Acoustic Transmission Loss Modeling

and Take Analysis Methods

for

Marine Structure Maintenance,
Pile Replacement, and Select Waterfront Improvements

at

Naval Station Norfolk

Norfolk, Virginia

May 2020

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TABLE OF CONTENTS

List of Tables

List of Figures

Abbreviations and Acronyms

Acronym	***Definition***
µPa	micropascal
$\mu Pa^2 sec$	micropascal-squared per second
3D	three-dimensional
CV	coefficient of variation
dB	decibels
dB re 1 µPa	decibels referenced to 1 micropascal
dB re 1 $\mu Pa^2 sec$	decibels referenced to 1 micropascal-squared per second
DFSP	Defense Fuel Supply Point
DPS	distinct population segment
E	endangered
ESA	Endangered Species Act
f	frequency
FHG	functional hearing group
HDPE	high-density polyethylene
HFcet	High-Frequency cetacean
Hz	hertz
kHz	kilohertz
LFcet	Low-Frequency cetacean
m	meter
MFcet	Mid-Frequency cetacean
MMPA	Marine Mammal Protection Act
MPU	maintenance, pile replacement, and upgrades
MWR	morale, welfare, and recreation
N/A	not applicable
NAVSTA	Naval Station
NC ES	North Carolina Estuarine System
NM	Northern Migratory
NMFS	National Marine Fisheries Service
No.	number/amount
PTS	permanent threshold shift
re 1 µPa	referenced to 1 micropascal
re 20 µPa	referenced to 20 micropascals
RMS	root mean square (sound pressure level)
SEL	sound exposure level
SEL_{CUM}	cumulative sound exposure level
SM	Southern Migratory
SPL	sound pressure level
sq km	square kilometer
T	threatened
TTS	temporary threshold shift
U.S.	United States
USFWS	U.S. Fish and Wildlife Service
ZOI	zone of influence

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1 Introduction

This document presents methods proposed for acoustic transmission loss modeling and marine mammal take estimates for marine structure maintenance, pile replacement, and upgrades (MPU) at Naval Station (NAVSTA) Norfolk, the Defense Fuel Supply Point Craney Island, and Lambert's Point Deperming Station. This document also presents the analysis used to determine species for inclusion in Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) consultations.

1.1 Federal Special Status to Be Included in Analysis

1.1.1 United States Fish and Wildlife Service Endangered Species Act Species

Threatened and endangered species that are under the jurisdiction of the United States (U.S.) Fish and Wildlife Service (USFWS) with the potential to occur within the project area were identified using the USFWS's Information for Planning and Consultation website (https://ecos.fws.gov/ipac/).

The Official Species List did not return any species under the jurisdiction of the USFWS (Appendix A, USFWS IPAC Report). However, the federally endangered West Indian manatee has been sporadically recorded in the lower Chesapeake Bay (see Table 2, in the MMPA species discussion in Section 1.1.3). In addition, the federally threatened piping plover has been historically documented at the nearby Craney Island Dredged Materials Management Area and may occur transiently in the area. As such, the Navy will include these species in ESA section 7 consultation with the USFWS.

1.1.2 National Marine Fisheries Service Endangered Species Act Species

Threatened and endangered species that are under the jurisdiction of the National Marine Fisheries Service (NMFS) with the potential to occur in the project area were identified using NMFS Section 7 Mapper[1]. A conservative project boundary and buffer was utilized in the mapper (Appendix B, NMFS Section 7 Mapper Results). The Section 7 Mapper returned eight species (Table 1).

In addition, critical habitat (Chesapeake Bay Unit 5: James River) has been designated in the James River for Atlantic sturgeon. This designated critical habitat is over 7.25 kilometers from the nearest pile driving location at NAVSTA Norfolk.

Several studies (Barco & Lockhart, 2015; 2016; Barco et al., 2018; 2017) were evaluated for sea turtle occurrences in the project area and surrounding region; based on these reports, all sea turtle species in Table 1 will be included in the analysis.

[1] https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=1bc332edc5204e03b250ac11f9914a27

Table 1 Endangered Species Act-Listed Species Identified by National Marine Fisheries Service Section 7 Mapper

Species	***Latin Name***	***DPS***	***Status***	***Life Stage***	***Behavior***	***Zone(s)***	***Season***
Reptiles							
Leatherback sea turtle	*Dermochelys coriacea*	N/A	E	Adults and juveniles	Migrating and foraging	Massachusetts (south of Cape Cod) through Virginia	1 May to 30 Nov
Loggerhead sea turtle	*Caretta caretta*	Northwest Atlantic DPS	T	Adults and juveniles	Migrating and foraging		
Kemp's ridley sea turtle	*Lepidochelys kempii*	N/A	E	Adults and juveniles	Migrating and foraging		
Green sea turtle	*Chelonia mydas*	North Atlantic DPS	T	Adults and juveniles	Migrating and foraging		
Fish							
Shortnose sturgeon	*Acipenser brevirostrum*	N/A	E	Adult	Migrating and foraging	James River and Chesapeake Bay	1 Jan to 31 Dec
						Chesapeake Bay	1 April to 30 Nov
					Overwintering	Chesapeake Bay	1 Nov to 28 Feb
Atlantic sturgeon	*Acipenser oxyriynchus oxyriynchus*	All DPSs	T/E	Subadult	Migrating and foraging	James River and Chesapeake Bay	15 Mar to 30 Nov
				Adult			
				Subadult		Chesapeake Bay	1 Jan to 31 Dec
				Adult			
		Chesapeake Bay DPS	E	Juvenile	Migrating and foraging	James River and Chesapeake Bay	1 Jan to 31 Dec
				Adult	Staging	James River	1 May to 30 Nov
Mammals							
North Atlantic right whale	*Eubalaena glacialis*	N/A	E	Adults and juveniles	Migrating	Mid-Atlantic (Cape Cod, Maine to Virginia)	1 Jan to 31 Dec
Fin whale	*Balaenoptera physalus*	N/A	E	Adults and juveniles	Migrating	Mid-Atlantic (Cape Cod, Maine to Virginia)	1 Jan to 31 Dec
					Foraging		
					Overwintering		1 Nov to 31 Jan
				Adult	Calving		1 Oct to 31 Jan

Key: DPS = distinct population segment; E = endangered; ESA = Endangered Species Act; N/A = not applicable; T = threatened.

1.1.3 Marine Mammal Protection Act Species

The following sections summarize available data on the occurrence of the potentially affected marine mammal species in these survey and monitoring areas and describe qualitatively the likelihood of encountering any of these species in the vicinity of the project area (Table 2). Reports that were evaluated for this application are listed in Table 2 and include nearshore at-sea surveys conducted on behalf of the Navy in the mouth of the Chesapeake Bay and the Navy's Virginia Capes training and testing area east of Virginia Beach, marine mammal stranding reports, and pinniped tracking and haulout monitoring in the vicinity of the Chesapeake Bay Bridge Tunnel. Sightings of marine mammals in shipboard surveys, telemetry studies, and haulout monitoring are the most useful evidence of the occurrence of a species in the area, but where sightings are scarce, the summaries below also utilize stranding reports as an indicator of the frequency of occurrence of a species.

Table 2 Marine Mammals Potentially Present Within the Lower Chesapeake Bay

Species and Stock[1]	*ESA Status*	*Relative Occurrence*	*Available Data*	*Data Source (See footnotes for citations)*
Fin whale (*Balaenoptera physalus)* Western North Atlantic stock	Endangered	Rare	Transect data, stranding data	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
North Atlantic right whale (*Eubalaena glacialis*) Western North Atlantic stock	Endangered	Rare	Stranding data, passive acoustic data	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 20
Humpback whale (*Megaptera novaeangliae*) Gulf of Maine stock	None	Likely	Transect data, stranding data	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Bottlenose dolphin (*Tursiops truncatus*) • Western North Atlantic Northern Migratory Coastal stock • Western North Atlantic Southern Migratory Coastal stock • Northern North Carolina Estuarine System Stock	None	• NM stock: Likely • SM stock: Likely • NC ES stock: Rare	Transect data, passive acoustic data, stranding data	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16
Harbor porpoise (*Phocoena phocoena*) Gulf of Maine/Bay of Fundy stock	None	Rare	Transect data, passive acoustic data	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16
Harbor seal (*Phoca vitulina*) Western North Atlantic stock	None	Likely	Haulout observations, tagged individual tracking	1, 2, 3, 4, 5, 6, 7, 8, 17, 18, 19
Gray seal (*Halichoerus grypus*) Western North Atlantic stock	None	Rare	A few haulout observations, tagged individual tracking	1, 2, 3, 4, 5, 6, 7, 8, 17, 18

Table 2 Marine Mammals Potentially Present Within the Lower Chesapeake Bay

Species and Stock[1]	*ESA Status*	*Relative Occurrence*	*Available Data*	*Data Source (See footnotes for citations)*
West Indian manatee *(Trichechus manatus)* Florida manatee	Endangered	Rare	A few sightings	1, 2, 21, 22, 23

Key: ESA = Endangered Species Act; NC ES = North Carolina Estuarine System; NM = Northern Migratory; SM = Southern Migratory.

Notes: Rare = Distribution of the species is near enough to the area that the species could occur there, or there are a few confirmed detections; Likely = Confirmed and regular detections of the species occur in the area year-round; Seasonal = Confirmed and regular detections of the species occur in the area on a seasonal basis; Year-round = Confirmed and regular detections of the species occur in the area year-round.

Data Sources: The following reports are fully cited in Section 2 (References)**:**

1. NMFS (2019a) stock assessments
2. Barco and Swingle (2014)
3. Swingle et al. (2014)
4. Swingle et al. (2015)
5. Swingle et al. (2016)
6. Swingle et al. (2017)
7. Swingle et al. (2018)
8. Costidis et al. (2019)
9. Aschettino et al. (2015)
10. Aschettino et al. (2016)
11. Aschettino et al. (2017)
12. Aschettino et al. (2018)
13. Aschettino et al. (2019)
14. Engelhaupt et al. (2014)
15. Engelhaupt et al. (2015)
16. Engelhaupt et al. (2016)
17. Rees et al. (2016)
18. Jones et al. (2018)
19. Ampela et al. (2019)
20. Davis et al. (2017)
21. Cummings et al. (2014)
22. Virginian-Pilot (2019)
23. Virginian-Pilot (2017)

1.1.3.1 Fin Whale

The Navy's nearshore marine mammal surveys have not reported fin whales within the Chesapeake Bay, but have reported two sightings of fin whales north of Joint Expeditionary Base Fort Story during winter-spring surveys conducted from January 2015 to March 2018. The largest number of fin whales reported in these surveys, most of which were detected east of Virginia Beach, was 10 individuals. Large whales do not strand often in Virginia (Swingle et al., 2015). Stranding reports include six fin whale strandings from 1988 through 2013 within the Chesapeake Bay, most of which occurred in the winter (Barco & Swingle, 2014). Single fin whale strandings were reported at Newport News, Virginia, in 2014 and 2017

(Swingle et al., 2015; Swingle et al., 2018), and no fin whale strandings were reported in 2015, 2016 or 2018 (Swingle et al., 2016; Swingle et al., 2017; Costidis et al., 2019).

The 2017 NMFS stock assessment for the Western North Atlantic stock of fin whales reported the minimum population estimate for the North Atlantic stock in U.S. waters was 1,618 (coefficient of variation [CV] = 0.33) based on 2011 NMFS shipboard and aerial surveys of part of the stock's range (NMFS, 2019a). Due to imprecise abundance estimates and long periods of time between surveys, a population trend analysis has not been conducted for fin whales.

The occurrence of fin whales in the project area is exceedingly low; therefore, this species is not carried forward for quantitative analysis.

1.1.3.2 North Atlantic Right Whale

The Navy's nearshore marine mammal surveys have not reported North Atlantic right whales within the Chesapeake Bay, but sightings have been reported to NMFS on the Virginia coast east of Virginia Beach (NMFS, 2019b), and passive acoustic recorders have detected North Atlantic right whales offshore (Davis et al., 2017). Stranding reports include four North Atlantic right whale strandings from 1988 through 2013 along the Virginia coast (Barco & Swingle, 2014). One additional stranding was reported near Virginia Beach in 2018 (Costidis et al., 2019), and no strandings were reported in 2014, 2015, 2016, and 2017 (Swingle et al., 2015; 2016; 2017; 2018).

