) focused on exploring the differences caused by aversion in NARWs (a critically endangered species) and harbour porpoises (a common species in coastal waters known to have strong behavioral reactions to sound). Aversion for these two marine mammal species was implemented by allowing the animats to change course away from the sound source, with low levels of aversion at low sound received levels, moderate aversions at moderate sound levels, and strong aversion at higher sound levels. The specific values are shown in the underwater acoustic and exposure modeling report (COP Volume III, Appendix R-2, Tables J-1 and J-2; Ocean Wind 2022a).

J.6. Ranges to Regulatory Thresholds Methods

The standard approach of taking the maximum sound received level across all depths was used to reduce the three-dimensional sound field to a two-dimensional plan view. The physical environment often produces an oddly shaped sound field. The 95th percentile of all the maximum ranges (R_{max}) for each direction from the source that exceeded the isopleth ($R_{95\%}$) was used to represent the range to regulatory isopleths (Figure J-3).

Two approaches were used to determine the ranges to regulatory level isopleths. The first was simply the $R_{95\%}$ value for the sound field, which is applied for fish and sea turtles. The second approach was based on the results of the animat modeling for marine mammals. This approach is called the Exposure Range. For each animat, the range to the closest point of approach that exceeds an acoustic threshold was determined, producing a distribution of ranges. The 95th percentile of this distribution was taken as the $ER_{95\%}$ and used to estimate the range to regulatory thresholds for the species represented by that animat.

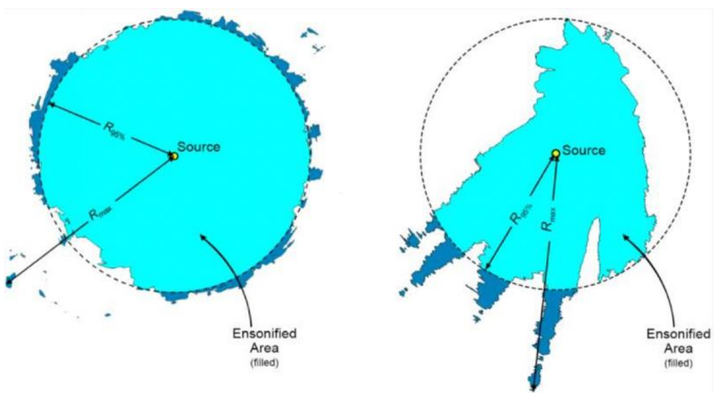

Figure J-3 Two Demonstrations of the Comparison Between the Maximum Range to the Regulatory Threshold (R_{max}) and the 95th percentile of All Maximum Threshold Ranges ($R_{95\%}$)

J.7. Marine Species Present in the Project Area

Thirty-nine marine mammal stocks (37 species) and four species of sea turtles potentially occur in the Offshore Project area (Table J-4). All the sea turtle species and six marine mammal species are listed under the ESA. Species with sufficient density to be potentially affected were modeled quantitatively. Rare species were not modeled because their low densities ensured that risks would approach zero.

Table J-4 Summarized List of Marine Mammal and Sea Turtle Species Present in the Project Area and their Abundance (rare species not modeled)

Species	Abundance	Modeled (Y/N)
Mysticetes		
Blue whale	402	Y
Fin whale	6,802	Y
Humpback whale	1,396	Y

