Coastal Virginia Offshore Wind (CVOW) Project

Request for the Incidental Harassment of Marine Mammals Incidental to Construction Activities on the Outer Continental Shelf (OCS) within Research Lease OCS-A 0497 and the Associated Export Cable Corridor

Submitted to NOAA National Marine Fisheries Service

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ACRONYMS AND ABBREVIATIONS

μPa	microPascal
AFTT	Atlantic Fleet Training and Testing
Applicant	Virginia Electric and Power Company, d/b/a Dominion Energy Virginia
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
Cm	centimeter
CVOW	Coastal Virginia Offshore Wind
dB	decibel
DMA	Dynamic Management Area
Dominion Energy	Dominion Energy Virginia
DP	dynamic positioning
ECM	Environmental Compliance Monitor
EIS	Environmental Impact Statement
ESA	Endangered Species Act
EOD	Explosive Ordnance Disposal
Ft	foot
GPS	global positioning system
HDD	horizontal directional drilling
HF	high-frequency
HRG	high-resolution geophysical
Hz	hertz
IHA	Incidental Harassment Authorization
Kg	kilograms
Km	kilometer
km/h	kilometer per hour
kHz	kilohertz
LF	low-frequency
M	meter
MBES	multibeam echo sounder
MEC	munitions and explosives of concern
MF	mid-frequency
Mi	mile
MMPA	Marine Mammal Protection Act
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Marine Fisheries Service
OCS	Outer Continental Shelf
OEIS	Overseas Environmental Impact Statement

PAM	Passive Acoustic Monitoring
PBR	Potential Biological Removal
Pm	peak shock wave pressure
PSO	Protected Species Observer
PTS	permanent threshold shift
RAP	Research Activities Plan
ROV	remotely operated vehicle
RMS	root mean square
SEL	sound exposure level
SELcum	cumulative SEL
SMA	Seasonal Management Area
SVP	sound velocity profile
TSS	total suspended solids
TTS	temporary threshold shift
USBL	ultra-short baseline
U.S. Navy	U.S. Department of the Navy
UME	Unusual Mortality Event
ZOI	Zone of Influence

1. Introduction

Virginia Electric and Power Company (the Applicant), d/b/a Dominion Energy Virginia (Dominion Energy), is proposing to conduct several activities off the coast of Virginia in the area of Research Lease of Submerged Lands for Renewable Energy Activities on the Outer Continental Shelf (OCS) Offshore Virginia (Lease No. OCS-A-0497) (the Lease Area; Figure 1-1) and along the 43-kilometer (km) (27-mile [mi]) Export Cable Corridor in support of the Coastal Virginia Offshore Wind (CVOW) Project. The Applicant submits this request for Incidental Harassment Authorization (IHA) pursuant to Section 101(a)(5) of the Marine Mammal Protection Act (MMPA) and 50 Code of Federal Regulations (CFR) § 216 Subpart I to allow for the incidental harassment of small numbers of marine mammals resulting from pile driving associated with installation of the wind turbine generator (WTG) foundations. The objective of the pile driving activities is to support installation of the WTG foundations (monopiles). Underwater sound resulting from Dominion's pile driving activities have the potential to result in incidental take of marine mammals in the form of harassment and/or take.

The regulations set forth in Section 101(a) (5) of the MMPA and 50 CFR § 216 Subpart I allow for the potential take by incidental harassment of marine mammals by a specific activity if the activity is found to have a negligible impact on the species or stock(s) of marine mammals. In order for the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NOAA Fisheries) to consider authorizing the taking by U.S. citizens of small numbers of marine mammals incidental to a specified activity (other than commercial fishing), a written request must be submitted to the Assistant Administrator. Such a request is detailed in the following sections.

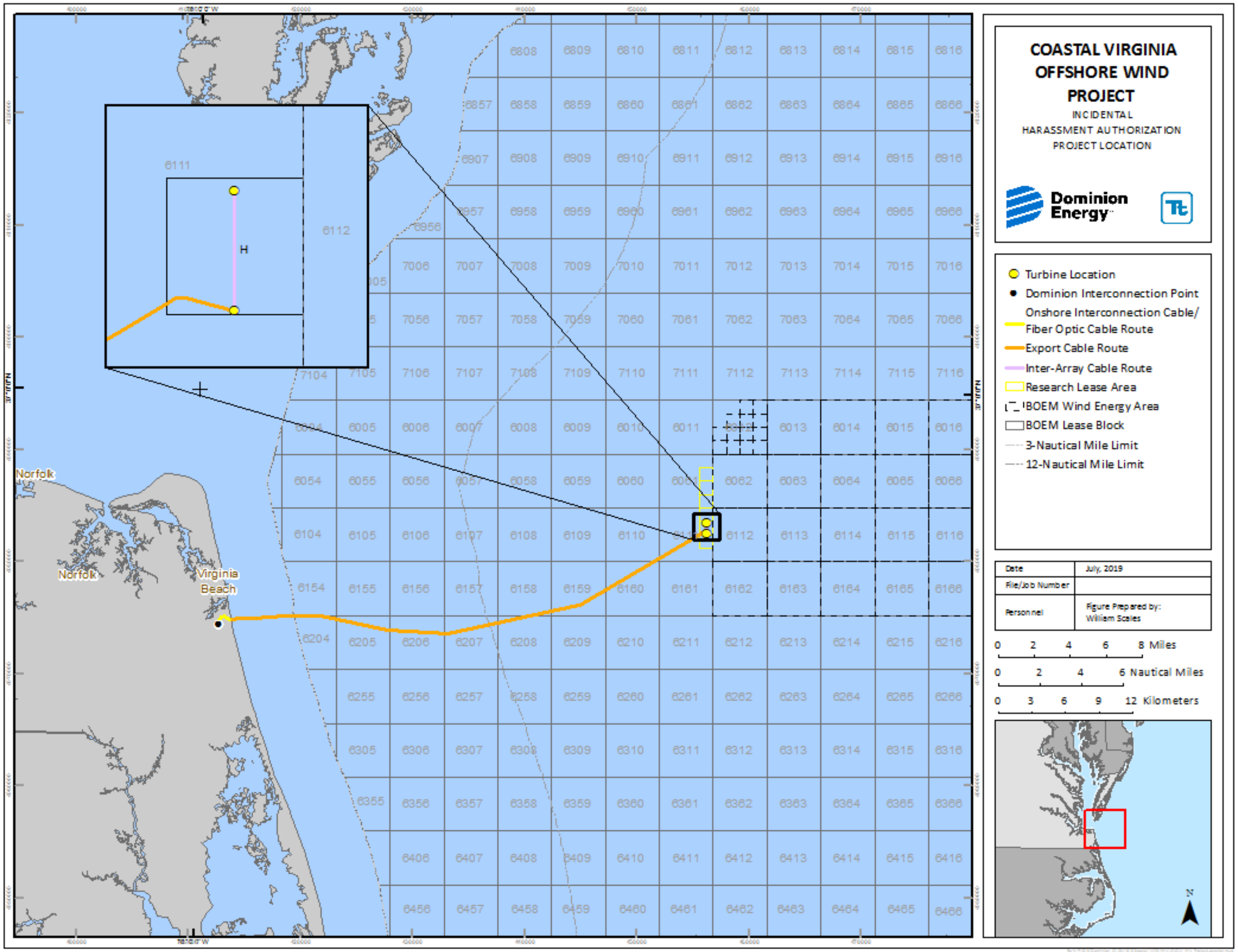

Figure 1-1. Project Location.

2. Description of Specified Activity

All proposed activities included in this application will be conducted in the marine environment in the CVOW Lease Area and along the Export Cable Corridor between the Lease Area and the Virginia shoreline, located in the lower Chesapeake Bay (see Figure 1-1).

The potential effects of underwater noise resulting in potential take by incidental harassment of marine mammals are federally managed by NOAA Fisheries under the MMPA to minimize the potential for both harm and harassment. Under the MMPA, Level A harassment is statutorily defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild; the actionable sound pressure level is not identified in the statute since the statute was written prior to the understanding of acoustic effects on marine mammals. The regulatory levels are contained in updated NOAA acoustic guidance (NOAA Fisheries 2016 and 2018a). The definition of Level B harassment was amended to be defined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered. Additionally, marine mammal stocks are defined as strategic or non-strategic; a strategic stock is one which the level of direct human-caused mortality exceeds the potential biological removal (PBR) level (maximum number of animals, not including in natural mortalities that may be removed annually from a marine mammal stock while allowing that stock to reach or maintain its optimal sustainable population level). This level is something that NOAA Fisheries considers in its designation of listing status. Mortalities are tracked via post-activity reporting to National Marine Fisheries Service (NOAA Fisheries).

The 2016 Acoustic Guidance (NOAA Fisheries 2016) formalized a practice in which NOAA Fisheries considered the onset of permanent threshold shift (PTS), which is an auditory injury, as a Level A harassment. The guidance also defines temporary threshold shift (TTS) and associated thresholds, although these are not currently associated with a level of take under the current NOAA Fisheries guidance. Level A harassment is said to occur as a result of exposure to high noise levels and onset of PTS. Under this NOAA Fisheries guidance, a system was established whereby marine mammal species were organized into 5 functional hearing groups based on their ability to detect certain sound frequencies. This Acoustic Guidance was based on findings published by the Noise Criteria Group (Southall et al. 2007) and replaced earlier NOAA Fisheries guidance, whish did not address potential impacts by the functional hearing groups. For transient and continuous sounds, it was concluded that the potential for injury is not just related to the level of the underwater sound and the hearing bandwidth of the animal but is also influenced by the duration of exposure. The evaluation of the onset of PTS provides additional species-specific insight on the potential for affect that is not captured by evaluations completed using the previous NOAA Fisheries thresholds for Level A and Level B harassment alone. In April of 2018, NOAA Fisheries updated the Technical Guidance for Assessing the Effect of Anthropogenic Sound on Marine Mammals (NOAA Fisheries 2018a). The April 2018 Revised Technical Guidance addressed implementation concerns and provided additional information to facilitate the use of the Guidance by applicants.

The Revised Technical Guidance identifies the predicted received levels for individual marine mammals at which they may experience changes in their hearing sensitivity (either temporary or permanent) from underwater anthropogenic sound sources (NOAA Fisheries 2018a). It established specific hearing criteria thresholds provided by NOAA Fisheries for each functional hearing group. These criteria apply hearing adjustment curves for each group which are known as M-weighting (see Table 2-1). Frequency weighting provides a sound level referenced to an animal's hearing ability either for individual species or classes of species, and therefore a measure of the potential of the sound to cause an effect. The measure that is obtained represents the perceived level of the sound for that animal. This is an important consideration because even apparently loud underwater sound may not affect an animal if it is at frequencies outside the animal's hearing range. In the Revised Technical Guidance (2018), there are five hearing groups: low-frequency (LF) cetaceans (baleen whales), mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales), and high-frequency (HF) cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid dolphins, Lagenorhynchus cruciger and L. australis), Phocid pinnipeds (true seals), and Otariid pinnipeds (sea lions and fur seals). It should be noted that bottlenose whales, Kogia, river dolphins cephalorhynchid dolphins, Lagenorhynchus cruciger and L. australis , Otariid pinnipeds, bottlenose whales, river dolphins, cephalorhynchid dolphins, L. cruciger, and L. australis do not occur within the Construction Area.

Table 2-1. M - Weighted Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) Criteria and Functional Hearing Range for Marine Mammals (NOAA Fisheries 2018a).

Functional Hearing Group	PTS Onset Impulsive	PTS Onset Non Impulsive	TTS Onset Impulsive	TTS Onset Non Impulsive	Functional Hearing Range
LF cetaceans (baleen whales)	219 (SPL_{pk}) & 183 (SEL_{cum})	199 (SEL_{cum})	213 (SPL_{pk})& 168 (SEL_{cum})	179 (SEL_{cum})	7 Hz to 35 kHz
MF cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	230 (SPL_{pk})& 185 (SEL_{cum})	198 (SEL_{cum})	224 (SPL_{pk}) & 170 (SEL_{cum})	178 (SEL_{cum})	150 Hz to 160 kHz
HF cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger & L. australis)	202 (SPL_{pk})& 155 (SEL_{cum})	173 (SEL_{cum})	196 (SPL_{pk}) & 140 (SEL_{cum})	153 (SEL_{cum})	275 Hz to 160 kHz
Phocid pinnipeds (underwater) (true seals)	218 (SPL_{pk}) & 185 (SEL_{cum})	201 (SEL_{cum})	212 (SPL_{pk}) & 170 (SEL_{cum})	181 (SEL_{cum})	50 Hz to 86 kHz
Otariid pinnipeds (underwater) (sea lions and fur seals)	232 (SPL_{pk}) & 203 (SEL_{cum})	219 (SEL_{cum})	226 (SPL_{pk}) & 188 (SEL_{cum})	199 (SEL_{cum})	60 Hz to 39 kHz

Notes:
PTS - permanent threshold shift
TTS - temporary threshold shift
dB – decibel
dB_{peak} – peak sound pressure level
Hz – hertz
kHz – kilohertz
SEL – sound exposure level
SEL_{cum} – cumulative SEL expressed as dB re 1 μPa^2
SPL_{pk} – zero-to-peak sound pressure level expressed as dB re 1 μPa

NOAA Fisheries has defined the threshold level for Level B harassment as a root-mean square sound pressure level (SPL_{rms}) 120 decibels referenced to 1 microPascal (dB re 1 μPa) (dB) for continuous noise and a $SPL_{rms,90\%}$ of 160 dB re 1 μPa for impulse noise. The sound produced by the proposed UXO detonation, high-resolution geophysical (HRG) equipment, and pile driving activities may approach or exceed ambient sound levels (i.e., threshold of perception or zone of audibility); however, actual perceptibility will be dependent on the hearing thresholds of the species under consideration and the inherent masking effects of ambient sound levels. The Level B harassment threshold criteria was not updated with the either the 2016 or 2018 technical guidance.

As discussed further in Section 6, evaluation of potential takes by incidental harassment of marine mammals resulting from the generation of underwater noise from the proposed HRG equipment and pile driving activities will be evaluated under the criteria for PTS onset for impulsive noise as prescribed in the Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals (Table 2-1).

2.1 HRG Equipment Use

The HRG equipment proposed by Dominion would include the following:

- Subsea positioning to calculate position by measuring the range and bearing from a vessel-mounted transceiver to an acoustic transponder;
- Depth sounding (multibeam echosounder) to determine water depths and general bottom topography (currently estimated to range from approximately 6 to 26 m (20 to 85 ft) in depth);
- Parametric sub-bottom profiler to provide high-resolution sub-bottom data laterally and vertically over all depth ranges; and
- Shallow penetration sub-bottom profiler (chirp) to map the near surface stratigraphy (top 0 to 5 m [0 to 16 ft] of soils below seabed).

Table 2-2 identifies the representative HRG equipment that may be used in support of construction activities. The make and model of the listed HRG equipment will vary depending on availability but will be finalized prior to commencing construction activities. Any HRG equipment selected would have characteristics similar to the systems described below.

Table 2-2. Summary of HRG Equipment Proposed for Use.

HRG System	Representative HRG Equipment	Operating Frequencies	RMS Source Level[1] (dB re 1 μPa m)	Peak Source Level[1] (dB re 1 μPa m)	Primary beamwidth (degrees)	Pulse Duration (millisecond)
Subsea Positioning / USBL	Sonardyne Ranger 2 USBL	35-55 kHz	194	200	90	1
Multibeam Sonar	SeaBat 7125	200 / 400 kHz[2]	221	220	128	2 to 6
Parametric Sub-Bottom Profiler	Innomar SES-2000 Medium 100	85 to 115 kHz	241[3]	N/A	2	0.07 to 2
Shallow Sub-Bottom Profiler (Chirp)	PanGeo HF Chirp	4.5 to 12.5	190	N/A	73	481.5

Notes:

[1] Source levels reported by manufacturer.[2] Operating frequencies are above all relevant marine mammal hearing thresholds, so are not assessed in this IHA.

[2] dB re 1 μPa m – decibels referenced to 1 microPascal at 1 meter

[3] The equipment specification sheets indicate a peak source level of 247 dB re 1 μPA m. The average difference between the peak and SPLRMS source levels for sub-bottom profilers measured by Crocker and Fratantonio (2016) was 6 db. Therefore, the estimated SPLRMS sound level is 241 dB re 1 μPA m.

kHz – kilohertz

RMS – root-mean-square

USBL – ultra short baseline

The HRG equipment would be utilized during installation of the foundations, WTGs and export and inter-array cables.

To complete export cable installation in one continuous run, Dominion Energy has proposed that cable installation operations would be conducted continuously 24 hours per day. Based on 24-hour operations for cable installation and daytime only pile driving, the estimated duration of the HRG equipment use would be approximately two months (including estimated weather down time) including 3 weeks for the Export Cable Corridor and 5 weeks in the Inter-Array Cable Corridor and at the wind turbine positions.

The deployment of HRG equipment, including the equipment planned for use during construction activity, produces sound in the marine environment that has the potential to result in harassment of marine mammals. Based on the frequency ranges and source levels of the potential HRG equipment planned to be used in support of installation activities (Table 2-2), the activities that have the potential to cause Level B harassment to marine mammals include the noise produced by Sonardyne Ranger 2 USBL, the Innomar SES-2000 Medium 100 sub-bottom profiler, and the PanGeo HF Chirp. We note here that the operating frequencies for all but the SeaBat 7125 are in the best hearing range for all marine mammal species that may potentially occur in the project area. However, the Innomar SES-2000 Medium 100 sub-bottom profiler operating frequencies are outside of the best hearing range for LF cetacean species (refer to Marine Mammal subsection below for more detail on marine mammal hearing groups). The Innomar SES-2000 sub-bottom profilers use the principle of “parametric” or “nonlinear” acoustics to generate a short narrow-beam sound pulse. The directionality for HRG equipment is relative to the maximum radiation level along the central axis perpendicular to the transducer surface, which, for the Innomar SES-2000 sub-bottom profiler, is a vertically directed downward beam pattern. Level A harassment may occur at distances from the Innomar SES-2000 100 sub-bottom profiler solely for HF cetaceans (harbor porpoise), though it is very unlikely to occur due to the one-degree beam width. For the LF and MF cetaceans, Level A harassment could only potentially occur so close to the HRG source such that Level A harassment is not anticipated, especially in consideration of the hearing ranges for LF cetaceans and with implementation of monitoring and mitigation measures (described in more detail in the “Estimated Take” and “Proposed Mitigation” sections below). Proposed mitigation, monitoring, and reporting measures are described in detail later in this document (please see “Mitigation Measures” and “Monitoring and Reporting”).

Preliminary analysis of noise produced during HRG activities was modeled and the potential for harassment of marine mammals was analyzed. However, due to the small size of the potential area of exposure to sound (less than 20 m for behavioral disturbance) it was determined that standard mitigation procedures as stipulated in the Research Activities Plan (RAP) conditions would be sufficient to avoid harassment of marine mammals. Therefore, it was concluded that incidental take, including both Level A and Level B, would not ocurrr and a take authorization request for these activities was unnecessary. Therfore, no incidental take will be requested for HRG surveys and these activies will no be further discussed in this application.

2.2 Cable-lay Activities

Specialist vessels specifically designed for laying and burying cables on the seabed will be used. The cable will be buried by the use of a jet plow or plow. Throughout the cable lay process, a dynamic positioning (DP) enabled cable lay vessel maintains its position (fixed location or predetermined track) by means of its propellers and thrusters using a Global Positioning System, which describes the ship’s position by sending information to an onboard computer that controls the thrusters. DP vessels possess the ability to operate with positioning accuracy, safety, and reliability without the need for anchors, anchor handling tugs and mooring lines. The underwater noise produced by subsea trenching operations depend on the equipment used and the nature of the seabed sediments but will be predominantly generated by vessel thruster use.

Thruster sound source levels may vary in part due to technologies employed and are not necessarily dependent on either vessel size, propulsion power or the activity engaged. DP thruster use was modeled as part of the underwater acoustic assessment conducted in support of Project permitting; however, thruster noise is non-impulsive and continuous in nature and is not expected to result in harassment and therefore cable-lay activities are not considered in the application.

Also, even though the USBL operates within the range of marine mammal hearing, due to the minimal size of the zones associated with use of this equipment (~ 10 m), the Applicant has determined that use of the USBL is unlikely to result in acoustic harassment to marine mammals, and, as such, the USBL will not be considered in this application.

2.3 Pile Driving

The Applicant will conduct pile driving activities to support installation of the WTG foundations. In most cases, foundations for offshore WTGs are constructed by driving piles into the seabed with hydraulic hammers. The pile driver operates by lifting a hammer inside the driver and dropping it onto a steel anvil. The anvil transmits the impulse into the top of the pile and the pile is forced into the sediment. Repeated blows drive the monopile to the desired depth, with the vertical travel of the pile decreasing with each blow as greater soil resistance is built up from the contact between the pile surface and the sediment. Each blow typically results in a travel of several centimeters. During this time, the hammer strikes the pile approximately once every two seconds.

The CVOW monopile will have a 7.8 m (26 ft) diameter at the seafloor and 6 m (20 ft) diameter flange. The length of the monopiles are 63 and 64 meters (207 and 210 ft). Pile driving activities will occur during daylight hours, unless a situation arises where ceasing the pile driving activity would compromise safety (both human health and environmental) and/or the integrity of the Project. Only one monopile will be driven at a time. It is anticipated that this activity will entail approximately 2 hours of pile driving to stabilize each monopile.

Predicting underwater noise levels during offshore pile driving is of great interest to foundation installation contractors who must comply with stringent noise emission thresholds. The acoustic energy emitted from pile driving is created upon hammer impact to the pile and travels into the water along different paths: 1. from the top of the pile where the hammer hits, through the air, into the water; 2. from the top of the pile, down the pile, radiating into the air while travelling down the pile, from air into water; 3. from the top of the pile, down the pile, radiating directly into the water from the length of pile below the waterline; and 4. down the pile radiating into the seafloor, travelling through the seafloor and radiating back into the water.

Near the pile, acoustic energy arrives from different paths with different associated phase and time lags which creates a pattern of destructive and constructive interference. The sound radiating from the pile itself was simulated using a vertical array of discrete point sources to accurately characterize vertical directivity effects in the near-field zone. Further away from the pile, the water and seafloor borne energy are the dominant pathways. The underwater noise generated by a pile-driving strike depends primarily on the following factors:

1. The impact energy and type of pile driving hammer,
2. Pile diameter and type of the pile,
3. Water depth, and
4. Subsurface hardness in which the pile is being driven.

Based on the frequency ranges of the potential equipment to be used in support of pile driving activities and hearing ranges of the marine mammals that have the potential to occur in the Lease Area, pile driving activities will have the potential to cause harassment as defined by the MMPA. However, noise mitigation measures have been incorporated into the analysis, specifically a bubble curtain. Bubble curtains are commonly used to reduce acoustic energy emissions from high-amplitude sources and are generated by releasing air through multiple small holes drilled in a hose or manifold deployed on the seabed near the source. The resulting curtain of air bubbles in the water provides significant attenuation for sound waves propagating through the curtain. The sound attenuating effect of the noise mitigation system bubble curtain or air bubbles in water is caused by: (i) sound scattering on air bubbles (resonance effect) and (ii) (specular) reflection at the transition between water layer with and without bubbles (air water mixture; impedance leap). Noise reduction achieved with a standard bubble curtain averages approximately 6 dB SEL re 1 µPa (Personal communication Jordan Carduner, NOAA Fisheries). The noise reduction realized with the Big Bubble Curtain is estimated at 10 to 13 dB (Bellman 2014) for the SEL metric with potentially higher attenuation rates for the Peak metric. Double bubble curtains can achieve around 15 dB SEL in noise reduction, based on measurements from European projects (Jan De Nul n.v. 2019). The Project will utilize double bubble curtains in order to achieve the greater noise reduction of this technology.

3. Dates, Duration, and Specific Geographic Region

3.1 Dates and Duration

The Applicant anticipates that pile driving will take place over approximately two days during May 2020. Each foundation is estimated to require two hours of pile driving to complete foundation installation. This schedule is based on an overall Project permitting and construction schedule. Pile driving activities will occur during daylight hours, unless a situation arises where ceasing the pile driving activity would compromise safety (both human health and environmental) and/or the integrity of the Project.

3.2 Specific Geographic Region

The pile driving activities will occur within the two turbine locations located in the approximately 8.6-km^2 (2,135-acre) CVOW Lease Area.

4. Species and Numbers of Marine Mammals

The Mid-Atlantic Environmental Assessment (BOEM 2012) reports a number of Atlantic species of marine mammals (whales, dolphins, porpoise, and seals) that may occur off the Virginia coast. All are protected by the MMPA, and 6 of the species in Table 4-1 are additionally listed under the Endangered Species Act (ESA). 33 marine mammal species are known to be present, at least seasonally, in the Lease Area (See Table 4-1). A description of the status and distribution of these species are discussed in detail in Section 5.

Table 4-1. Marine Mammals Known to Occur in the Marine Waters in Coastal and Offshore Virginia.

Common Name	Scientific Name	ESA and MMPA Status	Estimated Population	Stock
Odontocetes (Toothed Whales)				
Harbor Porpoise	*Phocoena phocoena*	MMPA	79,833	Gulf of Main/Bay of Fundy
Atlantic White-Sided Dolphin	*Lagenorhynchus acutus*	MMPA	48,819	W. North Atlantic
Common Dolphin	*Delphinus delphis*	MMPA	70,184	W. North Atlantic
Bottlenose Dolphin	*Tursiops truncatus*	Strategic[3]	3,751	W. North Atlantic, Southern Migratory Coastal
		MMPA	77,532	W. North Atlantic, Offshore
Clymene Dolphin	*Stenella clymene*	MMPA	Unknown	W. North Atlantic
Pantropical Spotted Dolphin	*Stenella attenuata*	MMPA	3,333	W. North Atlantic
Atlantic Spotted Dolphin	*Stenella frontalis*	MMPA	44,715	W. North Atlantic
Striped Dolphin	*Stenella coeruleoalba*	MMPA	54,807	W. North Atlantic
Risso's Dolphin	*Grampus griseus*	MMPA	18,250	W. North Atlantic
Spinner Dolphin	*Stenella longirostris*	MMPA	Unknown	W. North Atlantic
Killer Whale	*Orcinus orca*	MMPA	Unknown	W. North Atlantic
False Killer Whale	*Pseudorca crassidens*	Strategic[3]	442	W. North Atlantic
Melon-headed Whale	*Peponocephala electra*	MMPA	Unknown	W. North Atlantic
Sperm Whale	*Physeter macrocephalus*	Endangered	2,288	North Atlantic
Dwarf Sperm Whale	*Kogia sima*	MMPA	3,785[1]	W. North Atlantic
Pygmy Sperm Whale	*Kogia breviceps*	MMPA	3,785[1]	W. North Atlantic
Long-finned Pilot Whale	*Globicephala melas*	MMPA	5,636	W. North Atlantic
Short-finned Pilot Whale	*Globicephala macrorhynchus*	MMPA	28,924	W. North Atlantic
Blainville's Beaked Whale	*Mesoplodon densirostris*	MMPA	7,092[2]	W. North Atlantic

Table 4-1. Marine Mammals Known to Occur in the Marine Waters in Coastal and Offshore Virginia (continued).

Common Name	Scientific Name	ESA and MMPA Status	Estimated Population	Stock
True's Beaked Whale	*Mesoplodon mirus*	MMPA	7,092[2]	W. North Atlantic
Gervais' Beaked Whale	*Mesoplodon europaeus*	MMPA	7,092[2]	W. North Atlantic
Cuvier's Beaked Whale	*Ziphius cavirostris*	MMPA	6,532	W. North Atlantic
Sowerby's Beaked Whale	*Mesoplodon bidens*	MMPA	7,092[2]	W. North Atlantic
Mysticetes (Baleen Whales)				
Humpback Whale	*Megaptera novaeangliae*	MMPA	896	Gulf of Maine
Fin Whale	*Balaenoptera physalus*	Endangered	1,618	W. North Atlantic
Sei Whale	*Balaenoptera borealis*	Endangered	357	Nova Scotia
Minke Whale	*Balaenoptera acutorostrata*	MMPA	2,591	Canadian East Coast
Blue Whale	*Balaenoptera musculus*	Endangered	Unknown	W. North Atlantic
North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	445[4]	W. North Atlantic
Pinnipeds				
Harbor Seal	*Phoca vitulina*	MMPA	75,834	W. North Atlantic
Gray Seal	*Halichoerus grypus*	MMPA	27,131	W. North Atlantic
Harp Seal	*Pagophilus groenlandicus*	MMPA	Unknown	W. North Atlantic
Hooded Seal	*Cystophora cristata*	MMPA	Unknown	W. North Atlantic
Sirenia				
West Indian Manatee	*Trichechus manatus*	Threatened	Unknown	Florida

Notes:
[1] This estimate may include both the dwarf and pygmy sperm whales.
[2] This estimate includes Gervais' and Blainville's beaked whales and undifferentiated Mesoplodon spp. beaked whales.
[3] A strategic stock is defined as any marine mammal stock: 1) for which the level of direct human-caused mortality exceeds the potential biological removal level; 2) which is declining and likely to be listed as threatened under the ESA; or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA (http://www.ncseonline.org/nle/crsreports/biodiversity/biodv-11.cfm).
[4] Hayes et al., 2019 minimum population estimate; minimum estimate for abundance is 445. According to Pace et. al. 2017, the estimated population was 458 in 2015 with 17 mortalities in 2017.
Sources: Kenney and Vigness-Raposa 2009; Waring et al 2010; RI SAMP 2011; Waring et al 2011; Waring et al 2013; Waring et al. 2015; Waring et al. 2016; Pace et. al. 2017.