The 2018 NMFS stock assessment for the Western North Atlantic stock of right whales reported a best abundance estimate of 451 and a minimum population estimate of 445, based on sightings of identifiable individuals (NMFS, 2019a). Available population trend estimates for this species are inconsistent. A population growth rate of 2.5 percent (CV = 0.12) was reported for 1986 to 1992 (Knowlton et al., 1994), suggesting that the stock was showing signs of slow recovery. However, subsequent work suggested that survival probability of an individual (averaged at the population level) declined from 0.99 per year in 1980 to 0.94 in 1994 (Caswell et al., 1999; Best et al., 2001). Historical patterns of mortalities, including those in the first half of 2005, suggest an increase in the annual mortality rate that would reduce population growth by approximately 10 percent annually (Kraus et al., 2005). However, the population continued to grow since that apparent interval of decline until 2012. Examination of the minimum number alive population index calculated from the individual sightings database (as it existed on October 27, 2015) for 1990 to 2012 suggests a declining trend (NMFS, 2018a). NMFS (NMFS, 2018a) cautions interpreting the apparent downward trend in abundance in 2012, but without evidence to the contrary, it is possible that this deflection represents a true population decline.

The occurrence of North Atlantic right whales in the project area is exceedingly low; therefore, this species is not carried forward for quantitative analysis.

1.1.3.3 Humpback Whale

The Navy's nearshore survey effort for humpback whales (Aschettino et al., 2015; 2016; 2017; 2018) has identified high levels of occurrence in waters in and around the mouth of the Chesapeake Bay and the Virginia coast. The number of humpback whales identified in this study reflects the level of effort and study objectives in each field season, among other variables, but the number of unique humpback whales identified each season (31 during the 2014–2015 field season, 37 during the 2015–2016 field season, and 59 during the 2016–2017 field season) indicates the importance of the study area to this species. Several satellite-tagged humpback whales were detected west of the Chesapeake Bay Bridge

Tunnel, including two individuals with locations near NAVSTA Norfolk and Joint Expeditionary Base Little Creek (Aschettino et al., 2017). Group size was not reported in these surveys but appears to have been one to two individuals, most of which were juveniles.

Thirty-three humpback whale strandings were reported in Virginia between 1988 and 2013, of which 11 were within the Chesapeake Bay (Barco & Swingle, 2014). Additional strandings have been reported in Virginia in subsequent years (1 in 2015, 4 in 2016, 8 in 2017, 5 in 2018) (Swingle et al., 2017; Swingle et al., 2018; Costidis et al., 2019). Most of these animals showed signs of ship strikes or entanglement. In response to the increasing numbers of humpback whale strandings along the Atlantic coast from Maine through North Carolina, NMFS declared an Unusual Mortality Event in 2016. Strandings involved primarily juvenile whales and occurred in all seasons, but were most common in the spring.

The 2018 NMFS stock assessment for the Gulf of Maine stock of humpback whales reported a count of 896 individuals as the minimum number alive in 2015 (NMFS, 2019a). Current data suggest that the Gulf of Maine humpback whale stock is steadily increasing in numbers (NMFS, 2018a). This is consistent with an estimated average growth trend of 3.1 percent (standard error = 0.005) in the North Atlantic population overall for the period 1979 to 1993 (Stevick et al., 2003).

Because the results of recent tracking studies (see Table 2) document the occurrence of humpback whales in the project area, this species is carried forward for quantitative analysis.

1.1.3.4 Bottlenose Dolphin

Bottlenose dolphins are the most abundant marine mammal species encountered in surveys and stranding reports on the coast off Virginia Beach, Virginia, and in the Chesapeake Bay near NAVSTA Norfolk, and Joint Expeditionary Base Little Creek-Fort Story (Barco & Swingle, 2014; Engelhaupt et al., 2014; 2015; 2016). They occur in greatest numbers in this area annually from May through October. Densities in the nearshore zone were calculated as 3.88 individuals/square kilometer (sq km) in fall, 0.63 individuals/sq km in winter, 10 individuals/sq km in spring, and 3.55 individuals/sq km in summer. Bottlenose dolphins are also the most commonly stranded marine mammal in the state, with strandings mostly occurring from April through October, which corresponds to their abundance in shipboard surveys (Swingle et al., 2015). Barco and Swingle (2014) reported 1,593 strandings from 1988 to 2013, including an unusual mortality event that peaked in Virginia in 2013. Strandings in subsequent years ranged from 67 to 101 animals (Swingle et al., 2014; 2016; 2017; 2015).

The 2017 NMFS stock assessment for three bottlenose dolphin stocks that may be in the MPU project area reported an estimated abundance of 6,639 (CV = 0.41) for the Northern Migratory Coastal stock, 3,751 (CV = 0.60) for the Southern Migratory Coastal stock, and 823 (CV = 0.06) for the Northern North Carolina Estuarine System stock (NMFS, 2018a). An analysis of trends in abundance for common bottlenose dolphins coast-wide from New Jersey to Florida indicated a statistically significant decline in population size between 2011 and 2016 (Garrison et al., 2017), which may be a result of the unusual mortality event that occurred during 2013–2015.

Because results of recent studies (see Table 2) document the regular occurrence of bottlenose dolphins in the project area, this species is carried forward for quantitative analysis.

1.1.3.5 Harbor Porpoise

Reports from marine mammal surveys in Chesapeake Bay in the vicinity of NAVSTA Norfolk and the nearshore off Virginia Beach mention one sighting of a group of two harbor porpoises in 2015 (Engelhaupt et al., 2016), and passive acoustic recorders detected the species in low numbers near NAVSTA Norfolk and Joint Expeditionary Base Little Creek during winter and spring deployments from August 2012 to September 2013 (Engelhaupt et al., 2014). Stranding reports from 2004 to 2013 cite 89 harbor porpoise strandings along the mouth of the Chesapeake Bay and ocean-facing beaches on the Virginia Beach coastline (Barco & Swingle, 2014). Subsequent stranding reports from Virginia cite from one to five strandings annually from 2014 through 2018 (Swingle et al., 2015; 2016; 2017; 2018; Costidis et al., 2019). All of these reports indicate that harbor porpoises are most likely to be present in the region in winter and spring months, and observations of the species off the coasts of Maryland (Wingfield et al., 2017) and New Jersey (Whitt et al., 2015) support this finding.

Stranding reports discuss wide historic fluctuations in harbor porpoise strandings in Virginia, ranging from 40 porpoises in 1999 and 30 in 2001 to 2 each in 2011 and 2012 (Costidis et al., 2019), and 5 or fewer from 2014 to 2018 (Swingle et al., 2015; 2016; 2017; 2018; Costidis et al., 2019). These fluctuations in stranding numbers have not been correlated to fluctuations in population or stock abundance, threats such as potential fisheries bycatch, or other factors.

The 2018 NMFS stock assessment for the Gulf of Maine/Bay of Fundy stock reported an estimated abundance of 79,883 (CV = 0.32) (NMFS, 2019a). A trend analysis has not been conducted for this stock.

Because the results of recent studies (see Table 2) detected the presence of harbor porpoises in the project area, this species is carried forward for quantitative analysis.

1.1.3.6 Harbor Seal

Harbor seals are the most common pinnipeds in Virginia, and haul out on rocks around the portal islands of the Chesapeake Bay Bridge Tunnel and on mud flats on the nearby southern tip of the Eastern Shore from December through April. Surveys at the Chesapeake Bay Bridge Tunnel haulout sites recorded 112 harbor seal sightings during the 2014–2015 season, 186 sightings during the 2015–2016 season, 308 sightings during the 2016–2017 season, and 340 sightings during the 2017–2018 season (Rees et al., 2016; Jones et al., 2018). The Eastern Shore site had a best total estimate of 105 sightings during the 2015–2016 season and 196 sightings during the 2017–2018 season (Jones et al., 2018).

Harbor seals strand in low numbers on the coast of Virginia and Chesapeake Bay. From 1988 to 2013, 82 strandings were reported (Barco & Swingle, 2014), and in the following years from 1 to 4 stranded harbor seals were reported each year (Swingle et al., 2015; 2016; 2017; 2018; Costidis et al., 2019).

The 2018 NMFS stock assessment for the Western North Atlantic stock reported 75,834 (CV = 0.15) (NMFS, 2019a). This stock is present primarily in U.S. waters. Several researchers consider that harbor and gray seal distribution along the U.S. Atlantic coast appears to be expanding or shifting (DiGiovanni et al., 2011; DiGiovanni Jr. et al., 2018; Johnston et al., 2015). This range expansion may be due to rapid growth of gray seal populations in Canada and the Northeastern United States (Cammen et al., 2018). Count trend data for harbor and gray seals in southern New England and Long Island index sites from 1986 to 2011 indicate that harbor and gray seals are showing an increased use of their more southerly range and are extending their time spent at these haulout sites (DiGiovanni et al., 2011).

Because results of recent studies (see Table 2) document the occurrence of harbor seals in the project area, this species is carried forward for quantitative analysis.

1.1.3.7 Gray Seal

Haulout monitoring conducted during 2014–2015 and 2015–2016 at the Chesapeake Bay Bridge Tunnel reported only one individual for both survey seasons (Rees et al., 2016). Haulout monitoring conducted during 2016–2017 and 2017–2018 at the Chesapeake Bay Bridge Tunnel and the southern tip of the Eastern Shore of Virginia reported only one individual at the Eastern Shore for the 2017–2018 season (Jones et al., 2018).

Gray seals strand in low numbers on the coast of Virginia and the Chesapeake Bay. From 1988 to 2013, 15 strandings were reported (Barco & Swingle, 2014), and in the following years from 0 to 4 stranded gray seals were reported each year (Swingle et al., 2015; 2016; 2017; 2018; Costidis et al., 2019).

The 2018 NMFS stock assessment for the Western North Atlantic stock reported 27,131 (CV = 0.19) in U.S. waters (NMFS, 2019a). An additional portion of the stock occurs in Canadian waters. Gray seal abundance is likely increasing in U.S. and Canadian waters (NMFS, 2019a).

Because results of recent studies (see Table 2) document the occurrence of gray seals in the project area, this species is carried forward for quantitative analysis.

1.1.3.8 West Indian Manatee

The Florida subspecies of the West Indian manatee occurs primarily on the west and east coasts of Florida (Hostetler et al., 2018). The most recent Florida statewide population estimate is 8,810. This stock could potentially occur in the MPU project area, given their preference for inshore and coastal marine, brackish, and freshwater habitats. They have been reported between June and October, usually when water temperatures exceeded 20° Celsius (°68 Fahrenheit), along the coasts of North Carolina and Virginia (Cummings et al., 2014). In Virginia, the majority of sightings were reported from Virginia Beach into Chesapeake Bay in rivers and creeks, open ocean, and sounds and bays. From 1991 to 2012, 112 manatee sightings and nine strandings were reported from various sources (Cummings et al., 2014). More recent shipboard surveys, monitoring efforts, and stranding reports (see the list of citations in Table 2) in the MPU project area have not reported any manatee detections. One manatee sighting was reported on the shoreline at Virginia Beach in the summer of 2019 (Virginian-Pilot, 2019).

This species is under the purview of the USFWS for MMPA and ESA management and consultations. This species will be included in ESA consultations for this project. Although West Indian manatees have been reported in the Chesapeake Bay, their low likelihood of occurrence and lack of documented acoustic thresholds results in this species not being carried forward for quantitative analysis.

1.2 Species Threshold Criteria

The following sections discuss threshold criteria that will be applied to the analysis of pile driving effects for species listed in Section 1.1 (Federal Special Status to Be Included in Analysis) with the potential to be affected by the proposed projects. The following underwater sound metrics are used for these criteria:

- peak sound pressure level (SPL) in decibels referenced to 1 micropascal (dB re 1 μPa)
- root mean square (RMS) SPL in dB re 1 μPa

- sound exposure level (SEL) in dB re 1 µPa-squared per second (dB re 1 $\mu Pa^2 sec$)
- cumulative sound exposure level (SEL_{CUM}) in dB re 1 $\mu Pa^2 sec$

Airborne sound criteria are described as dB RMS SPL referenced to 20 µPa.