Species	Abundance	Modeled (Y/N)
Minke whale	21,968	Y
NARW	368	Y
Sei whale	6,292	Y
Odontocetes		
Atlantic spotted dolphin	39,921	N
Atlantic white-sided dolphin	93,233	Y
Bottlenose dolphin (offshore)	62,851	Y
Bottlenose dolphin (coastal)	6,639	Y
Clymene dolphin	4,237	N
False killer whale	1,791	N
Fraser's dolphin	Unknown	N
Killer whale	Unknown	N
Melon-headed whale	Unknown	N
Pan tropical spotted dolphin	6,593	N
Pilot whale, long-finned	39,215	Y
Pilot whale, short-finned	28,924	Y
Pygmy killer whale	Unknown	N
Risso's dolphin	35,215	Y
Rough-toothed dolphin	136	N
Short-beaked common dolphin	172,974	Y
Sperm whale	4,349	Y
Spinner dolphin	4,102	N
Striped dolphin	67,036	N
Beaked Whales		
Cuvier's beaked whale	5,744	N
Blainville's beaked whale	10,107	N
Gervais' beaked whale		N
Sowerby's beaked whale		N
True's beaked whale		N
Northern bottlenose whale	Unknown	N
***Kogia* spp.**		
Dwarf sperm whale	7,750	N
Pygmy sperm whale	7,750	N
Porpoises		
Harbour porpoise	95,543	Y
Pinnipeds		
Gray seal	27,300	Y
Harbor seal	61,136	Y
Harp seal	Unknown	N
Hooded seal	Unknown	N
Sirenians		
Florida Manatee	4,834	N

Species	Abundance	Modeled (Y/N)
Sea Turtles		
Leatherback sea turtle	--	Y
Loggerhead sea turtle	--	Y
Kemp's ridley sea turtle	--	Y
Green sea turtle	--	N

Source: NMFS 2021.

J.7.1 Marine Mammal Seasonality and Densities for Project Duration

Mean monthly density estimates (animals per 100 km^2) of all the marine mammal species in the Project area were derived using the Duke University Marine Geospatial Ecology Laboratory model results (Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b) (Table J-5), including the recently updated model results for the NARW. The updated NARW density model includes new abundance estimates for Cape Cod Bay in December. The modeling used the most recent 2010 to 2018 density predictions for the NARW (COP Volume III, Appendix R-2; Ocean Wind 2022a).

Densities were calculated for a 50-kilometer buffered polygon that encompassed the Lease Area perimeter. The 50-kilometer extent was derived from studies of mysticetes that demonstrate received levels, distance from the source, and behavioral context are known to influence the probability of behavioral response (Dunlop et al. 2017).

The mean density for each month was determined by calculating the unweighted mean of all 10- by 10-kilometer (5- by 5-kilometer for NARW) grid cells partially or fully within the analysis polygon. Densities were computed for an entire year to coincide with possible planned activities. In cases where monthly densities were unavailable, annual mean densities were used instead.

Although two stocks of bottlenose dolphins occur in or near the Project area, the coastal and offshore stocks (Table J-5), only one Roberts et al. (2016a, 2018) density model was available for the bottlenose dolphin species. Densities for both stocks were calculated by estimating the total bottlenose dolphin densities in the buffered area and then scaling by the relative abundances of each stock.

Table J-5 Mean Monthly Marine Mammal Density Estimates for All Modeled Marine Mammal Species within a 50-kilometer Buffer Around the Lease Area

Marine Mammals	Monthly Densities (animals per 100 km^2)												Annual Mean Density
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Fin whale	0.116	0.126	0.151	0.185	0.212	0.257	0.137	0.088	0.201	0.197	0.102	0.110	0.157
Minke whale	0.039	0.047	0.046	0.149	0.190	0.100	0.016	0.010	0.018	0.052	0.020	0.029	0.060
Humpback whale	0.068	0.046	0.049	0.048	0.056	0.043	0.007	0.006	0.021	0.061	0.043	0.077	0.044
NARW	0.335	0.396	0.464	0.444	0.054	0.004	0.002	0.001	0.002	0.004	0.021	0.161	0.157
Sei whale	0.001	0.001	0.001	0.012	0.010	0.003	0.001	0.001	0.001	0.003	0.002	0.002	0.003
Atlantic white sided dolphin	1.095	0.675	0.736	2.248	2.228	1.423	0.148	0.045	0.144	0.569	1.121	1.278	0.976
Short-beaked common dolphin	10.99	4.990	3.125	3.657	3.130	3.202	3.266	2.576	2.049	4.582	6.076	10.95	4.883
Bottlenose dolphin, coastal	0.313	0.094	0.105	0.343	1.048	2.157	2.368	3.229	2.094	1.127	0.957	0.470	1.192
Bottlenose dolphin, offshore	2.959	0.893	0.998	3.245	9.919	20.42	22.42	30.57	19.82	10.67	9.062	4.453	11.285
Risso's dolphin	0.024	0.015	0.008	0.007	0.010	0.015	0.103	0.101	0.033	0.010	0.012	0.031	0.031
Long-finned pilot whale	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
Short-finned pilot whale	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067
Sperm whale	0.001	0.001	0.001	0.002	0.003	0.011	0.018	0.012	0.014	0.006	0.003	0.001	0.006
Harbour porpoise	2.403	4.906	6.732	3.196	0.650	0.007	0.016	0.020	0.005	0.072	1.167	2.493	1.805
Seals	4.501	5.589	3.767	3.639	1.089	0.414	0.017	0.007	0.023	0.303	0.438	2.876	1.889