5. Affected Species Status and Distribution

As described in Section 4, there are up to 33 marine mammal species (whales, dolphins, porpoise, manatee, and seals) which are known to be present (some year-round, and some seasonally) in the Northwest Atlantic OCS region. NOAA Fisheries uses Marine Species Density Data Gap Assessments as developed by Roberts et al. (2018), which built upon models originally developed by the U.S. Department of the Navy to estimate marine mammal abundance (U.S. Navy) (2007), supplemented by data from other sources, to update species Stock Assessment Reports. These reports suggest that marine mammal density in the Mid-Atlantic region is patchy and seasonally variable. Currently there are a number of Unusual Mortality Events (UMEs) which NOAA Fisheries has evaluated and declared (NOAA Fisheries 2019) which include several of the species found in Virginia (minke whale, right whale, humpback whale, and harbor or grey seals). Of these, the most critical for this project are UMEs affecting the minke whale, right whale, and humpback whale.

The 6 ESA-listed marine mammal species known to be present year-round or seasonally in the waters of the Mid-Atlantic are the sperm whale, right whale, fin whale, blue whale, sei whale, and the West Indian manatee. The humpback whale, which may occur year-round, was recently revised and members of this stock are no longer considered endangered. The ESA-listed whale species are highly migratory and as such were thought to historically be present seasonally. However, they are increasingly seen throughout the summer and fall months while foraging, and in the winter during their migrations to warmer waters. Additionally, the larger whales (including right whales) are known to remain year-round in some cases. Dolphins, especially bottlenose, are known to be resident in Virginia coastal regions (Gubbins 2002).

While the fin, humpback, and right whales have the potential to occur within the Project Area, the sperm, blue, and sei whales are more pelagic and/or northern species, and their presence within the Project Area is less likely (Waring et al. 2007; 2010; 2012; 2013) but still possible. Recent 2018 Navy aerial and vessel survey taking place in the Project Area in waters off Norfolk Canyon in Virginia observed sperm, blue, and sei whales in April 2018 as well as right whales, fin whales, and humpback whales (Cotter 2019). The blue whale sighting was the first photographic record of this species in the nearshore area (US Navy Marine Species Monitoring 2018a). It may be that prey availability or changing habitat from climate change or other factors that are adjusting known distributions are refining previous findings.

The West Indian manatee has been sighted in Virginia waters; however, such events are infrequent. Because the potential for the West Indian manatee and blue whale to occur within the Project Area is low, these species will not be described further in this analysis. In addition, while strandings data exists for harbor and gray seals along the Mid-Atlantic coast south of New Jersey, their preference for colder, northern waters during the survey period makes their presence in the Project Area less likely during the summer and fall (Hayes et al 2019). Winter haul-out sites for harbor seals have been identified within the Chesapeake Bay region. Historic data indicates that seals were generally not present during summer and fall months, the months during which survey activities are planned (Waring et al. 2016) however more recent tagging and acoustic data in Virginia nearshore waters from 2 years of study are providing updated baseline data which indicate that seals utilize the area more than previously thought. There is now a regular seasonal occurrence of seals including harbor and gray between fall and spring (US Navy Marine Species Monitoring 2018b). Harbor seals are the predominant species seen. Coastal Virginia was thought to represent the southern extent of the habitat range for gray seals, with few stranding records reported for Virginia and sightings occurring only during winter months as far south as New Jersey (Waring et al. 2016) until recently. Similar to cetacean occurrence changes it may be that prey availability or changing habitat from climate change or other factors is adjusting known distributions or that a more focused survey effort is refining previous findings. Because the numbers of seals occurring in the Project Area if they were present is considered to be low, they species will not be described further in this analysis.

In general, the range of the remaining non-ESA whale species listed in Table 4-1 is outside the CVOW Project Area; they are usually found in more pelagic shelf-break waters, have a preference for northern latitudes, or are so rarely sighted that their presence in the Project Area is unlikely. Because the potential presence of these species in the Project Area is considered extremely low, they are not further addressed in this analysis.

The following subsections provide additional information on the biology, habitat use, abundance, distribution, and the existing threats to the non-endangered or threatened and endangered marine mammals that are both common in Virginia waters and have the likelihood of occurring, at least seasonally, in the Project Area. These species include the harbor porpoise, Atlantic white-sided dolphin, common dolphin, bottlenose dolphin, Atlantic spotted dolphin, Risso's dolphin, and the long-and short-finned pilot whale, minke whale, fin whale, humpback whale and right whale.

5.1 Toothed Whales (Odontoceti)

5.1.1 Sperm Whale (*Physeter macrocephalus*) – Endangered

Currently, there is no reliable estimate for the total number of sperm whales worldwide. The best estimate is that there are between 300,000 and 450,000 sperm whales, based on extrapolations from only a few areas that have useful estimates (Hayes et al. 2019). Estimates show about 1,665 in the northern Gulf of Mexico, 14,000 in the North Atlantic, 80,000 in the North Pacific, and 9,500 in the Antarctic (NOAA Fisheries 2018b; Waring et al. 2009). For the North Atlantic, the minimum population size has been estimated at 2,288 individuals (Hayes et al. 2019).

Sperm whales are highly social, with a basic social unit consisting of 20 to 40 adult females, calves, and some juveniles (Whitehead 2008). During their prime breeding period and old age, male sperm whales are essentially solitary. Males rejoin or find nursery groups during prime breeding season. While foraging, the whales typically gather in small clusters. Between diving bouts, sperm whales are known to raft together at the surface. Adult males often forage alone. Groups of females may spread out over distances greater than 0.5 nautical mile when foraging. When socializing, they generally gather into larger surface-active groups (Jefferson et al. 2008; Whitehead 2003). In the Northern Hemisphere, the peak breeding season for sperm whales occurs between March and June, and in the Southern Hemisphere, the peak breeding season occurs between October and December (NOAA Fisheries 2018b). There are no known breeding grounds off the coast of Virginia, though calving grounds are believed to exist around Cape Hatteras (Costidis et al 2017).

This species primarily preys on squid and octopus and are also known to prey on fish, such as lumpsuckers and redfish. Although sperm whales are generalists in terms of prey, specialization does appear to occur in a few places. The main sperm whale feeding grounds are correlated with increased primary productivity caused by upwelling.

The sperm whale is thought to have a more extensive distribution than any other marine mammal, except possibly the killer whale. This species is found in polar to tropical waters in all oceans, from approximately 70° N to 70° S (Whitehead 2003). It ranges throughout all deep oceans of the world, essentially from equatorial zones to the edges of the polar pack ice. In the Atlantic, sperm whales are found throughout the Gulf Stream and North Central Atlantic Gyre. The current abundance estimate for this species in the North Atlantic is 2,288 individuals. The species is listed as Endangered (Hayes et al. 2019).

Sperm whales show a strong preference for deep waters (Whitehead 2003). Their distribution is typically associated with waters over the continental shelf break and the continental slope and into deeper waters (Jefferson et al. 2008; Whitehead et al. 1992). Sperm whale concentrations near drop-offs and areas with strong currents and steep topography are correlated with high productivity. These whales occur almost exclusively found at the shelf break, regardless of season (Waring et al. 2001). Off the coast of Virginia, Sperm whales have recently been observed spending a significant amount of time near Norfolk Canyon and in waters over 1,800 m (6,000 ft)(U.S. Navy n.d., 2017). Sperm whales are somewhat migratory; however, their migrations are not as specific as seen in most of the baleen whale species. Sperm whales have been known to concentrate off Cape Hatteras during winter months, with a northward migration to Delaware and Virginia (Costidis et al 2017). In the North Atlantic, there appears to be a general shift northward during the summer, but there is no clear migration in some temperate areas (Whitehead 2003). Sperm whales are known to occur in the Project Area and may occur year-round though typically in waters that are further offshore. The overall likelihood of occurrence in the Project Area is moderately high.

5.1.2 Harbor Porpoise (*Phocoena phocoena*) – Non-Strategic

The harbor porpoise is likely to occur in the waters of the Mid-Atlantic during winter months, as this species prefers cold temperate and subarctic waters (Waring et al. 2012; Waring et al. 2011). Porpoise generally move out of the Mid-Atlantic during spring, migrating to the Gulf of Maine. Harbor porpoise are the smallest North Atlantic cetacean, measuring at only 1.4 m to 1.9 m (4.6 ft to 6.2 ft), and feed primarily on pelagic schooling fish, bottom fish, squid and crustaceans (Bjorge and Tolley 2009; Reeves and Read 2003). Most strandings of harbor porpoise from 2005 to 2009 occurred in Massachusetts. During this time, a total of 450 harbor porpoise have stranded along the U.S. Atlantic coast (Waring et al. 2012). An unusual mortality event in 2005 involved the stranding of 38 animals along the North Carolina coast from January 1 to March 28 (Waring et al. 2012). The current population estimate for harbor porpoise for the Gulf of Maine/Bay of Fundy stock is 79,833 (Waring et al. 2016; Hayes et al. 2019). Its hearing is in the high-frequency range (Southall et al. 2007).

The most common threat to the harbor porpoise is incidental mortality from fishing activities, especially from bottom-set gillnets. It has been demonstrated that the porpoise echolocation system is capable of detecting net fibers, but they must not have the "system activated" or else they fail to recognize the nets (Reeves et al. 2002). Roughly 365 harbor porpoise are killed by human-related activities in U.S. and Canadian waters each year. In 1999, a Take Reduction Plan to reduce harbor porpoise bycatch in U.S. Atlantic gillnets was implemented. The ruling implements time and area closures, with some areas closed completely while others are closed to gillnet fishing unless the gear meets certain restrictions. In 2001, the harbor porpoise was removed from the candidate species list for the ESA; a review of the biological status of the stock indicated that a classification of "Threatened" was not warranted (Waring et al. 2011). This species has been listed as "non-strategic" because average annual human-related mortality and injury does not exceed the potential biological removal (Waring et al. 2016; Hayes et al. 2019). The overall likelihood of occurrence in the Project Area is high.

5.1.3 Bottlenose Dolphin (*Tursiops truncatus*) – Non-Strategic Western North Atlantic Offshore Stock; Non-Endangered, Strategic Southern Coastal Migratory Stock

The bottlenose dolphin is a light- to slate-gray dolphin, roughly 2.4 to 3.7 m (8 to 12 ft) long with a short, stubby beak. Because this species occupies a wide variety of habitats, it is regarded as possibly the most adaptable cetacean (Reeves et al. 2002). It occurs in oceans and peripheral seas at both tropical and temperate latitudes. In North America, bottlenose dolphins are found in surface waters with temperatures ranging from 10 to 32°C (50 to 90°F). Its hearing is in the mid-frequency range (Southall et al. 2007).

The population of bottlenose dolphins in the North Atlantic consists of a complex mosaic of dolphin stocks (Waring et al. 2010). There are two distinct bottlenose dolphin morphotypes: migratory coastal and offshore. The migratory coastal morphotype resides in waters typically less than 20 m (65.6 ft) deep, along the inner continental shelf (within 7.5 km [4.6 mi] of shore), around islands, and is continuously distributed south of Long Island, New York into the Gulf of Mexico. This migratory coastal population is subdivided into 7 stocks based largely upon spatial distribution (Waring et al. 2016). Of these 7 coastal stocks, the Western North Atlantic migratory coastal stock is common in the coastal continental shelf waters off the North Carolina/Virginia border (Waring et al. 2016). These animals often move into or reside in bays, estuaries, the lower reaches of rivers, and coastal waters within the approximate 25 m depth isobath north of Cape Hatteras (Reeves et al. 2002; Waring et al. 2016). During winter, bottlenose dolphins are rarely observed north of the North Carolina/Virginia border (Waring et al. 2010).

Generally, the offshore migratory morphotype is found exclusively seaward of 34 km (21 mi) and in waters deeper than 34 m (111.5 ft). The offshore population extends along the entire continental shelf-break from Georges Bank to Florida during the spring and summer months and has been observed in the Gulf of Maine during the late summer and fall. However, the range of the offshore morphotype south of Cape Hatteras has recently been found to overlap with that of the migratory coastal morphotype, sampled as close as 7.3 km (4.5 mi) from the shore in water depths of 13 m (42.7 ft) (Waring et al. 2016; Hayes et al. 2019). NOAA Fisheries species stock assessment report estimates the population of Western North Atlantic offshore bottlenose dolphin stock at approximately 77,532 individuals and the Western North Atlantic southern migratory coastal stock at approximately 3,751 individuals (Waring et al. 2016; Hayes et al. 2019). Given the location of the Project Area, the southern coastal migratory stock has been considered to be the stock most likely to be impacted by Project activities.

Bottlenose dolphins feed on a large variety of organisms, depending on their habitat. The coastal, shallow population tends to feed on benthic fish and invertebrates, while deepwater populations consume pelagic or mesopelagic fish such as croakers, sea trout, mackerel, mullet, and squid (Reeves et al. 2002). Bottlenose dolphins appear to be active both during the day and night. Their activities are influenced by the seasons, time of day, tidal state, and physiological factors such as reproductive seasonality (Wells and Scott 2002).

The biggest threat to the population is bycatch because they are frequently caught in fishing gear, gillnets, purse seines, and shrimp trawls (Waring et al. 2016). They have also been adversely impacted by pollution, habitat alteration, boat collisions, human disturbance, and are subject to bioaccumulation of toxins. Scientists have found a strong correlation between dolphins with elevated levels of PCBs and illness, indicating certain pollutants may weaken their immune system (Ross 2002). Total U.S. fishery related mortality and serious injury for this stock is less than 10 percent of the calculated potential biological removal and, therefore, can be considered to be insignificant and approaching the zero mortality and serious injury rate. The common bottlenose dolphin in the western North Atlantic is not listed as threatened or endangered under the ESA, and the offshore stock is not considered strategic under the MMPA (Hayes et al. 2019). However, while the Southern Migratory Coastal Stock is not listed as threatened or endangered under the ESA, it is considered a strategic stock due to the depleted listing under the MMPA. The overall likelihood of occurrence in the Project Area is high.

5.1.4 Common Dolphin (*Delphinus delphis*) – Non-Strategic

The common (formerly short-beaked) dolphin is one of the most widely distributed cetaceans and occurs in temperate, tropical, and subtropical regions (Jefferson et al. 2008). Common dolphins feed on nutrient rich squids and small fish, including species that school in proximity to surface waters, and on mesopelagic species found near the surface at night (Waring et al. 2012; IUCN 2013). This species is found between Cape Hatteras and Georges Bank from mid-January to May. Between mid-summer and fall they migrate onto Georges Bank and the Scotian Shelf, and large aggregations occur on Georges Bank in fall (Waring et al. 2011). While this dolphin species can occupy a variety of habitats, common dolphins occur in greatest abundance within a broad band off the northeast edge of Georges Bank in the fall (Jefferson et al. 2008). Although this species is widely distributed, sightings in the vicinity of Hudson Canyon and points south have occurred at low densities (Waring et al. 2006). The species is less common south of Cape Hatteras, although schools have been reported as far south as the Georgia/South Carolina border (Jefferson et al. 2008). According to the species stock report, the best population estimate for the common dolphin off the U.S. Atlantic coast is approximately 70,184 individuals (Hayes et al. 2019). Its hearing is in the mid-frequency range (Southall et al. 2007).

Common dolphins can be found either along the 200- to 2,000-m (650- to 6,500-ft) isobaths over the continental shelf and in pelagic waters of the Atlantic and Pacific Oceans. They are present in the Western Atlantic from Newfoundland to Florida. The common dolphin is especially common along shelf edges and in areas with sharp bottom relief such as seamounts and escarpments (Reeves et al. 2002). They show a strong affinity for areas with warm, saline surface waters. Off the coast of the eastern United States, they are particularly abundant in continental slope waters from Georges Bank southward to about 35 degrees north (Reeves et al. 2002) and usually inhabit tropical, subtropical, and warm-temperate waters (Waring et al. 2009; 2016).

The common dolphin is also subject to bycatch. It has been caught in gillnets, pelagic trawls, and longline fishery activities. During 2008 to 2012, it was estimated that on average approximately 289 dolphins were killed each year by human activities (Waring et al. 2015). This number increased to 363 dolphins from 2009 to 2013 (Waring et al. 2016), and again from 2010 to 2014 where the number was estimated at 409 dolphins (Hayes et al. 2019). For the period of 2012 to 2016, this number dropped to 406 individuals (Hayes et al. 2019). This species is also the most common dolphin species to be stranded along the southern New England Coast (Kenney and Vigness-Raposa 2009). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as “non-strategic” (Waring et al. 2009; 2010; 2015; 2016; Hayes et al.; 2019). The overall likelihood of occurrence in the Project Area is high.

5.1.5 White-Sided Dolphin (*Lagenorhynchus acutus*) – Non-Strategic

The Atlantic white-sided dolphin can be found in cold temperate to subpolar waters in the North Atlantic within deep OCS and slope waters (Jefferson et al. 2008). In the western North Atlantic, this species occurs from Labrador and southern Greenland to the coast of Virginia (Jefferson et al. 2008). During winter and spring, concentrations of Atlantic white-sided dolphins can be found in the Mid-Atlantic region, particularly in deeper waters along the continental slope (Waring et al. 2012). Atlantic white-sided dolphins range between 2.5 and 2.8 m (8.2 ft to 9.2 ft) in length, with females being approximately 20 cm shorter than males (Jefferson et al. 2008). This species is highly social and is commonly seen feeding with fin whales. White-sided dolphins feed on a variety of small species, such as herring, hake, smelt, capelin, cod, and squid, with regional and seasonal changes in the species consumed (Jefferson et al. 2008). Other prey species include mackerel, silver hake, and several other varieties of gadoids (Waring et al. 2012). Recent population estimates for Atlantic white-sided dolphins in the Western North Atlantic Ocean places this species at 48,819 individuals (Hayes et al. 2019). This species can be found off the coast of southern New England during all seasons of the year but is usually most numerous in areas farther offshore at depth range of 100 m (330 ft) (Kenney and Vigness-Raposa 2009; Bulloch 1993; Reeves et al. 2002).

The biggest human-induced threat to the Atlantic white-sided dolphin is bycatch, because they are occasionally caught in fishing gillnets and trawling equipment. An estimated average of 328 dolphins each year were killed by fishery-related activities during 2003 to 2007 (Waring et al. 2010). From 2008 through 2012, an estimated annual average of 116 dolphins per year were killed (Waring et al. 2015), and from 2010 through 2014, the estimate decreased to 74 individuals annually (Hayes et al. 2019). During the period of 2012 to 2016, this number decreased to an estimated 30 individuals annually (Hayes et al. 2019). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as “non-strategic” (Waring et al. 2011; 2015). The overall likelihood of occurrence in the Project Area is high.

5.1.6 Atlantic Spotted Dolphin (*Stenella frontalis*) – Non-Strategic

There are two species of spotted dolphin in the Atlantic Ocean, the Atlantic spotted dolphin (Stenella frontalis) and the pantropical spotted dolphin (S. attenuata) (Perrin et al. 1987). Where they co-occur, the two species can be difficult to differentiate (Waring et al. 2006). The larger form is associated with continental shelf habitat while the smaller form is more pelagic, preferring offshore waters and waters around oceanic islands (Perrin, 2009). In addition, two forms of the Atlantic spotted dolphin exist, one that is large and heavily spotted and the other is smaller in size with less spots (Waring et al. 2012). The Atlantic spotted dolphin prefers tropical to warm temperate waters along the continental shelf 10 to 200 m (33 to 650 ft) deep to slope waters greater than 500 m (1,640 ft) deep. Their diet consists of a wide variety of fish and squid, as well as benthic invertebrates (Herzing 1997). According to the species stock report, the best population estimate for the Atlantic spotted dolphin is approximately 44,715 individuals (Hayes et al. 2019). Its hearing is in the mid-frequency range (Southall et al. 2007).

No fishing-related mortality of spotted dolphin was reported for 1998 through 2003 (Garrison 2004; Garrison and Richards 2004). Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as “non-strategic” (Waring et al. 2006; 2015). The overall likelihood of occurrence in the Project Area is moderately high.

5.1.7 Risso’s Dolphin (*Grampus griseus*) – Non-Strategic

Risso's dolphin is typically an offshore dolphin whose inshore appearance is uncommon (Reeves et al. 2002). Risso’s dolphin prefers temperate to tropical waters along the continental shelf edge and can range from Cape Hatteras to Georges Bank from spring through fall, and throughout the Mid-Atlantic Bight out to oceanic waters during winter (Wells et al. 2009). Risso's dolphins are usually seen in groups of 12 to 40 individuals. Loose aggregations of 100 to 200, or even several thousand, are seen occasionally (Reeves et al. 2002). Sightings of this species from surveys were mostly in the continental shelf edge and continental slope areas (Waring et al. 2011). The diet for this species is comprised mostly of squid (Baird, 2009). According to the species stock report, the best population estimate for Risso's Dolphin is approximately 18,250 individuals (Hayes et al. 2019).

Risso's dolphin has been subject to bycatch. It has been caught in gillnets and pelagic longline fishery activities. From 2005 through 2009, the mean annual fishery-related mortality or serious injury was 18 dolphins (Waring et al. 2011). From 2012 to 2016, the mean annual fishery-related mortality or serious injury was 49.7 dolphins (Hayes et al. 2019). The total U.S. fishery mortality and serious injury rate for this stock is not less than 10 percent of the calculated potential biological removal and, therefore cannot be considered to be insignificant and approaching zero; therefore, the status of Risso's dolphins is unknown but is not considered strategic (Hayes et al. 2019; Waring et al. 2016). The overall likelihood of occurrence in the Project Area is high.

5.1.8 Long-Finned and Short-Finned Pilot Whale (*Globicephala melas* and *Globicephala macrorhynchus*) – Non-Endangered, Strategic Western North Atlantic Stocks

The two species of pilot whales in the western Atlantic, the long-finned pilot whales and short-finned pilot whales, are difficult to differentiate. Therefore, both species are presented together, since much of the data is generalized for Globicephala species. Both species of pilot whale are more generally found along the edge of the continental shelf (a depth of 100 to 1,000 m [330 to 3,300 ft]), choosing areas of high relief or submerged banks. In the western North Atlantic, long-finned pilot whales are pelagic, occurring in especially high densities in winter and spring over the continental slope, then moving inshore and onto the shelf in summer and autumn following squid and mackerel populations (Reeves et al. 2002). They frequently travel into the central and northern Georges Bank, Great South Channel, and Gulf of Maine areas during the summer and early fall (May to October) (Hayes et al. 2019). Short-finned pilot whales prefer tropical, subtropical and warm temperate waters (Jefferson et al. 2008). The short-finned pilot whale ranges from New Jersey south through Florida, the northern Gulf of Mexico, and the Caribbean (Waring et al. 2011). Populations for both of these species overlap between North Carolina and New Jersey (Waring et al. 2012; Waring et al. 2011). The best population estimate for long-finned pilot whales is 5,636 individuals, and for short-finned pilot whales it is 28,924 (Hayes et al. 2019).

Pilot whales feed preferentially on squid but will eat fish (e.g., herring) and invertebrates (e.g., octopus, cuttlefish) if squid are not available. They also ingest shrimp (particularly younger whales) and various other fish species occasionally. These whales probably take most of their prey at depths of 200 to 500 m (600 to 1,650 ft), although they can forage deeper if necessary (Reeves et al. 2002). Pilot whales are subject to bycatch in gillnet fishing, pelagic trawling, longline fishing, and purse seine fishing. Approximately 215 pilot whales were killed or seriously injured each year by human activities from 1997 to 2001. Strandings involving hundreds of individuals are not unusual and demonstrate that these large schools have a high degree of social cohesion (Reeves et al. 2002). While there is insufficient data to determine population trends, both species are not listed as threatened or endangered under the ESA, but the Western North Atlantic stocks are strategic under the MMPA because the total U.S. fishery mortality and serious injury rate for these stocks exceed 10 percent of the calculated potential biological removal level (Hayes et al. 2019). The overall likelihood of occurrence in the Project Area is high.

5.2 Baleen Whales (Mysticeti)

5.2.1 North Atlantic Right Whale (*Eubalaena glacialis*) – Endangered

The North Atlantic right whale was listed as a federal endangered species in 1970. The North Atlantic right whale has seen a nominal 2 percent recovery rate since it was listed as a protected species (Hayes et al. 2019). Right whales are considered grazers as they swim slowly with their mouths open. They are the slowest swimming whales and can only reach speeds up to 10 mi per hour (16 km per hour [km/h]). They can dive at least 1,000 ft (300 m) and stay submerged for typically 10 to 15 minutes, feeding on their prey below the surface (Jefferson et al. 2008). Right whales' hearing is in the low-frequency range (Southall et al. 2007).

The right whale is a strongly migratory species that moves annually between high-latitude feeding grounds and low-latitude calving and breeding grounds. The present range of the western North Atlantic right whale population extends from the southeastern United States, which is utilized for wintering and calving, to summer feeding and nursery grounds between New England and the Bay of Fundy and the Gulf of St. Lawrence (Kenney 2009; Waring et al. 2011). The winter distribution of North Atlantic right whales is largely unknown, although offshore surveys have reported 1 to 13 detections annually in northeastern Florida and southeastern Georgia (Waring et al. 2013). A few events of right whale calving have been documented from shallow coastal areas and bays (Kenney 2009).

North Atlantic right whales may be found in feeding grounds within New England waters between February and May, with peak abundance in late March (Hayes et al. 2019). The offshore waters of Virginia, including waters of the Project Area, are used as a migration corridor for right whales. Right whales occur during seasonal movements north or south between important feeding and breeding grounds (Knowlton et al. 2002; Firestone et al. 2008). Right whales are known to have extensive movements both within and between their winter and summer habitats and their calving grounds are thought to extend as far north as Cape Fear, NC (Hayes et al. 2019). Right whales have been observed in coastal Atlantic waters year-round during all four seasons. They have been acoustically detected off Georgia and North Carolina in 7 of 11 months monitored (Hodge et al. 2015) and other recent passive acoustic studies of right whales off the Virginia coast demonstrate their year-round presence in Virginia (Salisbury et al. 2016), with increased detections in fall and late winter/ early spring. They are typically most common in the spring (late March) when they are migrating north and, in the fall, (e.g. October and November) during their southbound migration (Kenney and Vigness-Raposa 2009; NOAA Fisheries 2017a). There were sightings of up to 8 right whales on two separate days in coastal Virginia in April of last year (April 9 and 11, 2018; Cotter 2019). There are no marine mammal sanctuaries in the waters off Virginia.

The North Atlantic right whale was the first species targeted during commercial whaling operations and was the first species to be greatly depleted as a result of whaling operations (Kenney 2009). North Atlantic right whales were hunted in southern New England until the early twentieth century. Shore-based whaling in Long Island involved catches of right whales year-round, with peak catches in spring during the northbound migration from calving grounds off the southeastern United States to feeding grounds in the Gulf of Maine (Kenney and Vigness-Raposa 2009). Abundance estimates for the North Atlantic right whale population vary. From the 2003 United States Atlantic and Gulf of Mexico Marine Mammal Stock Assessments, there were only 291 North Atlantic right whales in existence, which is less than what was reported in the Northern Right Whale Recovery Plan (NOAA Fisheries 2005; Waring et al. 2004). This is a tremendous difference from pre-exploitation numbers, which are thought to be around 1,000 individuals. When the right whale was finally protected in the 1930s, it is believed that the North Atlantic right whale population was roughly 100 individuals (Waring et al. 2004). In 2015, the Western North Atlantic population size was estimated to be at least 476 individuals (Waring et al. 2016). That minimum population size estimate decreased to 445 individuals in 2018 (Hayes et al. 2019). Additional information provided by Pace et al. (2017), confirms that the probability that the North Atlantic right whale population has declined since 2010 is 99.99 percent. Data indicates that the number of adult females dropped from 200 in 2010 down to 186 in 2015 while males dropped from 283 to 272 in the same timeframe. Also cause for concern is the confirmed mortality of 17 individuals in 2017 alone (Pace et al. 2017). A UME was established for the North Atlantic right whale in June 2017 due to elevated stranding along the Atlantic coast, especially in the Gulf of St. Lawrence region of Canada. This UME for right whale strandings was declared in 2017 based on a high number of dead whales discovered in Canadian and U.S. waters and is still considered active with the current total at 30 whales (NOAA Fisheries 2019).

Contemporary anthropogenic threats to right whale populations include fishery entanglements and vessel strikes, although habitat loss, pollution, anthropogenic noise, and intense commercial fishing may also negatively impact their populations (Kenney 2009). Ship strikes of individuals can impact North Atlantic right whales on a population level due to the intrinsically small remnant population that persists in the North Atlantic (Laist et al. 2001). Between 2002 and 2006, a study of marine mammal stranding and human-induced interactions reported that right whales in the western Atlantic were subject to the highest proportion of entanglements (25 of 145 confirmed events) and ship strikes (16 of 43 confirmed occurrences) of any marine mammal studied (Glass et al. 2008). Bycatch of North Atlantic right whale has also been reported in pelagic drift gillnet operations by the Northeast Fisheries Observer Program, however, no mortalities have been reported (Glass et al. 2008). From 2010 through 2014, the minimum rate of annual human-caused mortality and serious injury to this species from fishing entanglements averaged 5.66 per year, while ship strikes averaged 1.01 whales per year (Hayes et al. 2019). From 2012 through 2016, this rate decreased slightly to an average 5.56 per year, while ship strikes also decreased to an average 0.41 whales per year (Hayes et al. 2019). Environmental fluctuations and anthropogenic disturbance may be contributing to a decline in overall health of individual North Atlantic right whales that has been occurring for the last 3 decades (Rolland et al. 2016). The NOAA Fisheries marine mammal stock assessment for 2018 reports that the low annual reproductive rate of right whales, coupled with small population size, suggests anthropogenic mortality may have a greater impact on population growth rates for the species than for other whales and that any single mortality or serious injury can be considered significant (Hayes et al. 2019).