1.2.1 Thresholds for Analysis of Hydroacoustic Effects to Fish from Pile Driving

The analysis of hydroacoustic effects of pile driving on fish will use threshold criteria recommended by Popper et al. (2014) based on their review of available data associated with fish and pile driving. The data used to set the criteria were from controlled experiments that mimicked pile driving on several fish species that varied in body type, swim bladder configuration, and internal morphologies. Based on swim bladder characteristics, guidelines for peak (dB Peak SPL) and SEL_{CUM} (dB SEL_{CUM}) noise sources were developed for mortality, recoverable injury (the lowest level where injury was found), and the onset of temporary threshold shift (TTS). Table 3 lists impact pile driving guidance for recoverable injury and the onset of TTS. The ESA-listed sturgeon species in the project area have swim bladders but no known swim bladder-associated structures in the auditory system that would enhance hearing. However, calculations will utilize criteria for fish with a swim bladder involved in hearing. The recoverable injury criterion uses one of two metrics; depending on results of transmission loss modeling for the proposed pile driving projects, the worst-case scenario (i.e., the metric that results in the largest zone of influence [ZOI]), will be selected for the effects analysis.

Table 3 Fish Impact Pile Driving Injury and Temporary Threshold Shift Guidance

Fish Category	*Recoverable Injury*[a, b]	*Temporary Threshold Shift*
No swim bladder	>216 dB SEL_{CUM}[c] or >213 dB Peak SPL	>186 dB SEL_{CUM}[c]
Swim bladder not involved in hearing (particle motion detection)	203 dB SEL_{CUM}[c] >207 dB Peak SPL	>186 dB SEL_{CUM}[c]
Swim bladder involved in hearing (primarily pressure detection)	203 dB SEL_{CUM}[c] >207 dB Peak SPL	186 dB SEL_{CUM}[c]

Source: (Popper et al., 2014)
Key: dB = decibels; SEL_{CUM} = cumulative sound exposure level; SPL = sound pressure level.
Notes:
a. Peak SPLs (dB Peak SPL) are referenced to 1 micropascal, and cumulative SEL (dB SEL_{CUM}) levels are referenced to 1 micropascal-squared per second.
b. Dual metric acoustic thresholds for impulsive sounds: Whichever results in the largest isopleth for calculating injury is used in the analysis.
c. Cumulative sound exposure level over 24 hours.

Noise levels from in-water activities not involving pile driving will typically not exceed existing underwater sound levels resulting from existing routine waterfront operations in the vicinity of any of the proposed project locations. Therefore, distances to thresholds will only be calculated for pile driving. Moreover, since vibratory pile drivers typically generate noise levels from 10 to 20 dB lower than impact pile drivers and do not produce waveforms with sharp rise times like impact drivers, injurious impacts on fish are typically not observed with vibratory pile driving (Washington State Department of Transportation, 2018). Therefore, distances to injury and TTS thresholds will only be calculated for impact pile driving.

There is little data on the behavioral response of fish to loud sounds in general (NMFS, 2015) and to pile driving specifically (Popper et al., 2014). The NMFS, in some but not all of their Biological Opinions addressing underwater sound, has used a fish behavioral threshold criteria of 150 dB RMS SPL. This threshold recommends a "safe limit" of fish exposure, meaning where no injury would be expected to occur, rather than a behavioral response (NMFS, 2018b). However, this threshold is not supported by the 2014 *ANSI Sound Exposure Guidelines*, and the scientific basis for it has not been documented (Popper et al., 2019). In addition, none of the current research available on fish behavioral response to sound makes recommendations for a behavioral threshold (NMFS, 2018b). As a result, without additional information supporting a behavioral threshold, the Navy does not find it appropriate to include this sound level as a threshold.

1.2.2 Thresholds for Analysis of Hydroacoustic Effects to Sea Turtles from Pile Driving

The analysis of hydroacoustic effects of pile driving on sea turtles will use 204 dB SEL as the injury threshold criterion, based on recommendations discussed in the Navy's *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)* (Navy, 2017a). For behavioral disturbance, the threshold will be 175 dB RMS SPL (Navy, 2017a). These criteria will be applied to all sea turtle species included in the analysis for the proposed pile driving projects.

1.2.3 Thresholds for Analysis of Hydroacoustic Effects to Marine Mammals from Pile Driving

The analysis of hydroacoustic effects of pile driving on marine mammals will use threshold criteria developed by NMFS based on a review of studies of hearing sensitivity of marine mammals (NMFS, 2018c). NMFS placed marine mammals into functional hearing groups (FHGs) based on their generalized hearing sensitivities. For example, the bottlenose dolphin is in the mid-frequency FHG with a generalized hearing range from 150 hertz (Hz) to 160 kilohertz.

NMFS (2018c) developed acoustic threshold levels for determining the onset of permanent hearing threshold shift (PTS) in marine mammal FHGs in response to underwater impulsive and non-impulsive sound sources (Table 4). The criteria use cumulative SEL metrics (dB SEL_{CUM}) and peak SPL (dB Peak SPL). NMFS equates the onset of PTS, which is a form of auditory injury, with Level A harassment under the MMPA and "harm" under the ESA. Behavioral disturbance threshold criteria listed in Table 4 have been generally accepted for underwater acoustic impacts analyses by NMFS (2005) and are based on literature reviews by Southall et al. (2007).

Airborne noise would have little impact on cetaceans because noise from airborne sources does not transmit as well under water (Richardson et al., 1995); thus, airborne noise would only be a potential problem for hauled-out pinnipeds near pile driving locations. Pinnipeds are not expected to be hauled-out in the project area but could be swimming in waters affected by elevated noise levels. NMFS has identified behavioral harassment threshold criteria for airborne noise generated by pile driving for pinnipeds regulated under the MMPA. Level A injury is unlikely due to airborne noise, and threshold criteria have not been established. The in-air acoustic threshold for harbor seal Level B behavioral harassment is 90 dB RMS SPL referenced to 20 micropascals (unweighted). For non-harbor seal pinnipeds the in-air acoustic threshold for Level B behavioral harassment is 100 dB RMS SPL referenced to 20 micropascals (unweighted).

Table 4 Injury and Disturbance Threshold Criteria for Underwater and Airborne Noise for Marine Mammals

Marine Mammals	***Airborne Noise (Impact and Vibratory Pile Driving) (re 20 µPa)[a, b]***	***Underwater Vibratory Pile Driving Noise (Non-impulsive Sounds) (re 1 µPa)[b]***		***Underwater Impact Pile Driving Noise (Impulsive Sounds) (re 1 µPa)***	
	Disturbance Guideline (Haulout)[c]	***PTS Onset (Level A) Threshold***	***Level B Disturbance Threshold***	***PTS Onset (Level A) Threshold[d]***	***Level B Disturbance Threshold***
Low-frequency cetaceans	Not applicable	199 dB SEL_{CUM}[e]	120 dB RMS SPL	219 dB Peak SPL[f] 183 dB SEL_{CUM}[e]	160 dB RMS SPL
Mid-frequency cetaceans	Not applicable	198 dB SEL_{CUM}[e]	120 dB RMS SPL	230 dB Peak SPL[f] 185 dB SEL_{CUM}[e]	160 dB RMS SPL
High-frequency cetaceans	Not applicable	173 dB SEL_{CUM}[e]	120 dB RMS SPL	202 dB Peak SPL[f] 155 dB SEL_{CUM}[e]	160 dB RMS SPL
Phocidae	Harbor Seal - 90 dB RMS SPL (unweighted) Gray Seal - 100 dB RMS SPL (unweighted)	201 dB SEL_{CUM}[e]	120 dB RMS SPL	218 dB Peak SPL[f] 185 dB SEL_{CUM}[e]	160 dB RMS SPL

Key: dB = decibels; PTS = permanent threshold shift; re 1 µPa = referenced to 1 micropascal; re 20 µPa = referenced to 20 micropascals; RMS = root mean square; SEL_{CUM} = cumulative sound exposure level; SPL = sound pressure level.

Notes:

a. Airborne disturbance thresholds not specific to pile driver type.

b. Underwater peak sound pressure levels (dB Peak SPLs) are referenced to 1 µPa and cumulative SEL (dB SEL_{CUM}) levels are referenced to 1 μPa^2sec. Airborne levels are referenced to 20 µPa.

c. Sound level at which pinniped haulout disturbance has been documented. This is not considered an official threshold but is used as a guideline.

d. Dual metric acoustic thresholds for impulsive sounds: Whichever results in the largest isopleth for calculating PTS onset is used in the analysis.

e. Cumulative sound exposure level over 24 hours.

f. Flat weighted or unweighted peak sound pressure level within the generalized hearing range.

1.3 Proxy Source Levels for Pile Driving

Proposed pile driving projects were identified by NAVSTA Norfolk engineering staff and are presented in Table 5 (fender pile replacement), Table 6 (new piers construction), and Table 7 (new piers fender pile replacements). Locations, pile types, driving method and any best management practices are also presented.

Best-fit/matching proxy source levels for these pile driving projects were obtained from *Pile Driving Noise Measurements at Atlantic Fleet Naval Installations* (Navy, 2017b) and other sources as appropriate, e.g., California Department of Transportation (2015) *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, Appendix 1 Compendium of Pile Driving Sound Data*.

Table 5 Fender Pile Types and Maximum Number to be Replaced at Each Location

Location	*Pier/Bulkhead*	*Existing Pile Types to Be Removed*		*Pile Types to Be Installed*	
		No.	*Type*	*No.*	*Type*
NAVSTA Norfolk Piers	Pier 1	385	12-inch timber	287	16-inch composite[1]
	Pier 09	533	12-inch timber	330	16-inch composite
	Pier 10	535	12-inch timber	330	16-inch composite
	Pier C	172	12-inch timber	80	16-inch composite
	Pier D	358	12-inch timber	108	16-inch composite
	Pier E	275	12-inch timber	108	16-inch composite
	Pier F	180	12-inch timber	88	16-inch composite
	Pier 12	100	12-inch timber	140	16-inch composite
	Pier 14	100	12-inch timber	45	16-inch composite
DFSP Craney Island	Pier Charlie	272	12-inch timber	258	16-inch composite
Lambert's Point Deperming Station	Pier A - Timber Dolphin	17	12-inch timber	17	16-inch composite
	Pier B	12	12-inch timber	12	16-inch composite

Key: DFSP = Defense Fuel Supply Point; NAVSTA = Naval Station; No. = number/amount.
Notes:
1. Composite piles may be solid high-density polyethylene plastic (HDPE plastic) or hollow core fiberglass.

Table 6 New Pier Construction Load-Bearing Piles, Maximum Number at Each Location

Location	*Existing Pile Types to Be Removed*		*Pile Types to Be Installed*	
	No.	*Type*	*No.*	*Type*
MWR Marina	50	12-inch timber	50	24-by-24-inch square pre-stressed concrete
V-Area	N/A	N/A	50	24-by-24-inch square pre-stressed concrete

Key: MWR = Morale, Welfare, and Recreation; NA = not applicable; No. = number/amount.

Table 7 New Pier Construction Fender/Guide Piles, Maximum Number to be Replaced at Each Location

Location	*Existing Pile Types to Be Removed*		*Pile Types to Be Installed*	
	No.	*Type*	*No.*	*Type*
MWR Marina	50*	12-inch timber*	50*	16-inch composite*
	40**	16-inch composite**	40**	16-inch composite**
V-Area	NA*	N/A*	50*	16-inch composite*
	40**	16-inch composite**	40**	16-inch composite**

Key: MWR = Morale, Welfare, and Recreation; NA = not applicable; No. = number/amount.
Notes:
* Initial upgrade/construction
**Maintenance replacements over 5-year project span (10 piles per year at each location)

1.4 Representative Pile Driving Sites for Acoustic Transmission Loss Modeling

Pile driving acoustic transmission loss will be modeled at six representative pile driving sites; near the seaward ends of Pier 3 and Pier 12, the Morale Welfare and Recreation Marina, and the V-Area at NAVSTA Norfolk (Figure 1); near the seaward end of Pier Charlie at Defense Fuel Supply Point Craney Island; and at Lambert's Point Deperming Station (Figure 2). Representative pile driving sites are located near the seaward ends of piers in order to model a conservative scenario for pile driving at each location.