Sources: Roberts et al. 2016a, 2016b, 2017, 2018, 2021a, 2021b

J.7.2 Turtle Seasonality and Densities for Project Duration

At-sea density estimates for sea turtles are extremely limited, particularly in the Project area. For this reason, Küsel et al. (2022) used sea turtle densities estimated for a different geographic region as surrogates for the Project area. A multi-year series of seasonal aerial surveys was conducted in the New York Bight region by Normandeau Associates and APEM for the New York State Energy Research and Development Authority (Normandeau Associates and APEM 2018a, 2018b, 2019a, 2019b, 2020). Four sea turtle species were reported as being present in the area during these surveys: loggerhead, leatherback, Kemp's ridley, and green turtles. The Normandeau Associates and APEM density estimates were used in the Küsel et al. analysis of sea turtle impacts rather than the older DoN (2007) sea turtle density estimates.

To obtain the densities used in the current study, the maximum seasonal abundance for each species was extracted. The abundance was corrected to represent the abundance in the entire offshore planning area and then scaled by the full offshore planning area to obtain a density in units of animals per km^2. Two categories listed in the reports included more than one species: one combined loggerhead and Kemp's ridley turtles, and the other included turtles that were observed but not identified to the species level. The counts within the two categories that included more than one species were distributed amongst the relevant species with a weighting that reflected the recorded counts for each species. For example, loggerhead turtles were identified far more frequently than any other species; therefore, more of the unidentified counts were assigned to them. The underlying assumption is that a given sample of unidentified turtles would have a distribution of species that was similar to the observed distribution within a given season.

The New York State Energy Research and Development Authority study (Normandeau Associates and APEM 2018a, 2018b, 2019a, 2019b, 2020) reported that in the survey area, most of the sea turtles recorded were loggerhead sea turtles, by an order of magnitude. Seasonal sea turtle densities used in animal movement modeling are listed in Table J-6 for loggerhead, leatherback, Kemp's ridley, and green sea turtles.

Table J-6 Sea Turtle Density Estimates Derived from New York State Energy Research and Development Authority Annual Reports

Common name	Density (animals/100 km^2)			
	Spring	Summer	Fall	Winter
Kemp's ridley turtle	0.05	0.991	0.19	0
Leatherback turtle	0	0.331	0.789	0
Loggerhead turtle	0.254	26.799	0.19	0.025
Green turtle	0	0.038	0	0

J.7.3 Seasonal Restrictions

There are two NARW seasonal management areas to the north and south of the Project area. Restrictions associated with these dynamic management areas are in effect between November 1 and April 30 annually. Vessels transiting these areas must comply with NMFS regulations and speed restrictions as applicable for NARWs.

J.8. Acoustic Impact Criteria

Marine mammal acoustic criteria used for the modeling effort were derived from the current U.S. regulatory acoustic criteria (Table J-7). PK pressure levels (L_{pk}) and frequency weighted accumulated SELs ($L_{E,24h}$) were taken from the NOAA Technical Guidance (2018) for marine mammal injury thresholds. SPL (L_p) for marine mammal behavioral thresholds were based on the unweighted NOAA (2005) and the frequency-weighted Wood et al. (2012) criteria.