Most ship strikes are fatal to the North Atlantic right whales (Jensen and Silber 2004). Right whales have difficulty maneuvering around boats and spend most of their time at the surface, feeding, resting, mating, and nursing, increasing their vulnerability to collisions. Mariners should assume that North Atlantic right whales will not move out of their way nor will they be easy to detect from the bow of a ship for they are dark in color and maintain a low profile while swimming (World Wildlife Fund 2005). To address potential for ship strike, NOAA Fisheries designated the nearshore waters of the Mid-Atlantic Bight as the Mid-Atlantic U.S. Seasonal Management Area (SMA) for right whales in December 2008. NOAA Fisheries requires that all vessels 19.8 m (65 ft) or longer must travel at 18.5 km/h (10 knots) or less within the right whale SMA from November 1 through April 30 when right whales are most likely to pass through these waters (NOAA Fisheries 2018c). The most recent stock assessment report noted that studies by Van der Hoop et al. (2015) have concluded large whale vessel strike mortalities decreased inside active SMAs but have increased outside inactive SMAs. The CVOW Wind Turbine Positions, Inter-Array Cable Corridor, and Export Cable Corridor are located within the right whale Mid-Atlantic SMA at the mouth of the Chesapeake Bay.

Based on the current knowledge of right whale occurrences and the establishment of an SMA around approaches to Chesapeake Bay, right whales have the potential to occur in the Project Area, , and overall likelihood of occurrence in the Project Area is high.

5.2.2 Humpback Whale (*Megaptera novaeangliae*) – Non-Endangered / Non-Strategic for West Indies Distinct Population Segment

The humpback whale was listed as endangered in 1970 due to population decrease resulting from overharvesting. Humpback whales were hunted as early as the seventeenth century, with most whaling operations having occurred in the nineteenth century (Kenney and Vigness-Raposa 2009). By 1932, commercial hunting within the North Atlantic may have reduced the humpback whale population to as few as 700 individuals (Breiwick et al. 1983). North Atlantic humpback whaling ended worldwide in 1966. The humpback whale population within the North Atlantic has been estimated to include approximately 11,570 individuals (Waring et al. 2015; 2016). Through photographic population estimates, humpback whales within the Gulf of Maine (the only region where these whales summer in the United States) have been estimated to consist of 600 individuals in 1979 (NOAA Fisheries 1991). According to the latest species stock assessment report, the best estimate of abundance for the Gulf of Maine stock of humpback whales is 896 individuals (Hayes et al. 2019).

Humpback whales feed on small prey that is often found in large concentrations, including krill and fish such as herring and sand lance (Waring et al. 2013; Kenney and Vigness-Raposa 2009). A majority of female humpback whales migrate from the North Atlantic to the Caribbean in winter, where calves are born between January and March (Blaylock et al. 1995). Not all humpback whales migrate to the Caribbean during winter, and numbers of this species are sighted in mid- to high-latitude areas during winter (Swingle et al. 1993). The Mid-Atlantic area may also serve as important habitat for juvenile humpback whales, evidenced by increased levels of juvenile strandings along the Virginia and North Carolina coasts (Wiley et al. 1995).

Contemporary human threats to humpback whales include fishery entanglements and vessel strikes. Glass et al. (2008) reported that between 2002 and 2006, humpback whales belonging to the Gulf of Maine population were involved in 77 confirmed entanglements with fishery equipment and 9 confirmed ship strikes. Humpback whales that were entangled exhibited the highest number of serious injury events of the six species of whale studied by Glass et al. (2008). A whale mortality and serious injury study conducted by Nelson et al. (2007) reported that the minimum annual rate of anthropogenic mortality and serious injury to humpback whales occupying the Gulf of Maine was 4.2 individuals per year. During this study period, humpback whales were involved in 70 reported entanglements and 12 vessel strikes and were the most common dead species reported. NOAA Fisheries records for 2006 through 2010 indicate 10 reports of mortalities as a result of collision with a vessel, and 29 serious injuries and mortalities attributed to entanglement (Waring et al. 2013). For the period 2012 through 2016, the minimum annual rate of human-caused mortality and serious injury to the Gulf of Maine humpback whale stock averaged 9.7 animals per year, including incidental fishery interaction records totaling 7.1; and records of vessel collisions totaling 2.6 (Hayes et al. 2019). In January 2016, a humpback whale UME was declared for the U.S. Atlantic coast due to elevated numbers of mortalities (a total of 105 strandings between 2016 and 2019) but the causes of these UME events have not been determined (Hayes et al. 2019; NOAA Fisheries 2019).

Humpback whales exhibit consistent fidelity to feeding areas within the northern hemisphere (Stevick et al. 2006), effectively creating six subpopulations that feed in six different areas during spring, summer, and fall. These populations can be found in the Gulf of Maine, the Gulf of St. Lawrence, Newfoundland/Labrador, western Greenland, Iceland, and Norway (Waring et al. 2013). Humpback whales migrate from these feeding areas to the West Indies (including the Antilles, the Dominican Republic, the Virgin Islands and Puerto Rico) where they mate and calve their young (NOAA Fisheries 1991; Waring et al. 2013). While migrating, humpback whales utilize the Mid-Atlantic as a migration pathway between calving/mating grounds to the south and feeding grounds in the north (Waring et al. 2013). Humpbacks typically occur within the Mid-Atlantic region year-round. Therefore, humpback whales have the potential to occur in the Project Area and overall likelihood of occurrence in the Project Area is high.

5.2.3 Fin Whale (*Balaenoptera physalus*) – Endangered

The fin whale was listed as federally endangered in 1970. This species is listed as endangered under the ESA and is designated as depleted under the MMPA. A final recovery plan for the fin whale was published in 2010 (NOAA Fisheries 2010).The best abundance estimate for fin whales in the western North Atlantic is 1,618 individuals (Hayes et al. 2019). Present threats to fin whales are similar to those that threaten other whale species, namely fishery entanglements and vessel strikes. Fin whales seem less likely to become entangled than other whale species. Glass et al. (2008) reported that between 2002 and 2006, fin whales belonging to the Gulf of Maine population were involved in only eight confirmed entanglements with fishery equipment. Furthermore, Nelson et al. (2007) reported that fin whales exhibited a low proportion of entanglements (eight reported events) during their 2001 to 2005 study along the western Atlantic. NOAA Fisheries data indicate two records with substantial evidence of fishery interactions causing mortality, with an additional two interactions resulting in serious injury from 2005 through 2009 (Waring et al. 2011). On the other hand, vessel strikes may be a more serious threat to fin whales. Glass et al. (2008) reported eight vessel strikes, while Nelson et al. (2007) reported ten strikes. NOAA Fisheries data indicate that nine fin whales were confirmed killed by collision from 2005 through 2009 (Waring et al. 2011). A study compiling whale/vessel strike reports from historical accounts, recent whale strandings, and anecdotal records by Laist et al. (2001) reported that of the 11 great whale species studied, fin whales were involved in collisions most frequently (31 in the United States and 16 in France). From 2005 to 2009, the minimum annual rate of mortality for the North Atlantic stock from anthropogenic causes was approximately 2.6 per year (Waring et al. 2011) while from 2009 to 2013, this number increased to 3.55 (Waring et al. 2016), and from 2010 to 2014, this number increased to 3.8 per year (Hayes et al. 2019). For the period 2012 through 2016, the minimum annual rate of human-caused mortality and serious injury to fin whales was 2.5 per year, including incidental fishery interaction records totaling 1.1 individuals, and records of vessel collisions totaling 1.4 whales (Hayes et al. 2019). Increase in ambient noise has also impacted fin whales, for whales in the Mediterranean have demonstrated at least two different avoidance strategies after being disturbed by tracking vessels (Jahoda et al. 2003).

Fin whales are the second largest living whale species on the planet (Kenney and Vigness-Raposa 2009). The range of fin whales in the North Atlantic extends from the Gulf of Mexico, Caribbean Sea, and Mediterranean Sea in the south to Greenland, Iceland, and Norway in the north (Jonsgård 1966; Gambell 1985). They are the most commonly sighted large whales in continental shelf waters from the Mid-Atlantic coast of the United States to Nova Scotia, principally from Cape Hatteras northward (Sergeant 1977; Sutcliffe and Brodie 1977; CeTAP 1982; Hain et al. 1992; Waring et al. 2011). Fin whales, much like humpback whales, seem to exhibit habitat fidelity to feeding areas (Waring et al. 2011; Kenney and Vigness-Raposa 2009). While fin whales typically feed in the Gulf of Maine and the waters surrounding New England, mating and calving (and general wintering) areas are largely unknown (Waring et al. 2011).

Strandings data indicate that calving may take place in the Mid-Atlantic region during October to January for this species (Hain et al. 1992).

Fin whales are present in the Mid-Atlantic region during all four seasons, although sightings data indicate that they are more prevalent during winter, spring, and summer (Waring et al 2012). While fall is the season of lowest overall abundance off Virginia, they do not depart the area entirely. Consequently, the likelihood of occurrence in the Project Area is high.

5.2.4 Sei Whale (*Balaenoptera borealis*) – Endangered

The sei whale is a widespread species in the world's temperate, subpolar, subtropical, and tropical marine waters. NOAA Fisheries considers sei whales occurring from the U.S. East Coast to Cape Breton, Nova Scotia, and east to 42°W as the "Nova Scotia stock" of sei whales (Waring et al. 2016; Hayes et al. 2019). Sei whales occur in deep water characteristic of the continental shelf edge throughout their range (Hain et al. 1985). In the waters off of Virginia, sei whales are rarely sited, however, a 2018 aerial survey conducted by the U.S. Navy recorded sei whales in the area surrounding Norfolk Canyon (U.S. Navy, n.d.).

Although sei whales may prey upon small schooling fish and squid, available information suggests that calanoid copepods and euphausiids are the primary prey of this species (Flinn et al. 2002). However, there is insufficient data pertaining to the diet and foraging of Sei Whales in the waters off of Virginia (Costidis et al 2017). Sei whales reach sexual maturity at 5-15 years of age. The calving interval is believed to be two to three years (Perry et al. 1999).

There is limited information on the stock identity of sei whales in the North Atlantic (Hayes et al. 2019). The best abundance estimate for the Nova Scotia stock of sei whales is 357; however, this estimate must be considered low and limited given the known range of the sei whale (Hayes et al. 2019; Waring et al. 2014; 2016). There are insufficient data to determine trends of the Nova Scotian sei whale population. From 2007 to 2011, the minimum annual rate of confirmed human-caused serious injury and mortality to Nova Scotian sei whales was 1.0 (Waring et al. 2014). From 2009 to 2013, this mortality rate was estimated at 0.4 (Waring et al. 2016). From 2010 through 2014, the minimum annual rate of human-caused mortality and serious injury was 0.8 (Hayes et al. 2019). This species is listed as endangered under the ESA and is designated as depleted under the MMPA. A final recovery plan for the sei whale was published in 2011 (NOAA Fisheries 2011). The overall likelihood of occurrence in the Project Area is moderate.

5.2.5 Minke Whale (*Balaenoptera acutorostrata*) – Non-Strategic

Minke whales are the smallest and are among the most widely distributed of all the baleen whales. They occur in the North Atlantic and North Pacific, from tropical to polar waters. Scientists currently recognize two subspecies of the so-called "common" minke whale: the North Atlantic minke and the North Pacific minke. Generally, they inhabit warmer waters during winter and travel north to colder regions in summer, with some animals migrating as far as the ice edge. They are frequently observed in coastal or shelf waters. Minke whales off the eastern coast of the United States are considered to be part of the Canadian East Coast stock. In the 2015 stock assessment, the estimate for minke whales in the Canadian East Coast stock was 20,741 (Waring et al. 2016). This population estimate substantially decreased to 2,591 individuals in the most recent stock assessment because estimates older than eight years were excluded from the newest estimate (Hayes et al., 2019). This new estimate should not be interpreted as a decline in abundance of this stock, as previous estimates are not directly comparable (Hayes et al., 2017; 2019). Minke whales have been observed south of New England during all four seasons; however, widespread abundance is highest in spring through fall (Waring et al. 2016). Their hearing is in the low-frequency range (Southall et al. 2007).

As is typical of the baleen whales, minke whales are usually seen either alone or in small groups, although large aggregations sometimes occur in feeding areas (Reeves et al. 2002). Minke populations are often segregated by sex, age, or reproductive condition. Known for their curiosity, minkes often approach boats. They feed on schooling fish (e.g., herring, sand eel, capelin, cod, pollock, and mackerel), invertebrates (squid and copepods), and euphausiids. Minke whales basically feed below the surface of the water, and calves are usually not seen in adult feeding areas.

Minke whales are affected by ship strikes and bycatch from gillnet and purse seine fisheries. From 2008 to 2012, the minimum annual rate of mortality for the North Atlantic stock from anthropogenic causes was approximately 9.9 per year (Waring et al. 2015), while from 2010 to 2014 this decreased to 8.25 per year (Hayes et al. 2019). This decrease continued during 2012 through 2016, where the average annual minimum detected human-caused mortality and serious injury was 7.7 minke whales per year (Hayes et al. 2019). In addition, hunting for Minke whales continues today, by Norway in the northeastern North Atlantic and by Japan in the North Pacific and Antarctic (Reeves et al. 2002). International trade in the species is currently banned. Average annual fishery-related mortality and serious injury does not exceed the potential biological removal for this species; therefore, NOAA Fisheries considers this species as “non-strategic” (Waring et.al. 2010; 2011; 2015; 2016; Hayes et al. 2019). A UME of minke whales was declared in January 2017 due to elevated stranding along the Atlantic coast, with a total of 73 whales stranded between 2017 and 2019 (Hayes et al. 2019; NOAA Fisheries 2019).The overall likelihood of occurrence in the Project Area is high.

6. Type of Incidental Taking Requested

The Applicant is requesting the authorization for potential non-lethal “taking” of small numbers of marine mammals by Level B Harassment to allow for incidental harassment resulting from pile driving activities. The request is based upon projected activities during the anticipated schedule as stated in Section 3.1.

The potential underwater noise impacts of anticipated activities were evaluated under the criteria prescribed for PTS Onset in the Revised Technical Guidance (NOAA Fisheries 2018a) .

In addition to incidental harassment resulting in behavioral changes and avoidance of the Project Area by marine mammals, pile driving has the potential to cause auditory and non-auditory impacts. Information presented in Section 2 shows the mortality and injury threshold criteria to be used to estimate the quantitative effects of pile driving sound sources for impact analyses.

7. Take Estimates for Marine Mammals

The Applicant seeks authorization for potential “taking” of small numbers of marine mammals due to incidental harassment under the jurisdiction of NOAA Fisheries in the proposed region of activity. Anticipated impacts to marine mammals from the proposed activities will be associated with noise propagation from HRG equipment use and pile driving activities. It should be noted that the estimates of exposure for marine mammals as presented in this section are conservative.

Most marine animals can perceive underwater sounds over a broad range of frequencies from about 7 Hz to more than 160 kilohertz (Table 2-1 presented in Section 2). Many of the dolphins and porpoises use even higher frequency sound for echolocation and perceive these high frequency sounds with high acuity. Marine mammals respond to low-frequency sounds with broadband intensities of more than about 120 dB re 1 µPa, or about 10 to 20 dB above natural ambient noise at the same frequencies (Richardson et al. 1991).

Sound is important to marine mammals for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding. Potential effects of anthropogenic sounds to marine mammals can include physical injury (e.g., temporary or permanent loss of hearing sensitivity), behavioral modification (e.g., changes in foraging or habitat-use patterns), and masking (the prevention of marine mammals from hearing important sounds).

7.1 Basis for Estimating Numbers of Marine Mammals that Might be "Taken by Harassment" from Pile Driving

7.1.1 Sound Propagation Model

The underwater acoustic propagation modeling for the pile driving operations was performed using a combination of a modified version of the RAM parabolic-equation model (Collins 1993, 1996) as well as Marshall Day Acoustic's dBSea program. RAM was used during initial screening and dBSea was ultimately used to complete the majority of calculations. dBSea is a 3D model built by importing bathymetry data and placing noise sources in the environment. Each source can consist of equipment chosen from either the standard or user defined databases. The user has control over the seabed and water properties including sound speed profile, temperature, salinity and current.

7.1.2 Calculation of Range to Regulatory Thresholds

Pile driving activities will occur during daylight hours, unless a situation arises where ceasing the pile driving activity would compromise safety (both human health and environmental) and/or the integrity of the Project. Impact pile driving included the analysis for the 600 kJ and maximum 1,000 kJ hammer energies, thereby describing the full range of sound levels expected throughout an entire piling sequence; however, for the purposes of calculating exposure estimates and distances to thresholds those numbers are all based on 1,000 kJ hammer energy. Soft-start mitigation procedures would be employed to reduce sound levels during the initial stages of driving a pile.

Assessment of proposed mitigation measures will consider the feasibility as well as the frequency range and expected noise reduction for the selected mitigation measure. Bubble curtains are commonly used to reduce acoustic energy emissions from high-amplitude sources and are generated by releasing air through multiple small holes drilled in a hose or manifold deployed on the seabed near the source. The noise reduction realized with the three different bubble curtain designs is estimated at 6 to 15 dB (Personal Communication Jordan Carduner, NOAA Fisheries; Bellman 2014; Jan De Nul n.v. 2019) for the SEL metric with potentially higher attenuation rates for the Peak metric. Note that while the contracter will utilize double bubble curtains, which are anticipated to achieve 15 dB of noise reduction, results are presented for bubble curtains, big bubble curtains, and double bubble curains.

Table 7-1 presents the maximum (R_{max}) radial distances that correspond to the peak SPLs (dB re 1 µPa) for impact pile driving. The levels presented in Table 7-1 correspond to auditory injury and disturbance criteria for marine mammals for both the unmitigated scenario and with three bubble curtain mitigation scenarios. Peak thresholds are unweighted. Several of the distances to peak thresholds do not change under the mitigated pile driving scenarios, as these distances will fall within the expected bubble curtain containment area of 100 m (328 ft).

Table 7-1. Maximum Radii (m) that Correspond to the Peak SPLs for Impact Pile Driving

Peak SPL (dB re 1 µPa)	Criteria	Rmax
Unmitigated		
202	PTS – HF cetaceans	325
218	PTS – Phocid pinnipeds	282
219	PTS – LF cetaceans	182
230	PTS – MFC cetaceans	N/A
Bubble Curtain (6 dB Reduction)		
202	PTS – HF cetaceans	80
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Big Bubble Curtain (10 dB Reduction)		
202	PTS – HF cetaceans	N/A
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Double Bubble Curtain (15 dB Reduction)		
202	PTS – HF cetaceans	N/A
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Notes: "N/A" indicates the distance to the threshold is so low it is undetectable in the modeling results.		

Table 7-2 presents the radial distances to the cumulative sound exposure levels during impact pile driving. Each foundation is anticipated to require up to 1 day (2 hours) of pile driving to complete the foundation installation. The drivability assessment predicts an upper bound estimate of 3,419 blows for the first foundation and 4,819 blows for the second position at a rate of 40 blows per minute. This represents a conservative assessment, since the actual number of blows for the first and second foundations are expected to be 3,381 and 2,448, respectively. Note tht the difference in blows between the first foundation and seccond positions is due to variability in soil conditions between the two WTG locations. One site has a layer of soft material that is expected to require fewer blows. The radii in Table 7-2 corresponds to marine mammal injury and disturbance criteria for a 24-hour SEL_{cum}.

Table 7-2. Radii (m) of M-Weighted SELcum Contours for Impact Pile Driving

SEL_{cum} (dB re 1 µPa^2 s)	Criteria	LFC		MFC		HFC		PINN	
		R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}
Unmitigated									
155	PTS– HF cetaceans	---	---	---	---	2,670	2,436	---	---
183	PTS – LF Cetaceans	5,930	5,432	---	---	---	---	---	---

Table 7-2. Radii (m) of M-Weighted SELcum Contours for Impact Pile Driving (continued)

SEL_{cum} (dB re 1 μPa² s)	Criteria	LFC		MFC		HFC		PINN	
		R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	397	364	---	---	1,722	1,500
Bubble Curtain (6 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	1,277	1114	---	---
183	PTS – LF Cetaceans	3,830	3,513	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	252	243	---	---	567	489
Big Bubble Curtain (10 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	314	281	---	---
183	PTS – LF Cetaceans	2,217	2,070	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	229	211	---	---	317	281
Double Bubble Curtain (15 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	233	217	---	---
183	PTS – LF Cetaceans	1,277	1,188	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	124	95	---	---	236	222

Notes:
"---" indicates no calculated radii because the given criterion is not applicable.

Table 7-3 describes the resultant distances to the Level B harassment of marine mammals threshold of 160 dB_{RMS90} ranges from 4 km to 5 km unmitigated and 1 km to 2.5 km depending on bubble curtain mitigation and hammer type. Note that the Project will utilize double bubble curtains. Table 7-4 and Table 7-5 indicate the calculated zones of influence (ZOIs) for Level A and Level B harassment based on the corresponding radii from Table 7-2 and Table 7-3.

Table 7-3. Radii (m) to 160 dBrms90 SPL (Level B Harassment) for Impact Pile Driving

dB rms90 SPL (dB re 1 μPa)	Hammer Energy	R_{max}	R_{mean}
Unmitigated			
160	1,000 kJ	5,175	5,050
Bubble Curtain (6 dB Reduction)			
160	1,000 kJ	3,580	3,245
Big Bubble Curtain (10 dB Reduction)			
160	1,000 kJ	2,520	2,450
Double Bubble Curtain (15 dB Reduction)			
160	1,000 kJ	1,370	1,264

Table 7-4. Pile Driving Activity ZOIs for Level A Harassment Based on Maximum Distances

Hammer Type	Number of Days	Calculated HF ZOI (km^2)	Calculated MF ZOI (km^2)	Calculated LF ZOI (km^2)	Calculated Phocid Pinniped ZOI (km^2)
Unmitigated					
1,000 kJ	2	22.396	0.495	110.474	9.316
Bubble Curtain					
1,000 kJ	2	5.123	0.200	46.048	1.010
Big Bubble Curtain					
1,000 kJ	2	0.310	0.165	15.441	0.316
Double Bubble Curtain					
1,000 kJ	2	0.171	0.048	5.123	0.175

Table 7-5. Pile Driving Activity Maximum Distances and ZOIs for Level B Harassment

Hammer Type	Number of Days	R_{max} Radii (m) to 160 dBrms90 SPL	Calculated ZOI (km^2)
Unmitigated			
1,000 kJ	2	5,175	84.134
Bubble Curtain			
1,000 kJ	2	3,580	28.274
Big Bubble Curtain			
1,000 kJ	2	2,520	19.950
Double Bubble Curtain			
1,000 kJ	2	1,370	5.896

7.1.3 Estimate of Numbers of Marine Mammals that Might be "Taken by Harassment" from Pile Driving

Typical estimates of potential take by incidental harassment are computed according to the following formula as provided by NOAA Fisheries:

$$Estimated\ Take\ =\ D\ x\ ZOI\ x\ (d)$$

Where:

D = average highest species density (number per m^2)
ZOI = maximum ensonified area to MMPA thresholds for impulsive noise (SPL_{rms},90% = 160 re 1 µPa)
d = number of days

Per new NOAA Fisheries' guidance for sound sources, the ZOI was calculated according to the following formula:

ZOI = maximum ensonified area around the sound source over the 2-hour a day operation duration.

The parameters in Table 7-4 and Table 7-5, including the total number of days for pile driving activities, estimated max radial distances, and the respective calculated ZOI for each mitigation type were used to estimate Level A and B harassment take for marine mammals. This represents an overly conservative duration, given pile driving activities are expected to be approximately 2 hours for each day. Density data from Roberts et al. (2016b; 2017; 2018) were mapped within the boundary of the ZOI for each WTG location (Figure 1-1) using geographic information systems. For the ZOI, the maximum densities as reported by Roberts et al. (2016b; 2017; 2018) were derived from spring, summer and fall seasonal averages. Spring included March, April, and May; summer included June, July and August; and Fall included September, October and November.

Distances to NOAA Fisheries noise criteria for Level A harassment isopleths for pile driving as listed in Table 7-4 have been used to calculate potential take for each mitigation type. Distances to NOAA Fisheries noise criteria to the $SPL_{rms,90\%}$ of 160 dB re 1 μPa Level B harassment isopleth for pile driving as listed in Table 7-5 have been used to calculate potential take for each mitigation type. The density estimates, ensonified area specific to either Level A or Level B harassment, as well as the projected duration of pile driving were then used to produce the results of take calculations provided in Table 7-6 and Table 7-7. It should be noted that calculations do not take into account whether a single animal is harassed multiple times or whether each exposure is a different animal. Therefore, the numbers in Table 7-6 and Table 7-7 are the maximum number of animals that may be harassed during the pile driving activities (i.e., the Applicant assumes that each exposure event is a different animal). For pinnipeds, because the seasonality of, and habitat use by, gray seals roughly overlaps with harbor seals, the same estimated abundance has been applied to both gray and harbor seals. Pinniped density data (as presented in Roberts et al. 2016b; 2017; 2018) were used to estimate pinniped numbers presented in Table 7-6 and Table 7-7. These data, as presented by Roberts et al. (2016b; 2017; 2018) do not differentiate between pinniped species. Specifically, for bottlenose dolphin, given the water depths for the WTG locations to be within 20 m (66 ft), and considering the proclivity for the southern coastal migratory stock to be found within coastal waters of approximate 25 m (82 ft) depth, it has been conservatively estimated that stocks would be mixed within this zone by an approximately 50 percent split. Potential take numbers have been estimated accordingly in Table 7-6 and Table 7-7 to reflect this possible split in stocks by equally splitting the total estimated take for this species.

7.2 Total Requested Level A and B Harassment Take

The following Table 7-8 summarizes the total Level A and B harassment take requested across all construction activities as described in Sections 7.1, assuming the bubble curtain (6 dB reduction) as the selected mitigation for pile driving. As indicated in the table, Dominion is requesting zero Level A harassment takes be authorized as takes estimation calcualtions indicated no Level A take would occur in any scenario with mitigation (as indicated in Table 7-6). Note that the Project will utilize a double bubble curtain and thus the calculation of Level B harassment based on use of a big bubble curtains is conservative. Also note that due to the implementation of mitigation measures as described in Section 12, including a 1,750-m radius (1.1-mi radius) exclusion zone for marine mammals as described in Section 12.3 and shut-down procedures as described in Section 12.7, the calculation of Level A harassment is conservative.

Table 7-6. Pile Driving Marine Mammal Density and Estimated Level A Harassment Take Numbers by Mitigation Type

Species	Maximum Seasonal Density [1] (No./100 km²)	Unmitigated		Bubble Curtain		Big Bubble Curtain		Double Bubble Curtain	
		Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population
Atlantic-spotted Dolphin	0.508	0.005	0.000	0.002	0.000	0.002	0.000	0.000	0.000
White-sided Dolphin	1.018	0.010	0.000	0.004	0.000	0.003	0.000	0.001	0.000
Bottlenose Dolphin – Offshore	23.861	0.118	0.000	0.095	0.000	0.039	0.000	0.012	0.000
Bottlenose Dolphin – Southern Migratory Coastal	23.861	0.118	0.000	0.095	0.000	0.039	0.000	0.012	0.000
Fin Whale	0.232	0.512	0.062	0.213	0.000	0.071	0.000	0.024	0.000
Harbor Porpoise	0.760	0.340	0.000	0.078	0.000	0.005	0.000	0.003	0.000
Humpback Whale	0.099	0.220	0.000	0.092	0.000	0.031	0.000	0.010	0.000
Minke Whale	0.096	0.213	0.000	0.089	0.000	0.030	0.000	0.010	0.000
North Atlantic Right Whale	0.077	0.169	0.000	0.071	0.000	0.024	0.000	0.008	0.000
Pilot Whales	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Risso's Dolphin	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Harbor Seal[2]	0.925	0.172	0.000	0.019	0.000	0.006	0.000	0.003	0.000
Gray Seal[2]	0.925	0.172	0.000	0.019	0.000	0.006	0.000	0.003	0.000
Sei Whale	0.002	0.004	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Common Dolphin	1.591	0.016	0.000	0.006	0.000	0.005	0.000	0.002	0.000
Sperm Whale	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes:

[1] Cetacean density values from Duke University (Roberts et al. 2016b, 2017, 2018)

[2] Pinniped density values from Duke University (Roberts et al. 2016, 2017, 2018) reported as "seals" and not species-specific. Would likely represent harbor seals off the Virginia coast.

