Request for Incidental Harassment Authorization for Marine Mammals for the New Fortress Energy Louisiana FLNG Project

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ACRONYMS AND ABBREVIATIONS

°C	degree Celsius
µPa	microPascal
AHT	Anchor Handling Tug
AIS	Automatic Identification Systems
Applicant	New Fortress Energy Louisiana FLNG LLC
bbl	barrel
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
CV	coefficient of variance
dB	decibel
dB re 1 µPa	decibels referenced to 1 microPascal
DP	Dynamic Positioning
DSV	Dive Support Vessel
DWH	Deepwater Horizon
DWP	deepwater port
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FLNG1	A set of three self-elevating platforms comprising a Gas Treating Platform, a Liquefaction Platform, and a Utilities Platform
FLNG2	A set of three pile-supported platforms comprising a Gas Treating Platform, a Liquefaction Platform, and a Utilities Platform
FSU	Floating LNG Storage Unit
FWS	U.S. Fish and Wildlife Service
GOM	Gulf of Mexico
GoMMAPPS	Gulf of Mexico Marine Assessment Program for Protected Species
HF	high frequency
hp	horsepower
Hz	hertz
IHA	Incidental Harassment Authorization
kg	kilogram
kHz	kilohertz
Kinetica	Kinetica Energy Express, LLC
kJ	kilojoule
km	kilometer
kts	knots
L_E	unweighted sound exposure level (dB re 1 µPa^2·s)
L_p	unweighted sound pressure (dB re 1 µPa)
L_{pk}	peak sound pressure
LF	low frequency
LNG	liquefied natural gas
LNGC	liquefied natural gas carrier
MEG	mono-ethylene glycol
MF	mid-frequency
mg/L	milligram per liter

MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
NGDC	National Geophysical Data Center
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
OCS	Outer Continental Shelf
PAM	passive acoustic monitoring
PBR	potential biological removal
Project	New Fortress Energy Louisiana FLNG Project
PSO	Protected Species Observer
PSU	practical salinity unit
PTS	permanent threshold shift
$R_{95\%}$	maximum range at which a sound level was calculated excluding 5 percent of the R_{max}
Rmax	maximum range at which the sound level was calculated in model
RCM	restricted catenary mooring
RMS	root mean square
SDM	Spatial Density Model
SEFSC	Southeast Fisheries Science Center
SEL	sound exposure level
SPL	sound pressure level
TTS	temporary threshold shift
UME	Unusual Mortality Event
WD-38	West Delta Lease Block 38
WD-39	West Delta Lease Block 39
ZOI	zone of influence

1.0 DESCRIPTION OF SPECIFIED ACTIVITY

1.1 Introduction

New Fortress Energy Louisiana FLNG LLC (“Applicant”), a limited liability company, is proposing to construct, own, and operate the New Fortress Energy Louisiana FLNG Project (“Project”), a deepwater port (“DWP”) export terminal in the West Delta Lease Block 38[1] (“WD-38”) approximately 12 nautical miles (“nm”) off the southeast coast of Grand Isle, Louisiana, in approximately 26-28 meters (85-91 feet) of water (Figure 1-1). The Applicant submits this request for an Incidental Harassment Authorization (“IHA”) pursuant to Section 101(a)(5) of the Marine Mammal Protection Act (“MMPA”) and 50 Code of Federal Regulations (“CFR”) Part 216 Subpart I to allow for the incidental harassment of small numbers of marine mammals resulting from construction activities in the Project Area during the construction of the DWP. The Applicant intends to use impact pile driving to install three of the six platforms comprising the DWP. Other components of the DWP include three self-elevating platforms, trenching of seafloor pipelines and tie-ins, and a Floating LNG Storage Unit (“FSU”) and associated anchoring system.

Offshore Project activities that fall within the span of this application would not begin prior to May 1, 2023 (Table 1-1). The National Oceanic and Atmospheric Administration (“NOAA”) National Marine Fisheries Service (“NOAA Fisheries”) has advised that construction activities (including impact pile driving) have the potential to cause acoustic harassment to marine species, in particular marine mammals.

The regulations set forth in Section 101(a)(5) of the MMPA and 50 CFR Part 216 Subpart I allow for the incidental take of marine mammals by a specific activity if the activity is found to have a negligible impact on the species or the stock(s) of marine mammals and will not result in unmitigable adverse impacts on the availability of the marine mammal species or stock(s) for certain subsistence uses. In for order 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 NOAA Assistant Administrator. This application constitutes such written request.

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[1] For the dual pipeline laterals from the Kinetica pipeline system, approximately 975 feet for northern lateral and 4,798 feet for southern lateral will be located within West Delta Lease Block 39, see Figure 1-2.

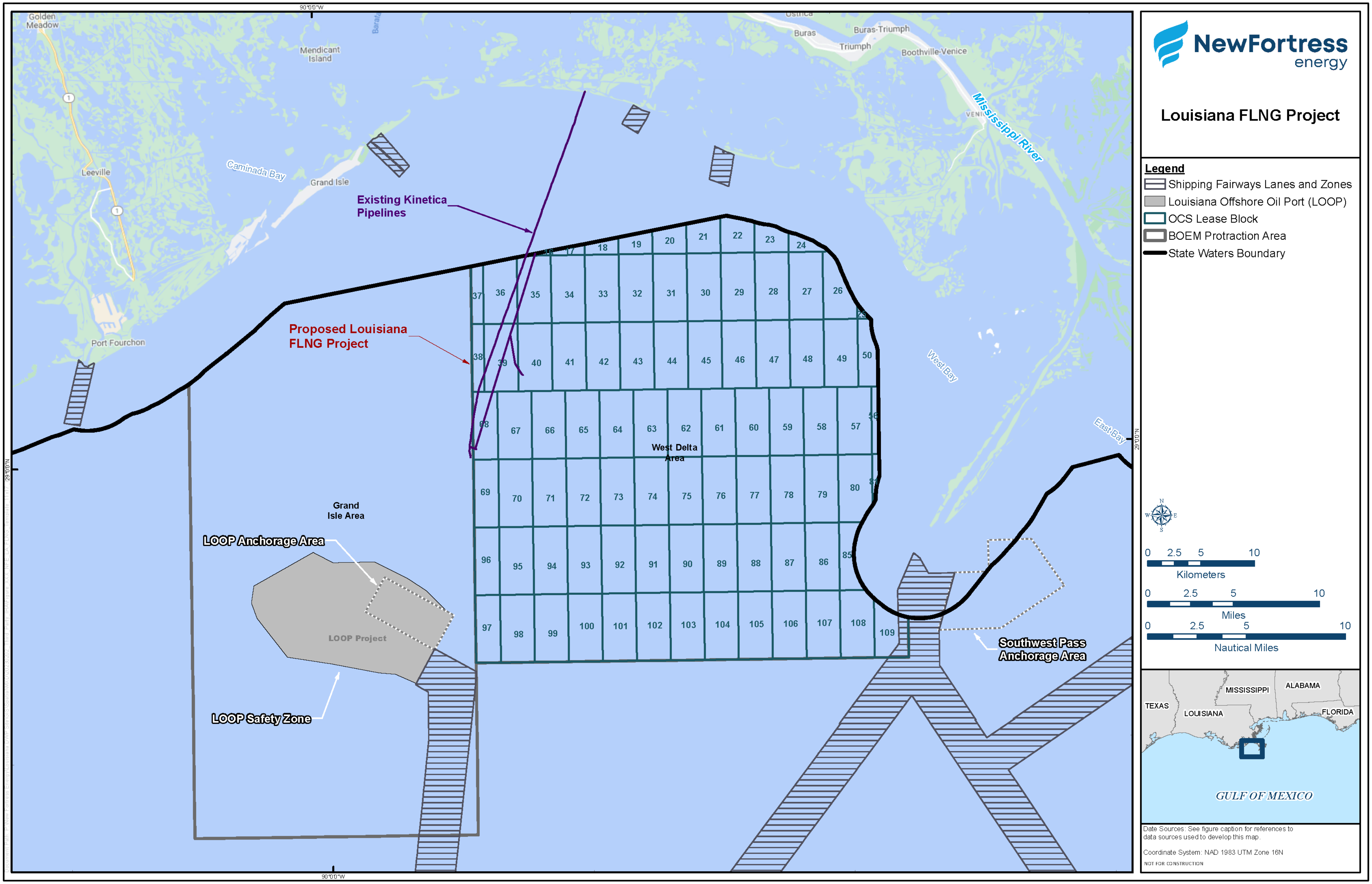

Figure 1-1 General Project Location

Table 1-1 Construction Schedule for Activities Permitted Under Incidental Harassment Authorization

Activity	2023											
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Impact pile driving to install fixed platforms for FLNG2 and topsides					X	X	X	X				

Construction activities not anticipated to result in acoustic harassment of marine mammals are not included under this Incidental Harassment Authorization (see Section 1.2.2), such as three self-elevating platforms, trenching of seafloor pipelines and tie-ins, and the deployment and anchoring of the FSU.

1.2 Proposed Activity

The Project will provide a safe and reliable source of much needed natural gas supplies to global markets in the form of liquefied natural gas (“LNG”). The Project is consistent with the Applicant’s commitment to make clean, affordable energy available to markets around the world. The Applicant is filing an application for a license to construct, own, and operate the DWP export terminal pursuant to the Deepwater Port Act of 1974, as amended, and in accordance with the U.S. Coast Guard’s and the Maritime Administration’s implementing regulations.

The Project will involve the installation of two nominal 1.4 million metric tonnes per annum liquefaction systems (FLNG1 and FLNG2) installed in WD-38 in approximately 26 to 28 meters (85 to 91 feet) of water. Each system will contain three platforms consisting of a Gas Treating Platform (P1 and P4), a Liquefaction Platform (P2 and P5), and a Utilities and Accommodations Platform (P3 and P6). The Gas Treating Platform will contain facilities to remove impurities (carbon dioxide, water, mercury, sulfur, and heavy metals) from the feed gas. Production modules will be located on the deck and will prepare the feed gas prior to liquefaction. A warm flare for accepting the warm and wet process streams will be located on this platform. A raw water system and emergency power will also be contained on this platform. The Liquefaction Platform will serve as the primary natural gas liquefaction plant. FLNG1 will incorporate self-elevating platforms (e.g., jack-up platforms or rigs), and FLNG2, which will be located adjacent to FLNG1, will utilize fixed platforms on piles driven by impact hammer (platforms P4, P5, and P6). FLNG2 will also house feed gas compressors. The feed gas supply to the Project will be transported to the WD-38 site via the existing Kinetica Energy Express, LLC (“Kinetica”) offshore natural gas pipeline system and two, newly constructed, 24-inch- and 20-inch-diameter pipeline laterals connecting the Kinetica pipeline system to the Project. Both FLNG1 and FLNG2 will be connected to a single FSU via a flexible, partially submerged, 220-meter (722-foot) cryogenic hose transfer system. The FSU will be positioned approximately 107 meters (350 feet) from the FLNGs. LNG carriers (“LNGCs”) will call on the Project approximately 40 times per year. Other than temporary construction staging areas, there are no onshore facilities associated with the Project. Staging for construction, if needed, will utilize existing staging, laydown, and warehouse space near Port Fourchon, Port Sulphur, or Venice. The general layout of these project components is shown on the Project Site Plan on Figure 1-2.