Table J-7 NMFS Regulatory Levels for Marine Mammals in dB for MMPA Level A and Level B Acoustic Threshold-Level Exposure from Impulsive and Non-impulsive Sources

Functional Hearing Group	Sound Source Type				
	Impulsive			Non-Impulsive	
	Level A SEL_{cum}	Level A SEL_{peak}	Level B dB_{rms}	Level A SEL_{cum}	Level B dB_{rms}
Low-frequency cetaceans	183	219	160	199	120
Mid-frequency cetaceans	185	230		198	
High-frequency cetaceans	155	202		173	
Phocid pinnipeds underwater	185	218		201	

Sources: NOAA 2005; Wood et al. 2012; NMFS 2018
SEL_{cum} = cumulative sound exposure level

Fish injury thresholds (PK and SEL) were derived from the Fisheries Hydroacoustic Working Group (2008) and Stadler and Woodbury (2009) for fish that are equal to, greater than, or less than 2 grams. Injury thresholds (PK and SEL) were obtained from Popper et al. (2014) for fish without swim bladders, fish with swim bladders not involved in hearing, and fish with swim bladders involved in hearing.

Behavioral thresholds for fish were developed by the NMFS Greater Atlantic Regional Fisheries Office (Andersson et al. 2007; Wysocki et al. 2007; Mueller-Blenkle et al. 2010; Purser and Radford 2011) (Table J-8).

Table J-8 Acoustic Metrics and Thresholds for Fish or Sea Turtles Currently Used by NMFS Greater Atlantic Regional Fisheries Office and BOEM for Impulsive Pile Driving

Faunal Group	Injury		Impairment		Behavior
	PTS		TTS		
	L_{pk}	$L_{E, 24hr}$	L_{pk}	$L_{E, 24hr}$	L_p
Fish equal to or greater than 2 grams	206	187	--	--	150
Fish less than 2 grams		183	--	--	
Fish without swim bladder	213	216	--	--	--
Fish with swim bladder not involved in hearing	207	203	--	--	--
Fish with swim bladder involved in hearing	207	203	--	--	--
Sea turtles	232	204	226	189	175

L_E = SEL (dB re 1 µPa square second); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

PK pressure levels (L_{pk}) and frequency-weighted accumulated SEL ($L_{E,24h}$) from Finneran et al. (2017) were used for the onset of PTS and TTS in sea turtles (Table J-8). Behavioral response thresholds for sea turtles were obtained from McCauley et al. (2000).

J.9. Marine Animal Exposure Estimates

J.9.1 Marine Mammals

The numbers of individual marine mammals predicted to receive sound levels above threshold criteria were determined using animal movement modeling. The modeled results assumed broadband attenuation of 10 dB and a summer sound speed profile. The modeling used to produce these results does not include aversion behavior in the animats.

J.9.2 Sea Turtles

The same type of animat modeling was also conducted for the sea turtle species in the Project area to determine the numbers of individual sea turtles predicted to receive sound levels above threshold criteria (Table J-11 to Table J-13). These animat modeling results assumed broadband attenuation of 10 dB, calculated in the same way as the marine mammal exposures.

J.10. Acoustic Exposures, Requested MMPA Takes, and Ranges to Acoustic Regulatory Thresholds for Impact Pile Driving Scenarios

The results in the acoustic modeling report of the multiple combinations of the two modeled seasons, varying levels of sound source attenuation, Acoustic Range method, and Exposure Range method are too numerous to replicate here but several marine mammal exposure and harassment take estimates are presented herein for various impact pile driving scenarios (Table J-9 and Table J-10) while exposure estimates for sea turtles for various pile driving scenarios have also been modeled (Table J-11 to Table J-13). A summary (Table J-14) of the ranges to the marine mammal acoustic thresholds is presented herein and is based on the acoustic range to the 95th maximum percentile ($R_{95\%}$); the resulting exposure ranges ($ER_{95\%}$) values are lower, based on summertime conditions and 10 dB of sound-source attenuation.