1.5 Acoustic Transmission Loss Model

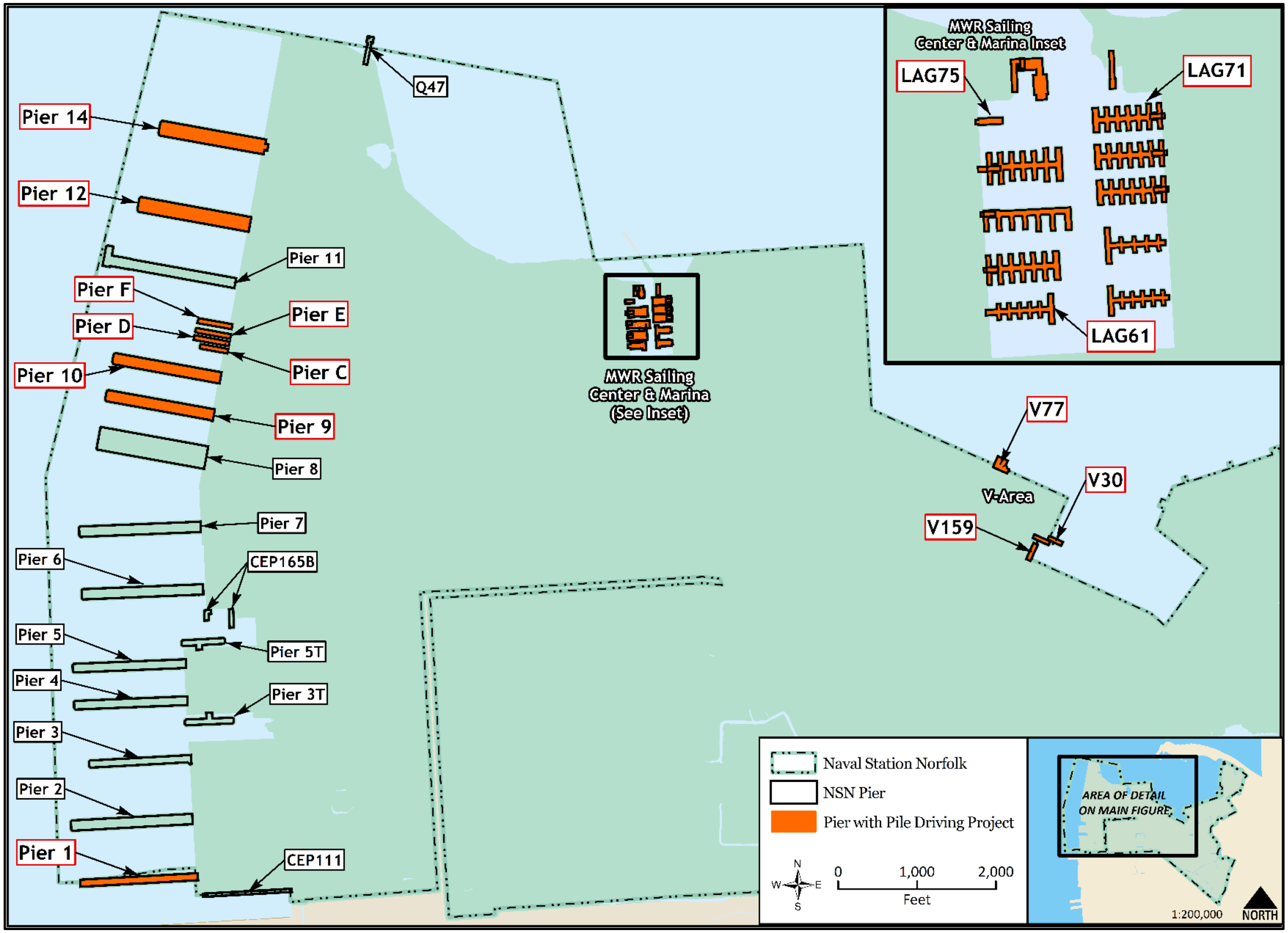
This section was prepared by P. H. Dahl and D. R. Dall'Osto of the University of Washington, Applied Physics Laboratory.

1.5.1 Model Overview

The following is an overview of the acoustic noise transmission loss model. A detailed description of the model is provided in Section 1.5.2 (Detailed Model Description).

1. At a given pile location, the wetted length for any pile equals the water depth.
2. The entire wetted length of the pile is assumed to transmit sound equally for all positions within this pile length span. The sound sources combine to form an incoherent line source of sound. This produces a more smoothed acoustic field, with strong spatial variation being averaged out.
3. For a given frequency, sound propagation over a transect for the incoherent line source is computed using the method of normal modes [2]. Sound propagation depends on both frequency and the changing bathymetric conditions of any particular transect.
4. To account for pile types (e.g., concrete, timber, or composite), frequencies are weighted by the corresponding third-octave spectrum for that pile type, normalized to the maximum value, and then summed.
5. A depth-average is then taken such that the final result gives sound propagation loss as a function of range (normalized to 10 meters, e.g., propagation loss at 10 meters is 0 dB). This calculation is undertaken at each pile source location in 1 degree increments.
6. A 10-meter proxy source value is then applied, such as 176 dB referenced to 1 µPa for RMS SPL and 189 dB referenced to 1 µPa for peak sound pressure level for a 24-inch square concrete pile. ZOI analysis can then be undertaken.
7. The above steps are also undertaken for modeling SEL. Marine mammal FHG weightings apply to Level A PTS thresholds based on SEL, and corresponding SEL_{CUM}. This requires a modification of the frequency content (depending on FHG).

2 The method of normal modes is a standard means to compute the acoustic pressure field in an underwater waveguide (a physical structure for guiding sound waves) that is bounded by the sea surface and seabed. It is particularly applicable to the case of pile driving where the frequencies are generally low and the water depth shallow.



Key: MWR – Morale, Welfare, and Recreation; NSN = Naval Station Norfolk

Figure 1 Naval Station Norfolk Piers

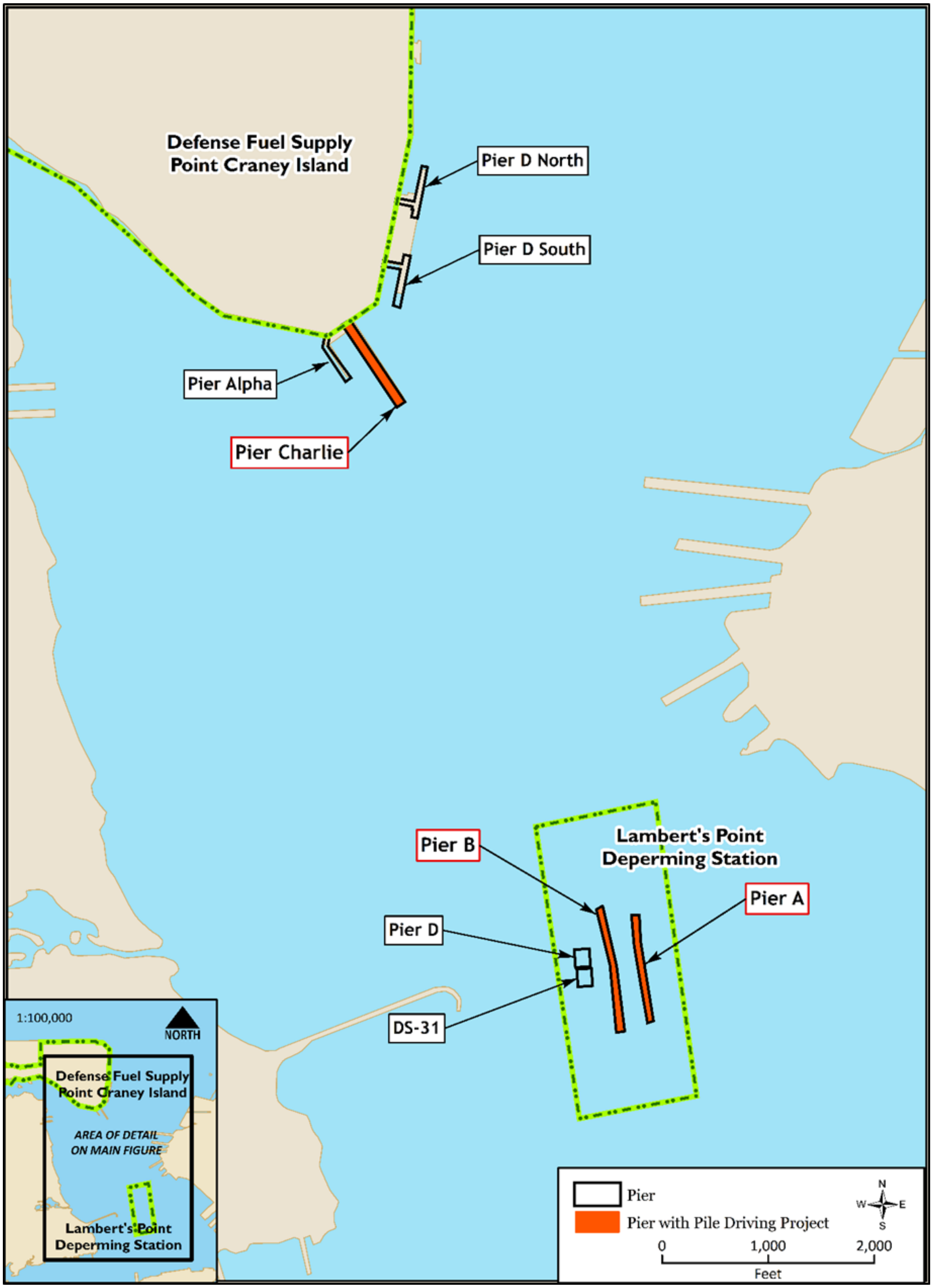
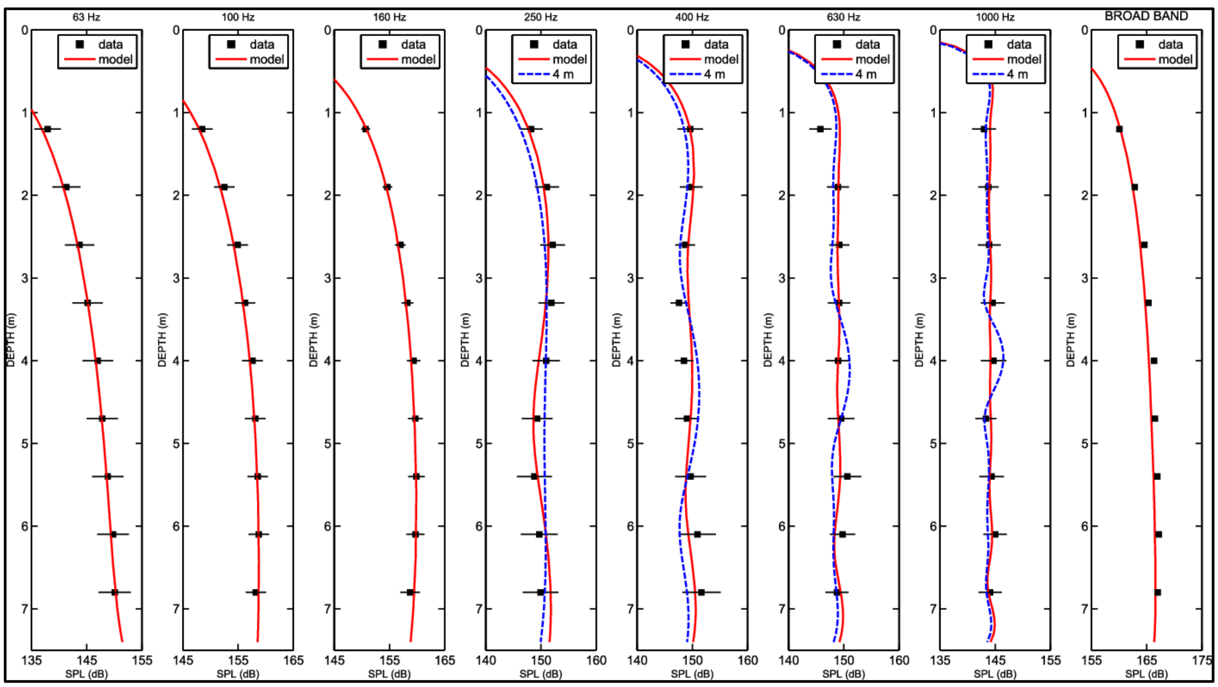


Figure 2 Craney Island Fuel Depot and Lambert's Point Deperming Station

1.5.2 Detailed Model Description

The approach to modeling acoustic transmission loss was based on approaches outlined in Dahl, Dall'Osto, and Farrell (2015), and Dall'Osto and Dahl (2017). Other approaches, e.g., Lippert, Ainslie, and von Estorff (2018), share some similarities but are not used because of the significant bathymetric variation associated with the project area.