Table 7-7. Pile Driving Marine Mammal Density and Estimated Level B Harassment Take Numbers by Mitigation Type

Species	Maximum Seasonal Density [1] (No./100 km²)	Unmitigated		Bubble Curtain		Big Bubble Curtain		Double Bubble Curtain	
		Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population	Calculated Take (No.)	Percent Population
Atlantic-spotted Dolphin	0.508	0.854	0.002	0.287	0.000	0.203	0.000	0.060	0.000
White-sided Dolphin	1.018	1.713	0.004	0.576	0.002	0.406	0.000	0.120	0.000
Bottlenose Dolphin – Offshore	23.861	20.076	0.026	13.493	0.017	4.760	0.006	1.407	0.001
Bottlenose Dolphin – Southern Migratory Coastal	23.861	20.076	0.533	13.493	0.347	4.760	0.133	1.407	0.027
Fin Whale	0.232	0.390	0.000	0.131	0.000	0.092	0.000	0.027	0.000
Harbor Porpoise	0.760	1.279	0.001	0.430	0.000	0.303	0.000	0.090	0.000
Humpback Whale	0.099	0.167	0.000	0.056	0.000	0.040	0.000	0.012	0.000
Minke Whale	0.096	0.162	0.000	0.054	0.000	0.038	0.000	0.011	0.000
North Atlantic Right Whale	0.077	0.129	0.000	0.043	0.000	0.031	0.000	0.009	0.000
Pilot Whales	0.020	0.034	0.000	0.011	0.000	0.008	0.000	0.002	0.000
Risso's Dolphin	0.011	0.019	0.000	0.006	0.000	0.004	0.000	0.001	0.000
Harbor Seal[2]	0.925	1.557	0.003	0.523	0.001	0.369	0.000	0.109	0.000
Gray Seal[2]	0.925	1.557	0.007	0.523	0.004	0.369	0.000	0.109	0.000
Sei Whale	0.002	0.003	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Common Dolphin	1.591	2.678	0.004	0.900	0.001	0.635	0.001	0.188	0.000
Sperm Whale	0.007	0.011	0.000	0.004	0.000	0.003	0.000	0.001	0.000

Notes:

[1] Cetacean density values from Duke University (Roberts et al. 2016b, 2017, 2018)

[2] Pinniped density values from Duke University (Roberts et al. 2016, 2017, 2018) reported as "seals" and not species-specific. Would likely represent harbor seals off the Virginia coast.

Table 7-8. Total Estimated Level A and B Harassment Take Numbers

Species[1]	Level A Harassment Take Authorization (No.)	Combined Level B Harassment Take Authorization (No.)
Atlantic-spotted Dolphin	0	0
White-sided Dolphin	0	1
Bottlenose Dolphin – Southern Migratory Coastal	0	14
Bottlenose Dolphin – Offshore	0	14
Fin Whale	0	0
Harbor Porpoise	0	1
Humpback Whale	0	0
Minke Whale	0	0
North Atlantic Right Whale	0	0
Pilot Whales	0	0
Risso's Dolphin	0	0
Harbor Seal[2]	0	1
Gray Seal[2]	0	1
Sei Whale	0	0
Common Dolphin	0	1
Sperm Whale	0	0

Notes:
[1] Cetacean density values from Duke University (Roberts et al. 2016b, 2017, 2018)
[2] Pinniped density values from Duke University (Roberts et al. 2016, 2017, 2018) reported as "seals" and not species-specific. Would likely represent harbor seals off the Virginia coast.

8. Anticipated Impacts of the Activity

Marine mammals are mobile and are expected to quickly leave an area when noise-producing construction activities are initiated. While Project activities may disturb more than one individual, short-term construction activities are not expected to result in population-level effects and individuals would likely return to normal behavioral patterns after pile driving has ceased or after the animal has left the construction area.

9. Anticipated Impacts on Subsistence Uses

There are no traditional subsistence hunting areas in the Construction Area.

10. Anticipated Impacts on Habitat

The installation of the two WTGs, including the foundation and scour protection at the base of each foundation, will result in a total impact of approximately 0.003 km^2 (0.76 acre). In this area, soft substrate will be permanently converted to hard substrate. Construction activities associated with the installation of the foundations and WTGs will also result in the temporary disturbance of 0.4 km^2 (100.0 acres) of substrate from the placement of jack-up vessel spuds, and construction vessel activity. Installation activity will likely result in some localized increases in TSS. Because of this, the relatively small footprint of the foundations, it is reasonable to conclude that effects to marine mammals from loss or modification of habitat will be insignificant or de minimums.

11. Anticipated Effects of Habitat Impacts on Marine Mammals

Impacts from loss of habitat from the WTG's will also be negligible and will only be associated with the physical footprint of the foundations and scour protection (a combined area of 0.003 km^2 [0.76 acre]). Because of this, the relatively small footprint of the foundations and scour protection, it is reasonable to conclude that effects to marine mammals from loss or modification of habitat will be insignificant or de minimums.

12. Mitigation Measures

The mitigation procedures outlined in this section provide a summary of mitigation procedures for pile driving, which could resulti in potential harassment of marine mammals. Dominion Energy, through their environmental consultant and Engineering Procurement and Construction contractor, Tetra Tech and Ørsted, respectively, as well as Ørsted's subcontractors, will develop a training program that will be provided to all crew prior to the start of construction, and during any changes in crew such that all personnel are fully aware and understand the mitigation, monitoring, and reporting requirements. The training program will be provided to NOAA Fisheries for review and approval prior to the start of construction. Confirmation of the training and understanding of the requirements will be documented on a training course log sheet. Signing the log sheet will certify that the crew members understand and will comply with the necessary requirements throughout the construction event. This training program will include vessel strike avoidance protocols (Section 12.1) and will be used to train an Environmental Compliance Monitor (ECM) if one is needed (Section 12.4 Visual Monitoring) to ensure the ECM can sufficiently monitor for the presence of marine mammals and ensure compliance with NOAA Fisheries mitigation, monitoring, and reporting requirements. A briefing will be conducted between the construction supervisors and crews, the PSOs/ECMs, and the Applicant at the outset of the project. The purpose of the briefing will be to establish responsibilities of each party, define the chains of command, discuss communication procedures, provide an overview of monitoring purposes, and review operational procedures.

PSO qualifications will include direct field experience on marine mammal observation surveys in the Atlantic Ocean/Gulf of Mexico. The Applicant will provide resumes of all proposed PSOs (including alternates) to the Bureau of Ocean Energy Management (BOEM) for review and approval by NOAA Fisheries prior to the start of construction.

The Applicant commits to engaging in ongoing consultations with NOAA Fisheries. Per the Lease, RAP, and RAPR approval conditions, the Applicant has committed to the following comprehensive set of mitigation measures during pile driving activities.

12.1 Vessel Strike Avoidance Procedures

The Applicant will ensure that vessel operators and crew maintain a vigilant watch for cetaceans, pinnipeds, and sea turtles during all construction activities. Construction vessel crew members responsible for navigation duties will receive site-specific training on marine mammal and sea turtle sighting/reporting and vessel strike avoidance measures. Vessel strike avoidance measures will include, but are not limited to, the following, except under extraordinary circumstances when complying with these requirements would put the safety of the vessel or crew at risk:

- All vessel operators and crew will maintain vigilant watch for cetaceans, pinnipeds, and sea turtles and slow down or stop their vessel to avoid striking these protected species.
- All vessel operators will comply with <18.5 km/hr (10 knot) speed restrictions in any Dynamic Management Area (DMA). In addition, vessels over 65 ft (19.8 m) operating from November 1 through April 30 will operate at speeds of <18.5 km/hr (10 knots) or less.
- All vessel operators will reduce vessel speed to <18.5 km/hr (10 knots) or less when mother/calf pairs, pods, or larger assemblages of non-delphinoid cetaceans are observed near an underway vessel.
- All construction vessels will maintain a separation distance of 500 m (1640 ft) or greater from any sighted North Atlantic right whale.
- If underway, vessels must steer a course away from any sited North Atlantic right whale at <18.5 km/hr (10 knots) or less until the 500 m (1,640 ft) minimum separation distance has been established. If a North Atlantic right whale is sited in a vessel's path, or within 100 m to an underway vessel, the underway vessel must reduce speed and shift the engine to neutral. Engines will not be engaged until the North Atlantic right whale has moved outside of the vessel's path and beyond 100 m (328 ft). If stationary, the vessel must not engage engines until the North Atlantic right whale has moved beyond 100 m (328 ft).
- All vessels will maintain a separation distance of 100 m (328 ft) or greater from any sighted non-delphinoid cetacean. If sighted, the vessel underway must reduce speed and shift the engine to neutral and must not engage the engines until the non-delphinoid cetacean has moved outside of the vessel's path and beyond 100 m (328 ft). If a construction vessel is stationary, the vessel will not engage engines until the non-delphinoid cetacean has moved out of the vessel's path and beyond 100 m (328 ft).
- All vessels underway will not divert to approach any delphinoid cetacean or pinniped. =Any vessel

underway will avoid excessive speed or abrupt changes in direction to avoid injury to the sighted delphinoid cetacean or pinniped.

- All vessels will maintain a separation distance of 50 m (164 ft) or greater from any sighted sea turtle or pinniped.

12.2 Seasonal Operating Requirements

The Applicant plans to restrict pile driving activities to the months of May through October in order to avoid the right whale migration period (November 1 to April 30) and to comply with right whale protections. To the extent practicable, activities will be conducted when the oceanographic conditions typically observed in the construction area (water temperature, salinity, depth, etc.), are idealistic to minimize sound propagation.

Between watch shifts in the two days prior to and throughout operations, the lead PSO of the monitoring team will consult NOAA Fisheries North Atlantic right whale reporting systems for the presence of North Atlantic right whales. The proposed activities will occur within the vicinity of the Right Whale Mid-Atlantic SMA at the mouth of the Chesapeake Bay. Activities conducted prior to May 1 will need to comply with the seasonal mandatory speed restriction period for this SMA (November 1 through April 30) for any work or transit within this area.

Throughout all phases of construction, the Applicant will monitor NOAA Fisheries North Atlantic right whale reporting systems for the establishment of a DMA. If NOAA Fisheries should establish a DMA in the Lease Area or cable route corridor(s) under construction, within 24 hours of the establishment of the DMA the Applicant will work with NOAA Fisheries to shut down and/or alter activities to avoid the DMA.

12.3 Exclusion and Monitoring Zone Implementation

The exclusion zone is the area within which, if an animal is sighted, pile driving will be shut down if feasible. The monitoring zone is typically established to provide a monitoring mechanism for minimizing impacts on marine mammals. The monitoring zone is larger than the exclusion zones and includes areas where Level B harassment may occur. The Applicant is proposing monitoring and exclusion zones, as follows.

At the onset of pile driving when the impact pile driving hammer is in use, an exclusion zone for the North Atlantic right whale will be established at "any distance" (i.e. a right whale observed by PSOs at any distance) when feasible, in addition to a 1,750-m radius (1.1-mi radius) exclusion zone for marine mammals, other than the North Atlantic right whale, to be established around each foundation. In addition, a monitoring zone of 3,580-m (2.2 mi) will be established and monitored for each pile during impact pile driving activities. This monitoring zone encompasses the maximum calculated radial distance for Level B harassment associated with impulse noise from the impact pile driving hammer with 6 dB of reduction and will be monitored for individual take during impact pile driving using this hammer, as described in Section 2. It is anticipated that the total pile-driving time for each foundation pile will take approximately two hours to complete. The Applicant will follow ramp-up procedures as detailed further below during each hammering event.

12.4 Visual Monitoring Program

Visual monitoring of the established exclusion zones and monitoring zones will be performed by qualified and NOAA Fisheries-approved PSOs located on the installation vessel.

Prior to initiation of any construction work, all crew members will undergo environmental training as mentioned in the introduction of Section 12, a component of which will focus on the procedures for sighting and protection of marine mammals and sea turtles.

In order to ensure that all environmental protocols are being followed, an ECM who has been trained (as discussed previously) will be in place and will act as Lead PSO. The ECM will take the lead in ensuring all monitoring and mitigation practices and marine mammal avoidance protocols are followed. This includes vessel strike avoidance measures and overseeing marine mammal and sea turtle observations and reporting.

A visual observer team comprised of four NOAA Fisheries-approved PSOs, operating in shifts, will be stationed aboard either the respective project vessel or a dedicated PSO-vessel. A minimum of two PSOs will be on duty at all times on every shift to mitigate for eye fatigue. During pile-driving activities, the two PSOs will be located on the installation vessel. All PSOs will work in shifts such that no one monitor will work more than 4 consecutive hours without a 2 hour break or longer than 12 hours during any 24-hour period.

Each PSO observational platform (i.e. pile driving vessel) will be equipped with the proper equipment for PSO observation. These include reticle binoculars and range finders. Reticle binoculars will give the PSOs the ability to calculate distances to marine mammals located in proximity to their respective exclusion zones and monitoring zones. Range finders will also be used in conjunction with reticle binoculars to support the sighting and monitoring of marine species. Digital single-lens reflex 35mm camera equipment will be used to record sightings and verify species identification. Visual Observations will take place from the highest practical vantage point on a given vessel. General 360-degree scanning will occur during the monitoring periods and each PSO will monitor 180 degrees of the field of vision and perform target scanning when alerted of a marine mammal presence. Position data will be recorded using hand-held or vessel based global positioning system (GPS) units for each sighting.

Each PSO will follow the protocols outlined above, using the equipment specified. The PSOs will begin monitoring the monitoring zone for at least 30 minutes prior to soft start of impact pile driving. PSOs will work in shifts as described above to monitor the associated exclusion and monitoring zones. All observations of marine mammals, including those outside the monitoring zone will be recorded as described below. Monitoring of both the exclusion and monitoring zones will continue throughout the construction activity and end approximately 30 minutes after pile driving is completed.

Data on all PSO (and ECM) observations will be recorded based on standard PSO collection requirements. This will include dates and locations of construction operations; time of observation, location and weather; details of the sightings (e.g., species, age classification [if known], numbers, behavior); and details of any observed “taking” (behavioral disturbances or injury/mortality). All data will be reviewed for quality control each evening by the Lead PSO and his designated assistants, and backed up. The data sheets or software files will be provided to both NOAA Fisheries and BOEM for review and approval prior to the start of construction activities.

12.5 Pre-Clearance of the Exclusion Zones

The Applicant will implement pre-defined clearance periods based on the established exclusion zone prior to the initiation of soft-start procedures (Section 12.6), if required. During this period, the exclusion zones will be monitored by the PSOs from the pile drving vessel using the appropriate visual technology for the specified duration.

Use of pile driving equipment will not begin until the associated exclusion zone is clear of all marine mammals for at least 30 minutes. Initial monitoring of the exclusion zone prior to soft start will be conducted with the assistance of night vision equipment to account for dark conditions at or just prior to dawn, if necessary. If a marine mammal is observed within an exclusion zone during the pre-clearance period, ramp-up may not begin until the animal(s) has been observed exiting its respective exclusion zone or until an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species). In addition, soft start of construction equipment , as described in section 12.6, will not be initiated if the exclusion zone cannot be adequately monitored (i.e., obscured by fog, sea state, or inclement weather) for a 30-minute period. If a soft start has been initiated before the onset of inclement weather, activities may continue through these periods if deemed necessary to ensure the safety and integrity of the Project.

Dominion Energy will use a double bubble curtain as a mitigation strategy to reduce sound during pile driving activities. Bubble curtains are commonly used to reduce acoustic energy emissions from high-amplitude sources and are generated by releasing air through multiple small holes drilled in a hose or manifold deployed on the seabed near the source. The resulting curtain of air bubbles in the water provides significant attenuation for sound waves propagating through the curtain.

12.6 Soft-Start Procedures

A soft-start will be used during at the commencement of pile driving. A soft start will not be initiated if the monitoring zone cannot be adequately monitored (i.e., obscured by fog, inclement weather, poor lighting conditions) for a 30-minute period. If a soft start has been initiated before the onset of inclement weather, activities may continue through these periods if deemed necessary to ensure the safety and integrity of the Project. A ramp-up or soft-start will be used at the beginning of each pile during impact pile driving in order to provide additional protection to marine mammals near the Project Area by using the assumption that a soft-start allows them to be alerted to and vacate the area prior to the commencement of full pile-driving activities. The soft-start requires an initial set of 3 strikes from the impact hammer at 40 percent energy with a one-minute waiting period between subsequent 3-strike sets. The procedure will be repeated two additional times.

12.7 Shut-Down Procedures

The exclusion and monitoring zone around the pile driving activities will be maintained, as previously described, by PSOs for the presence of marine mammals before, during, and after any pile driving activity. The operator will comply immediately with any call for shutdown by the Lead PSO.

An immediate shut-down of the HRG survey equipment will be required if a marine mammal is sighted at or within its respective exclusion zone (as defined in Section 11.3). The operator will comply immediately with any call for shut-down by the Lead PSO/ECM. Any disagreement between the Lead PSO/ECM and vessel operator will be discussed only after shut-down has occurred. Subsequent restart of the equipment can be initiated if the animal has been observed exiting its respective exclusion zone within 30 minutes of the shut-down or after an additional time period has elapsed with no further sighting (i.e., 15 minutes for small odontocetes and 30 minutes for all other species). However, there may be instances where the pile driving operation cannot be stopped. For impact pile driving, from an engineering standpoint, any significant stoppage of driving progress will allow time for displaced sediments along the piling surface areas to consolidate and bind. Attempts to restart the driving of a stopped piling may be unsuccessful and create a situation where a piling is permanently bound in a partially driven position. It is expected that while conducting impact pile driving, any marine mammals in the area will move away from the sound source.

If the acoustic source is shut down for reasons other than mitigation (e.g., mechanical difficulty) for brief periods (i.e., less than 30 minutes), it may be activated again without ramp-up, if PSOs/ECM have maintained constant observation and no detections of any marine mammal have occurred within the respective exclusion zones.

13. Arctic Plan of Cooperation

Potential impacts to species or stocks of marine mammals will be limited to individuals of marine mammal species located in the northeast region of the United States and will not affect Arctic marine mammals. Given that the Project is not located in Arctic waters, the activities associated with the Applicant's marine construction activities will not have an adverse effect on the availability of marine mammals for subsistence uses allowable under the MMPA.

14. Monitoring and Reporting

14.1 Monitoring

Visual monitoring protocols are described in Section 12.4.

14.2 Reporting

The Applicant will provide the following reports, as necessary, during the proposed activities:

- The Applicant will contact BOEM and NOAA Fisheries within 24 hours of the commencement of activities and again within 24 hours of the completion of the activities;
- The Applicant will report any observed injury or mortality in accordance with NOAA Fisheries' standard reporting guidelines; and
- Within 90 days after completion of activities, a draft technical report will be provided to BOEM and NOAA Fisheries that fully documents the methods and monitoring protocols, summarizes the data recorded during monitoring, estimates the number of listed marine mammals that may have been incidentally taken during activities, and provides an interpretation of the results and effectiveness of all monitoring tasks. Any recommendations made by NOAA Fisheries will be addressed in the final report prior to acceptance by NOAA Fisheries.

15. Suggested Means of Coordination Research

All marine mammal data collected by the Applicant during the proposed activities will be provided to NOAA Fisheries, BOEM, and other interested government agencies, and will be made available upon request to educational institutions and environmental groups. These organizations could use the data collected to study ways to reduce incidental harassment and evaluate its effects.

16. List of Preparers

Janelle Lavallee
Tetra Tech, Inc.
Project Manager

Ann Zoidis
Tetra Tech, Inc.
Marine Mammal Scientist

Timothy Feehan
Tetra Tech, Inc.
Senior Environmental Scientist

Alexandra Gibson
Tetra Tech, Inc.
Environmental Scientis
t

Adam Frankel
Marine Acoustics Inc.
Underwater Acoustician

Katherine Miller
Tetra Tech, Inc.
Environmental Scientist

Kathleen Vigness-Raposa
Marine Acoustics Inc.
Underwater Acoustician

Erik Kalapinski
Tetra Tech, Inc.
Underwater Acoustician

Tricia Pellerin
Tetra Tech, Inc.
Underwater Acoustician

James Kowalski
Tetra Tech, Inc.
Environmental Scientist

Elizabeth Kopecky
Tetra Tech, Inc.
Environmental Scientist

Kevin Fowler
Tetra Tech, Inc.
Underwater Acoustician

Katie Guttenplan
Tetra Tech, Inc.
Environmental Scientist

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Appendix A – Acoustic Modeling Report

TETRA TECH

To:	NOAA Fisheries
From:	Tetra Tech
Subject:	Coastal Virginia Offshore Wind Project: Appendix A, Supplement to the Underwater Acoustic Modeling Report
Date:	February 14, 2020

Appendix A to the request for Incidental Harassment Authorization (IHA) presents updates and revisions to the Underwater Acoustic Modeling Report filed in support of permitting the Coastal Virginia Offshore Wind Project (CVOW) in May and October 2018 (see Attachment 1). The information presented in this Appendix is meant to replace the information from the original report, which is provided in Attachment 1.

The original Underwater Acoustic Modeling Report (Attachment 1) analyzed potential underwater noise impacts, including those from impact pile driving activities, on marine species. Section 4.1 of that report describes the sound propagation model used to analyze underwater noise as RAMGeo; however, while that model was used during initial screening, it was in fact the dBSea program that was used to complete the calculations, including those for pile driving.

dBSea is a powerful software developed by Marshall Day Acoustics for the prediction of underwater noise in a variety of environments. The 3D model is built by importing bathymetry data and placing noise sources in the environment. Each source can consist of equipment chosen from either the standard- or user-defined databases. The user has control over the seabed and water properties including sound speed profile, temperature, salinity, and current.

Noise levels are calculated throughout the entire Project Area and displayed in 3D. To examine results in more detail, levels may be plotted in cross sections or a detailed spectrum may be extracted at any point in the 3D calculation area. Levels are calculated in octave or third octave bands. Two different solvers were used to account for the low and high-frequency ranges:

- dBSeaPE (Parabolic Equation Method): The dBSeaPE solver makes use of the parabolic equation method, a versatile and robust method of marching the sound field out in range from the sound source. This method is one of the most widely used in the underwater acoustics community and offers excellent performance in terms of speed and accuracy in a range of challenging scenarios.
- dBSeaRay (Ray Tracing Method): The dBSeaRay solver forms a solution by tracing rays from the source to the receiver. Many rays leave the source covering a range of angles, and the sound level at each point in the receiving field is calculated by coherently summing the components from each ray. This is currently the only computationally efficient method at high frequencies.

A summary of construction and operational scenarios incorporated into the underwater acoustic modeling analysis is provided in Table A-1 (replacing Table 5 from the Underwater Acoustic Modeling Report).

Table A-1. Underwater Noise Modeling Scenarios

Scenario	Description	Geographic Coordinate System NAD83 UTM10N	Apparent Source Level at 1 meter	Water Depth at Source
Scenario 1	Cable Lay Operations Position 1	422417, 4075190	177 dBrms	15 m
Scenario 2	Cable Lay Operations Position 2	433145, 4073712	177 dBrms	21 m
Scenario 3	Cable Lay Operations Position 3	444782, 4076187	177 dBrms	19 m
Scenario 4	Cable Lay Operations Position 4	451021, 4079909	177 dBrms	20 m
Scenario 5	WTG Installation	456196, 4083479 456196, 4082429	184 dBrms	25 m
Scenario 6	Impact Pile Driving – 600 kJ Hammer Energy	456196, 4083479 456196, 4082429	222 $dBrms_{90}$ 213 SEL 235 Peak	25 m
Scenario 7	Impact Pile Driving – 1,000 kJ Hammer Energy	456196, 4083479 456196, 4082429	224 $dBrms_{90}$ 215 SEL 237 Peak	25 m
Scenario 8	Operational Wind Turbine	456196, 4083479 456196, 4082429	140 to 150 dBrms	25 m

The apparent sound source level values for pile driving were calculated at 1 meter using underwater noise data from pile driving for the Walney Extension Offshore Wind Farm, which were normalized to a distance of 500 meters. Table A-2 (replacing Table 6 from the Underwater Acoustic Modeling Report) provides the normalized $RMS_{90\%}$ sound level values.

Table A-2 Normalization of Underwater Pile Driving Measurement Results

Measurement Site	Pile Diameter m	Measured Depth H1 m	Measured Distance R1 m	Impact Energy E1 kJ	MEASURED SPL dB re 1 µPa		$RMS_{90\%}$ re 1 µPa NORMALIZED TO 500 m	
					Peak	$RMS_{90\%}$	Impact Force 600 kJ	Impact Force 1000 kJ
Walney Extension	7.8	28	730	600	193	180	182	184
$RMS_{90\%}$ values estimated using a 125 millisecond pulse duration. Reference: Niras Consulting Ltd, 2017								

Separate acoustic analyses for pile driving using hammer energies of 600 kJ and 1,000 kJ were completed to describe the full range of sound levels expected throughout an entire piling sequence. Acoustic modeling results were given in terms of Peak sound pressure level (SPL), root mean square (RMS) SPL, and cumulative sound exposure level (SEL_{cum}) to demonstrate impacts relative to applicable regulatory thresholds. The revised evaluation presented in this supplement is based on the maximum expected hammer energy of 1,000 kJ.

Implementation of noise mitigation for impact pile driving activities was also considered. Within the original Underwater Acoustic Modeling Report (Appendix A Attachment), implementation of a big bubble curtain, with an anticipated reduction of 10 dB, was analyzed and mitigated acoustic modeling results presented. Since that time, Virginia Electric and Power Company (the Applicant), d/b/a Dominion Energy Virginia (Dominion Energy) is considering three different bubble curtain designs, with an estimated reduction ranging from 6 to 15 dB (Bellman 2014) for the SEL metric with potentially higher attenuation rates for the Peak metric. The maximum (R_{max}) radial distances to the regulatory thresholds relevant to the Project IHA are given in Tables A-3, A-4 and A-5, inclusive of bubble curtains assumed to provide 6, 10, and 15 dB sound reductions.

Table A-3 (replacing Table 9 of the Underwater Acoustic Modeling Report) presents the maximum (R_{max}) radial distances that correspond to the Peak SPLs (dB re 1 µPa) for impact pile driving. The levels presented in Table A-3 correspond to auditory injury and disturbance criteria for marine mammals for both the unmitigated scenario and with three bubble curtain mitigation scenarios. Peak thresholds are unweighted. Several of the distances to peak thresholds do not change under the mitigated pile driving scenarios, as these distances will fall within the expected bubble curtain containment area of 100 m (328 ft).

Table A-3. Maximum Radii (m) that Correspond to the Peak SPLs for Impact Pile Driving

Peak SPL (dB re 1 µPa)	Criteria	R_{max}
Unmitigated		
202	PTS – HF cetaceans	325
218	PTS – Phocid pinnipeds	282
219	PTS – LF cetaceans	182
230	PTS – MFC cetaceans	N/A
Bubble Curtain (6 dB Reduction)		
202	PTS – HF cetaceans	80
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Big Bubble Curtain (10 dB Reduction)		
202	PTS – HF cetaceans	N/A
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Double Bubble Curtain (15 dB Reduction)		
202	PTS – HF cetaceans	N/A
218	PTS – Phocid pinnipeds	N/A
219	PTS – LF cetaceans	N/A
230	PTS – MFC cetaceans	N/A
Notes: ”N/A” indicates the distance to the threshold is so low it is undetectable in the modeling results.		

Table A-4 (replacing Table 11 of the Underwater Acoustic Modeling Report) presents the radial distances to the cumulative sound exposure levels during impact pile driving. Each foundation is anticipated to require up to 1 day (2 hours) of pile driving to complete the foundation installation. The drivability assessment predicts an upper bound estimate of 3,419 blows for the first foundation and 4,819 blows for the second position at a rate of 40 blows per minute. This represents a conservative assessment, since the actual number of blows for the first and second foundations are expected to be 3,381 and 2,448, respectively. The radii in Table A-4 correspond to marine mammal injury and disturbance criteria and fish injury and behavioral disturbance criteria for a 24-hour SEL_{cum}.

Table A-4. Radii (m) of Unweighted and M-Weighted SELcum Contours for Impact Pile Driving

SEL_{cum} (dB re 1 μPa^2 s)	Criteria	LFC		MFC		HFC		PINN	
		R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}
Unmitigated									
155	PTS– HF cetaceans	---	---	---	---	2,670	2,436	---	---
183	PTS – LF Cetaceans	5,930	5,432	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	397	364	---	---	1,722	1,500
Bubble Curtain (6 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	1,277	1114	---	---
183	PTS – LF Cetaceans	3,830	3,513	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	252	243	---	---	567	489
Big Bubble Curtain (10 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	314	281	---	---
183	PTS – LF Cetaceans	2,217	2,070	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	229	211	---	---	317	281
Double Bubble Curtain (15 dB Reduction)									
155	PTS– HF cetaceans	---	---	---	---	233	217	---	---
183	PTS – LF Cetaceans	1,277	1,188	---	---	---	---	---	---
185	PTS - MF cetaceans PTS - Phocid pinnipeds	---	---	124	95	---	---	236	222

Notes:
"---" indicates no calculated radii because the given criterion is not applicable.

Table A-5 (replacing Table 13 of the Underwater Acoustic Modeling Report) describes the resultant distances to the Level B harassment of marine mammals threshold of 160 $dBrms_{90}$ ranges from 4 km to 5 km unmitigated and 1 km to 2.5 km, depending on bubble curtain mitigation and hammer type.

Table A-5 Radii (m) to 160 dBrms$_{90}$ SPL (Level B Harassment) for Impact Pile Driving

dB rms90 SPL (dB re 1 µPa)	Hammer Type	R_{max}	R_{mean}
Unmitigated			
160	600 kJ	4,380	4,275
160	1,000 kJ	5,175	5,050
Bubble Curtain (6 dB Reduction)			
160	600 kJ	3,280	3,043
160	1,000 kJ	3,580	3,245
Big Bubble Curtain (10 dB Reduction)			
160	600 kJ	2,110	2,060
160	1,000 kJ	2,520	2,450
Double Bubble Curtain (15 dB Reduction)			
160	160	1,215	1,127
160	1,000 kJ	1,370	1,264

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Attachment 1

UNDERWATER ACOUSTIC MODELING REPORT

(May/October 2018)

Coastal Virginia Offshore Wind Project (CVOW)

UNDERWATER ACOUSTIC MODELING REPORT

Dominion Energy

5000 Dominion Boulevard

Glen Allen, VA 23060

Submitted May and October 2018, Revised March 2020

EXECUTIVE SUMMARY

The construction and operation of offshore wind turbines generates underwater sound that can potentially have an environmental impact on the marine life in the area. An underwater noise propagation study has been performed to be used to assess the potential environmental impacts on marine mammals and fish for the proposed Coastal Virginia Offshore Wind Project to help inform Section 7 consultations.