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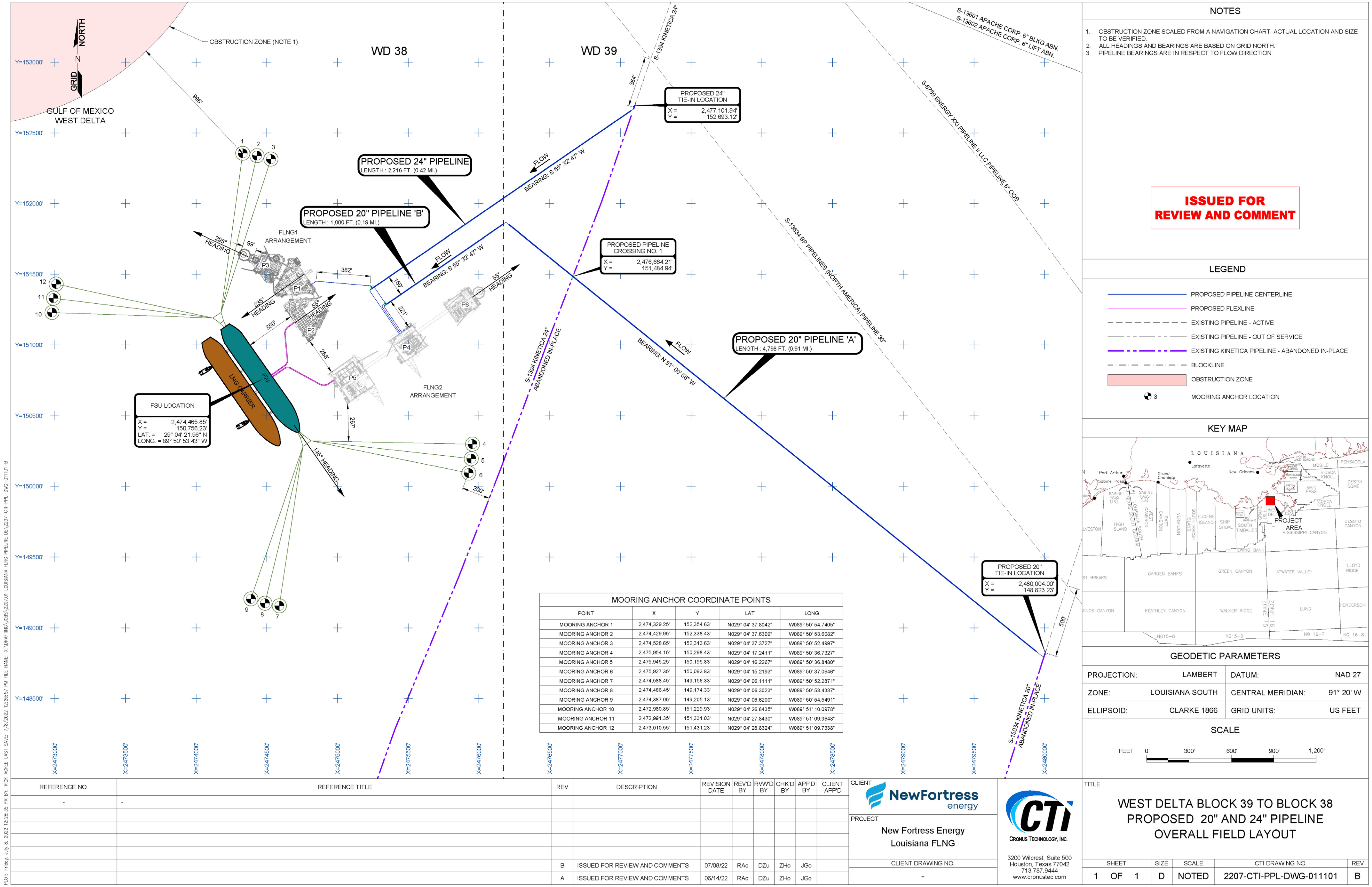

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NOTES

1. OBSTRUCTION ZONE SCALED FROM A NAVIGATION CHART. ACTUAL LOCATION AND SIZE TO BE VERIFIED.
2. ALL HEADINGS AND BEARINGS ARE BASED ON GRID NORTH.
3. PIPELINE BEARINGS ARE IN RESPECT TO FLOW DIRECTION.

ISSUED FOR REVIEW AND COMMENT

LEGEND

──	PROPOSED PIPELINE CENTERLINE
──	PROPOSED FLEXLINE
— — —	EXISTING PIPELINE - ACTIVE
— - —	EXISTING PIPELINE - OUT OF SERVICE
— · —	EXISTING KINETICA PIPELINE - ABANDONED IN-PLACE
— · —	BLOCKLINE
🟥	OBSTRUCTION ZONE
◑ 3	MOORING ANCHOR LOCATION

MOORING ANCHOR COORDINATE POINTS

POINT	X	Y	LAT	LONG
MOORING ANCHOR 1	2,474,329.25'	152,354.63'	N029° 04' 37.8042"	W089° 50' 54.7405"
MOORING ANCHOR 2	2,474,429.95'	152,338.43'	N029° 04' 37.6309"	W089° 50' 53.6082"
MOORING ANCHOR 3	2,474,528.65'	152,313.63'	N029° 04' 37.3727"	W089° 50' 52.4997"
MOORING ANCHOR 4	2,475,954.15'	150,298.43'	N029° 04' 17.2411"	W089° 50' 36.7327"
MOORING ANCHOR 5	2,475,945.25'	150,195.83'	N029° 04' 16.2267"	W089° 50' 36.8480"
MOORING ANCHOR 6	2,475,927.35'	150,093.83'	N029° 04' 15.2193"	W089° 50' 37.0646"
MOORING ANCHOR 7	2,474,588.45'	149,156.33'	N029° 04' 06.1111"	W089° 50' 52.2871"
MOORING ANCHOR 8	2,474,486.45'	149,174.33'	N029° 04' 06.3023"	W089° 50' 53.4337"
MOORING ANCHOR 9	2,474,387.05'	149,205.13'	N029° 04' 06.6200"	W089° 50' 54.5491"
MOORING ANCHOR 10	2,472,980.85'	151,229.93'	N029° 04' 26.8435"	W089° 51' 10.0978"
MOORING ANCHOR 11	2,472,991.35'	151,331.03'	N029° 04' 27.8430"	W089° 51' 09.9648"
MOORING ANCHOR 12	2,473,010.55'	151,431.23'	N029° 04' 28.8324"	W089° 51' 09.7338"

GEODETIC PARAMETERS

PROJECTION:	LAMBERT	DATUM:	NAD 27
ZONE:	LOUISIANA SOUTH	CENTRAL MERIDIAN:	91° 20' W
ELLIPSOID:	CLARKE 1866	GRID UNITS:	US FEET

SCALE

REFERENCE NO.	REFERENCE TITLE
-	-

REV	DESCRIPTION	REVISION DATE	REV'D BY	RVW'D BY	CHK'D BY	APP'D BY	CLIENT APP'D
B	ISSUED FOR REVIEW AND COMMENTS	07/08/22	RAc	DZu	ZHo	JGo	
A	ISSUED FOR REVIEW AND COMMENTS	06/14/22	RAc	DZu	ZHo	JGo	

CLIENT
NewFortress energy

PROJECT
New Fortress Energy
Louisiana FLNG

CLIENT DRAWING NO.
-

CRONUS TECHNOLOGY, INC.
3200 Wilcrest, Suite 500
Houston, Texas 77042
713.787.9444
www.cronustec.com

TITLE
WEST DELTA BLOCK 39 TO BLOCK 38
PROPOSED 20" AND 24" PIPELINE
OVERALL FIELD LAYOUT

SHEET	SIZE	SCALE	CTI DRAWING NO.	REV
1 OF 1	D	NOTED	2207-CTI-PPL-DWG-011101	B

Figure 1-2 Project Site Plan General Arrangement

For the purpose of this application, the Project Area is defined as the WD-38 Lease Block; Project activities will include installation of up to 26 piles, each 2.74 meters (108 inches) in diameter, to support the three fixed platforms comprising FLNG2. Other major components of construction and installation include trenching for the pipeline laterals and tie-ins, pile installation for the platforms, setting of the self-elevating platforms, and anchoring for the FSU and service vessel buoys. Of these activities, only pile installation for the three fixed platforms comprising FLNG2 has the potential to cause acoustic disturbance. Noise from Project-related operations including winching of anchor cables, thruster sounds from an Anchor Handling Tug ("AHT"), and support vessel traffic is not anticipated to be greater than the ambient noise levels in the Project Area, as vessel traffic increases as a result of the operations and maintenance of the Project will be negligible. Vessel traffic will increase during operations mainly for the transportation of supplies and maintenance crews. Given the amount of existing vessel traffic in the area, the noise associated with the Project-related supply vessels transiting to the offshore facilities will have a negligible contribution to the total ambient underwater sound levels. Vessel sound sources are sufficiently low that no injury is expected. Distances within which injury and/or harassment might occur are generally short. For these reasons, a detailed acoustic modeling analysis was not conducted. See Section 1.2.2 for a full description of Project activities not expected to result in take.

Take (unintentional, but not unexpected, taking of a protected species) as a result of underwater noise or other disturbances resulting in incidental harassment (any act of pursuit, torment, or annoyance which is divided into two categories: Level A and Level B) of marine mammals is 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. Note here that the actionable sound pressure level is not identified in the statute because the statute was written prior to the understanding of acoustic effects on marine mammals. The relevant levels are contained in NOAA acoustic guidance (NOAA Fisheries 2018). 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 in which the level of direct human-caused mortality exceeds the potential biological removal ("PBR") level (maximum number of animals, not including natural mortalities, which may be removed annually from a marine mammal stock while allowing that stock to reach or maintain its optimal sustainable population level). Mortalities are tracked via post-activity reporting to NOAA Fisheries.

The 2016 *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* ("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 due to high-level noise and labeled 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. Under this NOAA Fisheries guidance, a system was established whereby marine mammal species were organized into five 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. 2009) and replaced earlier NOAA Fisheries guidance, which did not address potential impacts by the functional hearing group. For transient and continuous sounds, it was concluded that the potential for injury is not only 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 effect that is not captured by evaluations completed using the previous NOAA Fisheries thresholds for Level A harassment alone. In April 2018, NOAA Fisheries released the *Revised Technical Guidance for Assessing the Effect of Anthropogenic Sound on Marine Mammals* ("Revised Technical Guidance"; NOAA Fisheries 2018). The Revised Technical Guidance addressed implementation concerns and provided additional information to facilitate use of the Guidance by applicants.

The Revised Technical Guidance (NOAA Fisheries 2018) 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 and establishes 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 1-2). Frequency weighting provides a sound level with respect 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 (NOAA Fisheries 2018), 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* dolphins, *Lagenorhynchus cruciger*, and *L. australis*), phocid pinnipeds (true seals), and otariid pinnipeds (sea lions and fur seals). It should be noted that this application addresses species known to occur within the Project Area; these include species from the LF and MF cetacean groups. It should also be noted that pinnipeds and HF cetaceans do not occur in the Project Area.

NOAA Fisheries has defined the threshold level for Level B harassment as a root-mean square ("RMS") sound pressure level ("SPL") of 120 decibels ("dB") referenced to 1 microPascal ("dB re 1 µPa") for continuous noise and a SPL of 160 dB re 1 µPa for impulsive noise. The sound produced by the proposed pile driving equipment activities may approach or exceed ambient sound levels (i.e., background or existing baseline Project Area noise level). Actual perceptibility of these noise sources 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 were not updated with either the 2016 Acoustic Guidance or 2018 Revised Technical Guidance.

As discussed further in Section 6, Take Estimates for Marine Mammals, evaluation of potential takes by incidental harassment of marine mammals resulting from the generation of underwater noise from the proposed pile-driving equipment activities will be evaluated under the criteria for PTS onset for impulsive noise as prescribed in the NOAA Fisheries (2018) Revised Technical Guidance (Table 1-2). NOAA Fisheries (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each hearing group for impulsive and non-impulsive, which are presented in terms of dual metrics: sound exposure level ("SEL") and unweighted sound pressure ("L_p"). The acoustic threshold levels for marine mammals are shown in Table 1-2 where $L_{E,\ 24h}$ is the cumulative sound exposure over a 24-hour period (dB re 1 $\mu Pa^2 \cdot s$), $L_{p,pk}$ is the peak sound pressure (dB re 1 µPa), and L_p is the root mean square sound pressure (dB re 1 µPa). The level B harassment thresholds are also provided in Table 1-2.

Table 1-2 Acoustic Threshold Levels for Marine Mammals

Hearing Group	Impulsive Sounds	
	Permanent Threshold Shift Onset	Behavior
Low-frequency cetaceans	219 dB ($L_{p,pk}$) 183 ($L_{E,\,LF,\,24h}$)	160 dB (L_p)
Mid-frequency cetaceans	230 dB ($L_{p,pk}$) 185 dB ($L_{E,\,MF,\,24h}$)	

Sources: Southall et al. 2019; NOAA Fisheries 2018, NOAA Fisheries 2005

$L_{E,\,24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s)
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa)
L_p = root mean square sound pressure (dB re 1 μPa)

1.2.1 FLNG2 Permanently Fixed Platform Construction Activities

The Applicant will conduct pile-driving activities to support installation of the three FLNG2 permanently fixed platforms. Piles will be installed as shown in the Pile Driving Specifications provided in Table 1-3.

Table 1-3 Pile-Driving Specifications for the Three FLNG2 Platforms

Platform	Number of Piles	Length of Pile (feet)	Diameter of Pile (inches)	Depth of Penetration (feet)	Estimated Hammer Blows
P4	12	385	108	260	17,052 total 1,421 per pile
P5	8	405	108	280	19,136 total 2,392 per pile
P6	6	345	108	220	14,352 total 2,392 per pile

Note: Hammer blows per pile vary with length of pile and depth of penetration. Hammer blows per day are based on daylight-only operations with a single hammer spread evenly across the construction window.
Nine days of active pile driving are estimated to complete all 26 piles. Estimated hammer blows vary from 3,942 to 7,144 per day depending on platform and pile segment being driven (most piles are assembled from three separate segments).