Table J-9 Number of Marine Mammal Level A and Level B Takes Requested for Impact Pile Driving of WTG 8-/11-meter Monopiles for the Effective Period of the Letter of Authorization (5 Years Total)

Marine Mammal Species		Level A Harassment Takes	Level B Harassment Takes
LFC	NARW	0	12
	Blue whale	0	4
	Fin whale	6	13
	Sei whale	0	1
	Minke whale	7	18
	Humpback whale	3	9
MFC	Atlantic white-sided dolphin	0	228
	Atlantic spotted dolphin	0	45
	Bottlenose dolphin, offshore	0	2,213
	Bottlenose dolphin, coastal	0	114
	Common dolphin	0	2,261
	Risso’s dolphin	0	30
	Long-finned pilot whale	0	10
	Short-finned pilot whale	0	10
	Sperm whale	0	3
HFC	Harbour porpoise	54	254

Marine Mammal Species		Level A Harassment Takes	Level B Harassment Takes
PW	Gray seal	3	133
	Harbor seal	4	134

PW = phocid pinnipeds in water

Table J-10 Number of Marine Mammal Level A and Level B Takes Requested for Impact Pile Driving of Either OSS Scenario (Three 8-/11-meter Monopiles or Three Jacket Foundations Composed of 16 2.44-meter Pin Piles Each) for the Effective Period of the Letter of Authorization (5 Years Total)

Marine Mammal Species		Three 8/11-meter Monopile Scenario		48 2.44-meter Pin Pile Scenario	
		Level A Harassment Takes	Level B Harassment Takes	Level A Harassment Takes	Level B Harassment Takes
LFC	NARW	0	0	0	3
	Blue whale	0	0	0	0
	Fin whale	0	0	1	2
	Sei whale	0	0	0	1
	Minke whale	0	1	1	5
	Humpback whale	0	0	0	3
MFC	Atlantic white-sided dolphin	0	9	0	57
	Atlantic spotted dolphin	0	9	0	45
	Bottlenose dolphin, offshore	0	79	0	455
	Bottlenose dolphin, coastal	0	4	0	40
	Common dolphin	0	86	0	624
	Risso’s dolphin	0	0	0	30
	Long-finned pilot whale	0	0	0	10
	Short-finned pilot whale	0	0	0	10
	Sperm whale	0	0	0	3
HFC	Harbour porpoise	3	11	17	73
PW	Gray seal	0	6	0	32
	Harbor seal	0	6	0	30

PW = phocid pinnipeds in water

Table J-11 WTG Monopile Foundations: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of 98 Monopiles

Sea Turtle Species	Injury		Behavior
	$L_{E,\,24h}$	L_{pk}	L_p
Kemp's ridley turtle	0.83	0	15.00
Leatherback turtle	0.25	0	6.61
Loggerhead turtle	7.50	0	168.84
Green turtle	0.06	0	0.47

Source: COP Volume III, Appendix R-2, Table 19; Ocean Wind 2022a
L_E = SEL (dB re 1 µPa square second); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-12 OSS Monopile Foundations: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of Three Monopiles

Sea Turtle Species	Injury		Behavior
	$L_{E,\,24h}$	L_{pk}	L_p
Kemp's ridley turtle	0.02	0	0.43
Leatherback turtle	<0.01	0	0.18
Loggerhead turtle	0.23	0	5.97
Green turtle	<0.01	0	0.01

Source: COP Volume III, Appendix R-2, Table 20; Ocean Wind 2022a
L_E = SEL (dB re 1 µPa square second); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-13 Pin Piles Supporting OSS Jacket Foundation: Number of Sea Turtles Predicted to Receive Sound Levels Above Exposure Criteria with 10 dB Attenuation for a Total of 48 Pin Piles

Sea Turtle Species	Injury		Behavior
	$L_{E,\,24h}$	L_{pk}	L_p
Kemp's ridley turtle	0	0	0.31
Leatherback turtle	0	0	0.44
Loggerhead turtle	0	0	14.70
Green turtle	0	0	0.02

Source: COP Volume III, Appendix R-2, Table 21; Ocean Wind 2022a
L_E = SEL (dB re 1 µPa square second); L_p = RMS sound pressure (dB re 1 µPa); L_{pk} = peak sound pressure (dB re 1 µPa)