Underwater sound emissions were modeled to cover the range of offshore construction scenarios. Modeling for the purpose of estimating the distances to regulatory thresholds from individual piling events is intended to help indicate the realistic worst-case scenarios for the specific hearing sensitive marine species. This modelling included calculating the maximum received sound levels across the entire water column with depth. In addition, a number of wind turbine foundation and cable lay installation scenarios were reviewed. Modeling results are presented with reference to sensitive marine mammal and fish receptors. Careful consideration was given to bathymetric features and sediment type as the environmental parameters that, if varied, will have the greatest effect on sound propagation.

The initial noise propagation study was performed based on the available knowledge for impact assessments for offshore wind turbine installation at the commencement of the study, which involved the extrapolation of data. This update to the initial noise propagation study was performed to extract the relevant model input parameters from an offshore construction field verification study involving the same prototype foundation design and pile driving mechanism with the installation occurring in a similar offshore setting as the CVOW project. This new information served to form the basis of subsequent calculations. This technical study has also been updated to address NMFS Guidance to more accurately assess the potential impacts of impulsive sounds. Both SELcum and Peak thresholds are presented since these are considered dual metric acoustic thresholds for impulsive sounds. However, the potential for the onset of auditory injury from prolonged exposure is subject to many uncertainties regarding species-specific as well as individual response mechanisms.

For pile driving, the study was revised to represent the full range of hammer energies that would be experienced throughout a typical piling sequence. The levels modeled comprise 600 kJ (representative initial piling) to 1,000 kJ (worst case) using the updated source terms and frequency spectrum. The propagation model used to estimate the potential ranges of impact was based on an energy flux approach which calculates the sound energy transmitted through the water column. The resulting sound contour isopleths have been projected as SEL, as a function of range for the worst-case pile driving location based on the drivability report, and are provided in Appendix A. The regulatory assessment impact threshold limits are given in Section 3 and modeling results and distances to these thresholds are summarized in Section 5. The updated technical analysis also includes the evaluation of bubble curtain systems as a potential mitigation strategy to reduce sound.

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LIST OF ACRONYMS

Acronym	Definition
μPa	micropascal
BBC	Big bubble curtain
CRM	Coastal Relief Model
cSEL	cumulative sound exposure level
dB	decibel
dBA	A-weighted decibel
Dominion	Virginia Electric and Power Company, a wholly owned subsidiary of Dominion Resources, Inc.
DP	dynamic positioning
ESA	Endangered Species Act
FEED	Front End Engineering Design
GAP	General Activities Plan
GEODAS	Geophysical Data System
HF	high frequency cetaceans
Hz	hertz
IBGS	Inward Battered Guide Structure
kHz	kilohertz
kJ	kilojoule
LF	low frequency cetaceans
MF	mid-frequency cetaceans
MMPA	Marine Mammal Protection Act
MW	megawatt
m^3	cubic meter
NAD	North American Datum
NGDC	National Geophysical Data Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer continental shelf
PE	Parabolic Equation
PTS	permanent threshold shift
RAM	Range-dependent acoustic model
RAMGeo	RAM modified for range-dependent sediment layers
R_{max}	maximum radial distance
R_{mean}	average radial distance
SEL	sound exposure level
SELcum	cumulative sound exposure level
SPL	sound pressure level
SSP	sound speed profile
TL	transmission loss
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VOWTAP	Virginia Offshore Wind Technology Advancement Project

WFA	weighting factor adjustment
WTG	wind turbine generator

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1 INTRODUCTION

Virginia Electric and Power Company, d/b/a Dominion Energy Virginia (Dominion, formerly d/b/a Dominion Virginia Power) is proposing the Coastal Virginia Offshore Wind Project (CVOW or Project [formerly the Virginia Offshore Wind Technology Advancement Project or VOWTAP]), a 12 megawatt (MW), two turbine offshore wind demonstration project located approximately 24 nautical miles (27 statute miles, 43 kilometers) offshore of the City of Virginia Beach, Virginia (Figure 1). Other offshore Project facilities include a 34.5 kilovolt (kV) Inter-Array Cable that will interconnect the two CVOW wind turbine generators (WTGs), and a 34.5 kV Export Cable that will convey electricity from the offshore WTGs to a landfall site located in Virginia Beach, Virginia (Figure 1).

Dominion is aware that construction and operation of the Project has the potential to cause acoustic harassment to marine species, in particular marine mammals, sea turtles, and fish populations. This updated technical appendix presents the acoustic modeling methodologies, as applied, to estimate the expected underwater noise levels generated during construction and operation of the proposed Project, including impact pile driving of wind turbine foundations, which is expected to generate the highest underwater sound levels. This acoustic analysis included the following steps completed in accordance with established protocols and best engineering practices:

- **Establish existing conditions** – Review literature and measurement data completed within the study area to assess the general underwater acoustic environment.
- **Source level development and acoustic modeling** – Determination of representative scenarios to describe the resultant underwater sound levels for specific construction and operational activities. Use of a computer-based model simulation to forecast exclusion zones for marine mammals.
- **Data interpretation** – Results used by marine biologists and fisheries experts to assess potential impacts and determine species-specific mitigation measures.
- **Noise mitigation analysis** – A preliminary review of candidate noise mitigation strategies to meet permitting requirements and National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries) regulations, with an emphasis on pile driving activities.
- **Compliance assessment** – To provide a demonstration of the feasibility of the Project to be constructed and operated in compliance with all applicable requirements and be adequately protective of all marine aquatic life.

The spatial distribution of received noise has been analyzed encompassing three construction scenarios, four unique cable lay construction locations, two pile driver hammer energies, and an estimation of underwater sound levels during future wind turbine operation. These modeling scenarios were developed in direct cooperation with the Project's engineering team to ensure an accurate representation of the activities and anticipated construction methods. Underwater noise levels were modeled with the widely-used and publicly available Range Dependent Acoustic Model (RAMGeo), based on the U.S. Navy's Standard Split-Step Fourier Parabolic Equation. The underwater acoustic propagation model accounted for the variation of the bathymetry, geoacoustic properties of the sea bottom, and seasonal variations of the sound speed profile in the water column, notionally bracketing the directional upper and lower propagation bounds (longest and shortest propagation distances) in terms of the acoustic footprint. The acoustic source levels for the construction and operational activities were estimated using best practices based on realistic proxies, suitably scaled where appropriate. The pile diameter and associated impact force in addition to the type, size, and propulsion power of typical vessels that may be utilized were considered in these estimations.

This study also included an extensive background literature review in order to obtain relevant information on similar offshore construction noise measurements data from offshore wind farm projects currently in operation for the purposes of model validation. The underwater noise modeling analysis includes an overview of applicable regulatory criteria and scientific based thresholds, and a detailed discussion of the acoustic analysis methodology and the model input parameters incorporated. Modeling results of the underwater acoustic analysis are presented as sound contour isopleths for the maximum over depth received sound level as a function of range. This technical report has been updated to address the NOAA Fisheries Technical Guidance for Assessing the Effect of Anthropogenic Sound on Marine Mammals which was finalized in July of 2016, as well as harassment criteria and interim thresholds for fish and sea turtles. Information provided is intended to form the basis for the assessment of potential biologically significant impacts.

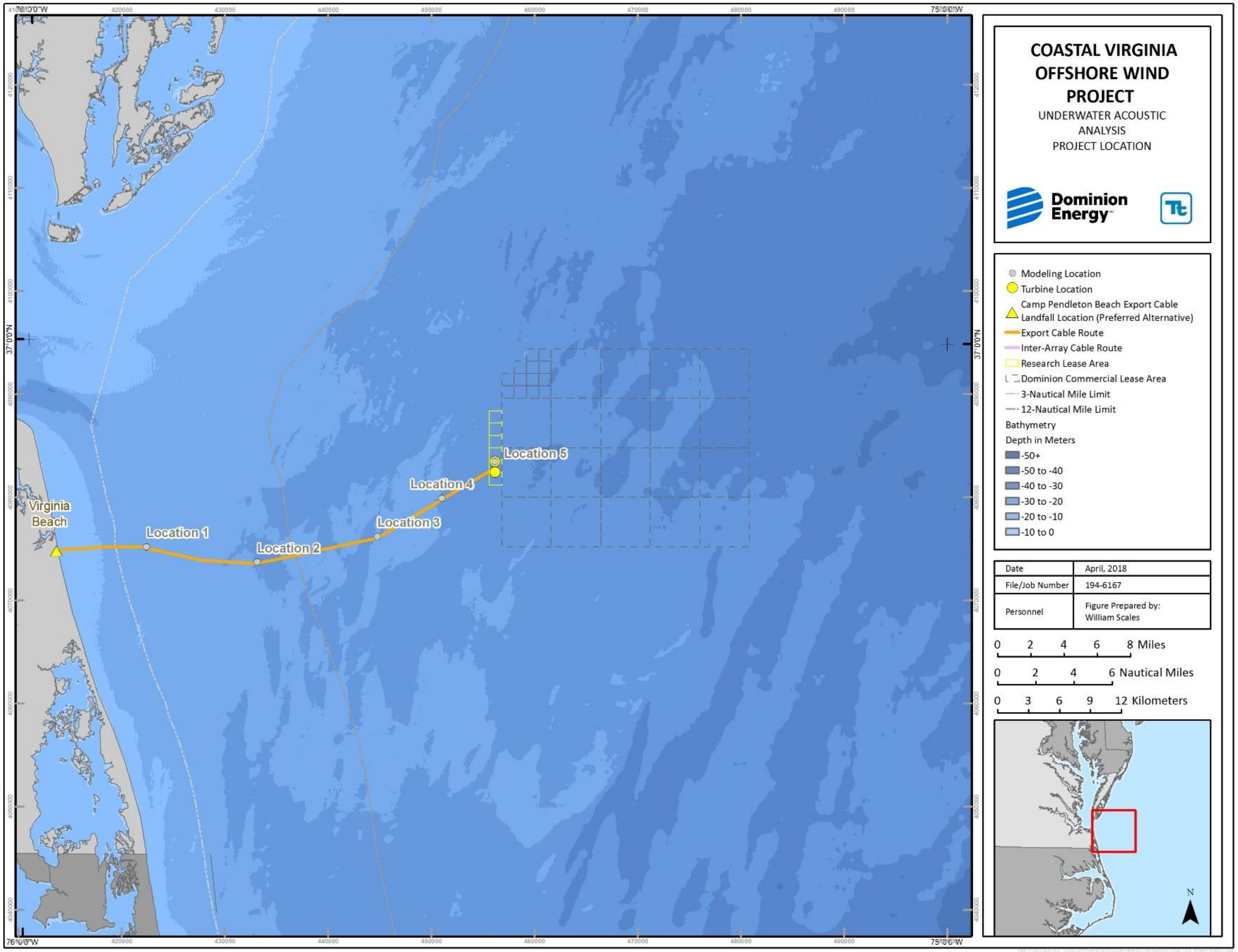

Figure 1. Overview of Project Area

2 EXISTING CONDITIONS

Underwater sounds, if they are intense enough, may cause behavioral responses, injury, or even death from concussion (Richardson et al. 1995). However, actual thresholds for behavioral responses to sounds in the natural environment depend on the range and levels of ambient noise that are persistently present. As is routine when conducting noise surveys in air, the significance of any noise as an annoyance can be related to the extent to which it exceeds background levels. Therefore, the prediction of possible masking effects, and the behavior of marine life, will also be influenced by the anticipated background noise levels. The propagation modeling considers the contribution of the Project in isolation; therefore, existing conditions and potential masking effects are not accounted for. In addition, review of the modeling results alone does not provide an indication of when marine life will acclimatize to certain sound levels.

The existing underwater acoustic environment can be described as a combination of many possible noise sources of both natural and man-made origins. Noise from natural sources is generated by physical or biological processes. Examples of physical noise sources are tectonic seismic activity, wind and waves; examples of biological noise sources are the vocalizations of marine mammals and fish. There can be a strong minute-to-minute, hour-to-hour, or seasonal variability in sounds from biological sources. Shallow water has been defined for the purposes of this hydroacoustic analysis as a water column less than 200 m deep. Research has shown that ambient noise is 5-10 dB higher in shallower water, which is linked to the influence of surface agitation and reflection by the bottom and may also be dependent on localized conditions of sea state and wind speed, varying both spatially and temporally. The ambient noise for frequencies above 1 kilohertz (kHz) is due largely to waves, wind, and heavy precipitation; however, it may be evident at frequencies down to 100-300 Hz during otherwise quiet times (Simmonds et al. 2004). Surface ocean wave interaction and breaking waves with spray have been identified as important sources of noise. Wind induced bubble oscillations and cavitation are also near-surface noise sources, major storms can give rise to noise in the 10-50 kHz band which can propagate to long ranges with the same mechanism and directionality as distant shipping. At areas within distances of 8-10 km of the shoreline, surf noise will be prominent in the frequencies ranging up to a few hundred hertz (Richardson et al. 1995), even during calm wind conditions.

Man-made noise sources can consist of contributions related to industrial development, offshore oil industry activities, naval operations, and marine research but the most predominant contributing noise source is generated by commercial ships and recreational watercraft. Noise from such ships dominates coastal waters and emanates from the ships' propellers and other dynamic positioning propulsion devices such as thrusters. The sound generated from main engines, gearboxes, generators transmitted through the hull of the vessel into the water column is considered a secondary sound source to that of vessel propulsion systems, as is the use of sonar and depth sounders which occur at generally high frequencies and attenuate rapidly. Other potential ship-related sources include vortex shedding from the hull and noise associated with the wake, noise generated by pipes open to, and discharging into the sea. Most shipping contributes in a frequency range of less than 1 kHz. In general, older vessels produce more noise than newer ones and larger vessels produce more than smaller ones, but this is not always the case. Although, typically, shipping vessels produce frequencies below 1 kHz, small leisure craft may generate sound with frequency components from

1 kHz, up to the 50 kHz range due to ppropeller cavitation at elevated speeds, which may generate noise at somewhat higher frequencies (Simmonds et al. 2004).

In addition to these sound sources, a considerable amount of background noise may be caused by biological activities. Aquatic animals make sounds for communication, echolocation, prey manipulation, and also as by-products of other activities such as feeding. Biological sound production usually follows seasonal and diurnal patterns, dictated by variations in the activities and abundance of the vocal animals. The frequency content of underwater biological sounds ranges from less than 10 Hz to beyond 150 kHz. Source levels show a great variation, ranging from below 50 dB to more than 230 dB_{RMS} re 1 µPa at 1 m. Likewise there is a significant variation in other source characteristics such as the duration, temporal amplitude, frequency patterns and the rate at which sounds are repeated (Wahlberg 2012). With all of the complexities involved, the capacity for acoustic models to estimate background levels is limited, so for that reason the acoustic modeling analysis presented is restricted to future Project construction and operational scenarios only.

2.1 Underwater Acoustic Concepts and Terminology

The sound level estimates presented in this modeling study are expressed in terms of several metrics and apply the use of averaging times to allow for interpretation relative to potential biological impacts on marine life. This section provides an overview of basic acoustical terms, descriptors, and concepts that should help frame the discussion of acoustics in this document. The majority of the information in the following sections is to provide further insight into how data and modeling results have been presented in accordance with regulatory reporting requirements and established criteria.

Reference Levels

Sound levels are reported on a logarithmic scale expressed in units of decibels (dB) and are reported in terms of linear (or unweighted) decibels. A decibel is defined as the ratio between a measured value and a reference value of 1 micropascal (µPa). A logarithmic scale is formed by taking 20 times the logarithm (base 10) of the ratio of two pressures: the measured sound pressure divided by a reference sound pressure. When evaluating sound propagation in the underwater environment, in comparison to the in-air environment (see Appendix M-1, In-Air Acoustic Modeling Report), many differences must be noted. The reference for underwater sound pressure is 1 µPa; however, in-air sound uses a reference of 20 µPa. Due to the difference in acoustic impedance, a sound wave that has the same intensity in air and in water will in water have a pressure that is 60 times larger than in air, with a displacement amplitude that will be 60 times less. Assuming pressure is maintained as a constant, the displacement amplitude in water will be 3580 times less than in air. To help demonstrate this relationship, Table 1 provides the corresponding values of sound pressure in air and in water having the same intensities at a frequency of 1 kiloHertz (kHz) as it relates to human-perceived loudness. This somewhat simplistic comparison does not account for the frequency dependent hearing capabilities of various species (e.g., marine species) or individual hearing response mechanisms.

Table 1. Sound Pressure Levels and Comparison to Relative Human Loudness Thresholds

Pressure in Air re 20 µPa/Hz	Pressure in Water re 1µPa/Hz	Relative Loudness (human perception of different reference sound pressure levels in air)
0	62	Threshold of Hearing
58	120	Potentially Audible Depending on the Existing Acoustic Environment
120	182	Uncomfortably Loud
140	202	Threshold of Pain
160	222	Threshold of Direct Damage
Source: Kinsler and Frey 1962		

Sound Level Metrics

Sound is the result of mechanical vibration waves traveling through a fluid medium such as air or water. These vibration waves generate a time-varying pressure disturbance that oscillates above and below the ambient pressure. Statistical levels describe the temporal variation in sound levels. Underwater sound pressure levels may change from moment to moment; some are sharp impulses lasting one second or less, while others may rise and fall over much longer periods of time. Statistical levels provide a percentile distribution of the time-varying sound levels.

Underwater sounds are classified according to whether they are transient or continuous. Transient sounds are of short duration and occur singly, irregularly, or as a part of a repeating pattern. For instance, an explosion represents a single transient event, whereas the periodic pulses from a ship's sonar are patterned transients. Broadband short duration transients are called pulses. Continuous sounds, which occur without pauses, may be further classified as periodic, such as the sound from rotating machinery or pumps, or aperiodic, such as the sound of a ship transiting. Shipping is considered a short-term continuous sound. These sounds normally increase in level with higher engine loads or as vessels approach an observation location and then diminish as they move away. Fixed-location continuous sounds are associated with an operational offshore wind turbine. The intensity of continuous noise is generally given in terms of the root mean square (RMS) sound pressure level (SPL). The RMS SPL is calculated by taking the square root of the average of the square of the pressure waveform over the duration of the time period. The RMS is also known as the quadratic mean and is a statistical measure of the magnitude of a varying quantity. Given a measurement of the time varying sound pressure p(t) from a given noise source at some location, the RMS SPL is computed according to the following formula:

$$\mathrm{dB_{RMS}\ SPL} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right)$$

Where T is the measurement period. Pulses are defined as brief, broadband, atonal, transients. These sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures. Pile driving using an impact hammer during construction is an example of underwater noise that is characterized as pulsed sound. The Peak SPL metric is commonly quoted for impulsive sounds and is used to characterize the maximum instantaneous sound pressure level attained by an impulse, p(t):

$$\text{Peak SPL} = 10\log_{10}\left[\frac{\max\left(\left|p^2(t)\right|\right)}{p_0^2}\right]$$

Where p(t) is the instantaneous pulse pressure as a function of time, measured over the pulse duration $0 \le t \le T$. At high intensities, the peak SPL can be a valid criterion for assessing whether a sound is potentially injurious but does not take into account the pulse duration or bandwidth of a signal, therefore it is not a good indicator of loudness. The peak pressure level of the sound pulse generated by impact piling will decay at a slightly higher rate compared to the energy in the pulse (the SEL is proportional to pulse energy) due to temporal dilation of the pulse that results from multiple reflections from the seabed and the sea surface as the sound pulse propagates. For pulsed noise, the RMS SPL level is measured over the pulse duration according to the following equation:

$$\text{dBrms}_{90}\ \text{SPL} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right)$$

For impulsive noise, the time interval (T_{90}) is defined as the "90% energy pulse duration" which is the interval over which the pulse energy curve rises from 5% to 95% of the total energy rather than a fixed time window. In addition, because the window length is used as a divisor, pulses that are more spread out in time have a lower RMS SPL for the same total acoustic energy.

The sound exposure level (SEL; dB re 1 μPa²·s) is a measure of the total acoustic energy contained in one or more acoustic events. The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T_{100}):

$$\text{SEL} = 10\log_{10}\left(\int_{T_{100}} p^2(t)dt \Big/ T_0 p_0^2\right)$$

where T_0 is a reference time interval of 1 s. The SEL represents the total acoustic energy received at a given location. Unless otherwise stated, sound exposure levels for pulsed noise sources (*i.e.*, impact hammer pile driving) presented in this report refer to a single pulse.

SEL can be calculated as a cumulative metric over periods with multiple acoustic events. In the case of impulsive sources like impact piling, SEL describes the summation of energy for the entire impulse normalized to one second and can be expanded to represent the summation of energy from multiple pulses. The latter is written SEL_{cum} denoting that it represents the cumulative sound exposure. The sound exposure level is often used in the assessment of marine mammal and fish behavior over an 24 hour time period.

The cumulative SEL (dB re 1 μPa²·s) can be computed by summing (in linear units) the SELs of the N individual events:

$$\text{SEL}_{cum} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{\text{SEL}_i}{10}}\right)$$

Spectral Levels

The unit of frequency is Hertz (Hz), measuring the cycles per second of the sound pressure waves. Acoustic modeling was completed for one-third octave band center frequencies in the range of 10 Hz to 8 kHz. One-third octaves are a series of electronic filters used to separate sound into discrete frequency bands, making it possible to know how sound energy is distributed as a function of frequency. Corresponding broadband sound levels sum the acoustic energy across all frequencies. These analyses quantitatively describe the frequency dependent sound environment for specific events or activities. The advantage of one-third octave band modeling is that it can resolve the frequency dependent propagation characteristics of a particular environment and can be summed to efficiently compute the overall broadband sound pressure level for any given receiver position within the water column.

Underwater sound levels may also be weighted according to marine mammal functional hearing groups using audiograms based on hearing sensitivities of species in these groups: low frequency cetaceans, mid-frequency cetaceans, high-frequency cetaceans, and pinnipeds. This is commonly referred to as M-weighting. M-weighting is applied to adjust the expected acoustic impact on a per-frequency basis. Weighting functions for low-frequency cetaceans (LF), mid-frequency cetaceans (MF) and high frequency cetaceans (HF) are presented below in Figure 2. The M-weighting functions are therefore very useful when determining the behavioral responses of marine mammals to any noise.

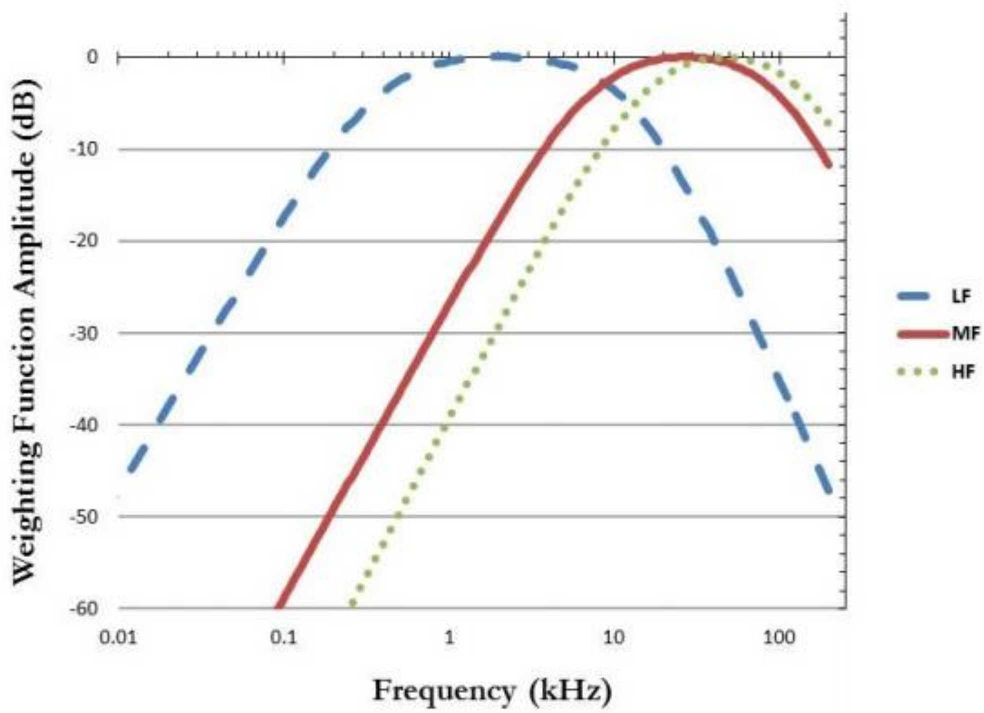

Figure 2. **Auditory M-weighting functions for low-frequency (LF), mid-frequency (MF) and high-frequency (HF) cetaceans. (NOAA 2016)**

Seawater Absorption

Absorption in the underwater environment involves a process of conversion of acoustic energy into heat and thereby represents a true loss of acoustic energy to the water. The primary causes of absorption have been attributed to several processes, including viscosity, thermal conductivity, and chemical reactions involving ions in the seawater. The viscosity of the medium causes sound energy to be converted into heat by internal friction. Some sound energy is converted into heat because sound waves alternately raise and lower the temperatures. Suspended particles are set to oscillating by the sound waves and in this process some of the sound energy is dissipated in the form of heat. This is especially the case if the particles are air bubbles. While each of these factors offers its own unique contribution to the total absorption loss, all of them are caused by the repeated pressure fluctuations in the medium as the sound waves are propagated. In these processes, the area over which the signal is spread remains the same, but the energy in the signal, and therefore the intensity, is decreased.

The absorption of sound energy by water contributes to the attenuation losses linearly with range and is given by an attenuation coefficient in units of decibels per kilometer (dB/km). This absorption coefficient is computed from empirical equations and increases with the square of frequency. For example, for typical open-ocean values (temperature of 10°C, pH of 8.0, and a salinity of 35 practical salinity units [psu]), the equations presented by Francois and Garrison (1982a, b) yield the following values for seawater absorption: 0.001 dB/km at 100 Hz, 0.06 dB/km at 1 kilohertz (kHz), 0.96 dB/km at 10 kHz, and 33.6 dB/km at 100 kHz. Thus, low frequencies are favored for long-range propagation.

Spatial Effects and Spreading

Transmission loss (TL) underwater is the accumulated decrease in acoustic intensity as an acoustic pressure wave propagates outwards from a source. The intensity of the source is reduced with increasing distance due to spreading. Spreading can be categorized into two models, spherical spreading and cylindrical spreading models. Three fundamental equations can be used to describe spreading losses. The first equation used for noise modeling covers TL for short ranges near the source, where sound energy spreads outward unimpeded by interactions at the sea surface or sea floor until the entire channel depth is ensonified. The following equation is used when r, the horizontal separation distance between sound source and receiver, is up to 1 times H, which is sometimes conservatively assumed as the average water depth. The equation also includes a range and frequency dependent absorption term, α.

$$TL = 20\log r + \alpha r$$

The intermediate (or transition zone) is defined as H ≤ r ≤ 8H where modified cylindrical spreading occurs accompanied by mode stripping effects (Richardson et al. 1995). The TL equation representing this intermediate range is given below:

$$TL = 15\log r + \alpha r$$

For underwater transmission in shallow water where the water depth is greater than five-times the sound wavelength, the 15 log r spreading loss factor in the above equation may extend beyond the range of 8H. Long range TL occurs where r > 8H. Due to the boundaries of the sea surface and sea floor, sound energy is not able to propagate uniformly in all directions from a source indefinitely; therefore, long range TL is represented as cylindrical spreading, limited by the channel boundaries. Cylindrical spreading propagation is applied using the equation given below:

$$TL = 10 \log r + \alpha r$$

These equations are based on free-field conditions that assume uniform sound spreading in an infinite, homogeneous ocean and neglect specific environmental effects, such as water column refraction and bottom reflections. Such factors are important in consideration of underwater sound propagation carried out over extended calculation distances, and thus strongly affect the accuracy of this methodology. The acoustic far-field is defined as the distance from a source, which is greater than the acoustic wavelength at a frequency of interest. Since the wavelength varies with frequency, the separation distance will vary with frequency with the lower frequencies having the longer wavelength, as measured in meters. The geometric far-field roughly begins at the distance from a source of sound which is greater than roughly four times the largest physical dimension of the area sound source(s). When in the geometric far-field, the sources have all essentially merged into one, so that measurements made even further away will be no different in terms of source contribution. The effects of source geometry and multiple sources operating concurrently, in the geometric far-field, are expected to be negligible. However, in the acoustic nearfield, under a practical spreading model, the ability to accurately calculate high level sound fields is limited.

Scattering and Reflection

Scattering of sound from the surface and bottom boundaries and from other objects is difficult to quantify and is site specific, but is extremely important in characterizing and understanding the received sound field. Reflection, refraction and diffraction from gas bubbles and other inhomogeneities in the propagating medium serve to scatter sound and will affect TL and occur even in relatively calm waters. If boundaries are present, whether they are “real” like the surface of the sea or “internal” like changes in the physical characteristics of the water, they affect sound propagation. The acoustic intensity received depends on the losses due to the path length as well as the amount of energy reflected from each interface. Multiple reflections may occur as the sound reflects alternately from the bottom and the sea surface. It is also very likely that some reflections or refractions may actually overlap others and cause constructive and destructive interference patterns.

Changes in direction of the sound due to changes of sound velocity are known as refraction. The speed of sound is not constant with depth and range but depends on the temperature, pressure and salinity. Of the three factors, the largest impact on sound velocity is temperature. The change in the direction of the sound wave with changes in velocity can produce many complex sound paths. It may produce locations in the ocean that a sound ray sent out from a particular transducer cannot penetrate. These are called shadow zones. It may also produce sound channels that can trap the sound and allow a signal to travel great distances with minimal loss in energy.