Impact pile driving involves weighted hammers that drive piles into the seafloor. Different methods for lifting and driving the hammer include hydraulic, steam, or cables/gravity. The acoustic energy is created upon impact and the energy 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 traveling 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, traveling through the seafloor and radiating back into the water. Near the pile, acoustic energy arrives from different paths with different associated stage and time lags, which creates a pattern of destructive and constructive interference. Farther 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:

- The impact energy and type of pile driving hammer,
- The size and type of the pile,
- Water depth, and
- Subsurface hardness in which the pile is being driven.

Up to 26 piles will be installed in the Project Area. All piles would be installed within the footprint of the three FLNG2 platforms, as shown in Figure 1-2. In general, pile driving activities will occur during daylight hours to allow visual observations of operations and visual observations for protected species conducted by the Protected Species Observer ("PSO") (see Section 11, Mitigation Measures). Pile driving may continue after dark when the installation of the same pile began during daylight (1.5 hours before [civil] sunset), when visual clearance zones were fully visible for at least 60 minutes and when pile driving must proceed for human safety or installation feasibility reasons. Pile driving will not be initiated in times of low visibility when the visual clearance zones (Section 11.3) cannot be visually monitored, as determined by the lead PSO on duty.

The envisaged use of pile driving is as follows:

1. An installation vessel is positioned to lower the pile in a controlled and safe manner until impact driving can drive the pile to final penetration depth.
2. Pile is upended from the main installation vessel and lowered to the seabed. Self-weight penetration is controlled by line-pull force in the crane depending on soil conditions.
3. While the vessel remains on position, the impact hammer is lowered onto the pile.
4. Soft-start procedures are initiated, which may consist of a sequence of lower-energy, spaced apart hammer blows until such time it is safe to ramp up blow count and hammer energy as required.
5. Impact hammering proceeds, with adjustments to hammer energy as required at the desired target blow rate, until the pile is lowered to its final penetration depth.
6. After pile driving has completed, the impact hammer is retrieved to the deck of the installation vessel. Noise-emitting pile-driving activities have concluded.

Propagation modeling was conducted using the maximum projected blow energy to calculate L_{pk} and SPL; however, a soft start and pile progression were also incorporated into the model to calculate SEL for each pile scenario as shown in Table 1-4. The worst case for each platform was assessed for each day to have a conservative approach. For platforms P5 and P6, only Day 3 (H1+H2+H3) was modeled as it was projected to have the greatest impact, and includes the potential impacts from Day 1 (H1) and Day 2 (H1+H2). The total number of blows in combination with the number of piles produces a cumulative SEL that is very similar for each day (see Section 6.1.3, Calculation of Range to Regulatory Thresholds). Due to differences in the specific geography and bathymetry of each pile, the combined environmental parameter effect on the sound speed profile resulted in the largest isopleths for the Day 3 scenario, so this scenario was carried forward in calculation of marine mammal exposures.

Table 1-4 Pile-Driving Progression Summary

Platform	Pile Segment	Hammer Energy %	Hammer Energy	Duration (minutes)[2]	Blows per Minute	Total Number of Blows per Hammer Energy[1]	Total Number of Blows per Day
P4	P1	20	460	36.53	30	1,096	5,684
		40	920	42.93	30	1,288	
		60	1,380	110.0	30	3,300	
P5	Day 1: P1	20	460	85.6	30	2,568	5,256

Table 1-4 Pile-Driving Progression Summary

Platform	Pile Segment	Hammer Energy %	Hammer Energy	Duration (minutes)[2]	Blows per Minute	Total Number of Blows per Hammer Energy[1]	Total Number of Blows per Day
		40	920	89.6	30	2,688	
	Day 2: P1+P2	20	460	17.07	30	512	6,736
		40	920	22.67	30	680	
		60	1,380	184.8	30	5,544	
	Day 3: P1+P2+P3	20	460	52.8	30	1,584	7,144
		40	920	22.4	30	672	
		60	1,380	162.93	30	4,888	
P6	Day 1: P1	20	460	64.2	30	1,926	3,942
		40	920	6.2	30	2,016	
	Day 2: P1+P2	20	460	12.8	30	384	5,052
		40	920	17	30	510	
		60	1,380	138.6	30	4,158	
	Day 3: P1+P2+P3	20	460	39.6	30	1,188	5,358
		40	920	16.8	30	504	
		60	1,380	122.2	30	3,666	

1 Total number of blows are based on the total number of piles installed per day.

2 Duration provided for all piles within a 24-hour period.

1.2.2 Project Activities Not Anticipated to Result in Take

1.2.2.1 Pipeline Lateral Construction Activities

The Project will require the construction of one 24-inch-diameter pipeline for the northern lateral and one 20-inch-diameter pipeline for the southern lateral to take gas from the Kinetica pipeline and send it to the Gas Treating Platforms (P1 and P4). The pipelines will be installed using a pipelay barge utilizing the S-lay pipelay installation method (described below). The barge will contain stations for pipe welding, weld inspection, and field joint application.

An installation anchor will be set at pre-determined locations along the pipeline corridor via an AHT. The anchors will be tested where the first segment of the pipeline will be tied off for lay initiation. The barge will then be pulled along the pipeline path via the pulling cable. Pipe joints will be 40 feet in length and pipe-laying operations will be in an assembly-line fashion. Each joint of pipe will be placed on a rack forward of the line-up station where the pipe is hydraulically aligned to the end of the previous pipe joint. As the laybarge advances, a new joint will be welded to the previous joint and the pipe will move through the various stations until it reaches the coating station. As the pipe approaches the stern of the barge it enters the pipeline stinger. The stinger will support and assist with the required radius of curvature as it transitions from the barge toward the seafloor. This is known as the S-lay mode pipelay installation. It is anticipated that pipelay operations will last 16 days.

Excavation of the trench will be via jet sled or similar pipe burial equipment utilizing the same AHT. The jet sled will be lowered over the pipe resting on the seafloor. Jet pumps will then be utilized to lower the pipe by jetting out the sediment from under the pipe. Jet trenching sleds for pipeline burial in soft sediment settings typically carry onboard water pumps totaling 300 to 800 horsepower (“hp”), though 3,000 to 4,000 hp units exist for deeper pipe burial or firm clay sediments. Jet sleds are generally pulled at 0.5 to 3 knots (“kts”). The pipe will be lowered below the seafloor to a sufficient depth to allow at least 3 feet of cover between the seafloor and the top of the pipe. The jetted trench typically has a V-shaped cross-section. If necessary, divers will utilize hand jetting equipment to ensure the required depth is achieved. After the pipe has been buried to the desired depth, a sled will be dragged back over the trench spoil to re-fill the trench.

Overall risk of harassment towards marine mammals is not anticipated during pipeline lateral construction activities. Transportation of pipe segments to the Project Area as well as pipe laydown will not pose a collision risk due to the slow movement of the vessel (2 kts or 1 meter per second) and slow pulling of the jet sled (pulled at 0.5 to 3 kts). Additionally, the Project will adhere to vessel speed restrictions as appropriate in accordance with Project mitigation measures, as addressed in Section 11.1, Vessel Strike Avoidance Procedures. Excavation of the trench via the jet sled will not produce acoustic noise as it uses onboard electric/hydraulic water pump(s) to jet out the sediment from under the pipe. Vessel sound sources are sufficiently low that no injury is expected. Distances within which injury and/or harassment might occur are generally short.

Total power of the water pump(s) in a likely jet sled configuration is less than 1,000 hp, generally much less than the total power of most construction vessels; therefore, acoustic sources would be less than sources from operation of construction vessels. Potential impacts to marine mammal foraging will not be anticipated as finfish and invertebrates are temporarily affected by the suspended sediments from the trenching process. The spatial extent of high concentrations of suspended sediments (> 10 milligrams per liter [“mg/L”]) is difficult to predict because of the variable currents in the Project Area, but the temporal extent of high concentrations of suspended sediments (> 10 mg/L) is likely to be less than 8 hours (USACE 2015; Lybolt 2022). Therefore, temporary disturbances from suspended sediment and foraging disturbance are not likely to constitute an impact. The possibility of behavioral reactions from noise would be prevented because noises are limited to vessel operations which are below threshold levels, and noise from ancillary equipment that has less power than vessels. The possibility of behavioral reactions would be further reduced by vessel strike avoidance and by use of visual observers as detailed in Section 11. Potential behavioral reactions from sediment suspension would not be anticipated because the jet sled is a single point source and the temporal extent of sediment suspension would be minimal. The Project Area has minimal habitat value (Tetra Tech 2022) and is not known to be important feeding/breeding grounds for the potentially affected species with no known biologically important areas (“BIAs”) (see Section 4). Additionally, the affected area during pipeline lateral construction activities is small and localized, and the probability of interaction with marine mammals is low. No collision, entanglement, acoustic take, and/or behavioral reactions affecting marine mammal are expected to result in harassment of marine mammals; therefore, pipeline lateral construction activities are not analyzed further in this application.

1.2.2.2 FLNG1 Self-Elevating Platform Construction Activities

The three platforms comprising FLNG1 will be towed to the site. Once on location and correctly positioned, the self-elevating platforms will be “pinned” to the seafloor by extending the legs into the ocean floor. They will then be jacked up clear of the water and ballasted to create a “pre-load” on the legs to push them into the seafloor to the point of resistance. When the legs go no further into the seafloor, the ballast will be discharged, and the platforms will be jacked up to the pre-determined height creating an "air gap" above any possible storm waves. Once the three platforms are set and confirmed to be installed within tolerances, they will then be elevated to their final operational air gaps. A small derrick barge will then be mobilized to install the interconnecting bridges between the platforms.

Overall risk of harassment towards marine mammals is not anticipated during self-elevating platform construction activities. Due to the slow movement of the vessel during transport of platforms (2 kts or 1 meter per second) and vessel speed restrictions in accordance with project mitigation measures (as addressed in Section 11.1, Vessel Strike Avoidance Procedures), collision with marine mammals is unlikely. Noises produced during the jack-up movement of the platforms and during the use of ancillary equipment are expected to be very low. The Project Area has minimal habitat value (Tetra Tech 2022) and is not known to be important feeding/breeding grounds for the potentially affected species (see Section 4). Therefore, the installation and extension of the legs into the seafloor will not significantly alter surrounding habitats.

Additionally, the affected area during FLNG1 self-elevating platform construction activities is small and localized, and the probability of interaction with marine mammals is low. No collision, acoustic take, or behavioral reactions affecting marine mammals are expected to result in harassment; therefore, FLNG1 self-elevating platform construction activities are not analyzed further in this application.

1.2.2.3 Anchoring System for FSU Construction Activities

The FSU will be anchored approximately 107 meters (350 feet) east-southeast from the FLNG Liquefaction Platforms (P2 and P5). Once the FSU is in position, a set of AHT vessels will install 12 drag embedment anchors and mooring chains, 6 each fore and aft (see Figure 1-2). Additionally, two mooring buoys will be employed for use by support vessels in this Project. A typical standby mooring buoy consists of a drag embedment anchor, studlink anchor chain, six-strand riser wire, buoy with rope connection below, and polypropylene rope. Final anchor placement for the FSU and service vessel buoy, and anchor chain sweep is estimated to affect 6.06 acres of seafloor.

Harassment to marine mammals is not anticipated during FSU anchoring activities. There is a low risk of marine mammal collision with the AHT vessels during installation of drag embedment anchors. Due to the slow movement of the vessels (2 kts or 1 meter per second) and vessel speed restrictions in accordance with project mitigation measures (as addressed in Section 11.1, Vessel Strike Avoidance Procedures), collision with marine mammals is unlikely. The studlink anchor chains, six-strand riser wire, rope, and polypropylene rope used to install the mooring buoys and drag embedment anchors will not pose as an entanglement risk for marine mammals. In particular, the standby mooring buoy is connected to an inflexible six-strand riser wire. The noises produced during the installation of the anchor and buoys are expected to be low. Thus, these operations will not generate acoustic or behavioral impacts.

The Project Area has minimal habitat value (Tetra Tech 2022) and is not known to be important feeding/breeding grounds for the potentially affected species (see Section 4). Therefore, the installation of drag embedment anchors will not significantly alter surrounding habitats. The affected area during for FSU anchoring activities is small and localized, and the probability of interaction with marine mammals is low. No collision, entanglement, acoustic take, and/or behavioral reactions affecting marine mammal are expected to result in harassment; therefore, anchoring system installation for the FSU are not analyzed further in this application.

1.2.2.4 Construction Vessel Transits

Construction of the Project will require the support of numerous vessels. Vessel types include specialized heavy lift ships and heavy lift barges, smaller barges and derricks with cranes to assemble the platforms, and a specialized pipeline construction laybarge assisted by tugs. Vessel types are detailed in the DWP Application Volume II, Appendix J "Construction Emission Calculations," and the list of vessels with abridged details is provided below in Table 1-5.