Table J-14 Exposure Ranges ($ER_{95\%}$) in Meters to Marine Mammal Threshold Criteria with 10-dB Sound Attenuation: Monopile Foundation (tapered 8- to 11-meter-diameter monopiles, two piles per day)

Species	$ER_{95\%}$ Injury (PTS) Threshold $L_{E\,24h}$/ $SEL_{cum,\,24h}$ (meters)		$ER_{95\%}$ Behavioral Threshold L_p/SPL_{rms} (meters)	
	Summer (May through November)	Winter (December only)	Summer (May through November)	Winter (December only)
LFC	1,650	2,490	3,130	3,450
MFC	0	0	3,090	3,410
HFC	880	1,430	3,070	3,370

Species	$ER_{95\%}$ Injury (PTS) Threshold $L_{E\ 24h}$/ $SEL_{cum,\ 24h}$ (meters)		$ER_{95\%}$ Behavioral Threshold L_p/SPL_{rms} (meters)	
	Summer (May through November)	Winter (December only)	Summer (May through November)	Winter (December only)
Pinnipeds in water	80	240	3,090	3,420
Sea turtles	300	440	1,060	1,260

J.11. MMPA Requested Takes and Ranges to Acoustic Regulatory Thresholds for Vibratory Pile Driving Installation and Cofferdams Removal

No Level A exposures from cofferdam installation and removal are expected based on density calculations. However, the Project is requesting a small number of Level A takes in the unlikely event that these species occur in the Level A zone. These requested Level A take numbers are 11 coastal bottlenose dolphins (one pod), 28 gray seals, and 28 harbor seals (Table J-15).

Table J-15 Number of Marine Mammal of Level A and Level B Takes Requested for Vibratory Pile Installation and Cofferdam Installation and Removal for the Effective Period of the Letter of Authorization (5 Years Total)

Marine Mammal Species		Level A Harassment Takes	Level B Harassment Takes
LFC	NARW	0	11
	Blue whale	0	0
	Fin whale	0	3
	Sei whale	0	0
	Minke whale	0	2
	Humpback whale	0	5
MFC	Atlantic white-sided dolphin	0	9
	Atlantic spotted dolphin	0	45
	Bottlenose dolphin, offshore	0	102
	Bottlenose dolphin, coastal	11	914
	Common dolphin	0	93
	Risso's dolphin	0	30
	Long-finned pilot whale	0	10
	Short-finned pilot whale	0	10
	Sperm whale	0	0
HFC	Harbour porpoise	0	102
PW	Gray seal	28	267
	Harbor seal	28	267

PW = phocid pinnipeds in water

Küsel et al. (2021) presented distance ranges to regulatory isopleths by marine mammal hearing groups for the vibratory installation and removal of cofferdams (Table J-16). The maximum distances to the Level A thresholds ranged from 7.7 meters for MFC to 128.2 meters for HFC. The maximum ranges to the Level B thresholds were 10,000 meters for all marine mammal hearing groups.

Table J-16 Distances to Weighted MMPA Level A Cumulative Sound Exposure Level Acoustic Thresholds (NMFS 2018) and Unweighted Level B root-mean-square Sound Pressure Level Acoustic Thresholds (NMFS 2012) for Marine Mammals Associated with Vibratory Pile Installation and Removal of Cofferdams

Marine Mammal Hearing Group	Level A Threshold SEL_{cum} (dB re 1 µPa^2 s)	Maximum Distance (m) to Level A Threshold	Level B Threshold SPL_{RMS} (dB re 1 µPa^2)	Maximum Distance (m) to Unweighted Level B Threshold
Low-frequency cetaceans	199	86.7	120	10,000
Mid-frequency cetaceans	198	7.7	120	10,000
High-frequency cetaceans	173	128.2	120	10,000
Phocid pinnipeds in water	201	52.7	120	10,000

Source (thresholds): NMFS 2012, 2018; source (distances): Küsel et al. 2021.
dB re 1 µPa^2 = decibel referenced to 1 microPascal squared; µPa^2 s = decibel referenced to 1 microPascal squared second; m = meter; SEL_{cum} = cumulative sound exposure level; SPL_{RMS} = root-mean-square sound pressure level