Frequency dependence due to destructive interference contributes to the weakening of the sound signal. Since the inhomogeneities in water are very small compared to the wavelength of the signal, this attenuation-effect will mostly contribute when the signals encounter changes in bathymetries and propagate through the sea floor and the subsurface. For variable bathymetries, the calculation complexity increases, as individual portions of the signal are scattered differently. However, if the acoustic wavelength is much greater than the scale of the seabed non-uniformities, as is most often the case for low-frequency sounds, then the effect of scattering on propagation loss become somewhat less important than other factors. Also, scattering loss occurring at the surface due to wave action will increase at higher sea states. For reflection from the sea-surface, it is assumed that the surface is smooth (i.e., reflection coefficient with a magnitude of -1). While a rough sea surface would increase scattering (and hence transmission loss) at higher frequencies, the scale of surface roughness is insufficient to have a significant effect on sound propagation at the lower frequencies where most of the energy is generated.

Cut-off Frequency

Sound propagation in shallow water is essentially a normal mode where a sound wave moves sinusoidally and has its own frequency and the sound channel is an acoustic waveguide. Each mode is a standing wave in the vertical direction that propagates in the horizontal direction at a frequency dependent speed. Each mode has a cutoff frequency, below which no sound propagation is possible. The cutoff frequency is determined based on the type of bottom material and water column depth. This limiting frequency (f_c) can also be calculated if the speed of sound in the sediment ($C_{sediment}$) is known (Hastings 2008) and seasonal temperature variation of the speed of sound of the seawater (C_{water}) is known using the following equation:

$$f_c = \frac{C_{water}}{4h} / \sqrt{1 - (C_{water})^2 / (C_{sediment})^2}$$

Where:
f_c = critical frequency
C_{water} = speed of sound of water
$C_{sediment}$ = speed of sound in sediment
h = water depth in the direction of sound propagation

In the Project Area, the speed of sound in the sediment is higher than in water, where it is approximated at 1500 m/s. Values for speed of sound in sediment will range from 1605 m/s in sand-silt sediment to 1750 m/s in predominantly sandy areas. Sound traveling in shallower regions of the Project Area will be subject to a higher cutoff frequency and a stronger attenuation than sound propagating as opposed to areas with greater water depths. Figure 3 graphically presents the cut-off frequency for different bottom material types. As shown in this plot, at a water depth of 25 m and a bottom condition consisting of predominantly of fine sand which is consistent with the WTG site locations. The approximate cutoff frequency would be expected to occur at approximately 50 Hz, with even higher attenuation rates occurring along the nearshore cable route. Significant sound energy would attenuate rapidly as sound sources occurring in shallower water are subject to much stronger attenuation below this frequency than what would occur in deeper ocean regions.

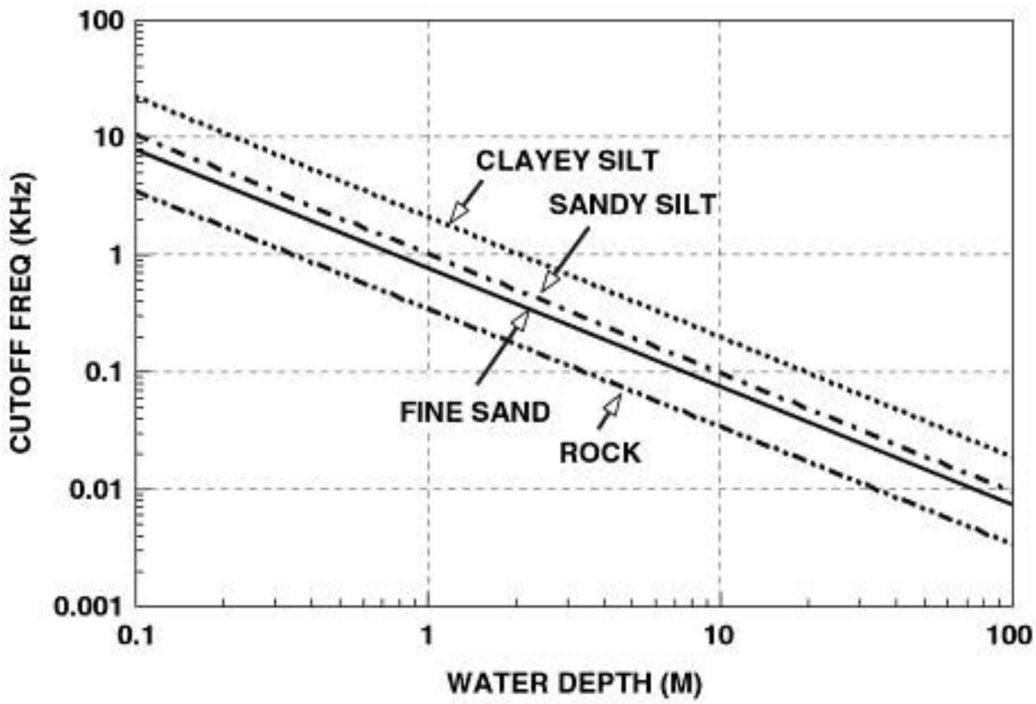

Figure 3. Cut-off Frequencies for Different Bottom Materials

Reference: Au, W. and M. Hastings. 2008. Principles of Marine Bioacoustics. Springer Science & Business Media, New York, New York .

3 REGULATORY CRITERIA AND SCIENTIFIC GUIDELINES

The potential harmful effects of high-level underwater sound can be summarized as lethal, physical injury and hearing impairment. In general, biological damage as a result of sound is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received on a cumulative basis. Other ways in which sound or noise can be detrimental to the marine mammals and fish is by causing behavioral disturbance and auditory masking. A regulatory and literature review was conducted to obtain and summarize the latest impact criteria in order to accurately assess the potential for adverse impact on marine mammals, sea turtles and fishery resources.

3.1 MMPA Thresholds for Lethal and/or Injurious Auditory Effects

The potential effects of underwater noise resulting in takes on marine mammals are federally managed by NOAA under the Marine Mammal Protection Act (MMPA) to minimize the potential for both harm and harassment. Under the MMPA, Level A harassment is statutorily defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild; however, the actionable sound pressure level is not identified in the statute. Level B harassment is defined as any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

In July of 2016, National Marine Fisheries Service (NMFS) finalized the Technical Guidance for Assessing the Effect of Anthropogenic Sound on *Marine Mammals*. Under this new NMFS guidance, Level A harassment is said to occur as a result of exposure to high noise levels and the onset of permanent hearing sensitivity loss, known as a permanent threshold shift (PTS). This revision to earlier NMFS guidelines is based on findings published by the Noise Criteria Group (Southall et al., 2007). For transient and continuous sounds, it was concluded that the potential for injury is not just related to the level of the underwater sound and the hearing bandwidth of the animal, but is also influenced by the duration of exposure. The evaluation of the onset of PTS provides additional species-specific insight on the potential for affect that is not captured by evaluations completed using the previous NMFS Level A harassment alone.

The NMFS guidance classifies impact pile driving as an "impulsive" sound source, which characterizes these activities as more injurious than "non-impulsive" sources, due to high peak sound pressures and rapid rise times. The higher risk of damage does not stem from the duration of exposure, but rather the "critical level", where the short duration high peak pressures can be less than the ear's integration time, leading to potential damage to an animal's hearing before it can perceive the onset mechanical fatigue.

Frequency weighting provides a sound level referenced to an animal's hearing ability either for individual species or classes of species, and therefore a measure of the potential of the sound to cause an effect. The measure that is obtained represents the perceived level of the sound for that animal. This is an important consideration because even apparently loud underwater sound may not effect an animal if it is at frequencies outside the animal's hearing range. In the NMFS final Guidance document, there are five hearing groups: Low-frequency (LF) cetaceans (baleen whales), Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales), High-frequency (HF) cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* and *L. australis*), Phocid pinnipeds (true seals), and Otariid pinnipeds (sea lions and fur seals). It should be noted that Otariid pinnipeds do not occur within the Study Area.

Table 2. Summary of Generalized Hearing Ranges and PTS Thresholds of Marine Mammals (NMFS, 2016)

Functional Hearing Group	PTS Onset Impulsive	PTS Onset Non-Impulsive	Functional Hearing Range
LF cetaceans (baleen whales)	219 dB_{peak} & 183 dB SEL_{cum}	199 dB SEL_{cum}	7 Hz to 35 kHz
MF cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	230 dB_{peak} & 185 dB SEL_{cum}	198 dB SEL_{cum}	150 Hz to 160 kHz
HF cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, Lagenorhynchus cruciger & L. australis)	202 dB_{peak} & 155 dB SEL_{cum}	173 dB SEL_{cum}	275 Hz to 160 kHz
Phocid pinnipeds (underwater) (true seals)	218 dB_{peak} & 185 dB SEL_{cum}	201 dB SEL_{cum}	50 Hz to 86 kHz
Otariid pinnipeds (underwater) (sea lions and fur seals)	232 dB_{peak} & 203 dB SEL_{cum}	219 dB SEL_{cum}	60 Hz to 39 kHz
Notes: The peak SPL is un-weighted (i.e., flat weighted), whereas the cumulative SEL criterion is M-weighted for the given marine mammal functional hearing group. Peak sound pressure (dBpeak) has a reference value of 1 μPa, and cumulative sound exposure level (SELcum) has a reference value of 1 micropascal squared-seconds (1μPa2s). The recommended accumulation period is 24 hours.			

PTS is considered "Level A harassment" under the MMPA. However, NOAA NMFS (2016a) does not address "Level B harassment." Because the new guidance does not address "Level B harassment," NOAA Fisheries uses an interim sound threshold guideline of 160 dB rms re 1µPa for pulsed sound and 120 dB rms re 1µPa received level for continuous sound. Within this zone, the sound produced by the proposed project may periodically approach or exceed ambient sound levels (i.e., threshold of perception or zone of audibility); however, actual perceptibility will be dependent on the hearing thresholds of the species under consideration and the inherent masking effects of ambient sound levels.

Marine mammal responses to sound can be highly variable, depending on the individual hearing sensitivity of the animal, the behavioral or motivational state at the time of exposure, past exposure to the noise which may have caused habituation or sensitization, demographic factors, habitat characteristics, environmental factors that affect sound transmission, and non-acoustic characteristics of the sound source, such as whether it is stationary or moving (NRC 2003). There is much intra-category and intra-species variability in behavioral response. Therefore, the criteria for use in assessing the spatial extent of marine mammal disturbance due to a continuous and multiple pulse sound should be viewed as probabilistic and precautionary.

In addition, according to the NMFS Guidance SEL_{cum} is recommended for use with non-impulsive sounds (page 1 of Guidance) and thus is not an appropriate metric to capture all the effects of impulsive sounds from monopole installation. This is stated directly on page 30 of the guidance: "*Thus, SEL_{cum} is not an appropriate metric to capture all the effects of impulsive sounds (i.e., often violates EEH; NIOSH 1998), which is why instantaneous PK level has also been chosen as part of NMFS' dual metric acoustic thresholds for impulsive sounds.*" The use of (cumulative) SEL as further stated in the new NOAA Guidelines "*is a simplifying assumption to accommodate sounds of various SPLs, durations, and duty cycles. .... this approach assumes exposures with equal SEL result in equal effects, regardless of the duration or duty cycle of the sound*". The guidance goes on to say "*It is well-known that the equal energy rule will **over-estimate** the effects of intermittent noise*….(Ward, 1997). [page 67]". NOAA NMFS (2016a).

3.2 Fish and Sea Turtle Species

The hearing capabilities and sensitivities of fish vary from species to species, but are believed to form three functional hearing groups, e.g., fishes with swim bladders mechanically linked to the ears, fishes with swim bladders not linked to the ears, and fishes without swim bladders. Fish species with a reduced or no swim bladder tend to have a relatively low auditory sensitivity, fish having a fully functional swim bladder tend to be more sensitive, and fish with a close coupling between the swim bladder and the inner ear are most sensitive. In addition, while some fish are sensitive to sound pressure, all fish are capable of detecting particle motion or the rate of displacement of fluid particles by acoustic pressure. The existing body of literature relating to the impacts of sound on marine species can be divided into three categories: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects include lethal and sub-lethal physical damage; physiological effects include primary and secondary stress responses; and behavioral effects include changes in exhibited behaviors. Fish behavior in response to noise is not well understood. Sound pressure levels that may deter some species, may attract others. Behavioral changes might be a direct reaction to a detected sound or a result of anthropogenic sound masking natural sounds that fishes make use of in their normal behavior. Risk of injury or mortality resulting from noise is generally related to the effects of rapid pressure changes, such that the sound intensity is an important factor for the degree of hearing loss, as is the frequency, the exposure duration, and the length of the recovery time.

While impact pile driving activity has been linked to fish mortality, there are insufficient data to indicate the percentage of fish killed, whether some species are more susceptible to sound than others, and the exacting distance at which fish are killed (Hastings and Popper 2005). It is possible that fish outside a designated zone of influence are damaged, and that ultimately this damage would lead to death later. Moreover, there are numerous complicating factors with pile driving that might impact fish.

An interagency work group, including the U.S. Fish and Wildlife Service (USFWS) and the NMFS, has reviewed the best available scientific information and developed criteria for assessing the potential of pile driving activities to cause injury to fish (FHWG 2008). The workgroup established dual sound criteria for injury, measured 33 feet away from the pile, of 206 dB re 1µPa Peak and 187 dB accumulated sound exposure level (dB SELcum; re: 1μPa^2 sec) and 183 dB accumulated SEL for fish less than 2 grams.

The NOAA Fisheries also currently recognizes a 150 dB_{RMS} level as the threshold for disturbance to salmon, bull trout and Atlantic sturgeon. Based on their assessment, sound pressure levels in excess of 150 dB re 1 µPa are expected to cause temporary behavioral changes, such as elicitation of a startle response or avoidance of an area. Those levels are not expected to cause direct permanent injury. That is not to say that exposure to noise levels of 150 dB_{RMS} will always result in behavioral modifications, but that there is the potential, upon exposure to noise at this level, to experience some behavioral response (e.g., temporary startle to avoidance of an ensonified area). In summary, based on the best available information on other fish species, underwater noise at or above the levels presented in Table 3 have the potential to cause injury or behavioral modifications for fish.

The hearing capabilities of sea turtles are poorly known, and there is limited information on the effects of noise on sea turtles. Some studies have demonstrated that sea turtles have fairly limited capacity to detect sound, although all results are based on a limited number of individuals and must be interpreted cautiously. NOAA Fisheries has not yet established acoustic thresholds for effects to sea turtles. It is predicted that protection of sea turtles from noise associated with pile driving would be addressed through consideration and mitigation for thresholds established for fish and marine mammals. A 180 dB_{RMS} exclusion zone is expected to prevent mortalities, injuries, and most auditory impacts and has recently been adopted on similar offshore energy projects.

Table 3. Acoustic Criteria and Metrics for Fishes and Sea Turtles

Fish Group	Injury[1]		Physiological	Behavior
	SEL_{cum} dB re 1 $\mu Pa^2 s$	dB Peak dB re 1 µPa	dB rms dB re1 µPa	dB rms dB re 1 µPa
Small fish (mass <2 g)	183 [a]	206 [a]	--	150 [b]
Large fish (mass ≥2 g)	187 [a]	206 [a]	--	150 [b]
Sea turtles	--	--	180 [b]	166 [b]

Reference: U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM). Effects of Noise on Fish, Fisheries, an d Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities, Literature Synthesis, 2012

a = Stadler and Woodbury, 2009.b = GARFO, 2016.

4 ACOUSTIC MODELING METHODOLOGY

Acoustic modeling was conducted for primary-noise generating activities occurring during Project construction and operation. The following subsections describe the modeling program used, the modeling scenarios, and acoustic model input values.

4.1 Sound Propagation Model

The underwater acoustic propagation modeling for this updated study was performed using a modified version of the RAM parabolic-equation (PE) model (Collins 1993, 1996). RAM was developed at the US Naval Research Laboratory and has been extensively benchmarked and is widely used as a reference model in the underwater acoustics community. RAMGeo is a version of RAM source code modified to handle sediment layers that are range dependent and parallel to the bathymetry and computes acoustic fields in 3-D by modeling transmission loss along evenly distributed radial traverses covering a 360 º swath from the source (so-called N×2-D modeling). This methodology consists of a set of algorithms that calculates transmission loss based on a number of factors including the distance between the source and receiver along with basic ocean parameters (e.g., depth, bathymetry, geoacoustic properties of sediment type, and the ocean's temperature-depth sound speed profile).

The extremely efficient PE code copes naturally with range-dependent environments and overcomes the principle limitation of the PE method, which is the lack of accuracy for energy propagating at large angles to the horizontal (Duncan and Maggi, 2006). Use of the PE method allows for a one-way wave equation that can be solved by a range-marching technique with a proper starting field (i.e., near-field underwater sound pressure level). The forward propagating field is obtained at a given range from the field at a previous range after having also accounted for boundary conditions at the top and bottom of the domain, in other words the solution (i.e., the underwater received sound pressure level) is marched in range.

The PE algorithm assumes that outgoing reflected and refracted sound energy dominates scattered sound energy and computes the solution for the outgoing (one-way) wave equation. At low frequencies, the contribution of scattered energy is very small compared to the outgoing sound field. An uncoupled azimuthal approximation is used to provide gridded 2-D TL values in range and depth with a geo-referenced dataset to automatically retrieve the bathymetry and acoustic environment parameters along each propagation transect radiating from the sound source.

The received sound field within each vertical radial plane is sampled at various ranges from the source with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The received sound level at a given location along a given transect is taken as the maximum value that occurs over all samples within the water column below. The TL values produced by the model are used to attenuate the spectral acoustic output levels of the sound source to generate received sound levels along a transect. These values are then summed across frequencies to provide broadband received levels.M-weighting was applied for multiple hearing groups, including low-frequency cetaceans, mid-frequency cetaceans, high-frequency cetaceans, phocid pinnipeds in water, and otariid pinnipeds in water, to weight the importance of received sound levels according to marine mammal hearing sensitivity, in accordance with the 2016 NOAA

Technical Guidance (NMFS 2016). Marine mammal weighting calculations and contour isopleth were further visualized using the dBSea software package version 2.2.4, developed by Marshall Day Acoustics.

4.2 Modeling Environment

The accuracy of underwater noise modeling results is largely dependent on the referenced sound source data and the accuracy of the intrinsically dynamic data inputs used to describe the medium between the path and receiver, including sea surface conditions, water column, and sea bottom. The exact information required can never be obtained for all possible modeling situations, particularly for long-range acoustic modeling of temporally varying sound sources where uncertainties in model inputs increase at greater propagation distances from the source. Model input variables incorporated into the calculations are further described as follows.

4.2.1 Bathymetry

For geometrically shallow water, sound propagation is dominated by boundary effects. Bathymetry data represent the 3D nature of the subaqueous land surface and was obtained from the National Geophysical Data Center (NGDC) US Coastal Relief Model (NOAA Satellite and Information Service 2005); the horizontal resolution of this data set is 3 arc-seconds. NGDC's 3 arc-second U.S. Coastal Relief Model (CRM) provides the first comprehensive view of the U.S. coastal zone, integrating offshore bathymetry with land topography into a seamless representation of the coast. The CRM spans the U.S. East and West Coasts, the northern coast of the Gulf of Mexico, Puerto Rico, and Hawaii, reaching out to, and in places even beyond, the continental slope. The Geophysical Data System (GEODAS) is an interactive database management system developed by the NGDC for use in the assimilation, storage and retrieval of geophysical data. GEODAS software manages several types of data including marine trackline geophysical data, hydrographic survey data, aeromagnetic survey data, and gridded bathymetry/topography.

The datasets, originally with a horizontal resolution of 20 m, were linearly interpolated on a regular grid and extended 40 km from the WTG locations. The bathymetric data was sampled by creating a fan of 90 radials at a given angular spacing. This grid was then used to determine depth points along each modeling radial transect. The underwater acoustic modeling takes place over these radial planes in set increments depending on the acoustic wavelength and the sampled depth. These radial transects were used for modeling both the construction and operation of the Project, with each radial centered on the given Project sound source or activity. Figure 1 presents the bathymetries within the Project Area.

4.2.2 Sediment

Sediment type (e.g., hard rock, sand, mud) directly impacts the speed of sound as it is a part of the medium in which the sound propagates. Sediment information for the Project study area was obtained from the U.S. Geological Survey (USGS) Continental Margin Mapping Program, which includes an extensive east coast sediment study. For the immediate project site, the geoacoustic properties were defined up to a maximum depth of 110 meters with information from the CVOW geotechnical study. The layers used in the modeling and the main geoacoustic properties is provided in Table 4 with the bottom type in the Project Area defined as predominantly sand.

Table 4. Overview of seabed geoacoustic profile used for the modelling (Cp = compressed wave speed, αs (dB/λ) = compressional attenuation, p = density).

Seabed Layer (m)	Material	Geoacoustic Properties
0 to 4	Silty fine SAND	Cp = 1650 m/s αs (dB/λ) = 1.1 dB/ λ p = 1,800
4 to 12	Sandy lean CLAY	Cp = 1560 m/s αs (dB/λ) = 0.2 dB/ λ p = 1,600
12 to 24	Fat CLAY (with shell fragments and sand pockets)	Cp = 1470 m/s αs (dB/λ) = 0.08 dB/ λ p = 1,200
24 to 52	Silty fine to medium SAND	Cp = 1650 m/s αs (dB/λ) = 1.1 dB/ λ p = 1,800
52 to 60	Sandy lean CLAY (with shell fragments)	Cp = 1560 m/s αs (dB/λ) = 0.2 dB/λ p = 1,560
60 to 72	Lean CLAY (with sand)	Cp = 1470 m/s αs (dB/λ) = 0.08 dB/ λ p = 1,200
72 to 85	Silty fine SAND	Cp = 1700 m/s αs (dB/λ) = 1.0 dB/ λ p = 1,605
85 to 110	Fat CLAY	Cp = 1470 m/s αs (dB/λ) = 0.08 dB/ λ p = 1,200

Reference: Hamilton 1976, Hamilton 1982, Hamilton and Bachman 1982, APL 1994.

4.2.3 Seasonal Sound Speed Profiles

The speed of sound in sea water depends on the temperature T [°C], salinity S [ppt], and depth D [m] and can be described using sound speed profiles (SSPs). Oftentimes, a homogeneous or mixed layer of constant velocity is present in the first few meters. It corresponds to the mixing of superficial water through surface agitation. There can also be other features such as a surface channel, which corresponds to sound velocity increasing from the surface down. This channel is often due to a shallow isothermal layer appearing in winter conditions, but can also be caused by water that is very cold at the surface. In a negative sound gradient, the sound speed decreases with depth, which results in sound refracting downwards which may result in increased bottom losses with distance from the source. In a positive sound gradient as predominantly present in the winter season, sound speed increases with depth and the sound is, therefore, refracted upwards, which can aid in long distance sound propagation. The construction timeframe is expected to run from May through mid-July. For the majority of construction modeling scenarios the May SSP (Figure 4) was chosen due to it exhibiting worst case characteristics in terms of long range propagation effects. For the wind turbine operational scenario, the February SSP (Figure 5) was worst case on an annual basis, with May temperatures colder at the bottom and February temperatures colder at the surface, as shown on the corresponding plots.

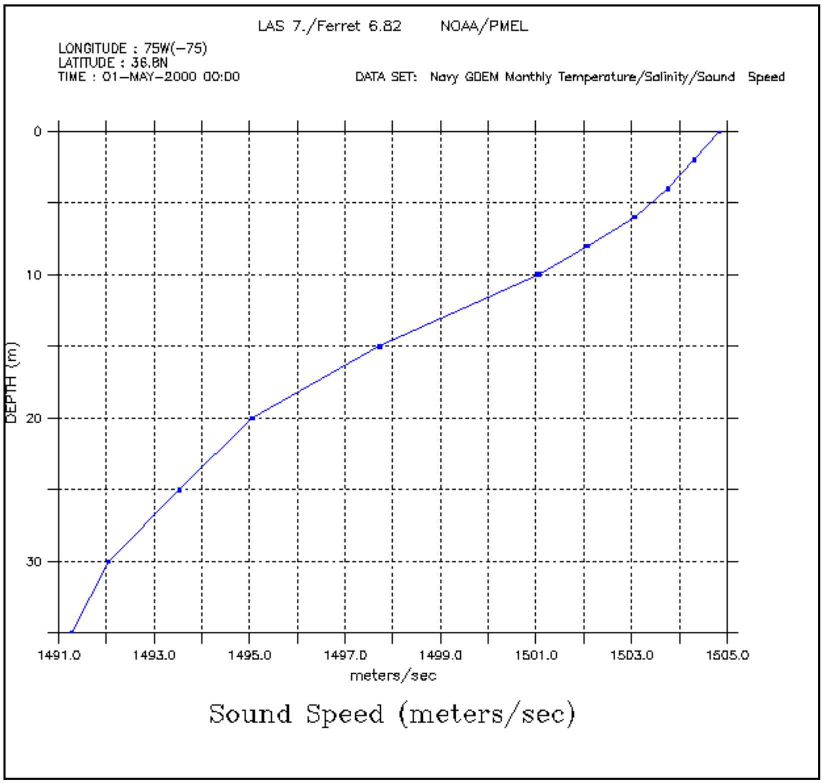

Figure 4. Average May Sound Speed Profile as a Function of Depth

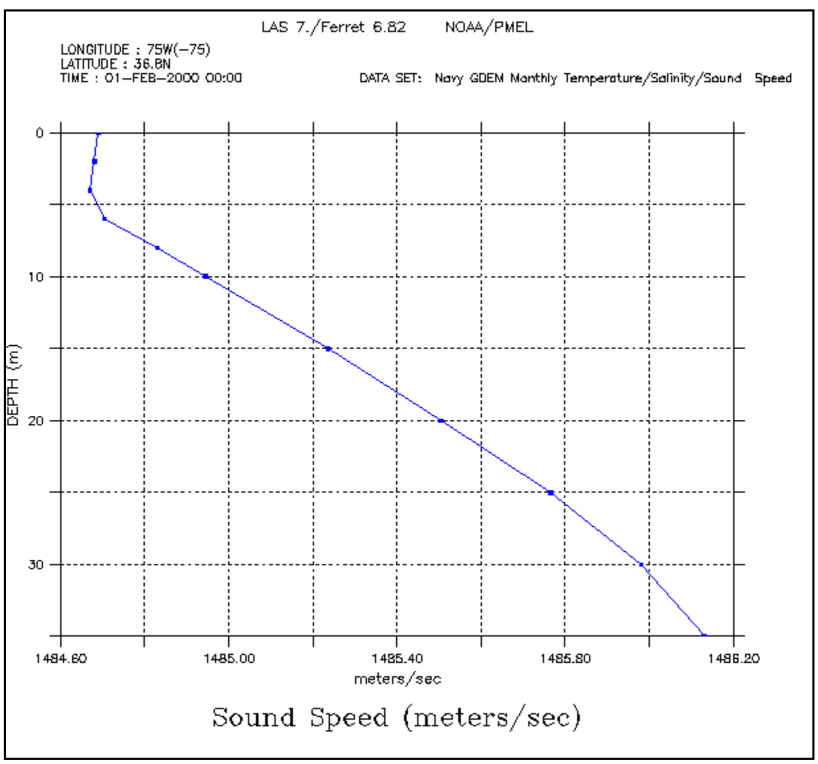

Figure 5. Average February Sound Speed Profile as a Function of Depth

4.3 Acoustic Modeling Scenarios

The representative acoustic modeling scenarios were derived from descriptions of the expected construction activities and operational conditions through consultations between the Project design and engineering teams. The subsections that follow provide more detailed information about the parameters used to model the noise sources associated with each scenario. Sound source level data were unavailable for several vessels and activities identified at the time of writing. Therefore, a literature review was conducted in order to identify source level measurements from comparable equipment performing similar activities. Proxy source levels for each of the modeling scenarios presented in this report were derived from literature, engineering guidelines, and underwater source measurements of similar equipment and activities. Vessel source levels were based on proxy sources which are not considered public documents. However, the project proponent has reviewed for the specific vessels being considered for the project and have been deemed representative based on dynamic thruster characteristics.

Reasonable and appropriate source level information was derived for wind turbine operation, impact pile driving, cable lay operations, and Dynamically Positioned (DP) vessels expected to be used in support of the WTG installation. The source level descriptions and source depth assumptions are key inputs to the acoustic propagation model. The source level is stated as a spectral level as a function of frequency – e.g. in one-third octave bands and summed as an overall broadband level. The level of an acoustic source is a measure of the acoustic emission at the source. It is related to the radiant intensity and acoustic power of the source, but it is rarely described in these terms. By convention, underwater acoustic source levels are routinely defined as the acoustic pressure at 1m distance from idealized point source, i.e. dB re 1 µPa at 1m by extrapolating back to a reference range of one meter from the source using a version of the simplified free field modeling (see Section 2.1). Extrapolating back to 1 meter to derive an apparent sound source level is particularly prone to error due to the fact that the assumptions used in this derivation are not typically stated. In this particular shallow water environment, the reliance on a simplistic geometric spreading model to use back-propagation to calculate a source’s apparent source level is near impossible due to the due to the variability in factors such as bathymetry and sediment properties. This has recently been considered in detail within the specific domain of Environmental Impact Assessments (Farcas et al. 2016), with similar conclusions. Received levels, if appropriately documented (Merchant et al. 2015; Robinson et al. 2014), should however be most useful when comparing different construction and operational scenarios.

However, since most of the data are presented in this way, this format has been maintained here, with the calculation of the apparent source normalized to the CVOW project site based on far-field measurements completed at similar sites. A summary of construction and operational scenarios incorporated into the underwater acoustic modeling analysis is provided in Table 5. The basis for these source levels are provided below.