Table 1-5 Vessels Used During Construction

Construction Sequence	Construction Activity	Vessel Type	Power Rating (hp)	Operating Schedule (hours)
1	Pipeline Installation	Pipelay Vessel	3,600	384
1	Pipeline Installation	AHT Vessel #1	5,000	192
1	Pipeline Installation	AHT Vessel #2	5,000	192
1	Pipeline Installation	Pipehaul Support Tug	4,200	324
1	Pipeline Installation	Pre-Lay Survey Vessel	1,800	48
1	Pipeline Trenching	Trenching Barge	7,200	336
1	Pipeline Trenching	AHT Vessel #1	5,000	168
1	Pipeline Trenching	AHT Vessel #2	5,000	168
1	FSU Installation	AHT Vessel	5,000	480
1	FLNG1 Installation	Tug #1	5,000	744
1	FLNG1 Installation	Tug #2	5,000	744
1	FLNG1 Installation	Tug #3	5,000	744
1	FLNG1 Installation	Derick Barge - Bridge Installation	3,600	96
1	Diving Spread	DP Dive Support Vessel	12,740	996
1	Diving Spread	Supply Boat	1,800	996
1	Pre-commissioning, Flooding and Testing	Jack-Up Boat Generator	831	888
1	Pre-commissioning, Flooding and Testing	Spud Barge Generator	831	888
1	Pre-commissioning, Flooding and Testing	Supply Boat	1,800	444
2	Diving Spread	DP Dive Support Vessel	12,740	1,428
2	Diving Spread	Supply Boat	1,800	1,428
2	FLNG2 Installation	Pioneering Spirit	127,397	600
2	FLNG2 Installation	Tug #1	5,000	600
2	FLNG2 Installation	Tug #2	5,000	600
2	Diving Spread	DP Dive Support Vessel	12,740	828
2	Diving Spread	Supply Boat	1,800	828

Table 1-5 Vessels Used During Construction

Construction Sequence	Construction Activity	Vessel Type	Power Rating (hp)	Operating Schedule (hours)

Construction will deploy approximately 17 generators, each 1,944 hp, on certain vessels and on the FLNG platforms with operating schedules ranging from 12 to 708 hours.

Construction will deploy one barge-mounted crane, 660 hp, operating for approximately 312 hours.

Typical Gulf of Mexico crew boats will be used during construction to transfer staff and supplies as needed.

AHT = anchor handling tug
DP = dynamic positioning
FSU = Floating LNG Storage Unit
hp = horsepower

Delivery of the FLNG platforms will be via tow and may use multiple large tugs (4,600- to 9,000-hp vessels, two to three at a time). These large field moves may also use a single offshore tug with more than 20,000 hp. Typical Gulf of Mexico (“GOM”) crew boats will be used as needed during construction. For each vessel type, the route plan for the vessel operation area will be developed to meet industry guidelines and best practices in accordance with International Chamber of Shipping guidance. The Project will require operational Automatic Identification Systems (“AIS”) on all vessels associated with the construction, operation, and decommissioning of the Project, pursuant to U.S. Coast Guard and AIS carriage requirements. AIS will be required to monitor the number of vessels and traffic patterns for analysis and compliance with vessel speed requirements. All vessels will operate in accordance with applicable rules and regulations for maritime operation within U.S. federal and state waters. Similarly, all aviation operations, including flying routes and altitude, will be aligned with relevant stakeholders including Federal Aviation Administration and state and local regulations. Additionally, the Project will adhere to vessel speed restrictions as appropriate in accordance with project mitigation measures and any superseding NOAA requirements, as addressed in Section 11.1, Vessel Strike Avoidance Procedures.

Helipads are provided on the Utilities Platforms (P3 and P6) mainly for emergency situations. The Applicant does not anticipate utilizing helicopters during standard construction to transport supplies and staff.

.Noise from the vessels emanates from the ships’ propellers and other Dynamic Positioning (“DP”) propulsion devices such as thrusters. The sound generated from main engines, gearboxes, and generators transmitted through the hull of the vessel into the water column is considered a secondary sound source to that of vessel propulsion systems. Additionally, the Project will adhere to vessel speed restrictions as appropriate in accordance with the mitigation measures detailed in Section 11.1, Vessel Strike Avoidance Procedures. Due to the planned mitigation, neither disturbance of nor collision with marine mammals is anticipated, and take associated with those activities is not analyzed in this application.

2.0 DATES, DURATION, AND SPECIFIC GEOGRAPHIC REGION

2.1 Dates and Duration

Only the platform construction sequence for FLNG2 falls within the request of this IHA. Offshore Project activities that fall within the span of this application would not begin prior to May 1, 2023 (Table 2-1). Additional activities are planned prior to May 2023 that are not included as these activities are not anticipated to result in harassment of marine mammals, such as installation of three self-elevating platforms, trenching of seafloor pipelines and tie-ins, and deployment and anchoring system of the FSU and service buoys. Pile driving activities will occur for a total of 3 days per platform (P4, P5, and P6), and may occur anytime from May through August depending on Project progress. While there are multiple density datasets in this region including Roberts et al. (2016) and the NOAA Southeast Fisheries Science Center ("SEFSC") (2022) datasets, NOAA Fisheries has determined the NOAA SEFSC (2022) dataset to be the best available dataset. Therefore, the NOAA SEFSC (2022) dataset was carried forward in take calculations for the action planned from May through August (see Section 6).

Table 2-1 Construction Schedule for Activities Permitted Under Incidental Harassment Authorization

Activity	2023											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Impact pile driving to install fixed platforms for FLNG2					X	X	X	X				

Other construction activities are not included under this IHA, such as three self-elevating platforms, trenching of seafloor pipelines and tie-ins, and deployment and anchoring of the FSU and service buoys.

The Project will be constructed in two sequences as summarized in Table 2-2 and described further below.

Table 2-2 Overall Construction Sequencing

Sequence Date	Construction Activity
Q2 2023	Install one lateral 24-inch pipeline and one lateral 20-inch pipeline from Kinetica system to Gas Treating Platform of self-elevating system (FLNG1)
	Position and install self-elevating platforms for FLNG1.
	Install CMS for FSU and support vessel standby buoys.
	Position and moor FSU; install connecting cryogenic hose transfer system between FLNG1 liquefaction platform and FSU.
	Flood, cut, and install spools to Kinetica pipeline, tie-in to self-elevating FLNG1 riser.
Q2-Q3 2023	Install approximately 610 feet of 24-inch pipeline to extend south pipeline lateral to fixed platform FLNG2.
	Install fixed platforms for FLNG2 and topsides, install connecting cryogenic hose transfer system to FSU.
	Install riser tie-in spools.

FSU = Floating LNG Storage Unit
CMS = Catenary Mooring System

2.1.1 Construction Sequence 1

Installation of Sequence 1 will begin with pipelaying activities, where a pipelay spread will be mobilized and DP trials will be conducted (Q2 2023, Table 2-2). Pipeline segments will be lain on the seafloor and flooded with filtered sea water to hold in place in preparation for lowering into the trench. The lowering may be performed by the pipelay vessel or a smaller vessel with suitable equipment. Selection and methods will be determined by the installation contractor. The pipelay vessel will install the 24-inch and 20-inch pipelines consecutively.

The FSU restricted catenary mooring ("RCM") system will be pre-installed and "wet parked" with recovery buoys until arrival of the FSU. A large anchor handling tug will be used to transport and install the mooring anchors and chain mooring lines. The northeast mooring line will be marked with transponders and floats to mark its location during the installation of the Utilities Platform (P3).

In parallel, tugs will begin the wet tow operation for the Utilities Platform (P3). Upon arrival, the Utilities Platform will lower its legs to the seafloor, preload, and elevate itself to an air gap of approximately 10 feet above mean sea level. The transponders and visual buoys will be monitored to ensure suitable clearance between the northwest leg and the mooring line is maintained.

The tugs will then repeat the wet tow operation for the Gas Treating Platform (P2). Upon its arrival, and prior to lowering the legs, the Gas Treating Platform will be positioned using a combination of the three tugs and cross-tensioning of the mooring winches from the Utilities Platform (P3). The Gas Treating Platform's legs will then be lowered, preloaded, and elevated to the same deck level as the Utilities Platform. The tugs will then repeat the entire process for the Liquefaction Platform (P2). Once the three platforms are set and confirmed to be installed within tolerances, they will be elevated to their final operational air gaps. A small derrick barge will then be mobilized to install the interconnecting bridges between the platforms.

A Dive Support Vessel ("DSV") will be mobilized to setup at the Kinetica pipeline. The flooded pipelines will be cut and a segment removed. The exposed ends will be prepared by removal of all coatings, the weld seam will be ground flush, and the pipe ultrasonically inspected to ensure suitable wall thickness. Mechanical connectors with Ring Type Joint flanges will be installed. After the mechanical connectors are installed, the divers will then connect the northern pipeline segment to the northern mechanical connector by installing flanged tie-in spools. The southern pipeline segment will then be tied into the southern mechanical connector with flanged tie-in spools.

The DSV will relocate to the planned location of Liquefaction Platform (P2) and install interconnecting subsea tie-in spools between the pre-installed northern pipeline segments and then the southern pipeline segments.

Finally, the DSV will relocate to the Gas Treating Platform (P1) and install subsea riser tie-in spools between the pre-installed northern and southern pipelines and the pre-installed risers on the platform's leg.

Each subsea tie-in spool will be covered with prefabricated concrete mattresses after installation is complete to protect the pipe spools.

After the FSU arrives, it will be assisted by tugs to complete the mooring process. The tugs will be used to help position the FSU and to recover the mooring buoys and hand-over to the RCM connections to the FSU to complete the mooring process. The procedure will begin with the bow and then the stern. After this point, the transloading hose may be passed from the Liquefaction Platform (P2) to the FSU and connected with support of a support vessel.

2.1.2 Construction Sequence 2

Construction sequence 2 will involve installation of FLNG2 (May-August 2023, Table 2-2). The FLNG2 Gas Treating Platform (P4), Liquefaction Platform (P5), and Utilities Platform (P6) are a fixed-jacket design, which differs from the installation methodology of the self-elevating platforms utilized for

FLNG1. As such, the fixed-jacket design requires the jacket be set on the seafloor, then pin piles driven through the corner legs to support the jacket and deck.

Installation activities will begin with the jacket and pin piles for the Liquefaction Platform (P5), after which the deck will be installed as a single unit. This methodology will be repeated for the Gas Treating Platform (P4), then finally the Utilities Platform (P6). There will be one jacket per platform for a total of three jacket platforms with a different number of pin piles per jacket. P4 will have four pin piles installed in 3 days, P5 will have eight pin piles installed in 3 days, and P6 will have six pin piles installed. For the estimated total pile driving per day please see Table 1-4. When all platforms are installed, the interconnecting bridges will be installed.

Upon completion of FLNG2, a DSV will be mobilized to FLNG1, where the riser tie-in spool on the southern pipeline lateral will be exposed by removing the concrete mattresses. The isolation valves will be closed and the riser and riser tie-in spool will be flooded and flushed. The riser tie-in spool will be removed with a blind flange installed on the Gas Treating Platform (P1) southern pipeline lateral riser.

Divers will then install interconnecting spools from this southern pipeline lateral to the pre-installed riser on the Gas Treating Platform (P4). This series of spools will be leak tested, then flushed with a chemical (such as MEG [mono-ethylene glycol] or Menthol). When FLNG2 is ready to receive gas, the subsea isolation valves at FLNG1 will be opened. Finally, this series of spools will be covered with concrete mattresses to provide mechanical protection and cover. Upon completion, the DSV will be demobilized.

2.2 Specific Geographic Region

The Project will be located within the GOM, approximately 12 nm (22 kilometers [“km”]) off the coast of Grand Isle, Louisiana at a depth of 26 to 28 meters (85 to 91 feet) (Figure 1-1). With the exception of a 975-foot section for the northern lateral and 4,798-foot section of the southern lateral that will be in Outer Continental Shelf (“OCS”) block West Delta Lease Block 39 (“WD-39”), all Project components will be located in OCS WD-38 (Figure 1-2).

The geologic setting of this portion of the GOM was controlled by the separation of the North American and South American tectonic plates (Sawyer et al. 1991; Jacques and Clegg 2002). This rifting is associated with the breakup of the supercontinent, Pangea, during the Mesozoic Era (approximately 252.3 to 66 million years ago). During the Jurassic Period (approximately 157 million years ago) the rifting plates formed numerous basins and allowed large volumes of salty ocean water to fill these subsided areas and be trapped.

Surficial sediments in the GOM have been broadly classified as consisting of sands, silts, and clays in the Mississippi delta area. The Texas-Louisiana shelf is broad and flat with a width that ranges from 32 to 90 km (20 to 56 miles) offshore from the coastline. It is scattered with relict reefs and salt domes (Bryant et al. 1991). This wide shelf is described as having sediments dominated by silts and fine sands collectively described as a “blanket of mud” that has been provided by the Mississippi River. This mud is rather thin, less than 8 meters (26 feet) thick throughout (Ward 2017). Sedimentation rates in the Mississippi River delta where the Project is located were estimated to range 0.12 to 1.24 centimeters (0.05 to 0.49 inches) per year for various temporal periods between 1806 and 1997 (Turner et al. 2003). Rates were found to be highly variable between locations based on the proximity and influence from the Mississippi River delta.