For this model, the general method involves representing the wetted length of the pile as a line distribution of sound sources, with the line source length corresponding to water depth at the pile location. This current approach differs slightly from Dahl et al. (2015). It first evaluates the acoustic normal mode functions; however, these functions are added together incoherently, or without regard to the phase of each mode function. This allows for the simplifying assumption of uniform excitation over the length of the line source, rather than computing individual sources separately. The accuracy of this approach is confirmed by the matching of modeled curves with empirical data as detailed in Dahl et al. (2015) (see Figure 3, below).

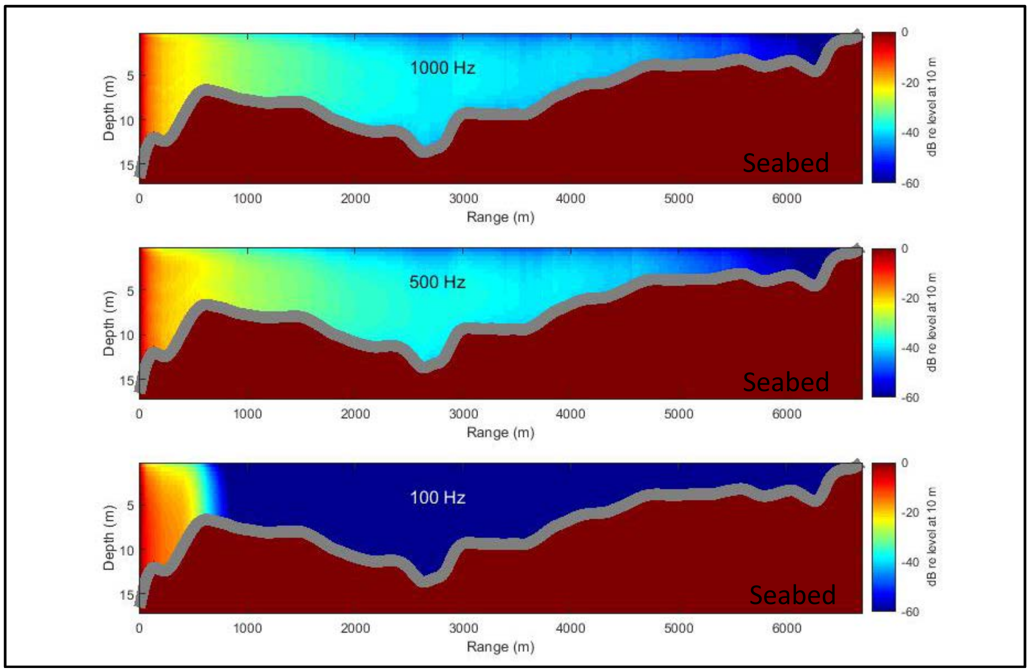


Key: dB = decibels; Hz = hertz; m = meters; SPL = sound pressure level.
Notes: First seven plots left to right: Third-octave band mean-square pressure in dB re 1 µPa versus measurement depth (symbols) with band center frequency identified. Solid lines are computed results. For comparison only, results based on an incoherent sum of modes from a point source at depth of 4 meters (dashed lines) are shown for 250, 400, 630, and 1000 Hz; lower frequencies results are less distinguishable from the incoherent line source model. Right-most plot: broadband mean-square pressure based on the linear summation of the 16 third-octave bands at 63–2000 Hz with corresponding incoherent line source model.

Figure 3 Model Curves for Each Third-Octave Band from Dahl et al. (2015)

This approach is taken for each pile type regardless of pile composition (e.g., timber or concrete) with the influence of pile type, and noise metric (e.g., peak SPL or SEL) subsequently added to the final result in terms of a calibration factor based on correspondingly measured pile data taken at 10 meters from the pile. This means both impact and vibratory pile driving are treated in the same manner, apart from the measured pile data applied at range 10 meters because the goal is in modeling the averaged transmission or propagation loss. Thus, for example, the detailed, pressure waveform simulations given by Dahl and Dall'Osto (2017) associated with the Mach wave[3] from impact pile driving would necessarily be averaged out over range and provide little additional information.

As described in Dahl et al. (2015), the complex pressure field, $p(r,z;f)$ at acoustic frequency, f, range, r, and receiver depth, z, is computed using adiabatic mode theory[4] which allows for and accommodates gradual changes in depth as a function of range from the pile. It is the magnitude square of this quantity, $|p(r,z;f)|^2$, that is ultimately used and computations are limited to the frequencies corresponding to the one-third octave band center frequencies that correspond to one-third octave spectra obtained from pile driving noise measurements made at Atlantic Fleet installations from 2013-2016 (Navy, 2017b). These one-third octave spectra differ depending on pile type, and the accommodation of such differences, including the frequency dependency associated with different marine mammal weightings, is discussed subsequently. Next we illustrate (Figure 4) the behavior of $|(r,z;f)|^2$ for three representative third-octave band center frequencies, f, at 100 Hz, 500 Hz and 1000 Hz, for a *notional* transect meant to represent depth versus range conditions around the Norfolk installation sites.



Key: dB = decibels; Hz = hertz; m = meters; re = referenced to.
Note: The field is from an incoherent sum of uniformly excited modes.

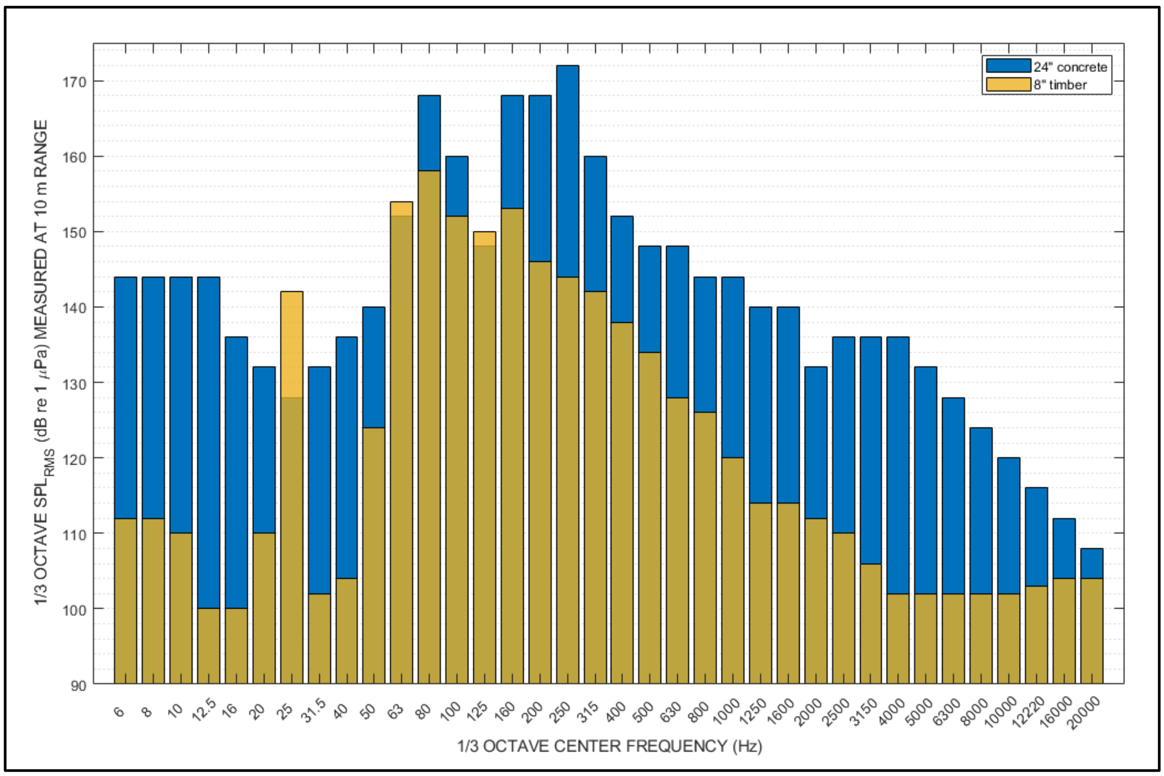
Figure 4 Pressure Magnitude Squared Field (Expressed in Decibels [dB]) for Three Acoustic Frequencies as a Function of Range and Depth over a Notional Depth versus Range Transect associated with the Norfolk Installation Sites

[3] The dominant underwater noise from impact driving is from the Mach wave associated with the radial expansion of the pile that propagates down the pile after impact at supersonic speed.

[4] Normal mode functions apply to a given frequency, seabed condition and water depth. In the event the latter changes reasonably slowly with range, separate mode functions can be computed and the technique of blending of such functions for different ranges is associated with adiabatic mode theory. Adiabatic mode theory is utilized for pile driving applications in Dahl et al. (2015), and further information is found in references therein.

Figure 5 shows examples of weighting functions for two piles data (extracted by the University of Washington team) as originally published in Navy (2017b) (p. Figure B9 [concrete] and B10 [timber]). For the concrete piles maximum third-octave band spectrum level is 172 dB at 250 Hz, and the next highest level is 168 dB at frequencies 80 Hz, 160 Hz and 200 Hz, or 4 dB lower than the highest level.[5] Thus, at 250 Hz we identify a spectral weighting, *S(f)*, equal to 1 (corresponding to 0 dB), whereas at 80, 160 and 200 Hz, *S(f)* equals 0.398 (corresponding to – 4 dB). This inventory is continued for all third-octave center frequencies; for example at 1000 Hz the level is 144 dB or 28 dB lower than the highest level, setting *S(f)* equals 0.0016 and thus it is anticipated that frequencies in the neighborhood of 1000 Hz contribute little to the overall acoustic field predicted at some range.

As a final step we multiply $<|(r,)|^2>$ by *S(f),* for the 36 third-octave center frequencies as shown in Figure 5, and add the results. For example, for concrete piles at *f*= 250 Hz, prior to such addition $<|p(r,f)|^2>$ is multiplied by 1, whereas at *f*= 1000 Hz, $<|p(r,f)|^2>$ is multiplied by 0.0016 (In practice the first six frequencies, up to about 40 Hz, add very little to the final sum given that $<|p(r,f)|^2>$ for frequencies less than about 40 Hz significantly reduces the contribution for this frequency range).