Table 5. Underwater Noise Modeling Scenarios

Scenario	Description	Geographic Coordinate System NAD83 UTM10N	Apparent Source Level	Water Depth at Source
Scenario 1	Cable Lay Operations Position 1	422417, 4075190	177 dBrms	15 m
Scenario 2	Cable Lay Operations Position 2	433145, 4073712	177 dBrms	21 m

Scenario	Description	Geographic Coordinate System NAD83 UTM10N	Apparent Source Level	Water Depth at Source
Scenario 3	Cable Lay Operations Position 3	444782, 4076187	177 dBrms	19 m
Scenario 4	Cable Lay Operations Position 4	451021, 4079909	177 dBrms	20 m
Scenario 5	WTG Installation	456196, 4083479 456196, 4082429	184 dBrms	25 m
Scenario 6	Impact Pile Driving – 600 kJ Hammer Energy	456196, 4083479 456196, 4082429	211 $dBrms_{90}$ 220 SEL 231 Peak	25 m
Scenario 7	Impact Pile Driving – 1,000 kJ Hammer Energy	456196, 4083479 456196, 4082429	213 $dBrms_{90}$ 222 SEL 233 Peak	25 m
Scenario 8	Operational Wind Turbine	456196, 4083479 456196, 4082429	140 to 150 dBrms	25 m

4.3.1 Cable Lay Operations

Specialist vessels specifically designed for laying and burying cables on the seabed will be used. The cable will be buried along the cable route by the use of a jet plow or plow. Throughout the cable lay process, a DP enabled cable lay vessel maintains its position (fixed location or predetermined track) by means of its propellers and thrusters using a Global Positioning System, which describes the ship's position by sending information to an onboard computer that controls the thrusters. DP vessels possess the ability to operate with positioning accuracy, safety, and reliability without the need for anchors, anchor handling tugs and mooring lines. The underwater noise produced by subsea trenching operations depend on the equipment used and the nature of the seabed sediments, but will be predominantly generated by vessel thruster use.

Thruster sound source levels may vary in part due to technologies employed and are not necessarily dependent on either vessel size, propulsion power or the activity engaged. Cable installation contractors have not yet been identified for Project construction; therefore, data on any vessel specific thrusters is not available at this time. The sound source level assumption employed in the underwater acoustic analysis was 177 dB and a vessel draft of 7 meters for placing source depth. For the purposes of the underwater acoustic modeling analysis, it was assumed that cable laying activities will be continuous and may occur on a 24-hour schedule. Thruster noise is generated by cavitation and has a relatively flat spectrum shape due to the large number of random bursts caused by various sized bubbles collapsing. The discrete spectral "blade rate" component occurs at multiples of the rate at which any irregularity in the flow pattern or in the impeller itself is intercepted by the impeller blades (Fischer 2000).

4.3.2 Heavy Lift Vessel and WTG Installation

Installation of the WTG structures will involve the use of supply and service vessels including an offshore heavy lift jack up vessel, operation support vessel, a high speed heavy cargo vessel, and a specialized wind turbine installation vessel, many of which are equipped with thrusters. Thrusters are propellers located below the water line and may either be mounted in tunnels running crosswise through the vessel's hull or hung below the vessel's hull. Thrusters can generate elevated underwater noise and are used intermittently. Broadband linear source values were estimated to range from 177 to 183 dB assuming full engine loads occurring during short term pushing, pulling, or lifting operations. To allow the vessels to remain on station. For the purposes of providing the acoustic modeling analysis, the apparent sound source level was adjusted up to 184 dB to account for cumulative effects of multiple support vessels operating concurrently.

4.3.3 Pile Driving

In most cases, foundations for massive offshore wind turbine structures are constructed by driving piles into the seabed with hydraulic hammers. The pile driver operates by lifting a hammer inside the driver and dropping it onto a steel anvil. The anvil transmits the impulse into the top of the pile and the pile is forced into the sediment. Repeated blows drive the monopile to the desired depth, the vertical travel of the pile decreasing with each blow as greater soil resistance is built up from the contact between the pile surface and the sediment. Each blow typically results in a travel of several centimeters. During this time, the hammer strikes the pile approximately once every two seconds.

Predicting underwater noise levels during offshore pile driving is of great interest to foundation installation contractors who must comply with stringent noise emission thresholds. The CVOW monopile will have a 7.8 m diameter at the seafloor and 6 m diameter flange. The length of the monopile ranges from 62.5 to 64 meters. Only one monopile will be driven at a time. The acoustic energy is created upon impact and travels into the water along different paths: 1. from the top of the pile where the hammer hits, through the air, into the water; 2. from the top of the pile, down the pile, radiating into the air while travelling down the pile, from air into water; 3. from the top of the pile, down the pile, radiating directly into the water from the length of pile below the waterline; and 4. down the pile radiating into the seafloor, travelling through the seafloor and radiating back into the water.

Near the pile, acoustic energy arrives from different paths with different associated phase and time lags which creates a pattern of destructive and constructive interference. The sound radiating from the pile itself was simulated using a vertical array of discrete point sources to accurately characterize vertical directivity effects in the near-field zone. Further away from the pile, the water and seafloor borne energy are the dominant pathways. The underwater noise generated by a pile-driving strike depends primarily on the following factors:

1. The impact energy and type of pile driving hammer,
2. Pile diameter and type of the pile,
3. Water depth, and
4. Subsurface hardness in which the pile is being driven.

The acoustic energy radiated into the aquatic environment by a struck pile is directly correlated to the kinetic energy that the impact hammer imparts to it. Engineering considerations about pile penetration and load bearing capacity dictate that the impact hammer energy must be matched to the pile and to the resistance of the underlying substrate (Parola 1970). Greater hammer impact energy is required for larger diameter piles to achieve the desired load bearing capacity. The water depth also has a strong influence. As more of the surface area is exposed at greater water column depths, a higher percentage of sound energy may be introduced directly into the aquatic environment.

Table 6 presents underwater sound measurement data collected for impact pile driving of cylindrical steel piles with similar diameter, water column depths, seafloor characteristics, and impact forces, in the context of an offshore oceanic environment. These data show that the noise level increases by 10 $\log_{10}(E_2/E_1)$ as the blow energy is increased from E_1 to E_2 which was lower than previously reported in other study documents (Schultz-von et al. 2006; Stephen P. Robinson et al. 2007). The normalization methodology also accounts for variations in depth and distance and is described by the following equation for the expected maximum impact force necessary to install the 7.8 meter diameter pile:

$$L_{normalized} = L_{measured} + 10\log_{10}\left(\frac{25}{H_1}\right) + 15\log_{10}\left(\frac{R_1}{500}\right) + 10\log_{10}\left(\frac{600}{E_1}\right)$$

Where: L = sound pressure level
H_1 = depth at which the original pile driving measurement was completed
R_1 = distance at which the original measurement was taken
E_1 = impact hammer force for the original measurement
E_2 = estimated maximum hammer force 600 kJ

Measured underwater noise data from pile driving of a 7.8 meter diameter pile for the Walney Extension Offshore Wind Farm was referenced with additional adjustments to the normalization function. The last two columns of Table 6 present the key sound metrics that were used in the determination of biological significance, rms_{90} SPL normalized to a distance of 500 meters and applied in subsequent modeling calculations. Pile driving sound is characterized as impulsive, which has somewhat unique features in comparison to other sounds. Impulsive sounds can have moderate average, but very high instantaneous pressure peaks, which might be harmful to the auditory system. For the purposes of assessing compliance with the NOAA Fisheries cause and effect for impulsive sound, the reporting of sound generated during impact pile driving must employ a RMS SPL "averaged over the duration of the pulse". A typical pile driving impulse duration is approximately 125 milliseconds with principal energy contained within the first 30 to 40 milliseconds. The measured peak sound level represents the maximum of these high instantaneous pressure peaks. As shown in Table 6, the normalized $RMS_{90\%}$ range from 182 to 184 dB at a reference distance of 500 meters for the expected pile driver hammer energy of 600 kJ to 1000 kJ.

Table 6. Normalization of Underwater Pile Driving Measurement Results

Measurement Site	Pile Diameter m	Measured Depth H1 m	Measured Distance R1 m	Impact Energy E1 kJ	MEASURED SPL dB re 1 µPa		$RMS_{90\%}$ re 1 µPa NORMALIZED TO 500 m	
					Peak	$RMS_{90\%}$	Impact Force 600 kJ	Impact Force 1000 kJ
Walney Extension	7.8	28	730	600	192	179	182	184

$RMS_{90\%}$ values estimated using a 125 millisecond pulse duration.
Reference: Niras Consulting Ltd, 2017

The SEL is the level of a sound energy averaged over a stated 1-second duration with the same sound energy as occurring during the pressure pulse. The normalized SELs the range from 173 to 175 dB at a reference distance of 500 meters for the expected pile driver hammer energy of 600 kJ to 1000 kJ. If the strikes are all equal force, the SEL_{cum} can be computed from the single-strike SEL based on the total number of strikes using the following equation:

$$\text{Cumulative SEL } (SEL_{cum}) = \text{Received SEL} + 10 * \log(\# \text{ number of strikes})$$

That is, the SEL_{cum} increases by 10 dB with every tenfold increase of the number of strikes. In actuality, the pile driving would initially start at the lower range of impact force, and ramp up to a maximum impact force to reach final design penetration and seat the piles. The calculation has assumed this expected impact force of 600 kJ would occur over an entire piling sequence, with the 1000 kJ force occurring for a comparatively shorter duration at the very end of the installation to adequately seat the monopile, if necessary.

4.3.4 WTG Operation

When the WTGs are operational, the main source of underwater noise will be from the working of the gears in the nacelle at the top of the tower (Nedwell et al. 2004). This noise/vibration is transmitted into the sea by the structure of the tower itself, and manifests as low frequency noise. Other transmission pathways are via the tower and the seabed, or through the air and air/water interface, but those pathways are unlikely to be as important as the pathway directly through the tower (Nedwell et al. 2004). A review of other published studies indicate that source levels from operating offshore WTGs that have monopile foundations show peak frequencies occurring predominantly below 500 Hz, and that the apparent source level range from 140 to 153 dB re 1µPa at 1m (Nedwell et al. 2004). Similar measurements by Nedwell indicate that the steady state background in an offshore oceanic environment also occurs within this frequency range, which implies masking effects. The available field data showed that although the absolute level of turbine noise increases with increasing wind speed, the noise level relative to background noise (i.e., from wave action, entrained bubbles) remained relatively constant.

5 ACOUSTIC MODELING RESULTS

By employing field verified underwater measurement data, resultant sound levels are representative of vessels and equipment that are likely to be employed during Project activities. Acoustic modeling algorithms were applied to estimate received sound levels from various Project construction and operational phases to determine distances to biologically significant threshold levels as defined by NOAA Fisheries. Analysis methods accounted for the Project's shallow water environment, considering both spatial and seasonal factors in conjunction with estimations of source levels. The default weighting function adjustment (WFA) of 2 kHz for pile driving as described in the NMFS guidance document (NMFS, 2016) was not used. NMFS concedes that using the default WFAs will result in larger impact distances than more sophisticated modeling (NMFS 2016). The modeling software, dBsea (©Marshall-Day) was used to predict the underwater sound fields using more precise weighting functions (NMFS 2016) to compute SELcum rather than the default WFAs.

Acoustic modeling was conducted for the scenarios described in Section 4.3 and the results of those analyses are presented in the subsequent subsections. Maps of modeled un-weighted acoustic sound fields are provided in Appendix A, which present color-coded unweighted decibel isopleths projected onto scaled mapping. These sound contour maps show that the highest noise levels from impact pile driving are to be found where the sound is able to propagate away from the source in deeper water for the furthest distance, before being attenuated by bottom loss in shallower water. The results of the hydroacoustic modeling calculations are presented in two different formats. For Scenario 1 through 5 (Figure A-1 through A-5), each contour illustrates the received rms SPL in dB re 1 µPa, the maximum sound pressure level over the measurement period. For Scenarios 6 and 7 (Figure A-6 and A-7), sound level contour maps show the total sound energy contained in a single pile driving pulse in SEL dB re 1µPa²s in 10 dB increments, and Figure A-8 and A-9 showing the same pile driving scenarios with the implementation of mitigation in the form of a Big Bubble Curtain (BBC).

The expected acoustic fields for each of the modeled scenarios are presented as tabularized distances to the specific NOAA Fisheries Level A and Level B thresholds. The distances in the tables are given in meters from a given source location with R_{max} indicates the greatest maximum radial distance from the source to the specified threshold value. The R_{mean} indicates the average distance from source at which the sound level would be present, i.e. an average circular area that would encompass an area exposed to sound at or above that level, regardless of the actual geometrical shape of the noise footprint. Both RMS SPL and SELcum descriptors apply the maximum level over all sampled depths at the given radial transect. The resultant dataset will be used to estimate how many marine mammals and other species of concern would receive a specified amount of sound energy in a given time period and for use in developing monitoring and/or mitigation programs, as necessary.

5.1 Cable Lay Operations

The use of DP thrusters and jet plow activities were modeled at four locations along the cable lay route. The locations were chosen to provide analysis on different water depths and bathymetry profiles affect the area of impact. For the 180 dB_{RMS} threshold for sea turtles, it was concluded that the distance will be negligible. During operation, thrusters would generate noise which exceeds and Level B harassment threshold 120 dB_{RMS} to a maximum distance of over 20 kilometers.

The maximum distance to the 150 dB_{RMS} behavior threshold for the fish would be 350 meters from a DP vessel with thrusters operating at full power for the worst case cable lay position. Peak thresholds will not be exceeded to any appreciable distance. The SEL cumulative levels will vary as they are dependent on duty cycles which are difficult to predict. Distance to SELcum thresholds are expected to be substantially lower than the pile driving scenarios.

The modeled acoustic fields are presented as a radii of distances to the specific sound level thresholds and marine mammal hearing groups in Table 7 for the worst case Cable Lay position 1. A sound contour isopleth map of the modeled acoustic field in color-coded unweighted decibel isopleths projected onto scaled mapping is provided as Figures A-1 through A-4.

Table 7. Distances to Maximum-Over-Depth Sound Level for Cable Lay Operations Linear and M-weighted for the Four Functional Hearing Groups

SPL rms (dB re 1 µPa)	Unweighted	LF cetaceans	MF cetaceans	HF cetaceans	Phocid pinnipeds
	Range (m)				
180	N/A	N/A	N/A	N/A	N/A
170	80	N/A	N/A	N/A	N/A

SPL rms (dB re 1 µPa)	Unweighted	LF cetaceans	MF cetaceans	HF cetaceans	Phocid pinnipeds
	Range (m)				
160	125	75	N/A	N/A	N/A
150	350	120	N/A	N/A	N/A
140	2,625	150	N/A	N/A	75
130	8,800	1,250	N/A	N/A	125
120	23,000	4,000	N/A	N/A	325

5.2 Heavy Lift Vessel and Wind Turbine Installation

Vessels associated with WTG installation were also evaluated in terms of potential impacts to marine species. For sea turtles, the distance to the 180 dB_{RMS} threshold will be negligible, not measurable to any appreciable distance. Noise impacts to distances further out will vary based on differences in the bathymetry. The maximum distance to the Level B harassment threshold of 120 dB_{RMS} is 17 km.

The results of the modeling analysis indicate the maximum distances to the 150 dB_{RMS} behavior threshold for fish is 600 meters. Peak thresholds will not be exceeded to any appreciable distance. The SEL cumulative levels will vary as they are dependent on duty cycles which are difficult to predict. Distance to SELcum thresholds are expected to be substantially lower than the pile driving scenarios.

The modeled acoustic fields are presented as a radii of distances to the specific sound level thresholds and marine mammal hearing groups in Table 8. A sound contour isopleth map of the modeled acoustic field in color-coded unweighted decibel isopleths projected onto scaled mapping is provided in Appendix A.

Table 8. Distances to Maximum-Over-Depth Sound Level for Heavy Lift Vessel and Wind Turbine Installation Linear and M-weighted for the Four Functional Hearing Groups

dB SPL rms (dB re 1 µPa)	Unweighted	LF cetaceans	MF cetaceans	HF cetaceans	Phocid pinnipeds
	Range (m)				
180	50	N/A	N/A	N/A	N/A
170	100	N/A	N/A	N/A	N/A
160	125	80	N/A	N/A	N/A
150	600	125	N/A	N/A	50
140	2,850	300	N/A	N/A	100
130	7,250	1,450	N/A	N/A	130
120	17,000	4,600	50	N/A	500

5.3 Pile Driving

Pile driving activities will occur during daylight hours starting approximately 30 minutes after dawn and ending 30 minutes prior to dusk, unless a situation arises where ceasing the pile driving activity would compromise safety (both human health and environmental) and/or the integrity of the Project. Impact pile driving included the analysis for the 600 kJ and maximum 1000 kJ hammer energies, thereby describing the full range of sound levels expected throughout an entire piling sequence. Figures A-6 and A-7 in

Appendix A provide sound contour isopleth mapping of the modeled acoustic fields in color-coded unweighted decibel isopleths projected onto scaled mapping for the two hammer energies. Soft-start mitigation procedures would be employed to reduce sound levels during the initial stages of driving a pile, which will reduce risk of impacts as the distance to thresholds would be significantly shorter as the cumulative SEL generally increases more rapidly at close range to the pile and less rapidly at greater ranges from the pile where the received sound levels are lower. The use of soft-start may also be effective in deterring aquatic life allowing movement to a safe distance prior to the full energy piling being reached by allowing time for a fleeing animal to reduce its exposure to the sound.

Assessment of proposed mitigation measures will consider the feasibility as well as the frequency range and expected noise reduction for the selected mitigation measure. Bubble curtains are commonly used to reduce acoustic energy emissions from high-amplitude sources and are generated by releasing air through multiple small holes drilled in a hose or manifold deployed on the seabed near the source. The resulting curtain of air bubbles in the water provides significant attenuation for sound waves propagating through the curtain.

The sound attenuating effect of the noise mitigation system BBC or air bubbles in water is caused by :(i) sound scattering on air bubbles (resonance effect) and (ii) (specular) reflection at the transition between water layer with and without bubbles (air water mixture; impedance leap). The noise reduction realized with the bubble curtain is estimated at 10 to 13 dB (Bellman 2014) for the SEL metric with potentially higher attenuation rates for the Peak metric. Figures A-8 and A-9 in Appendix A provide sound contour isopleth mapping of the modeled acoustic fields for the mitigated pile driving scenarios with a BBC.

Peak Sound Pressure Level

Table A-3 of Appendix A presents the maximum (R_{max}) radial distances that correspond to the peak SPLs (dB re 1 µPa) for impact pile driving. The levels presented in Table A-3 correspond to auditory injury and disturbance criteria for marine mammals and injury criteria for fish for both the unmitigated scenario and with the BBC. Peak thresholds are unweighted. Several of the Peak distances to thresholds do not change under the mitigated pile driving scenario, as these distances will fall within the expected bubble curtain containment area of 100 meters.

Cumulative Sound Exposure Levels

Each foundation is anticipated to require up to 1 day to complete the installation. The drivability assessment predicts an upper bound estimate of 1,333 blows for the first foundation (position A01) and 2,470 blows for the second position (position A02) at a rate of 30 blows per minute. The radii in Tables 10 and A-4 of Appendix A correspond to marine mammal injury and disturbance criteria and fish injury and behavioral disturbance criteria for a 24-hour SEL_{cum}.

Table 10. Radii (m) of Unweighted and M-Weighted SEL$_{cum}$ Contours for Impact Pile Driving – 600 kJ

SEL$_{cum}$ (dB re 1 µPa^2 s)	Critera	Unweighted		LFC		MFC		HFC		PINN	
		R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}	R_{max}	R_{mean}
155	PTS– HF cetaceans							1,625	1,450		
183	Injury – Small fish (mass <2 g) PTS - LF cetaceans	6,100	5,200	4,300	3,900						
185	PTS - MF cetaceans PTS - Phocid pinnipeds					250	250			1,000	850
187	Injury – Large fish (mass >2 g)	4,400	3,900								
Big Bubble Curtain Mitigated											
155	PTS– HF cetaceans							<200	<200		
183	Injury – Small fish (mass <2 g) PTS - LF cetaceans	3,575	2,950	1,450	1,250						
185	PTS - MF cetaceans PTS - Phocid pinnipeds					<200	<200			200	200
187	Injury – Large fish (mass >2 g)	2,625	2,050								

Sound Pressure Levels (RMS$_{90\%}$)

As shown in Tables 11 and A-5 of Appendix A, the resultant distances to the Level B Harassment of marine mammals threshold of 160 dB$_{RMS90}$ ranges from 4 km to 5 km unmitigated and 2 km to 2.5 km with BBC. Hearing recovery time would be expected during significant gaps in piling. The 12 hour period represents the daylight time window that pile driving would occur and allows for overnight recovery time for the fish during the day after pile driving has stopped. The distances to the 150 dB$_{RMS90}$ threshold for fisheries resources range from 8.75 km to 11.375 km unmitigated and 4.57 km to 5.67 km with the BBC. The distances to the 166 dB$_{RMS90}$ threshold for sea turtles range from 2.7 km to 3.15 km unmitigated and 1.175 to 1.5 km with the BBC. The historical Level A threshold or 180 dB$_{RMS90}$ for injury of marine mammals, which is still currently in use for sea turtles, ranges from 700 m to 800 m unmitigated and 280 m to 350 m with the BBC.

Table 11. Radii (m) of dB_{rms90} SPL Contours for Impact Pile Driving – 600 kJ

dB rms90 SPL (dB re 1 µPa)	Criteria	R_{max}	R_{mean}
150	Disturbance – Fish	9.725	8,750
160	Disturbance – Marine Mammals	4,380	4,275
166	Disturbance – Sea Turtles	2,700	2,650
180	Injury – Seaturtles (Marine Mammals - Historic)	700	680
Bubble Curtain Mitigated			
150	Disturbance – Fish	4,700	4,570
160	Disturbance – Marine Mammals	2,110	2,060
166	Disturbance – Sea Turtles	1,200	1,175
180	Injury – Seaturtles (Marine Mammals - Historic)	300	280

5.4 Wind Turbine Operation

Underwater noise from the operation of the wind farm has also been modeled using proxy sources and based on actual measurement data (Lindell, 2003 and Nedwell et al. 2007), and shows that noise levels within the boundary of the Project are not likely to be significantly above ambient noise, but may increase the ambient noise slightly during periods of calm seas and low shipping traffic. It should be noted that a major contribution to the ambient noise would result from sea-state, which would be expected to increase as the turbines rotational speed increases with wind speed.

Acoustic modeling of underwater operational sound was performed for the design wind condition during normal operations. The predicted sound level from operation of a wind turbine has been estimated at only 130 dB at 20 m from the wind turbine foundation and attenuates to the 120 dB_{RMS} threshold level at a relatively short distance of 100 m. These levels are very close to the expected regularly reoccurring ambient noise. The WTGs are located approximately 3,450 ft (1,050 m) apart from one another; so no cumulative effects above 120 dB_{RMS} threshold will occur.

The operational effects of the Project are anticipated to be minimal, with no adverse effect to marine mammals and aquatic life. Underwater noise levels in this range may be perceptible to marine mammals that swim close to an operating wind turbine, but would not adversely affect them or their prey. Although the effect on fish response is more difficult to establish given the lack of information available in the scientific literature, there is indicative evidence that fish would be unlikely to show significant avoidance to the noise levels radiating from the turbine and received sound levels will be below the 150 dB_{RMS} behavioral threshold set for listed species. Vessels servicing the Project site will produce underwater sounds typical of existing vessel traffic in the area; therefore, the Project poses no unique or special risk to marine life.

6 CONCLUSION

Several activities during the construction phase will result in underwater noise above the background noise levels. The primary noise source will be the impact piling activity, whereas activities such as wind turbine and cable installation are expected to introduce significantly lower levels of noise.

Underwater sound levels produced during Project construction are not expected to be of sufficient duration to cause long term effects on marine mammals, sea turtles and fisheries within the Project Area. Temporary avoidance behavior due to Project related noise and vessel activity is likely to occur during the construction period. In addition, the implementation of mitigation and monitoring techniques, such as observation of time-of-year windows, the use of protected species observers during project construction activities that are known to generate high-intensity sound levels, and the establishment of exclusion and monitoring zones as well as ramp-up and shut-down procedures during pile driving events have proven to minimize impacts on marine species should they occur in the Project Area. Dominion will conduct field verifications of actual impact pile driving and DP vessel thruster noise during installation of the CVOW monopile foundations and the Inter-Array and Export Cables for model validation purposes and to further determine the effectiveness of the mitigation measures employed.

The assessment of underwater noise levels associated with the operational phase of the Project shows expected underwater noise levels to be well below thresholds established to be adequately protective of all marine life.

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Attachment A – Sound Contour Isopleth Figures

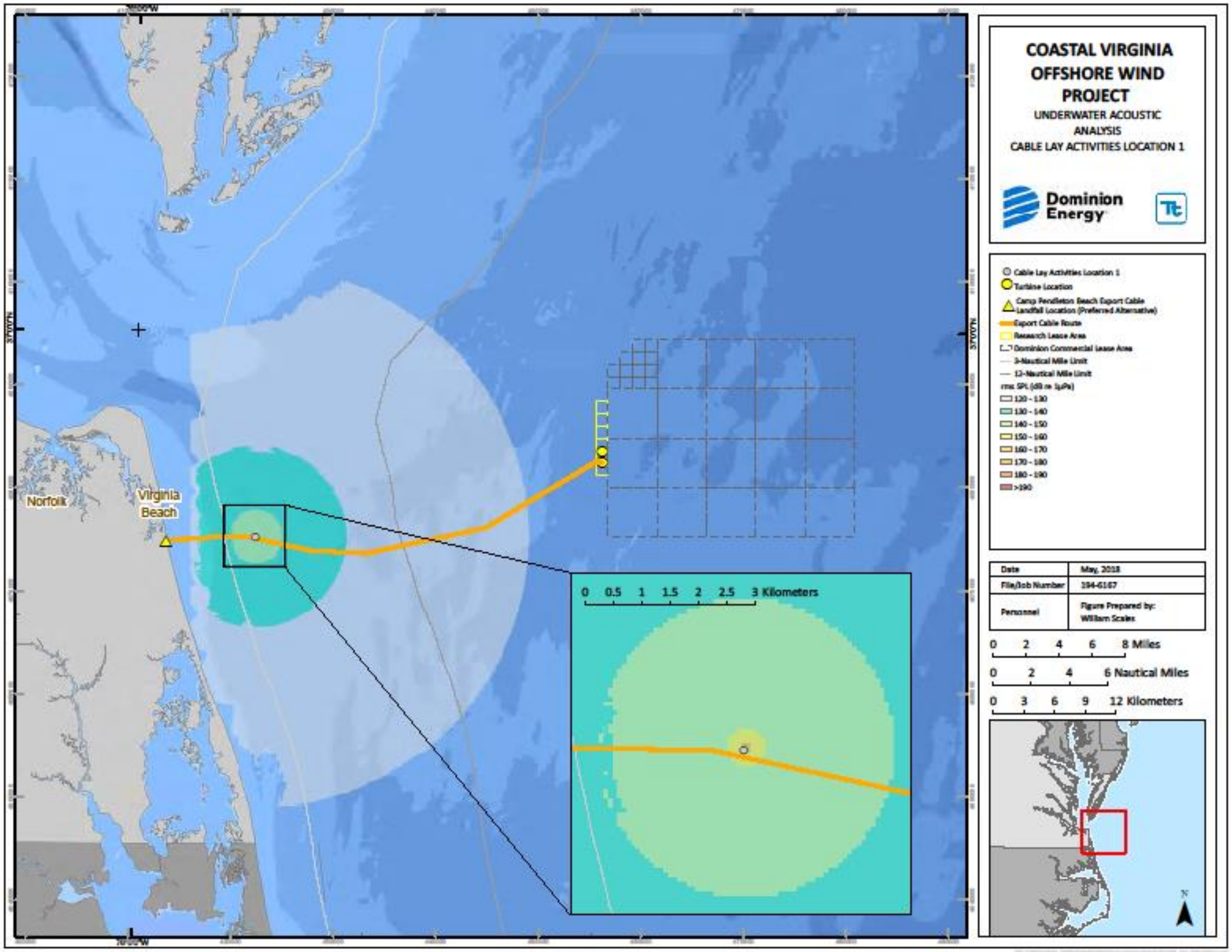

Figure A-1. **Scenario 1: Received Sound Levels, RMS Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Cable Lay Operations at Location 1**