An extensive network of hydrocarbon seeps exists throughout the continental slope of the GOM. These seeps contribute hydrocarbons to the surface sediments and water column, particularly in the central GOM (Sassen et al. 1993a, 1993b). Seepage of oil and gas is a natural phenomenon occurring when deep oil and gas deposits migrate to the earth's surface (Ward 2017). In addition to hydrocarbon seeps, other subsurface influences affecting sediments and bottom waters of the continental slope include seawater trapped during the settling of sediments, dissolution of underlying salt domes, and deep-seated formation waters rich in barium. Hydrocarbon seeps are extensive throughout the continental slope and contribute hydrocarbons to the surface sediments and water column, especially in the northwestern and north-central offshore region. Estimates of the total volume of seeping oil in the GOM range from 511,200 barrels ("bbl") to 1,278,000 bbl per year (Transportation Research Board and National Research Council 2003). In addition to hydrocarbon seeps, other fluids leak from the underlying sediments into the hypolimnion along the continental slope.

While the coastal waters of Louisiana are heavily influenced by a number of drainage systems (lakes and rivers), the Mississippi River is the greatest influence on the coastal waters in the vicinity of the Project location. Draining from 31 states, the Mississippi River is 322 km (2,302 miles) long and discharges, on average, , 17,329 cubic meters (612,000 cubic feet) of water per second into the GOM. Louisiana sounds and bays and extensive tidal marshes act to delay mixing, resulting in extensive areas of mesohaline (middle salinity) conditions (MMS 1992). Compared with the waters of other states along the northern GOM, Louisiana's estuaries and open nearshore waters are low in salinity and high in nutrient concentrations (MMS 1992). Water discharged from the Mississippi River is typically very turbid and full of nutrients, primarily nitrogen and phosphorus. While nutrients provide sustenance to marine ecosystems in the GOM, high levels from runoff can cause an area of hypoxia to form in the GOM south of the Mississippi River Delta. High nutrient levels in the water can result in eutrophication, promoting algal blooms and fish kills (Knockaert 2021).

To a lesser extent, the Atchafalaya River also has influence on the on the coastal waters in the vicinity of the Project location. The Atchafalaya River is a 220-km-long (137-mile-long) distributary of the Mississippi River and Red River in southern Louisiana (LDEQ 2014). The Atchafalaya Basin is located in south-central Louisiana and is bounded by the Mississippi River and Tributaries system levees. The basin encompasses approximately 1,513 square km (374,000 acres) of fresh marsh, bottomland hardwoods, cypress swamps, and open water, including the largest contiguous tract of fresh marsh in the state (CWPPRA 2022). With the direction of the Mississippi River's flow towards the modern Plaquemines-Belize Delta, river sediment deposition has increased resulting in an emergent delta, the Atchafalaya Delta, which has grown each year since 1973 to its present size of 29 square km (11.3 square miles) (CWPPRA 2022).

Water quality on the continental shelf west of the Mississippi River is predominantly influenced by the input of sediment, nutrients, and pollutants from the Mississippi and Atchafalaya Rivers, combining to discharge approximately 3.32 billion pounds of nitrogen and 3.14 million pounds of phosphorus into the GOM in 2017 (EPA 2019). The GOM "Dead Zone" is a condition of shelf water stratification during summer months that results in a large hypoxic zone along the Louisiana–Texas shelf in bottom waters. Waters with low dissolved oxygen concentration (less than 2 mg/L) are consistent with hypoxia. Excessive nutrients (nitrogen, phosphorus, sewage) and other oxygen-demanding contaminants fuel the production of phytoplankton, which in turn fuels blooms of often toxic dinoflagellates (Rabalais and Turner 2019). Die off and decomposition of plankton and dinoflagellates collected in bottom waters cause dissolved oxygen levels to drop (Rabalais and Turner 2019). A hypoxic condition then forms during warm, calm spring and summer months when the water column becomes vertically stratified and bottom water mixing with oxygenated surface waters does not occur (Rabalais and Turner 2019). This hypoxic condition persists until wind-driven circulation events mix the water column (Coogan et al. 2019).

In the marine waters off the coast of Louisiana, sea surface salinities tend to increase with distance from the Mississippi. Typical sea surface salinities tend to range from 23.4 to 36.5 practical salinity units ("PSU") (Balthis et al. 2013). Bottom water salinities tend to be less variable, ranging from 31.1 to 36.5 PSU, with lower salinities associated with shallower inner-shelf locations (Balthis et al. 2013). Marine, open ocean salinities tend to be higher than nearshore areas, ranging in salinities from 35.9 and 36.7 PSU (Balthis et al. 2013). Surface temperatures average 30.7 degrees Celsius ("°C") while bottom temperatures average 26.4°C, decreasing with depth (Balthis et al. 2013). In deeper marine/open ocean locations, temperatures range from 19.0ºC to 28.4ºC and averaging 22.7ºC, which are colder and more variable than nearshore temperatures that average 27.9ºC (Balthis et al. 2013).

3.0 SPECIES AND NUMBERS OF MARINE MAMMALS

Hayes et al. (2022) reports 21 species of marine mammals (whales and dolphins) that may occur in the GOM region, all of which are protected under the MMPA. Rice's whales and sperm whales are listed under the Endangered Species Act ("ESA"; see Table 3-1) but are unlikely to occur in the Project Area. These species are included in this application in the unlikely event these endangered species occur to ensure proper mitigation measure are in place and a full analysis of potential impacts is presented. A description of the status and distribution of the species likely to occur in the Project Area will be discussed further in Section 4.0.

Table 3-1 Marine Mammals Known to Occur in the Marine Waters in the Northern Gulf of Mexico

Common Name	Scientific Name	MMPA and ESA Status	Estimated Population (number)	Stock [1]
Mysticetes (Baleen Whales)				
Balaenopteridae (Rorquals)				
Rice's whale	*Balaenopteridae ricei*	MMPA: Strategic	51	GOM
Odontocetes (Toothed Whales)				
Delphinidae (Dolphins)				
Atlantic Spotted Dolphin	*Stenella frontalis*	MMPA: Non-strategic	21,506	GOM
Bottlenose Dolphin	*Tursiops truncates*	MMPA: Strategic	332	GOM, B30-Mississippi River Delta
		MMPA: Strategic	3,046	GOM, B29
				GOM, B02-Mississippi Sound
				GOM, B03-Mississippi Sound
				GOM, B04-Mississippi Sound
				GOM, B05-Mississippi Sound
				GOM, B31-Bay Boudreau

Table 3-1 Marine Mammals Known to Occur in the Marine Waters in the Northern Gulf of Mexico

Common Name	Scientific Name	MMPA and ESA Status	Estimated Population (number)	Stock [1]
		MMPA: Strategic	122	GOM, B06-Mobile Bay/Bonsecour Bay
		MMPA: Strategic	0	GOM, B07-Perdido Bay
		MMPA: Strategic	33	GOM, B08-Pensacola Bay/East Bay
		MMPA: Strategic	179	Choctawhatchee Bay Stock
		MMPA: Non-strategic	199	St. Andrew Bay
		MMPA: Non-strategic	158	Sarasota Bay, Little Sarasota Bay
		MMPA: Non-strategic	142	St. Joseph Bay
		MMPA: Strategic	439	St. Vincent Sound, Apalachicola Bay, St. George Sound
		MMPA: Strategic	491	Apalachee Bay
		MMPA: Strategic	unknown	Waccasassa Bay, Withlacoochee Bay, Crystal Bay
				St. Joseph Sound, Clearwater Harbor
				Tampa Bay
				Estero Bay
				Chokoloskee Bay, Ten Thousand Islands, Gullivan Bay
				Whitewater Bay
				Florida Keys (Bahia Honda to Key West)
		MMPA: Strategic	0	Caloosahatchee River
		MMPA: Strategic	826	Pine Island Sound, Charlotte Harbor, Gasparilla Sound, Lemon Bay

Table 3-1 Marine Mammals Known to Occur in the Marine Waters in the Northern Gulf of Mexico

Common Name	Scientific Name	MMPA and ESA Status	Estimated Population (number)	Stock [1]
		MMPA: Non-strategic	3,870	Terrebonne-Timbalier Bay Estuarine System Stock
		MMPA: Strategic	2,306	Barataria Bay Estuarine System Stock
		MMPA: Non-strategic	63,280	GOM Continental Shelf Stock
		MMPA: Non-strategic	16,407	GOM, Eastern Coastal Stock
		MMPA: Non-strategic	11,543	GOM Northern Coastal Stock
		MMPA: Non-strategic	20,759	GOM Western Coastal Stock
		MMPA: Non-strategic	7,462	GOM Oceanic Stock
		MMPA: Non-strategic	37	West Bay
Clymene Dolphin	*Stenella clymene*	MMPA: Strategic	513	GOM
False Killer Whale	*Pseudorca crassidens*	MMPA: Non-strategic	494	GOM
Fraser's Dolphin	*Lagenodelphis hosei*	MMPA: Non-strategic	213	GOM
Killer Whale	*Orcinus orca*	MMPA: Non-strategic	267	GOM
Melon-Headed Whale	*Peponocephala electra*	MMPA: Non-strategic	1,749	GOM
Pantropical Spotted Dolphin	*Stenella attenuata*	MMPA: Non-strategic	37,195	GOM
Pygmy Killer Whale	*Feresa attenuate*	MMPA: Non-strategic	613	GOM
Risso's Dolphin	*Grampus griseus*	MMPA: Non-strategic	1,974	GOM
Rough-Toothed Dolphin	*Steno bredanensis*	MMPA: Non-strategic	unknown	GOM
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	MMPA: Non-strategic	1,321	GOM
Spinner Dolphin	*Stenella longirostris*	MMPA: Strategic	2,991	GOM
Striped Dolphin	*Stenella coeruleoalba*	MMPA: Strategic	1,817	GOM
Sperm Whales				
Dwarf Sperm Whale	*Kogia sima*	MMPA: Non-strategic	336 [2]	GOM

Table 3-1 Marine Mammals Known to Occur in the Marine Waters in the Northern Gulf of Mexico

Common Name	Scientific Name	MMPA and ESA Status	Estimated Population (number)	Stock [1]
Pygmy Sperm Whale	*Kogia breviceps*	MMPA: Non-strategic	336 [2]	GOM
Sperm Whale	*Physeter microcephalus*	MMPA: Strategic ESA: Endangered	1,180	GOM
Beaked Whales				
Blainville's Beaked Whale	*Mesoplodon densirostris*	MMPA: Non-strategic	98	GOM
Cuvier's Beaked Whale	*Ziphius cavirostris*	MMPA: Non-strategic	18	GOM
Gervais' Beaked Whale	*Mesoplodon europaeus*	MMPA: Non-strategic	20	GOM

Notes:
1 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 (NOAA Fisheries 2021a).
2 This estimate includes both the dwarf and pygmy sperm whales.
ESA = Endangered Species Act
GOM = Gulf of Mexico
MMPA = Marine Mammal Protection Act
Sources: Hayes et al. 2022

4.0 AFFECTED SPECIES STATUS AND DISTRIBUTION

Approximately 21 different species of marine mammals have been recorded in the GOM (Würsig 2017; Hayes et al. 2022). Of these, 19 are considered to be regularly occurring species in the region, though only bottlenose dolphins are likely to occur in the vicinity of the Project or vessel transit routes (NOAA Fisheries 2021b). Bottlenose dolphins are present year-round in the nearshore waters of the GOM and are expected to have a common occurrence within the vicinity of the Project. The occurrence of Atlantic spotted dolphins, pantropical spotted dolphins, and Risso's dolphins in the vicinity of the Project or vessel transit routes is possible although unlikely; however, their status and distribution are discussed in Section 4.2.4 for completeness. The sperm whale and Rice's whale are listed as threatened or endangered with no designated critical habitat for either of these marine mammal species in the northern GOM. Their occurrence near the Project and thus exposure to Project stressors is possible but unlikely.

4.1 Baleen Whales (Mysticetes)

4.1.1 Rice's Whale (*Balaenopteridae ricei*) – Endangered / Strategic

The Rice's whale is an endangered species in the GOM that is genetically distinct from the Bryde's whale and is listed as endangered (Rosel et al. 2021). Rice's whale is a candidate for listing in the region with a core distribution east of the Project Area (WDC 2022). The Rice's whale was only recently listed as endangered under the ESA in 2019 and is one of the most endangered large baleen whale species in the world. The northern GOM stock is still referred to as Bryde's whale in the most recent stock assessment report (Hayes et al. 2022) and is considered strategic under the MMPA (Hayes et al. 2022). A recovery plan is in progress for the Rice’s whale by the Marine Mammal Commission (“MMC”) and NOAA Fisheries (MMC 2022).