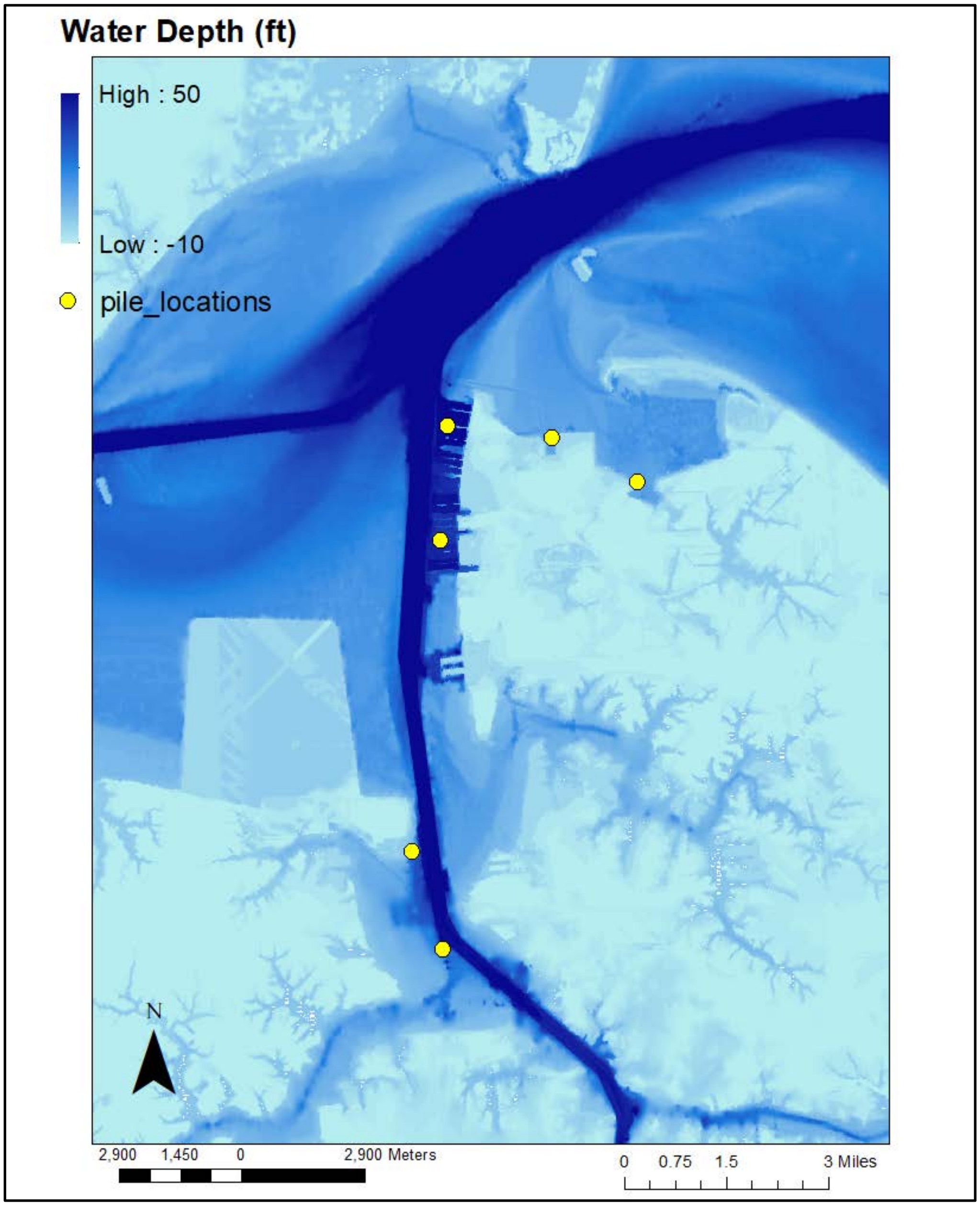


Key: " = inches; dB re 1 μPa = decibels referenced to 1 micropascal; Hz = hertz; m = meters; RMS = root mean square; SEL = sound exposure level; SPL = sound pressure level.

Figure 5 Third-Octave Band Spectra as Taken from Figure B9 (Concrete) and B10 (Timber) of the *Pile Driving Noise Measurements at Atlantic Fleet Naval Installations* (Navy, 2017b)

[5] As a reminder, the data in Figure 5 represent a third-octave spectrum and not a spectral density, thus frequency-dependent bandwidth at each center frequency has been accounted for. The total RMS sound pressure level is obtained through appropriate summation of the individual band levels as shown.

The above computation is undertaken for every transect that radiates away from the pile source location in increments of 1 degree, where each depth-range transects is extract from bathymetry map (Figure 6) covering the Norfolk installation site. The result will be range and transect (or azimuthal) dependent, however other more subtle effects such as diffraction or bending around land-forms or channeling, are accounted for. Therefore, an additional component representing such horizontal refraction phenomena is added using the approach outlined in Dall'Osto and Dahl (2017). This additional diffractive/three-dimensional (3D) modeling component is also frequency dependent.

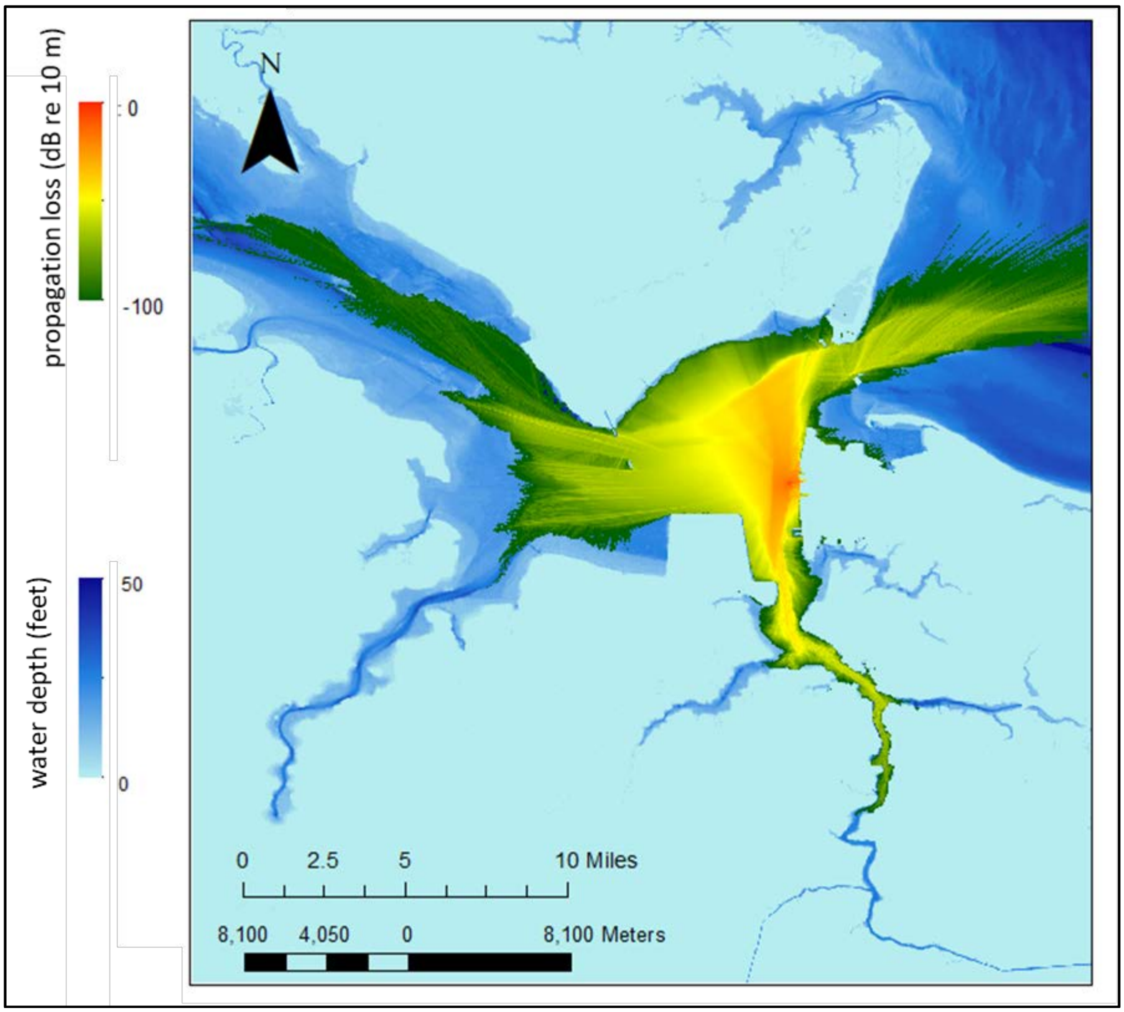


Key: ft = feet.

Figure 6 Six Pile Locations Representing Source Locations from which Acoustic Propagation Modeling is Undertaken

To model the field beyond an obstruction, a 3D propagation model is used to modify the Nx2D result for blocked-regions. (Such a result is often referred to as Nx2D, meaning the result is two-dimensional (2D) in range and depth, with the N referring to a different 2D result corresponding to a different azimuth as indexed by N). The 3D effects that carry sound into blocked regions relate predominately to propagation of the lowest mode, and blocked-regions from any given Nx2D result are filled with a numerical solution to the horizontal dependence of mode-1. Figure 7 shows final acoustic propagation loss as a function of Cartesian coordinates centered on the pile location, relative to range 10 meters from the pile source, such that propagation loss at range 10 meters is by definition 0 dB. This figure now includes all key effects: those due to changing depth and those due to significant obstructions of the acoustic path, both being dependent upon frequency.

Figure 7 represents a preliminary step towards estimating range-dependent isopleths delineating the particular ZOI for marine mammal impact assessment. The following section outlines this final step towards generating relevant isopleths.



Key: dB = decibels; m = meters; re = referenced to.

Figure 7 Example of Depth Averaged Propagation Loss in Decibels (Referenced to a Range of 10 Meters) for Pier 3

Continuing with the concrete pile case, Table 13 of *Pile Driving Noise Measurements at Atlantic Fleet Naval Installations* (Navy, 2017b) identifies 10-meter data for RMS SPL as 176 dB re 1 μPa, peak SPL as 189 dB re 1 μPa, and SEL[6] as 163 dB re 1 μPa^2sec. Thus, these values are applied at range 10 meters, and the propagation modeling then estimates the corresponding value at some farther range and azimuth from the pile source. For example, the green-colored areas in Figure 7 indicate a propagation loss of approximately 100 dB, and thus we estimate a peak SPL of 189-100 or 89 dB re 1 μPa in such areas. A similar analysis can be applied to RMS SPL and SEL; additionally the SEL 10-meter value may be further modified by the total number of pile strikes to form SEL_{CUM}.

A summary of the 10-meter data used as sound proxy levels for this study along with sources of this data is provided in Table 8.

Table 8 Underwater Noise Source Levels Modeled for Underwater Impact and Vibratory Pile Driving Measured at a Range of 10 Meters

Pile Type	*Installation Method*	*Pile Diameter (inches)*	*RMS SPL (dB re 1 μPa)*	*Peak SPL (dB re 1 μPa)*	*SEL (dB re 1 μPa^2sec)*
24 in Square pre-stressed concrete	Impact hammer	24	176	189	163
16 in Composite	Impact hammer	16	165	177	157
	Vibratory driver	16	158	N/A	N/A
12 in Timber[1]	Vibratory driver[2]	12	158	N/A	N/A

Sources: Concrete: (Navy, 2017b), Table 13; Composite impact: (California Department of Transportation, 2015), Figure 17.2; Composite/timber vibratory: (Navy, 2017b), Table 6.
Key: dB re 1 μPa = decibels referenced to 1 micropascal; dB re 1 μPa^2sec = decibels referenced to 1 micropascal-squared per second; N/A = not applicable; RMS = root mean square; SEL = sound exposure level; SPL = sound pressure level.
Notes:
1. Source level for vibratory installation of timber piles was used for vibratory extraction.
2. For vibratory driving where SEL is not included in the table, SELcum = the RMS SPL value + 10log10(time), where time is the nominal duration for vibratory installation.

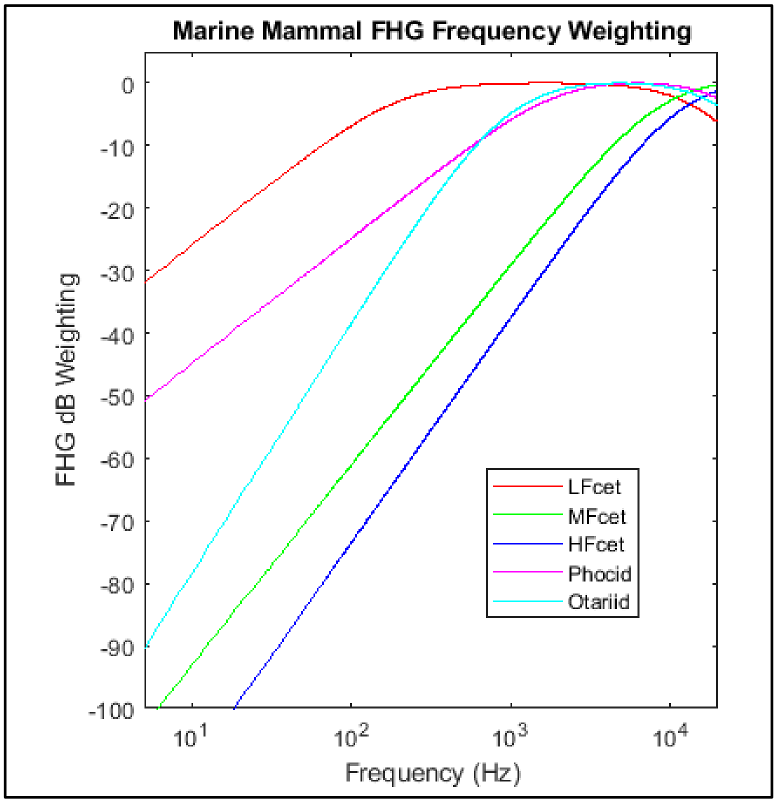
Several differing situations for determining marine mammal ZOI for Level B and A impacts can be now be assessed, upon applying the appropriate 10-meter pile source datum, in conjunction with some estimate of the spectral content for the particular pile, such as in timber versus concrete (Figure 5), as will be done in the following section.