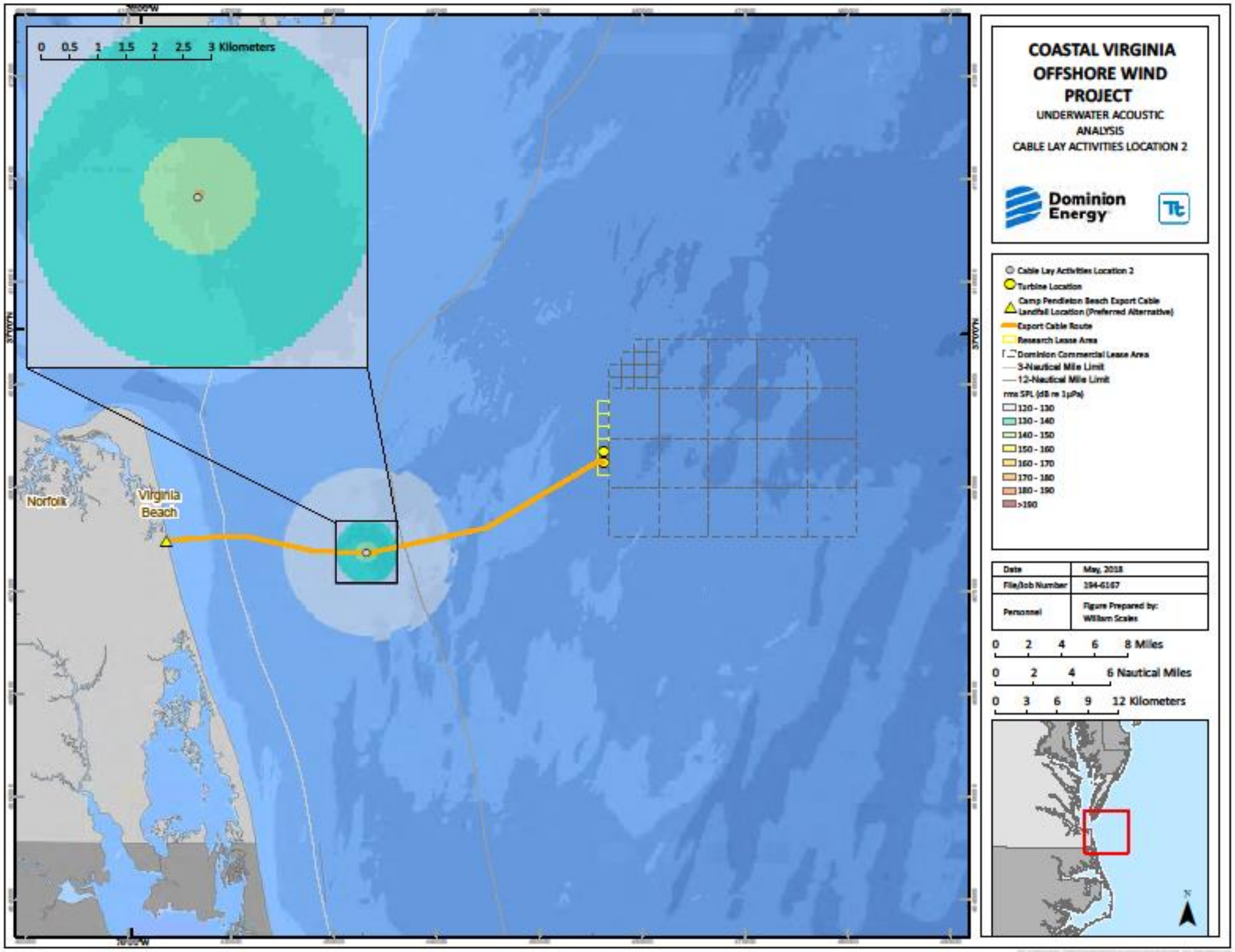

Figure A-2. Scenario 2: Received Sound Levels, RMS Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Cable Lay Operations at Location 2

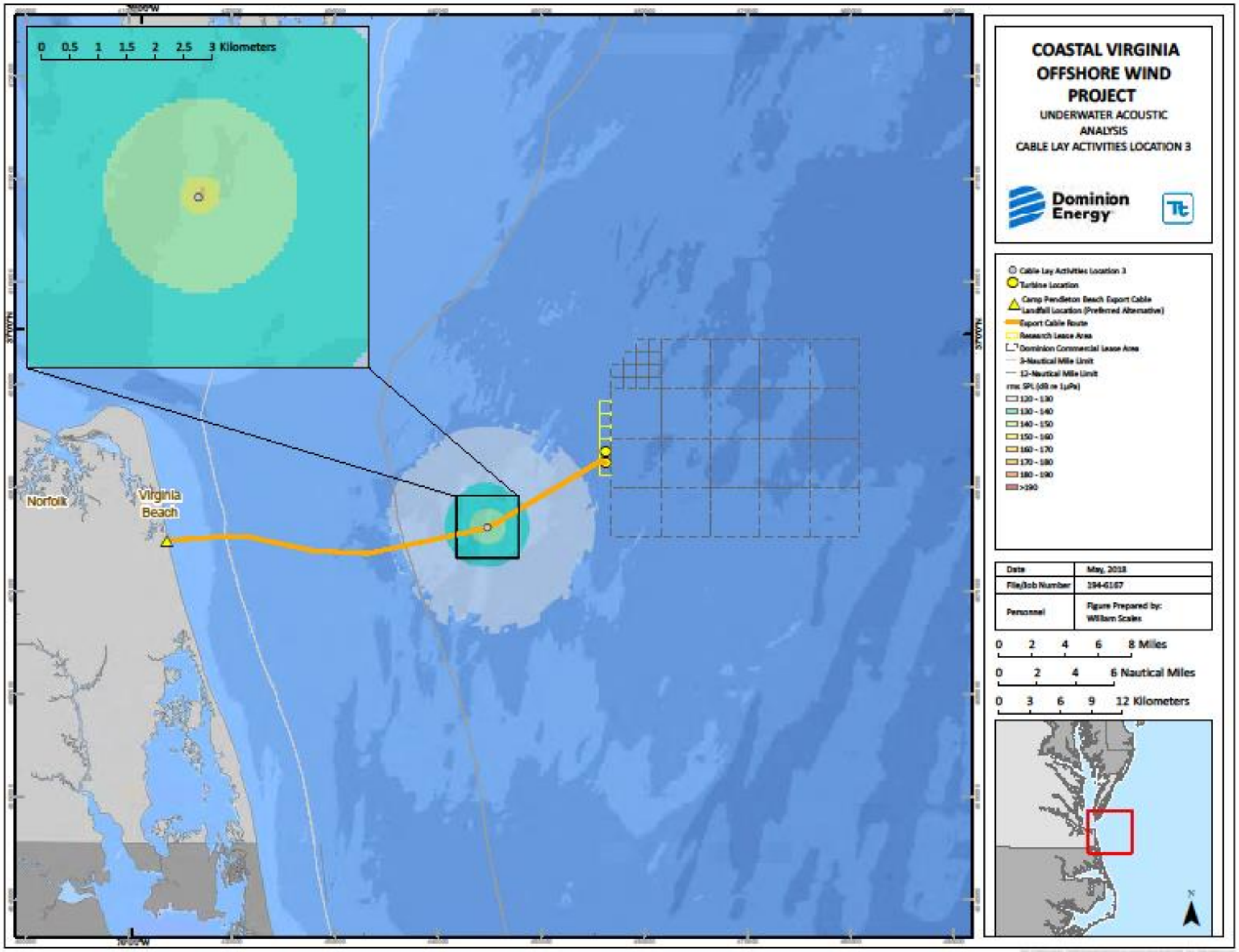

Figure A-3. Scenario 3: Received Sound Levels, RMS Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Cable Lay Operations at Location 3

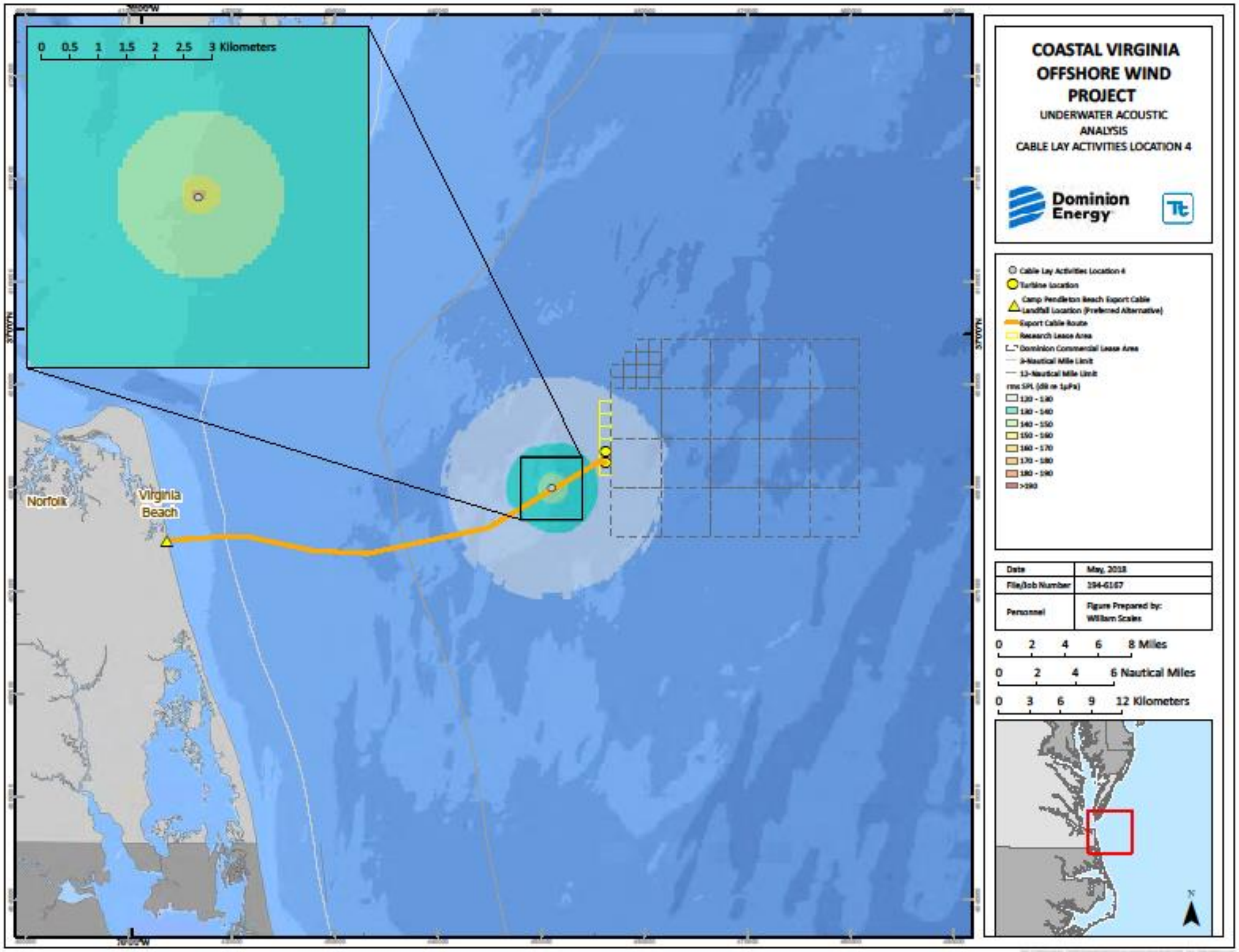

Figure A-4. Scenarion 4: Received Sound Levels, RMS Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Cable Lay Operations at Location 4

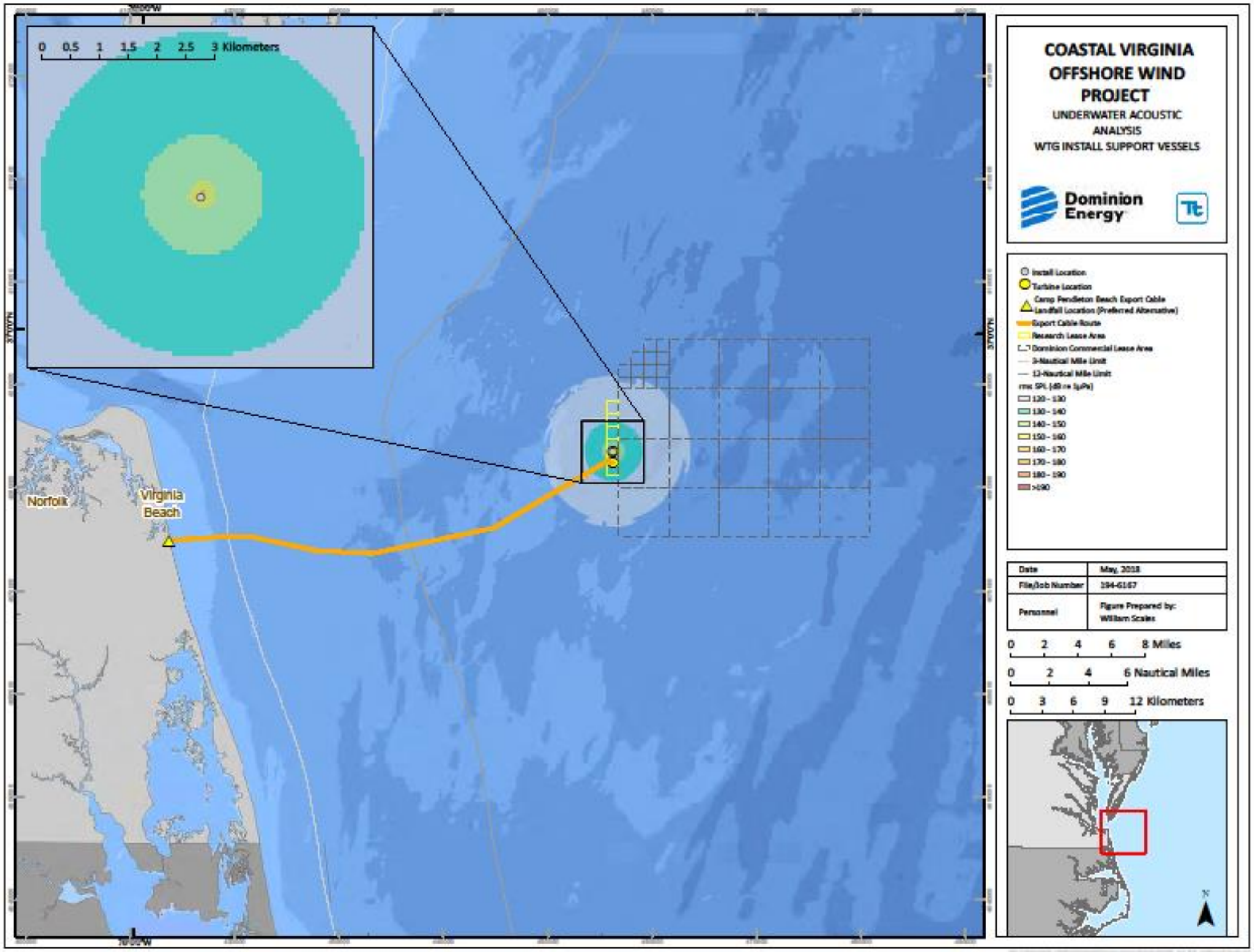

Figure A-5. Scenario 5: Received Sound Levels, RMS Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Wind Turbine Installation at Project Site

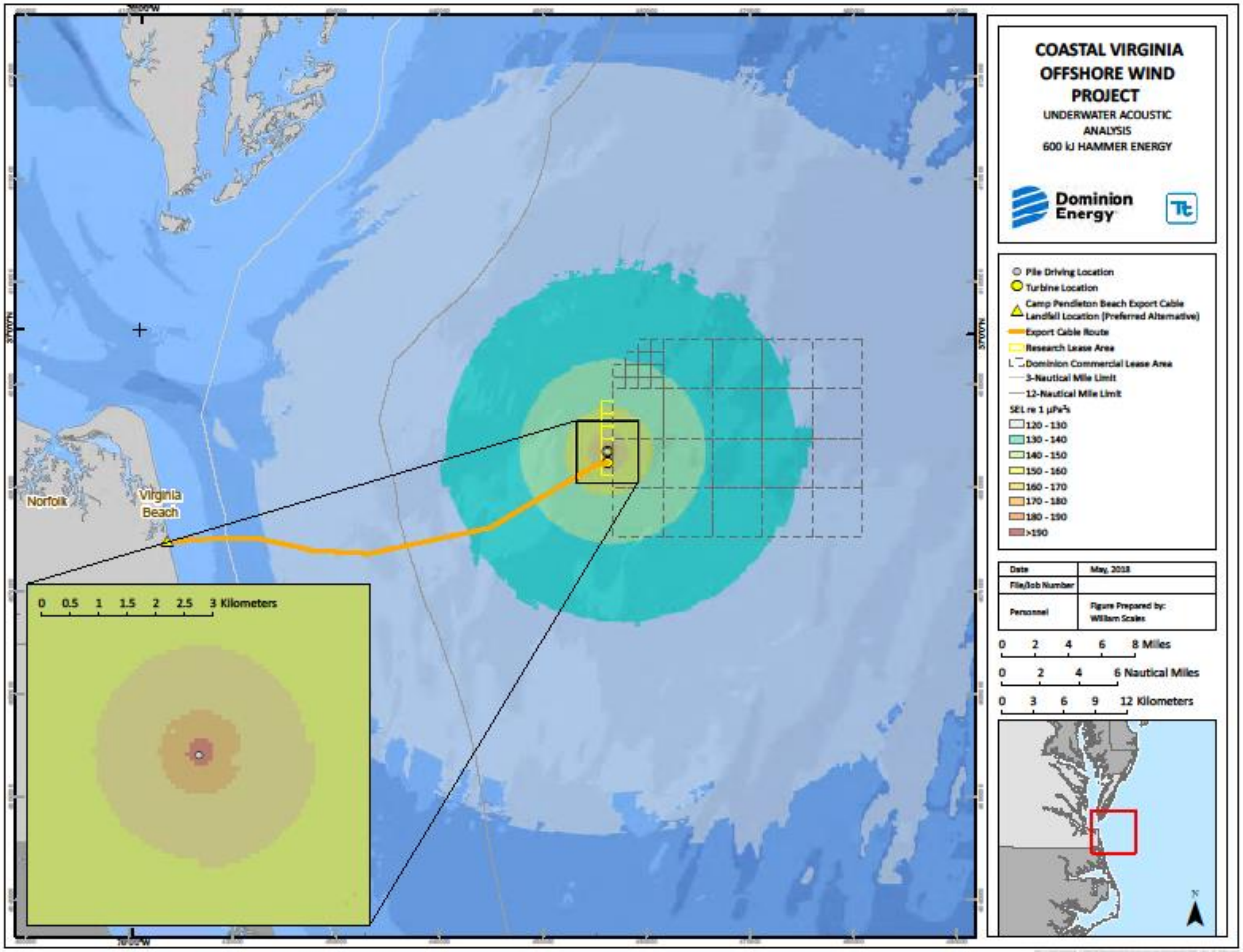

Figure A-6. Scenario 6: Received Sound Levels, SEL (Single Strike) Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Pile Driving at Expected Hammer Energy (600 kJ)

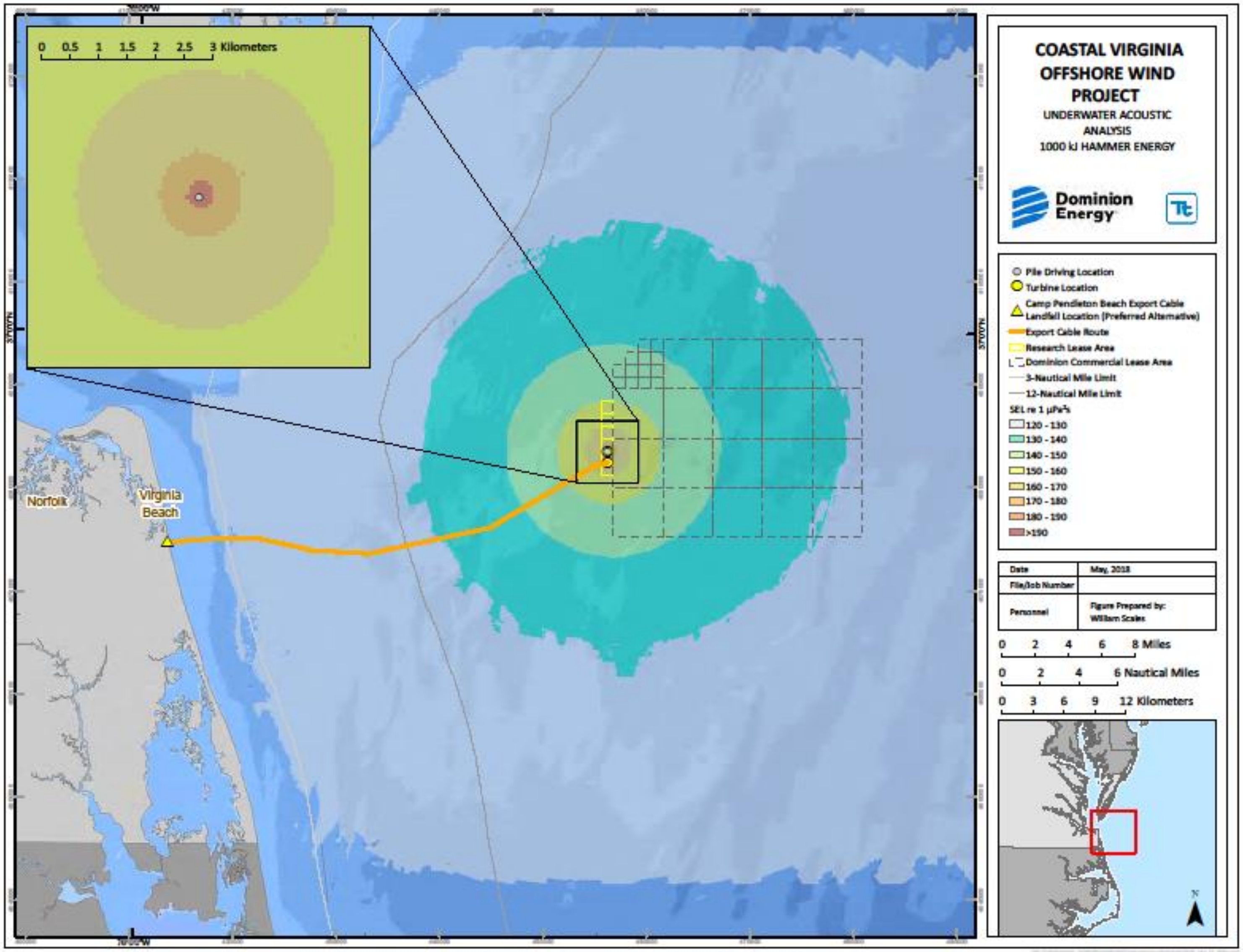

Figure A-7. Scenario 7: Received Sound Levels, SEL (Single Strike) Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Impact Pile Driving at Maximum Hammer Energy (1000 kJ)

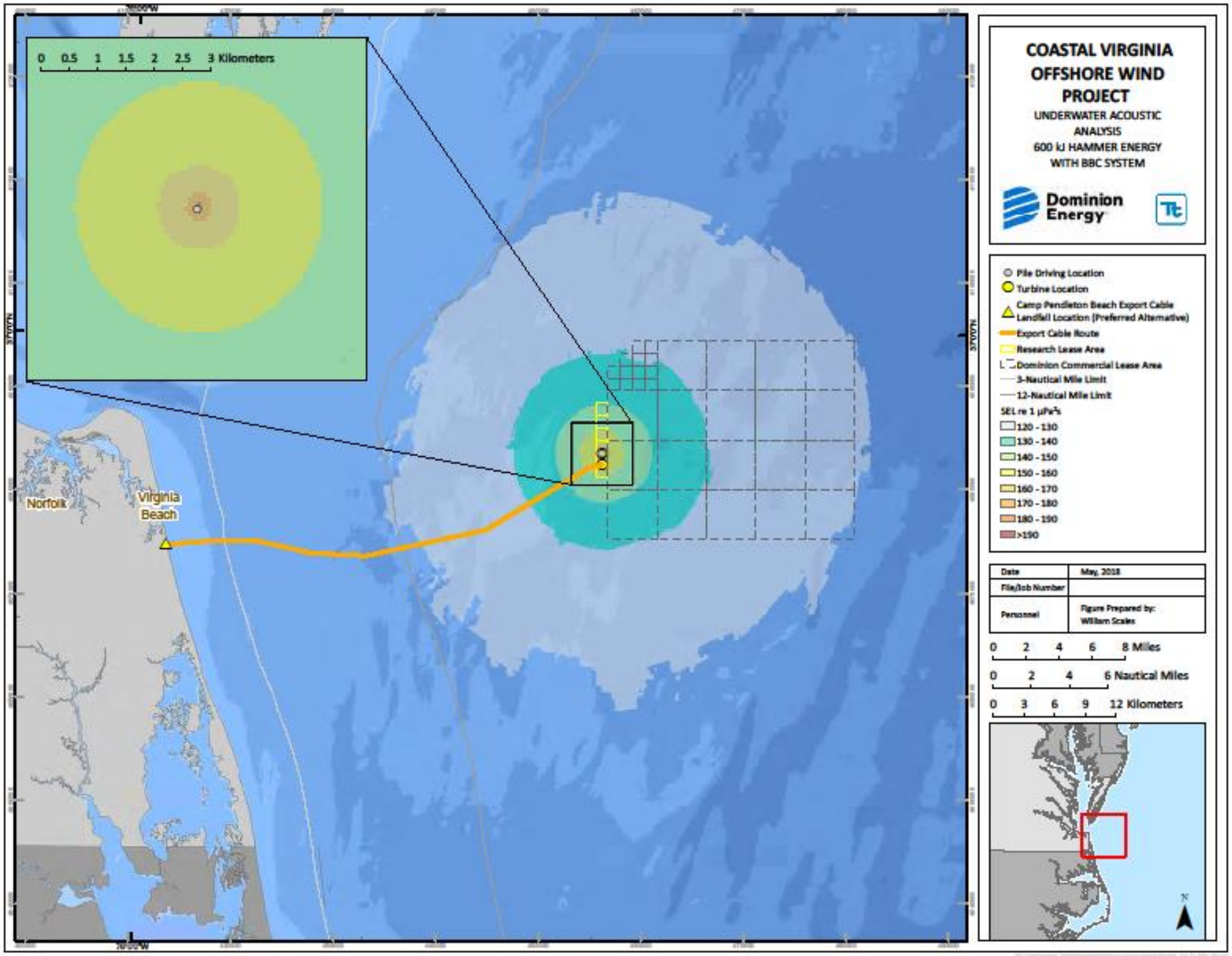

Figure A-8. Scenario 6: Received Sound Levels, SEL (Single Strike) Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Pile Driving at Expected Hammer Energy (600 kJ) with BBC

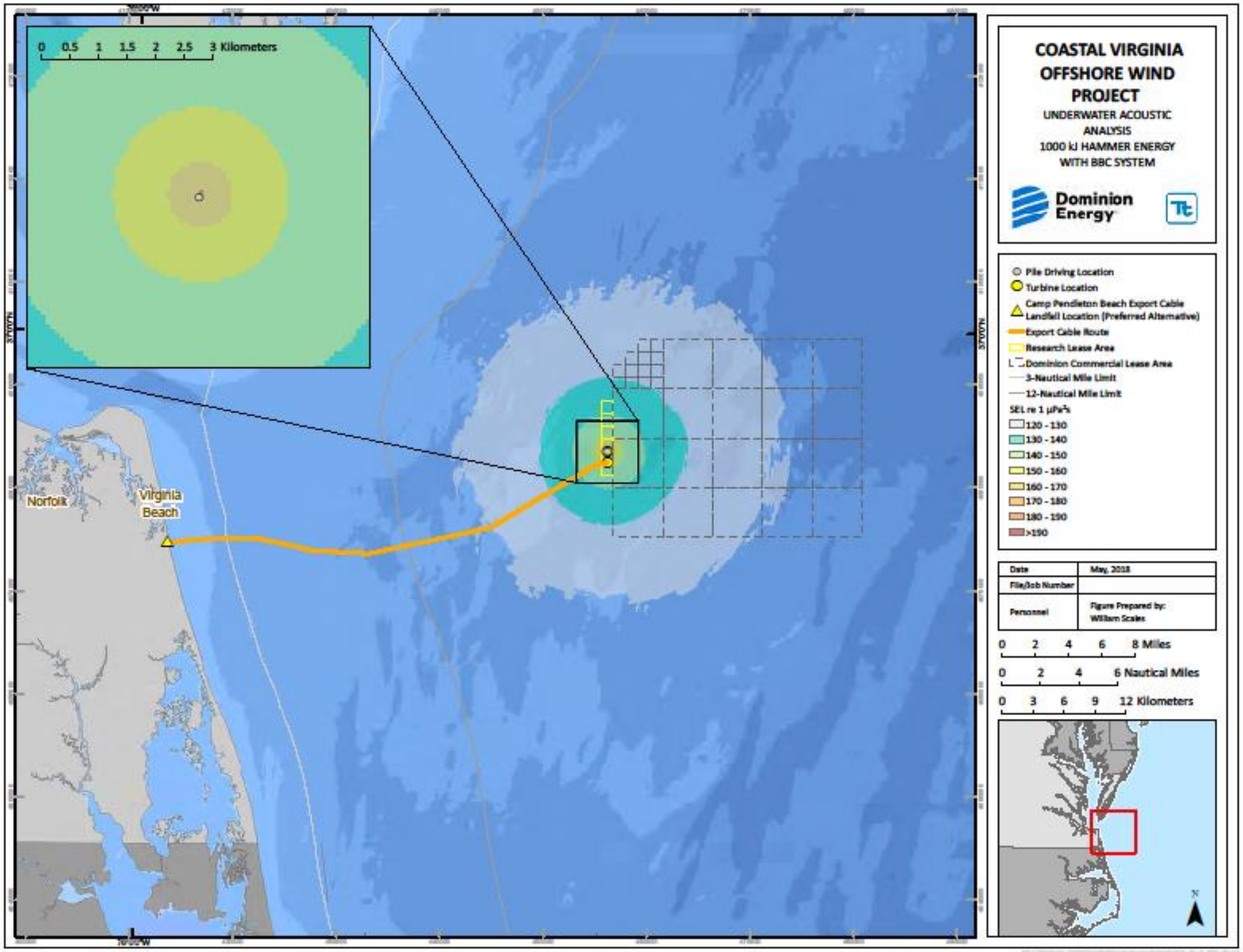

Figure A-9. Scenario 7: Received Sound Levels, SEL (Single Strike) Broadband (10 Hz–8 kHz) maximum-over-depth sound pressure levels for Impact Pile Driving at Maximum Hammer Energy (1000 kJ) with BBC