J.12. MMPA Requested Takes and Ranges to Acoustic Regulatory Thresholds for UXO Detonations

Hannay and Zykov (2021; Tables 9–36) present ranges to regulatory isopleths for the various sites, explosive weights, body sizes, and species groups of marine mammals, sea turtles, and marine fishes. Information on the total number of marine mammal takes for UXO surveys, maximum ranges to the regulatory thresholds for any site, and body size of marine mammals and sea turtles is summarized herein (Table J-17 and Table J-18) for unmitigated and mitigated (10-dB reduction) scenarios. The ranges for fish injury peak pressure were 847 meters unmitigated and 290 meters with 10 dB of mitigation.

Determining the maximum UXO ranges to regulatory thresholds for impulse signals required assessing body size. A set of representative animal masses for smaller and larger animals in several species categories of marine mammals and sea turtles was selected (Hannay and Zykoy 2021, Section 7.1). Five body mass categories of marine mammals and sea turtles were developed, with high and low body mass ranges (Hannay and Zykoy 2021, Table 7), with turtles included in the group with HFC, with the body size masses ranging from 5 kilograms (harbour porpoise calf) to 16,000 kilograms (adult sperm whale).

Table J-17 Total Number of Marine Mammal Level A and Level B Takes Requested for the Detonation of 10 UXOs for the Effective Period of the Letter of Authorization (5 Years Total)

Marine Mammal Species		10 dB of Attenuation		No Attenuation	
		Level A Harassment Takes	Level B Harassment Takes	Level A Harassment Takes	Level B Harassment Takes
LFC	NARW	0	8	0	19
	Blue whale	0	0	0	0
	Fin whale	0	10	6	27
	Sei whale	0	0	0	1
	Minke whale	0	7	4	19
	Humpback whale	0	4	2	10
MFC	Atlantic white-sided dolphin	0	4	2	20
	Atlantic spotted dolphin	0	45	0	45

Marine Mammal Species		10 dB of Attenuation		No Attenuation	
		Level A Harassment Takes	Level B Harassment Takes	Level A Harassment Takes	Level B Harassment Takes
	Bottlenose dolphin, offshore	0	67	24	366
	Bottlenose dolphin, coastal	0	7	3	39
	Common dolphin	0	19	7	103
	Risso’s dolphin	0	30	0	30
	Long-finned pilot whale	0	10	0	10
	Short-finned pilot whale	0	10	0	10
	Sperm whale	0	0	0	3
HFC	Harbour porpoise	31	152	235	882
PW	Gray seal	3	49	21	176
	Harbor seal	3	49	21	176

PW = phocid pinnipeds in water

Table J-18 Summary of Maximum UXO Ranges (meters) to Regulatory Thresholds for Auditory Injury in Marine Mammals and Sea Turtles for Peak Pressure and SEL Metrics for Unmitigated Scenario

Functional Hearing Group	Injury Type	Metric	
		Peak Pressure	SEL
LFC	Level A (PTS)	2,497	9,580
	Level B (TTS)	4,813	22,500
MFC	Level A (PTS)	758	1,840
	Level B (TTS)	1,450	6,660
HFC	Level A (PTS)	16,098	12,300
	Level B (TTS)	31,202	23,700
PW	Level A (PTS)	2,785	4,990
	Level B (TTS)	5,369	15,300
Turtle	Level A (PTS)	610	1,580
	Level B (TTS)	1,170	5,670

Note: Maximum ranges are based on worst-case scenario modeling results for charge size E12 (454 kilograms) and site (S1, S2, S3, S4) (Hannay and Zykov 2021).
PW = phocid pinnipeds in water

Table J-19 Summary of Maximum UXO Ranges (meters) to Regulatory Thresholds for Non-Auditory Injury and Mortality in Marine Mammals and Sea Turtles for Peak Pressure for Unmitigated Scenario

Injury Type	Marine Mammal Species	Adult	Pup/Calf
Mortality	Baleen whale/sperm whale	121	334
	Minke whale	194	453
	Beaked whale	392	602
	Dolphins, kogia, pinnipeds, turtles	580	814
	Porpoise	628	868
Lung Injury	Baleen whale/sperm whale	262	648

Injury Type	Marine Mammal Species	Adult	Pup/Calf
	Minke whale	402	843
	Beaked whale	746	1,084
	Dolphins, kogia, pinnipeds, turtles	1,052	1,421
	Porpoise	1,127	1,518
Onset Gastrointestinal Injury		359	359

Note: Maximum ranges are based on worst-case scenario modeling results for charge size E12 (454 kilograms) and deepest water depth (45 meters) based on 1% of animals exposed (mortality/lung injury) (Hannay and Zykov 2021).