However, there remains one additional element to the calculations which pertains to implementing the marine mammal FHG weightings, NMFS (2018c) replotted in Figure 8, where the abbreviations LFcet, MFcet and HFcet correspond to Low-Frequency, Mid-Frequency and High-Frequency cetacean FHG.

The marine mammal FHG weightings apply to Level A PTS thresholds based on SEL, and corresponding SEL_{CUM}. These FHG weightings do not apply to thresholds based on peak SPL, nor do they apply to Level

[6] This is a "single strike" SEL value. The cumulative strike value, or SEL_{CUM}, is generated by adding $10\log_{10}(N)$ where N is the number of strikes to the single strike value.

B (behavioral) thresholds corresponding to an RMS SPL of 120 or 160 dB re 1 μPa (for vibratory or impact driven pile, respectively).

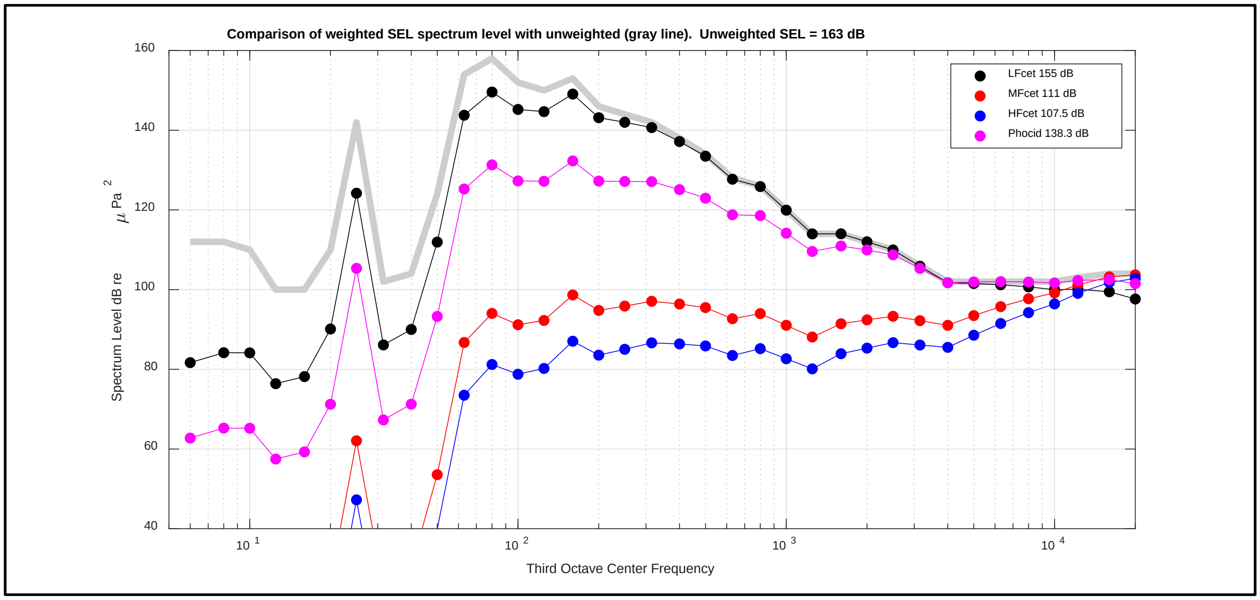


Key: dB = decibels; FHG = functional hearing group; HFcet = High-Frequency cetacean; Hz = hertz; LFcet = Low-Frequency cetacean; MFcet = Mid-Frequency cetacean; SEL = sound exposure level.

Figure 8 National Marine Fisheries Service Marine Mammal Functional Hearing Group Weighting as Function of Frequency

Referring again to the data third-octave spectrum for concrete piles from Figure 5 to illustrate the effect of marine mammal FHG weighting. In Figure 9, the unweighted spectrum levels are shown in the upper figure. (Note: the appropriate unweighted SEL 10-meter value from Table 13 of *Pile Driving Noise Measurements at Atlantic Fleet Naval Installations* (Navy, 2017b) equals 163 dB re μPa^{2}sec, thus the levels shown in Figure 9 are appropriately offset to match *Pile Driving Noise Measurements at Atlantic Fleet Naval Installations* (Navy, 2017b) Table 13). The lower figure shows the corresponding weighted spectra, and for the MFcet and HFcet there is a substantial reduction single SEL (119.5 and 113.7, respectively) owing to the influence of FHG weighting.

Application of the NMFS FHG weighting changes the calculations as follows: For un-weighted case, the data in Figure 9 indicates that *S(f)*, is set to 1 for 250 Hz and for 4000 Hz *S(f)* is < 1, insofar as the maximum unweighted spectrum level occurs at 250 Hz. However, for MFcet weighting, 4000 Hz is the prominent spectral band, and *S(f)* is set to 1, whereas for 250 Hz *S(f)* is now set just below 1. The net result is that MFcet FHG weighting significantly reduces the 10-meter values for SEL from the corresponding un-weighted levels, and ultimately tends to significantly reduce the ZOI associated for marine mammals within this FHG.



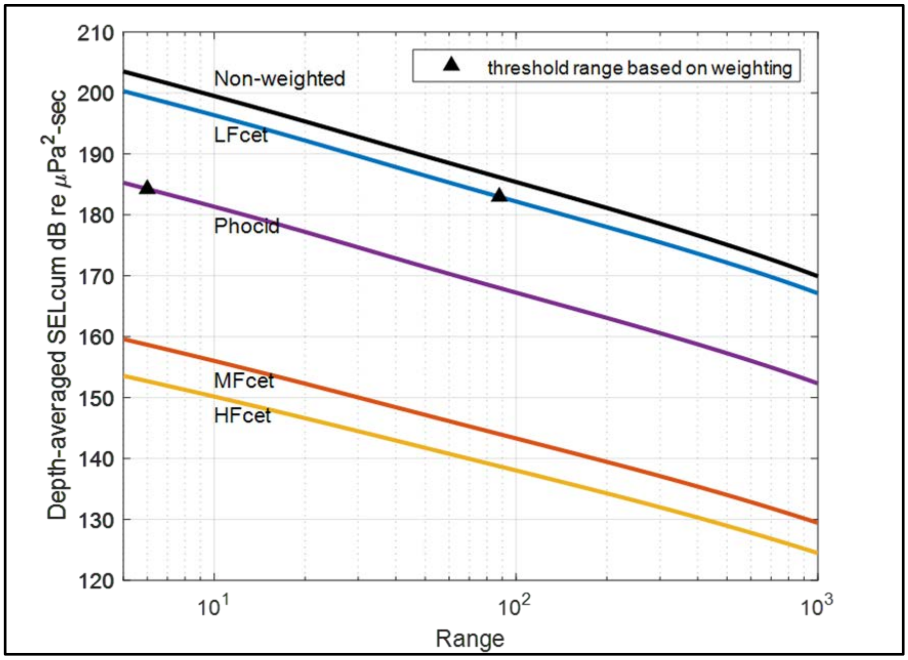
Key: dB re 1 μPa²sec = decibels referenced to 1 micropascal-squared per second; HFcet = High-Frequency cetacean; LFcet = Low-Frequency cetacean; MFcet = Mid-Frequency cetacean; SEL = sound exposure level.

Figure 9 Unweighted Sound Exposure Level (SEL) Spectrum Corresponding to Concrete Piles (Spectrum is Scaled Version of Figure 5) with Single Strike SEL Equal to 163 dB re 1 μPa²sec and Corresponding Spectra as Result of Application of Four of the Five National Marine Fisheries Service Marine Mammal Functional Hearing Group Weightings and Corresponding Weighted Single Strike SEL (see legend)

A simple demonstration of this effect is shown in Figure 10, based on the SEL data shown in Figure 9, and assuming 4,500 strikes of 24-inch concrete pile giving a non-weighted SEL_{CUM} of 199 dB re 1 μPa²sec at range 10 meters. The demonstration is not intended to represent the range-dependent modeling undertaken in this study, as this calculation assumes as constant water depth of 13 meters, but it does represent a kind of upper bound on ranges to thresholds that might apply to this study.

The PTS onset thresholds SEL_{CUM} from impulsive noise for the four marine mammal FHGs discussed here are as follows: LFcet (183), MFcet (185), HFcet (155) and Phocid (185), as given by Table ES3 in NMFS (2018c). In Figure 10, we observe that the PTS isopleth range for LFcet is about 90 meters when FHG weighting is applied and about 200 meters without FHG weighting. For the case of Phocid pinnipeds, the PTS isopleth range is 6 meters, and for MFcet and HFcet, this range is much less than 10 meters.

The acoustic loss transmission model described above was applied at the six representative sites for the impact and vibratory pile driving projects identified by NAVSTA Norfolk Department of Public Works. Project specifics including piles driven per day, number of pile strikes per pile (for impact driving), and duration of driving per pile (for vibratory driving) were also provided by Public Works personnel and used in the model. Bathymetry data used in the model consisted of a digital elevation model that merged the Virginia Beach, Virginia, One-third Arc-Second Mean High Water Coastal Digital Elevation Model (National Geophysical Data Center, 2007) with higher resolution data provided by NAVSTA Norfolk Department of Public Works that covered the NAVSTA Norfolk piers to produce a final merged raster. Areas (ZOIs) where the noise exceeded the threshold criteria specified in Section 1.2 (Species Threshold Criteria) were identified.



Key: dB re 1 µPa²sec = decibels referenced to 1 micropascal-squared per second; SEL = sound exposure level.
Note: Calculation is made following the procedure in this study but in this case applied to constant water depth of 13 meters.

Figure 10 Depth-Averaged Cumulative Sound Exposure Level (SEL_{CUM}) for Non-Weighted and Functional Hearing Group–Weighted Cases Based on a 10-Meter SEL_{CUM} of 199 dB re 1 µPa²sec

1.6 Marine Mammal Take Calculations

Generally, marine mammal take calculations will be modeled after the process used in the recent letter of authorization application for the Marine Structure Maintenance and Pile Replacement Program for Navy Region Northwest (Navy, 2018). Estimating exposure of marine mammal species to noise levels that exceed the threshold criteria will require the following tasks, as discussed in the subsections below.

1.6.1 Evaluate Potential Presence of Each Species

Table 1 and Table 2 list species that have the potential to occur in the proposed project area. Historical occurrence records, density information, and site-specific survey reports will be evaluated to determine the likelihood that any species could be exposed to pile driving noise from the proposed projects. Density sources will be the Navy's Marine Species Density Database Phase III (Navy, 2017c) and other recent survey reports from the NAVSTA Norfolk vicinity, e.g., Aschettino et al. (2018); Engelhaupt et al. (2016) and Rees et al. (2016). However, using a density-based analysis for species that occur infrequently at project locations does not adequately account for their unique temporal and spatial distributions.[7] For these species, historical occurrence and group size were reviewed, and species that

[7] In previous MMPA applications, a density based exposure analysis was required for intermittently occurring species. The analyses often resulted in zero exposure estimates. NMFS subsequently requested that future Navy

have a reasonable likelihood of exposure to pile driving at NAVSTA Norfolk locations were carried forward in the analysis. A discussion was provided for each species listed in Table 1 and Table 2 that justifies its inclusion or exclusion from the analysis.