Distinguishing features for Rice’s whales include a sleek body with pointed pectoral fins, uniform dark gray coloration with a pale belly. Rice’s whales have a large, three-ridged head that is about one-quarter of its body length, a large, broad fluke, and a hooked dorsal fin that is located two-thirds down its back (MMC 2022). Rice’s whales have grooves in their throat that expand when engulfing their prey. Due to the limited data on the diet of Rice’s whales, it is believed they forage on the seafloor during deep dives down to 271 meters (889 feet), feeding on plankton, krill, and copepods in the water column (WDC 2022). Rice’s whales’ hearing is in the LF range (NOAA Fisheries 2018).

Recognized as a new species in 2021, Rice’s whales are referred to as Bryde’s whales in previous studies conducted in the GOM. Rice’s whales are the only known baleen whale to occur year-round in the GOM (Soldevilla et al. 2017). The historic range of Rice’s whales was believed to be wide like that of Bryde’s whales, occurring in the Atlantic, Pacific, and Indian Oceans (MMC 2022). However, recent genetic analyses have indicated that the Rice’s whale is a separate species with year-round occurrence primarily in the northern GOM (Soldevilla et al. 2017). Survey efforts have increased to better understand the distribution of this species; however, minimal sightings have been recorded (Soldevilla et al. 2017). Several Bryde’s-like whales have been documented in the GOM that are believed to have been Rice’s whales, questioning whether the habitat of this species could expand west of the Mississippi River delta. Passive acoustic monitoring (“PAM”) has proven useful in monitoring Rice’s whale occurrence in the northeastern GOM (Soldevilla et al. 2017). Several marine mammal studies utilizing PAM deployments and visual detections were conducted by the NOAA Southeast Fisheries Science Center between 2015 and 2018 to understand Rice’s whale distribution and habitat in the GOM (Soldevilla et al. 2017). Passive acoustic data identified whale calls unique to Rice’s whales, localizing the occurrence of certain individuals outside of their preferred habitat near De Soto Canyon and west of Louisiana towards Texas in water depths ranging from 100 to 400 meters (328 to 1,312 feet). Throughout the year, Rice’s whale calls were more commonly detected in the western GOM than the eastern GOM despite their core habitat being in the eastern GOM. This finding suggests Rice’s whales venture farther out into the GOM than previously thought (Soldevilla et al. 2017). While they occur year-round in their preferred northeastern habitat, acoustic data during this study detected a slight decrease in recorded calls during the winter (Soldevilla et al. 2017). Other than this finding, no notable seasonal migrations were observed in the GOM for this species.

The best abundance estimate for Rice’s whale in the northern GOM is 51 (Coefficient of Variance [“CV”]=0.50) (Hayes et al. 2022). This estimate is from oceanic surveys covering waters from the 200-meter isobath to the U.S. Exclusive Economic Zone (“EEZ”) during summer 2017 and summer/fall 2018 (Garrison et al. 2020). Like Bryde’s whales, Rice’s whales faced heavy commercial whaling from 1911 to 1987 and became severely depleted. Unfortunately, exact population levels of Rice’s whales and Bryde’s whales during periods of commercial whaling are unknown. Fishery-related mortality for this species from 2014 to 2018 is unknown as there was no documentation for this stock. Mean annual mortality from human-causes from 2014 to 2018 was predicted to be 0.5. Average annual fishery-related mortality and serious injury does not exceed the PBR for this species. Three commercial fisheries that could interact with this stock include the Category I Atlantic Ocean, Caribbean, GOM large pelagics longline fishery, and two Category III fisheries, the Southeastern U.S. Atlantic, GOM, and Caribbean snapper-grouper. No strandings have been documented in the GOM from 2014 to 2018. An Unusual Mortality Event (“UME”) was declared for cetaceans in the northern GOM from March 2010 to July 2014 including those stranded, during, and after the Deepwater Horizon ("DWH") oil spill (Hayes et al. 2021). Models predicted a total of 2.3 Rice's whales died during the period 2014–2018 from oil exposure, and experienced a 22 percent maximum stock reduction due to the oil spill (Hayes et al. 2021). Anthropogenic threats to Rice's whale populations include entanglement in fishing gear, seismic surveys, vessel strikes, vessel traffic, and airgun pulses (Soldevilla et al. 2017; MMC 2022). Entanglement in fishing gear has been shown to cause acute mortality in Rice's whales in the GOM due to reduced foraging, starvation, infection, hemorrhaging, and debilitation (Soldevilla et al. 2017). Given the Rice's whale occurrence in the northern GOM near the De Soto Canyon, their presence in the Project Area is possible but unlikely.

4.1.2 Sperm Whale (*Physeter microcephalus*) – Endangered / Strategic

The sperm whale is listed as endangered under the ESA and is designated as strategic under the MMPA (Hayes et al. 2022).

Sperm whales are dark gray on their back and light gray on their belly. They are the largest toothed whale on Earth with males averaging up to 15 meters (49 feet) long and up to 36,000 kilograms ("kg"), and females averaging up to 11 meters (36 feet) long and up to 20,000 kg (Würsig 2017). The maximum size of a male sperm whale is 20 meters (66 feet). The head of a sperm whale grows disproportionately to its body as it ages, reaching up to one-fifth to one-third the size of its body in males. Its blowhole is located at the upper front of its head rather than in the middle of the back like other whales. A dorsal ridge is located on the back with no dorsal fin. Sperm whales spend a majority of their time deep diving for food (up to 1,000 meters [3,280 feet]) where they consume large squid, sharks, skates and rays. Sperm whale hearing is in the MF range (NOAA Fisheries 2018).

Aerial surveys have documented sperm whales widespread throughout tropical and polar waters, specifically along the continental slope and oceanic waters (Hayes et al. 2022). During the eighteenth and nineteenth centuries, the sperm whale population was impacted by commercial whaling in the GOM, one of the few areas exploited by the U.S. (Würsig 2017). An estimated 1,179 sperm whales were killed in the GOM (Reeves et al. 2011). Seismic surveys began in the 2000s with focus on sperm whales, finding a significant habitat in the GOM where they reside year-round (Würsig 2017; Hayes et al. 2022). The sperm whale population in the GOM is considered to be distinctly different from the North Atlantic stock, primarily in their behavior. Sperm whales have been observed in a matriarchal society with females remaining in their groups and males leaving to socially isolate. The females remain in the tropical and subtropical regions while the males socially isolate themselves and travel as far as the polar regions. This behavior has been documented in the GOM and is believed differ from those in the North Atlantic (Würsig 2017).

The best abundance estimate for the northern GOM sperm whale is 1,180 (CV=0.28) (Hayes et al. 2022). This estimate is from summer 2017 and summer/fall 2018 oceanic surveys covering waters from the 200-meter isobath to the seaward extent of the U.S. EEZ (Hayes et al. 2022). Anthropogenic threats to sperm whale populations include entanglement in fishing gear, seismic surveys, vessel strikes, and active naval sonars (Hayes et al. 2022). Anthropogenic noises resulting from geological and geophysical surveys due to oil exploration have impacted this population the most, resulting in reduction in foraging efforts by the species and thus starvation during the surveys (Farmer et al. 2018). A total of 36 sperm whale strandings were recorded in the GOM from January 2000 through September 2017 (Farmer et al. 2018), and a total of 7 sperm whale strandings occurred in the northern GOM from 2014 to 2018 (Hayes et al. 2022). Seismic- and/or vessel-related mortality has been reported for sperm whales in the northern GOM due to high activity in shipping lanes; however, no vessel strikes have been documented from the 2014–2018 period. Only one incident of a vessel strike in the GOM was recorded, which occurred in 1990 in Grand Isle, Louisiana.

Fishery-related mortality during the 2014–2018 period was 0.2 sperm whales for this stock (Hayes et al. 2022). The only fishery involved was the large pelagics longline fishery. The two commercial fisheries that could interact with this stock are the Category I Atlantic Highly Migratory Species longline fishery and the Category I Atlantic Ocean, Caribbean, GOM large pelagics longline fishery. No takes of sperm whales have been documented from these fisheries. Mean annual mortality due to human-caused actions (i.e., DWH oil spill) during the 2014–2018 period was 9.4. Human interaction was observed for one of the strandings and no human interaction was observed for the other strandings. A UME was declared for cetaceans from March 2010 to July 2014 in the northern GOM. Six sperm whale strandings were part of this UME due to the DWH oil spill. This UME included cetaceans stranded prior to, during, and after the oil spill. A population model was developed to determine the impact of the spill on the northern GOM stock, estimating a 7 percent maximum reduction in population for sperm whales. An estimated 94 sperm whales died from 2010 to 2013 due to oil exposure. Average annual fishery-related mortality and serious injury does not exceed the PBR for this species (Hayes et al. 2022). The Project Area does not have abundant food resources for this species, and therefore the occurrence of sperm whales is considered possible but unlikely (NOAA Fisheries 2021c).

4.2 Toothed Whales (Odontoceti)

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

Atlantic spotted dolphins are not listed as threatened or endangered under the ESA and this stock is not considered strategic.

The Atlantic spotted dolphin has a robust body that can reach from 1.5 to 2.3 meters (5 to 7.5 feet) with light spots on their dark backs and dark spots on their belly. They have a tall, curved dorsal fin that is located halfway down their back and have long, slender beaks (Jefferson et al. 2015). There are two types of Atlantic spotted dolphin in the GOM: a larger, very spotted dolphin found over the continental shelf and a smaller, less spotted dolphin found in deeper waters off the shelf and around oceanic islands (Viricel and Rosel 2014). Atlantic spotted dolphins consume surface fishes, squid, and crustaceans. Hearing for Atlantic spotted dolphins is in the MF range (NOAA Fisheries 2018).

Atlantic spotted dolphins occur throughout the warm temperate, subtropical, and tropical waters of the GOM and the Atlantic Ocean (Hayes et al. 2022). They have a widespread distribution that ranges from the U.S. East Coast (GOM to Cape Cod, Massachusetts), the Azores, and Canary Islands to Gabon and Brazil. Their distribution may be affected by warm currents such as the Gulf Stream. This species is commonly observed in the waters of the northern GOM continental shelf up to 200 meters (656 feet) and out around 457 meters (1,500 feet) in depth (Hayes et al. 2022). The best abundance estimate for this species in the northern GOM is 21,506 (CV=0.26) (Hayes et al. 2022). This estimate comes from an aerial survey during summer 2017 over the continental shelf, and an estimate from summer 2017/2018 over oceanic waters (Garrison et al. 2020; Garrison and Stokes 2021). Primary threats to this species include entanglement in fishing gear, bycatch, vessel strikes, anthropogenic noise, pollution, and habitat degradation. There are two commercial fisheries that could interact with this stock in the GOM: the Category I Atlantic Ocean Caribbean, GOM large pelagics longline fishery and the Category II Southeastern U.S. Atlantic GOM shrimp trawl fishery (Hayes et al. 2022).

Fishery-related mortality and serious injury for this stock from 2015 to 2019 was 36 (CV=0.47). Due to the DWH oil spill, 231 Atlantic spotted dolphins and common bottlenose either died or were injured from 2015 to 2019 (Hayes et al. 2022). During the 2015–2019 period, three Atlantic spotted dolphins were stranded in the GOM: one dolphin was in Alabama in 2017, one was in Alabama in 2018, and one was in Florida in 2019. There have been three Atlantic spotted dolphin UMEs in the northern GOM since 1990. Average annual fishery-related mortality and serious injury does not exceed the PBR for this species. A UME was declared for cetaceans in the northern GOM from March 2010 through July 2014 during the DWH oil spill in which 14 strandings of Atlantic spotted dolphins occurred. The PBR for this stock is 166. The occurrence of this species in the Project Area is unlikely.

4.2.2 Pantropical Spotted Dolphin (*Stenella attenuata*) – Non-Strategic

Pantropical spotted dolphins are not listed as threatened or endangered under the ESA and this stock is not considered strategic.

Pantropical spotted dolphins are typically 1.8 to 2.2 meters (6 to 7 feet) in length at adulthood and have a long, slender, white tipped beak (Jefferson et al. 2015). While they are very similar to the Atlantic spotted dolphin, they are also distinguished by a dark coloration on their backs stretching from their head to between the dorsal fin and the tail flukes (Jefferson et al. 2015). They occur throughout the warm temperate, subtropical, and tropical waters of the GOM and the Atlantic Ocean (Hayes et al. 2022). They are seen year-round throughout the northern GOM where they occur in oceanic waters off the continental shelf and feed on mesopelagic and epipelagic fishes, crustaceans, and squid (Würsig 2017). Hearing for Atlantic spotted dolphins is in the MF range (NOAA Fisheries 2018).