J.13. MMPA Take Request and Ranges to Acoustic Regulatory Thresholds for HRG Survey Sources

Summarized here are the total number of marine mammal takes and distances to the regulatory thresholds for marine mammal hearing groups associated with use of nine types of shallow and medium sound sources or comparable sound source categories during HRG surveys (Table J-20 and Table J-21), which were presented in the MMPA Letter of Authorization application for the Project (Ocean Wind 2022b).

Table J-20 Annual Number of Marine Mammal Level A and Level B Takes Requested for HRG Surveys

Marine Mammal Species		Years 1, 4,and 5 (88 days of HRG surveys per year)		Years 2 and 3 (180 days of HRG surveys per year)	
		Level A Harassment Takes	Level B Harassment Takes	Level A Harassment Takes	Level B Harassment Takes
LFC	NARW	0	3	0	6
	Blue whale	0	0	0	0
	Fin whale	0	2	0	3
	Sei whale	0	0	0	1
	Minke whale	0	1	0	2
	Humpback whale	0	1	0	3
MFC	Atlantic white-sided dolphin	0	4	0	7
	Atlantic spotted dolphin	0	45	0	45
	Bottlenose dolphin, offshore	0	266	0	548
	Bottlenose dolphin, coastal	0	29	0	58
	Common dolphin	0	27	0	55
	Risso’s dolphin	0	30	0	30
	Long-finned pilot whale	0	10	0	10
	Short-finned pilot whale	0	10	0	10
	Sperm whale	0	3	0	3
HFC	Harbour porpoise	0	21	0	42
PW	Gray seal	0	42	0	87
	Harbor seal	0	42	0	87

PW = phocid pinnipeds in water

Table J-21 Distance to Weighted MMPA Level A and Unweighted MMPA Level B Marine Mammal Hearing Group Thresholds Associated with Use of Each Type of HRG Sound Source or Comparable Sound Source Category

HRG Sound Source	Distance to MMPA Level A Threshold (meters)					Distance to MMPA Level B (meters)
	LFC (SEL_{cum} threshold)	MFC (SEL_{cum} threshold)	HFC (SEL_{cum} threshold)	HFC (SPL_{0-pk} threshold)	PW (SEL_{cum} threshold)	All (SPL_{RMS} threshold)
Shallow Sub-Bottom Profilers						
ET 216 CHIRP	<1	<1	2.9	NA	0	9
ET 424 CHIRP	0	0	0	NA	0	4
ET 512i CHIRP	0	0	<1	NA	0	6
GeoPulse 5430	<1	<1	36.5	NA	<1	21
TB CHIRP III	1.5	<1	16.9	NA	<1	48
Medium Sub-Bottom Profilers						
AA Triple plate S-Boom (700/1,000J)	<1	0	0	4.7	<1	34
AA Dura-spark UHD (500J/400 tip)	<1	0	0	2.8	<1	141
AA Dura-spark UHD 400+400	<1	0	0	2.8	<1	141
GeoMarine Geo-Source Dual 400 Tip Sparker	<1	0	0	2.8	<1	141

Source: Application for MMPA Letter of Authorization, Ocean Wind 2022b: Table 1-30
AA = Applied Acoustics; CHIRP = Compressed High-Intensity Radiated Pulse; ET = EdgeTech; NA=not applicable; PW = phocid pinnipeds in water; SEL_{cum} = cumulative sound exposure level; SPL_{0-pk} = zero to peak source level; TB = Teledyne Benthos; UHD = Ultra-high Definition

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