1.6.2 Estimate the Area of Impact Where Noise Levels Exceed Acoustic Thresholds for Marine Mammals

See Section 1.5 (Acoustic Transmission Loss Model) for detailed discussion of modeling effort. For the marine mammal species carried forward in this analysis, the distances from pile driving sources to thresholds were calculated for each pile driver type, pile type and pile size (pile driving scenarios) associated with the proposed projects. The acoustic transmission loss models described in Section 1.5 (Acoustic Transmission Loss Model) were used to model distances to PTS onset and Level B disturbance using the criteria listed in Table 4. The ZOIs for each pile driving scenario were depicted in figures and tabular form.

1.6.3 Estimate Potential Exposures of Marine Mammal Species to Above-Threshold Noise Levels

Either of two formulas were used for this calculation, depending on the species' spatial and temporal occurrence:

- For species with rare or infrequent occurrence, the formula will be:

  (1) Exposure estimate = probable abundance during construction × probable duration,

where:

  probable abundance = maximum expected group size

  probable duration = probable duration of animal(s) presence at construction sites during in-water work window. In the Northwest Marine Structure Maintenance and Pile Replacement Letter of Authorization, duration was assumed to be 2 days, equivalent to a transit by a project site going in one direction and then back.

- For species with density estimates available for the proposed project area, the formula will be:

  (2) Exposure estimate = N × ZOI × maximum days of pile driving,[8]

where:

  N = density estimate used for each species

  ZOI = zone of influence, the area where noise exceeds the noise threshold value

The following assumptions were used to calculate potential exposures to impact and vibratory pile driving noise for each threshold:

Incidental Harassment Authorization applications for Puget Sound not use a density estimate for marine mammal species with a low likelihood of occurrence. Therefore, to obtain Incidental Harassment Authorization coverage for potential exposure to these animals for more recent projects such as the Northwest Marine Structure Maintenance and Pile Replacement, the Navy augmented the requested take based on historical frequency of occurrence, typical group size, and expected transit time through the project area.

[8] The product is rounded up to a whole number.

- For formula 2, each species is assumed to be present in the project area each day during pile driving, with possible adjustments based on seasonal occurrences. The time frame for takings would be one potential take (e.g., one Level B harassment exposure) per individual, per 24 hours.
- Pile extraction will utilize a vibratory pile driver with source levels similar to pile installation.
- For projects that do not have a pile type or size specified, the pile type, size, and installation/extraction method that produces the largest ZOI will be used to estimate exposure of marine mammals to noise impacts. For example, if piles may be concrete up to 24 inches for a particular project, the exposure analysis would assume that all of the piles would be 24-inch concrete.
- All pilings installed at each site will have an underwater noise disturbance distance equal to the pile that causes the greatest noise disturbance (generally the piling farthest from shore) installed with the method that has the largest ZOI. Underwater vibratory installation generally results in a larger ZOI than impact pile driving. ZOIs for impact hammer will likely be encompassed by larger ZOIs from vibratory drivers.
- Pile driving days for each project were provided by the Navy and included both pile extraction and installation.

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Appendix A
USFWS IPAC Report

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Virginia Ecological Services Field Office
6669 Short Lane
Gloucester, VA 23061-4410
Phone: (804) 693-6694 Fax: (804) 693-9032
http://www.fws.gov/northeast/virginiafield/

In Reply Refer To: December 19, 2018
Consultation Code: 05E2VA00-2019-SLI-1363
Event Code: 05E2VA00-2019-E-03090
Project Name: Marine Infrastructure Maintenance and Pile Driving Activities at Naval Station Norfolk

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Any activity proposed on National Wildlife Refuge lands must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 *et seq.*), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2) (c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries

12/19/2018 Event Code: 05E2VA00-2019-E-03090 1

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Virginia Ecological Services Field Office
6669 Short Lane
Gloucester, VA 23061-4410
(804) 693-6694

Project Summary

Consultation Code: 05E2VA00-2019-SLI-1363

Event Code: 05E2VA00-2019-E-03090

Project Name: Marine Infrastructure Maintenance and Pile Driving Activities at Naval Station Norfolk

Project Type: SHORELINE USAGE FACILITIES / DEVELOPMENT

Project Description: Conduct waterfront infrastructure maintenance and pile driving activities at Naval Station Norfolk over a 5-year period. Included Naval Station Norfolk, Craney Island Fuel Depot, and Lambert's Point Deperming Station.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/36.91622221305198N76.3377093468257W

Counties: Hampton, VA | Norfolk, VA | Portsmouth, VA

Endangered Species Act Species

There is a total of 0 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.

12/19/2018 Event Code: 05E2VA00-2019-E-03090 1

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

THERE ARE NO REFUGE LANDS OR FISH HATCHERIES WITHIN YOUR PROJECT AREA.

Appendix B
National Marine Fisheries Service Section 7 Mapper Results

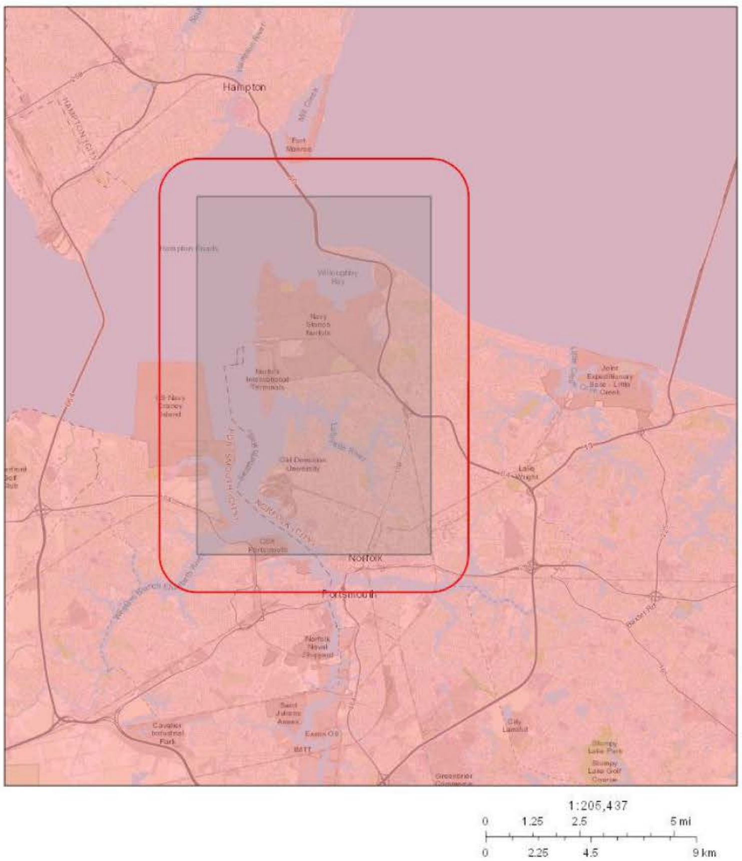
12/19/2018

Drawn Action Area & overlapping S7 Consultation Areas

Area of Interest (AOI) Information

Area : 59,925.26 acres

Dec 19 2018 16:30:39 Eastern Standard Time



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

1/3

12/19/2018

Summary

Name	Count	Area(acres)	Length(mi)
Atlantic Sturgeon	8	113,043.50	N/A
Shortnose Sturgeon	4	56,186.10	N/A
Atlantic Salmon	0	0	N/A
Sea Turtles	4	113,185.23	N/A
Atlantic Large Whales	5	39,454.20	N/A
In or Near Critical Habitat	0	0	N/A

Atlantic Sturgeon

#	Feature ID	Species	Life Stage	Behavior	Zone
1	ANS_JAM_SUB_MAF	Atlantic sturgeon	Subadult	Migrating & Foraging	James River
2	ANS_JAM_JUV_MAF	Atlantic sturgeon	Juvenile	Migrating & Foraging	James River
3	ANS_JAM_ADU_MAF	Atlantic sturgeon	Adult	Migrating & Foraging	James River
4	ANS_CHB_SUB_MAF	Atlantic sturgeon	Subadult	Migrating & Foraging	Chesapeake Bay
5	ANS_CHB_JUV_MAF	Atlantic sturgeon	Juvenile	Migrating & Foraging	Chesapeake Bay
6	ANS_CHB_ADU_MAF	Atlantic sturgeon	Adult	Migrating & Foraging	Chesapeake Bay
7	ANS_C50_SUB_MAF	Atlantic sturgeon	Subadult	Migrating & Foraging	N/A
8	ANS_C50_ADU_MAF	Atlantic sturgeon	Adult	Migrating & Foraging	N/A

#	From	Until	From (2)	Until (2)	Area(acres)
1	03/15	11/30	N/A	N/A	14,550.00
2	01/01	12/31	N/A	N/A	14,550.00
3	03/15	11/30	N/A	N/A	14,550.00
4	03/15	11/30	N/A	N/A	13,878.70
5	01/01	12/31	N/A	N/A	13,878.70
6	03/15	11/30	N/A	N/A	13,878.70
7	01/01	12/31	N/A	N/A	13,878.70
8	01/01	12/31	N/A	N/A	13,878.70

Shortnose Sturgeon

#	Feature ID	Species	Life Stage	Behavior	Zone
1	SNS_JAM_ADU_MAF	Shortnose sturgeon	Adult	Migrating & Foraging	James River
2	SNS_CHB_ADU_WIN	Shortnose sturgeon	Adult	Overwintering	Chesapeake Bay
3	SNS_CHB_ADU_MAF	Shortnose sturgeon	Adult	Migrating & Foraging	Chesapeake Bay
4	SNS_C50_ADU_MAF	Shortnose sturgeon	Adult	Migrating & Foraging	N/A

#	From	Until	From (2)	Until (2)	Area(acres)
1	01/01	12/31	N/A	N/A	14,550.00
2	11/01	02/28	N/A	N/A	13,878.70
3	01/01	12/31	N/A	N/A	13,878.70
4	04/01	11/30	N/A	N/A	13,878.70

Sea Turtles

2/3

12/19/2018

#	Feature ID	Species	Life Stage	Behavior	Zone
1	LTR_STS_AJV_MAF	Leatherback sea turtle	Adults and juveniles	Migrating & Foraging	Massachusetts (S of Cape Cod) through Virginia
2	LOG_STS_AJV_MAF	Loggerhead sea turtle	Adults and juveniles	Migrating & Foraging	Massachusetts (S of Cape Cod) through Virginia
3	KMP_STS_AJV_MAF	Kemp's ridley sea turtle	Adults and juveniles	Migrating & Foraging	Massachusetts (S of Cape Cod) through Virginia
4	GRN_STS_AJV_MAF	Green sea turtle	Adults and juveniles	Migrating & Foraging	Massachusetts (S of Cape Cod) through Virginia

#	From	Until	From (2)	Until (2)	Area(acres)
1	5/1	11/30	*No Data*	*No Data*	28,296.31
2	5/1	11/30	*No Data*	*No Data*	28,296.31
3	5/1	11/30	*No Data*	*No Data*	28,296.31
4	5/1	11/30	*No Data*	*No Data*	28,296.31

Atlantic Large Whales

#	Feature ID	Species	Life Stage	Behavior	Zone
1	RIT_WRS_AJV_MIG	North Atlantic right whale	Adults and juveniles	Migrating	Mid-Atlantic (Cape Cod, MA to VA)
2	FIN_WFS_AJV_MIG	Fin whale	Adults and juveniles	Migrating	Mid-Atlantic (Cape Cod, MA to VA)
3	FIN_WFS_AJV_WIN	Fin whale	Adults and juveniles	Overwintering	Mid-Atlantic (Cape Cod, MA to VA)
4	FIN_WFS_AJV_FOR	Fin whale	Adults and juveniles	Foraging	Mid-Atlantic (Cape Cod, MA to VA)
5	FIN_WFS_ADU_CLV	Fin whale	Adult	Calving	Mid-Atlantic (Cape Cod, MA to VA)

#	From	Until	From (2)	Until (2)	Area(acres)
1	1/1	12/31	*No Data*	*No Data*	7,890.84
2	1/1	12/31	*No Data*	*No Data*	7,890.84
3	11/1	1/31	*No Data*	*No Data*	7,890.84
4	1/1	12/31	*No Data*	*No Data*	7,890.84
5	10/1	1/31			7,890.84

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