The best abundance estimate for this species in the northern GOM is 37,195 (CV=0.24) (Hayes et al. 2022). This estimate is from summer/fall 2018 oceanic surveys covering waters from the 200-meter isobath to the seaward extent of the U.S. EEZ (Garrison et al. 2020). Primary threats to this species include entanglement in fishing gear, ocean noise, human harassment and feeding activities (NOAA Fisheries 2022). The mean annual mortality and serious injury from 2014-2018 related to human-caused actions from the DWH oil spill was 241 (Hayes et al. 2022). Average annual fishery-related mortality and serious injury does not exceed the PBR for this species. A UME was declared for cetaceans in the northern GOM from March 2010 through July 2014 and included those stranded before, during, and after the DWH oil spill (Hayes et al. 2021). Three pantropical dolphins were stranded in 2011 as part of this UME. From the DWH oil spill, this stock suffered a 9 percent maximum reduction in population size (DWH MMIQT 2015). An estimated 2,367 pantropical dolphins died from 2010 to 2013 due to high exposure to oil. Occurrence of this species in the Project Area is unlikely.

4.2.3 Bottlenose Dolphin (*Tursiops truncatus*) – Non-Strategic Northern GOM Continental Shelf Stock; -Strategic GOM Western Coastal Stock; Non-Strategic Northern GOM Oceanic Stock

Bottlenose dolphins occur in coastal, shelf, and oceanic waters worldwide, across temperate and tropical latitudes. The population of bottlenose dolphins in the GOM 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 meters (66 feet) deep, along the inner continental shelf (within 7.5 km of shore) and around islands; it is continuously distributed south of Long Island, New York into the GOM (Hayes et al. 2022). Thirty-eight stocks of common bottlenose dolphins reside in the GOM including 33 bay, sound, and estuary stocks in the inshore waters, three coastal stocks (western, northern, and eastern), the northern GOM Continental Shelf

Stock, and the northern GOM Oceanic Stock (Waring et al. 2013). This migratory coastal population is subdivided into four stocks, based largely upon spatial distribution (Litz et al. 2019). There are three stocks that may be found in the vicinity of the Project Area: the Northern GOM Continental Shelf Stock; GOM Western Coastal Stock; and the Northern GOM Oceanic Stock. The occurrence, density, habitat usage, and sightings data of the Barataria Bay Estuarine System Stock, and the Mississippi Sound, Lake Borgne, Bay Boudreau Stock, were analyzed and results indicated that these stocks are unlikely to be impacted by Project activities and therefore are not discussed further in the application.

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). Hearing for bottlenose dolphins is in the MF range (Southall et al. 2009).

Bottlenose dolphins appear to be active during both 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). They are light- to slate-gray in color, roughly 2.4 to 3.7 meters (8 to 12 feet) long, and have short, stubby beaks. They show sexual dimorphism between males and females, with males being larger and heavier. The species' hearing is in the MF range (Southall et al. 2009; NOAA Fisheries 2018). In general, the species occupies a wide variety of habitats, thus 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°C to 32°C.

GOM Western Coastal Stock: Bottlenose dolphins under the GOM Western Coastal Stock are not listed as threatened or endangered under the ESA, and this stock is not strategic. The GOM Western Coastal Stock has the possibility to occur within the vicinity of the Project Area. This morphotype occupies the Mississippi River delta to the Texas-Mexico border where there is an arid to temperate climate, sand beaches, coastal marshes, and freshwater inputs (Hayes et al. 2022). The abundance estimates for the Western Coastal Stock of common bottlenose dolphins were based upon tracklines and sightings in waters from the shoreline to the 20-meter isobath and between the Texas-Mexico border and the Mississippi River delta. The seasonal abundance estimates for this stock were 18,601 (CV=0.30; summer) and 21,766 (CV=0.14; fall) (Hayes et al. 2022).

The best abundance estimate for this stock is 20,759 (CV=0.13) (Garrison and Stokes 2021). Human-caused mortality and serious injury for the Western Coastal Stock from 2015 to 2019 is unknown. The 5-year unweighted mean annual mortality estimate for 2015 to 2019 for the commercial shrimp trawl fishery was 32 (CV=0.65) (Hayes et al. 2022). The mean annual fishery-related mortality and serious injury during the 2015–2019 period for strandings identified as fishery-caused was 0.4. Mean annual mortality and serious injury during 2015-2019 due to other human-caused actions such as the DWH oil spill and foreign fisheries was predicted to be 3.2. There are five commercial fisheries that could interact with this stock. These include three Category II fisheries (Southeastern U.S. Atlantic, GOM shrimp trawl; GOM menhaden purse seine; and GOM gillnet); and two Category III fisheries (GOM blue crab trap/pot; and the Atlantic Ocean, GOM, Caribbean commercial passenger fishing vessel [hook and line]).

Northern GOM Continental Shelf Stock: Bottlenose dolphins under the Northern GOM Continental Shelf Stock are not listed as threatened or endangered under the ESA, and this stock is not strategic. The northern GOM shelf stock is likely to occur within the Project Area. This stock inhabits waters from 20 to 200 meters (66 to 656 feet) deep from the U.S.-Mexican border to the Florida Keys. The seasonal abundance estimates for this stock were 74,959 (CV=0.15; summer) and 52,090 (CV=0.14; fall) (Hayes et al. 2022).

The best abundance estimate available for the northern GOM Continental Shelf Stock of common bottlenose dolphins is 63,280 (CV=0.11) (Hayes et al. 2022). This estimate is from an inverse-variance weighted average of seasonal abundance estimates from aerial surveys conducted during summer 2017 and fall 2018. From March 2010 to July 2014, NOAA Fisheries declared a UME for cetaceans in the northern GOM including those stranded prior to, during, and after the DWH oil spill (Hayes et al. 2022). It was predicted that a total of 3,384 continental shelf dolphins died during 2010-2014 due to oil spill exposure. In addition to exposure to the DWH oil spill, bottlenose dolphins were injured and killed by fishery-related activities. From 2015 to 2019, the mean annual fishery-related mortality and serious injury was 64 (CV=0.34). There are four commercial fisheries that could interact with this stock including one Category II fishery (Southeastern U.S. Atlantic, GOM shrimp trawl commercial fishery), and three Category III fisheries (Southeastern U.S. Atlantic, GOM shark bottom longline/hook-and-line; Southeastern U.S. Atlantic, GOM, Caribbean snapper-grouper and other reef fish; and Atlantic Ocean, GOM, Caribbean commercial passenger fishing vessel (hook and line).

Northern GOM Oceanic Stock: Bottlenose dolphins under the Northern GOM Oceanic Stock are not listed as threatened or endangered under the ESA, and this stock is not strategic. The northern GOM Oceanic stock is likely to occur within the Project Area. The documented habitat range for this stock extends south from the 200-m isobath of the GOM toward the seaward extend of the EEZ (Hayes et al. 2021).

The best abundance estimate for the northern COM Oceanic Stock is 7,462 (CV = 0.31) (Hayes et al. 2021). This estimate is from an inverse-variance weighted average of seasonal abundance estimates from aerial surveys conducted during summer 2017 and fall 2018.

From March 2010 to July 2014, NOAA Fisheries declared a UME for cetaceans in the northern GOM including those stranded prior to, during, and after the DWH oil spill (Hayes et al. 2022). Population models estimated that 308 oceanic bottlenose dolphins died during 2010-2013 as a result of the DWH oil spill, with an additional 160 estimated mortalities from this stock in 2014 (Hayes et al. 2021). No fisheries-related mortalities or serious injuries have been documented in this stock in recent years, and the PBR for the stock is 58 (Hayes et al. 2021).

4.2.4 Risso's Dolphin (*Grampus griseus*) – Non-Strategic

Risso's dolphins are not listed as threatened or endangered under the ESA and this stock is not considered strategic (Hayes et al. 2022).

Risso's dolphins are characterized by their robust, dark gray body that accumulates several white scars. Younger individuals do not have this scarring and are dark in color, and as they age, they become lighter in color. They have a narrow tailstock, a small dorsal fin, and a blunt head. Risso's dolphins tend to travel in groups up to 30 individuals of other species of dolphins but have also been observed to socially isolate. During their long dives near the continental shelf (up to 305 meters [1,000 feet]), Risso's dolphins consume fish, krill, squid, octopus, and cuttlefish (MBARI 2019). Risso's dolphin hearing is in the MF range (NOAA Fisheries 2018). They occur throughout oceanic waters but are concentrated in continental slope waters in the GOM (Maze-Foley and Mullin 2006). This species has been observed in all seasons in the northern GOM (Hansen et al. 1996; Mullin and Hoggard 2000). There are insufficient data to determine any population trend for this stock. Hearing for Risso's dolphins is in the MF range (NOAA Fisheries 2018).

The best abundance estimate for this stock is 1,974 (CV=0.46) (Hayes et al. 2022). This estimate is from summer 2017 and summer/fall 2018 oceanic surveys covering waters from the 200-meter isobath to the U.S. EEZ (Garrison et al. 2020). Risks to Risso's dolphins include bycatch from trawling and gillnet activities. Two takes of Risso's dolphins were observed in the northeast bottom trawl fisheries in 2016. From 2015 to 2019, 31 Risso's dolphin strandings occurred on the U.S. Atlantic coast; however, none showed evidence of human interaction. Human-caused mortality for this stock from 2015-2019 was 3 (CV=0.09). The PBR for this species is 301, and the average annual fishery-related mortality and serious injury does not exceed the PBR for this species. Other human-caused actions resulted in a mean mortality of 5.3 from 2014 to 2018 (Hayes et al. 2022). Fishery-related mortality and serious injury was zero from 2014 to 2018 for this stock. Occurrence of this species in the Project Area is possible, but considered unlikely based on sightings data (OBIS 2023).

5.0 TYPE OF INCIDENTAL TAKING REQUESTED

The Applicant is requesting the authorization for potential non-lethal "taking" of small numbers of marine mammals to allow for incidental harassment resulting from the pile-driving activities associated with the installation for FLNG2. The request is based upon projected construction activities during the anticipated schedule as stated in Section 2.1.

The potential underwater noise impacts of anticipated Project activities were evaluated against the criteria prescribed in the revised NOAA Fisheries (2018) Revised Technical Guidance. To ensure that the potential for Level B harassment is avoided and/or minimized to the maximum extent possible, the Applicant has committed to the mitigation measures as outlined in Sections 11.0, Mitigation Measures, and 13.0, Monitoring and Reporting.

As detailed in Section 1.2, Proposed Activity, pile-driving activities would generate underwater noise with sounds exceeding the 160 $dB_{RMS90\%}$ re 1 μPa threshold for Level B harassment for impulsive sound harassment for certain hearing groups and pieces of equipment. The Applicant is requesting the authorization for the incidental take by Level B harassment of small numbers of marine mammals pursuant to Section 101 (a) (5) of the MMPA and in accordance with 50 CFR Part 216 Subpart I, in support of the Applicant's Project activities. Level A harassment is not anticipated as a result of construction activities. This request is being submitted to specifically address Project activities in support of the Applicant's development of an LNG export facility, as further detailed in Section 6, Take Estimates for Marine Mammals.

6.0 TAKE ESTIMATES FOR MARINE MAMMALS

The Applicant seeks authorization for potential "taking" of small numbers of marine mammals under the jurisdiction of NOAA Fisheries in the proposed Project Area. Anticipated impacts to marine mammals from Project activities will be associated with noise propagation from impact pile driving. It should be noted that the estimates of exposure for marine mammals as presented in this section are conservative, and thus actually may be lower.

Most marine animals can perceive underwater sounds over a broad range of frequencies from about 7 hertz ("Hz") to more than 160,000 Hz (160 kilohertz ["kHz"]) (Table 6-1). Many of the dolphins and porpoises use even higher frequency sound for echolocation and perceive these high frequency sounds with high acuity.

Table 6-1 Functional Hearing Range of Marine Mammals

Species	Estimated Auditory Bandwidth
LF cetaceans (baleen whales)	7 Hz to 35 kHz
MF cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
HF cetaceans (true porpoises, Kogia, river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*)	275 Hz to 160 kHz
Phocid pinnipeds (underwater) (true seals)	50 Hz to 86 kHz

Source: NOAA Fisheries 2018
HF = high frequency
Hz = hertz
kHz = kilohertz
LF = low frequency
MF = mid-frequency

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).

6.1 Basis for Estimating Numbers of Marine Mammals that Might be Taken by Harassment from Impact Pile Driving Associated with FLNG2 Permanently Fixed Platform Construction Activities

6.1.1 Propagation Models

Underwater sound propagation modeling is summarized here; however, full details can be found in Appendix A. Underwater sound propagation modeling was completed using dBSea, a software developed by Marshall Day Acoustics for the prediction of underwater noise in a variety of environments. The 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. Noise mitigation methods may also be included. The user has control over the seabed and water properties including sound speed profile, temperature, salinity, and current. Noise levels are calculated to the extent of the bathymetry area. 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 calculation area. Levels are calculated in third octave bands from 12.5 Hz to 20 kHz.

6.1.2 Model Input Parameters

The representative acoustic modeling scenarios were derived from descriptions of the expected construction activities through consultations between the Project design and engineering teams. The scenarios modeled were ones where potential underwater noise impacts of marine species were anticipated, including impact pile driving for a fixed-jacket design associated with the three FLNG2 platforms (i.e., P4, P5, and P6). Tetra Tech developed its empirical model based on literature, engineering guidelines, and underwater source measurements and acoustic modeling assessments of similar equipment and activities (see Appendix A).

A summary of construction scenarios included in the underwater acoustic modeling analysis is provided in Table 6-2. The model accounts for differences in hammer energy, number of strikes, installation duration, sound source level, and pile progression as appropriate for the fixed jacket piles. The pile diameters (in inches) selected for the pile-driving modeling scenarios were based on the proposed Project Design Envelope considerations provided by the Applicant. The subsections that follow provide more detailed information about the parameters used to model the noise sources associated with each scenario, which refer to the P4, P5, and P6 platform locations. For all impact piling scenarios, it was assumed that the maximum rated hammer energy of 1,380 kilojoules ("kJ") would be employed; however, that hammer energy assumption is considered conservative. The actual transferred energy to the pile during installation will be less than the maximum rated hammer energy, with losses in energy from sources such as heat and friction. Impact pile-driving scenarios for each day were included in the modeling analysis. Day 3 (H1+H2+H3), which was projected to have the greatest impact and includes the potential impacts from Day 1 (H1) and Day 2 (H1+H2), was modeled as the worst-case scenario and presented here for platforms P5 and P6. The total number of blows in combination with the number of piles produces a cumulative SEL that is very similar for each day. Due to differences in the specific geography and bathymetry of each pile, the combined environmental parameter impact on the sound speed profile resulted in the largest isopleths for the Day 3 scenario. To be conservative, the largest isopleth resulting from the Day 3 scenario was carried forward for calculation of marine mammal exposures.

Table 6-2 Underwater Acoustic Modeling Scenarios – Pile Installation

Platform	Activity Description	Maximum Hammer Energy (kJ)	Duration of Pile Installation (min)	Total Hammer Blows[1]	Location (UTM Coordinates) for Modeling Locations	Sound Source Level (No Attenuation)
P4	108-inch-diameter Pile (includes 4 piles per day): 2.743 m	Impact Pile Driving: 1,380	190	5,684	223,049 m, 3,219,466 m	**236 $L_{p,pk}$** **210 $L_{E,\ 1sec}$** **220 L_p**
P5	108-inch-diameter Pile (includes 8 pile segments per day): 2.743 m	Impact Pile Driving: 1,380	238	7,144	222,890 m, 3,219,450 m	**236 $L_{p,pk}$** **210 $L_{E,\ 1sec}$** **220 L_p**
P6	108-inch-diameter Pile (includes 6 pile segments per day): 2.743 m	Impact Pile Driving: 1,380	122	5,358	223,176 m, 3,219,585 m	**236 $L_{p,pk}$** **210 $L_{E,\ 1sec}$** **220 L_p**

1 Total hammer blows are based on the total piles per day.
kJ = kilojoule
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa)
$L_{E,\ 1sec}$ = cumulative sound exposure over a 24-hour period (dB re 1 $\mu Pa^2 \cdot s$)
L_p = root mean square sound pressure (dB re 1 μPa)
m = meter
UTM = Universal Transverse Mercator

The pile-driving scenarios were modeled using a vertical array of point sources spaced at 1-meter intervals, distributing the sound emissions from pile driving throughout the water column. The vertical array was assigned third-octave band sound characteristics adjusted for site-specific parameters discussed above, including expected hammer energy and number of blows. Third octave band center frequencies from 12.5 Hz up to 20 kHz were used in the modeling. The spectra used in the modeling are shown in Figure 6-1.

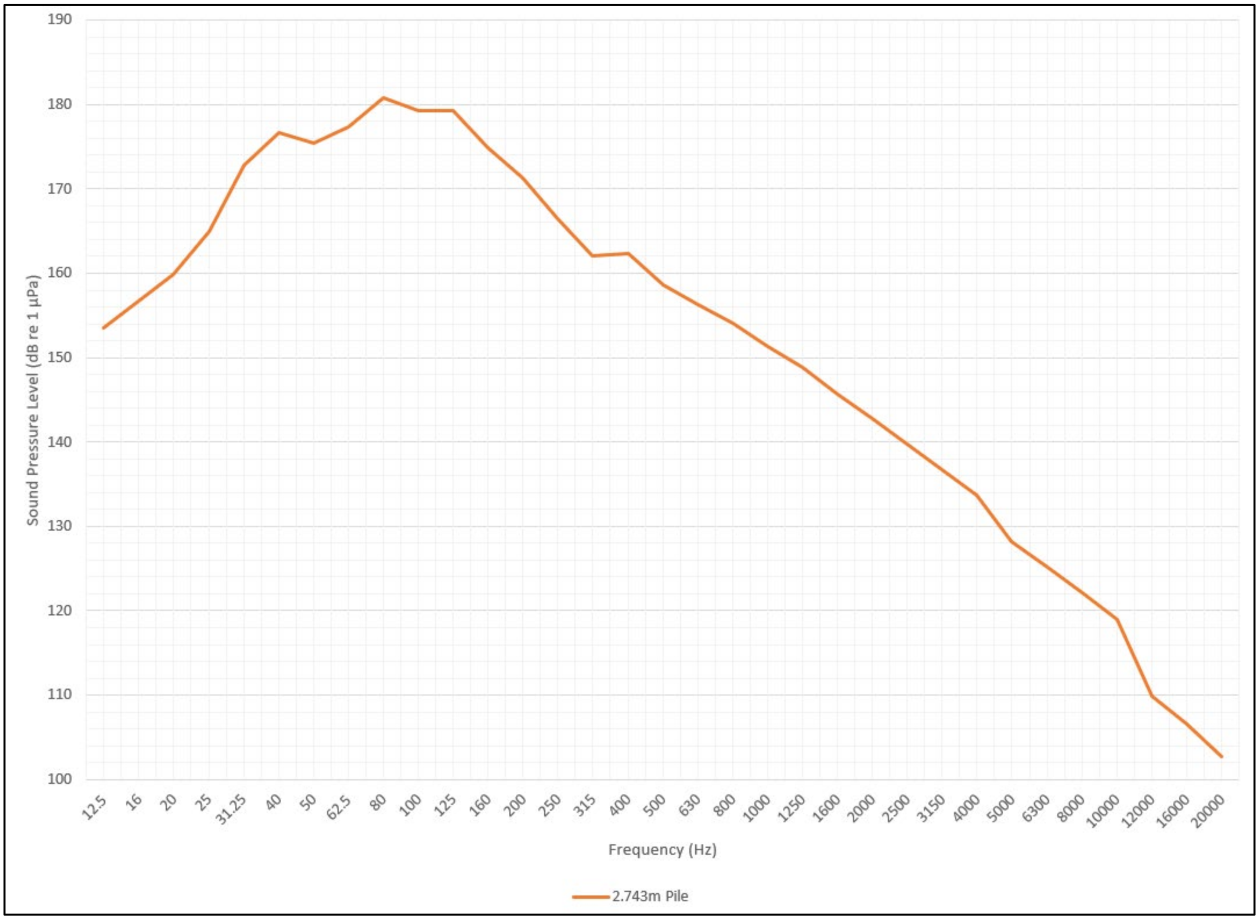

Figure 6-1 Impact Pile-Driving Spectral Source Levels

Bathymetry data represent the three-dimensional nature of the subaqueous land surface and were obtained from the National Geophysical Data Center ("NGDC") and a U.S. Coastal Relief Model (NOAA Satellite and Information Service 2020); the horizontal resolution of this dataset is 3 arc seconds (90 meters). NGDC's 3 arc-second U.S. Coastal Relief Model 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 Coastal Relief Model spans the U.S. East and West Coasts, the northern coast of the GOM, Puerto Rico, and Hawaii, reaching out to, and in places even beyond, the continental slope. The Geophysical Data System is an interactive database management system developed by the NGDC for use in the assimilation, storage, and retrieval of geophysical data. Geographical Data System software manages several types of data including marine trackline geophysical data, hydrographic survey data, aeromagnetic survey data, and gridded bathymetry/topography.

Sediment type (e.g., hard rock, sand, mud, clay) directly impacts the speed of sound since it is a part of the medium in which the sound propagates. For the underwater acoustic assessment, the sea floor is expected to be predominantly clay. The geoacoustic properties with information on the compositional data of the surficial sediments were informed by estimated geophysical and geotechnical data provided by the Applicant. The sediment layers and the geoacoustic properties used in the modeling analysis of the impact piling are defined in Table 6-3. The term "compressional" refers to the fact that particle motion of the sound wave is in the same direction as propagation. The term "compressional sound speed" refers to the speed of sound in the sediment along the direction of acoustic propagation. The term "compressional attenuation" refers to how much sound (dB) is lost per wavelength (λ) of the signal. Finally, density is the physical density (ρ) of the sediment. Ranges are provided for the different geoacoustic properties because the values vary depending on the location specifically being modeled for a given scenario.

Table 6-3 Geoacoustic Properties of Sub-bottom Sediments as a Function of Depth

Seabed Layer (meters)	Material	Geoacoustic Properties
0 to 19	Clay	Cp = 1,470 m/s; αs (dB/λ) = 0.1 dB/λ; ρ = 1,200 kg/m^3
19 to 54	Clay-Silt	Cp = 1,515 m/s; αs (dB/λ) = 0.2 dB/λ; ρ = 1,500 kg/m^3
54	Sand	Cp = 1,680 m/s; αs (dB/λ) = 1.0 dB/λ; ρ= 1,900 kg/m^3

dB/λ = decibel per wavelength
kg/m^3 = kilogram per cubic meter
m/s = meter per second

The speed of sound in sea water depends on the temperature T (°C), salinity S (part per thousand), and depth D (meters), and can be described using sound speed profiles. 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 downward, 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 upward, which can aid in long-distance sound propagation. The construction timeframe for pile-driving activities to support installation of the three FLNG2 permanently fixed platforms with underwater noise impact is expected to be May through August 2023. For the construction modeling scenarios, after completing a sensitivity analysis, the December sound speed profile was used in the model as it exhibited maximum case characteristics for long-range noise propagation effects. The speed of sound profile information was obtained using the NOAA Sound Speed Manager software incorporating the World Ocean Atlas 2009 extension algorithms. Additional details pertaining to the sound speed profile sensitivity analysis conducted for the Project can be found in Appendix A.

6.1.3 Calculation of Range to Regulatory Thresholds

To determine the ranges to the defined threshold isopleths, a maximum received level-over-depth approach was used. This approach uses the maximum received level that occurs within the water column at each sampling point. Both the maximum range at which the sound level was calculated in model (R_{max}) and the maximum range at which a sound level was calculated excluding 5 percent of the R_{max} ($R_{95\%}$)

ranges were calculated for each of the regulatory thresholds. The R_{max} is the maximum range in the model at which the sound level was calculated. The $R_{95\%}$ is the maximum range at which a sound level was calculated excluding 5 percent of the R_{max}. The $R_{95\%}$ excludes major outliers or protruding areas associated with the underwater acoustic modeling environment. Regardless of shape of the calculated isopleths, the predicted range encompasses at least 95 percent of the area that would be exposed to sound at or above the specified level. All distances to injury thresholds presented are presented in terms of the $R_{95\%}$ range.

The results for marine mammal injury and behavioral onset for platforms P4, P5, and P6 are shown in Tables 6-4, 6-5, and 6-6 for the applicable SEL, peak sound pressure ("L_{pk}"), and SPL metrics. To be conservative, the 6 dB attenuated isopleths were used for take purposes. However, up to 10 dB attenuation can be expected. The results display trends that are expected including increasingly reduced distances as greater levels of noise mitigation are applied. In addition, the smallest distances to thresholds are observed for the L_{pk} acoustic thresholds while the largest distances were observed for the 183 dB SEL LF cetacean, 155 dB SEL HF cetacean, and 160 dB SPL Marine Mammal criteria. The calculated values for all platforms were all fairly comparable, which is expected since they are positioned in proximity to one another and therefore are at similar water depths and bottom conditions, and experience similar bathymetry and sound speed profile influences. The largest distance was determined to be 4,662 meters corresponding to the 183 dB SEL LF cetacean criterion without mitigation at P5.

Table 6-4 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile Driving at P4 Location

Hearing Group	**Metric**	**Threshold (dB)**	**Location P4**		
			Hammer Energy – 1,380 kJ		
			Pile Diameter - 2.743 m		
			Attenuation (dB)		
			0	**6**	**10**
Low-Frequency Cetaceans	$L_{E,24hr}$[1,3]	183	3,929	2,010	1,238
	$L_{p,pk}$[1,3]	219	39	23	13
Mid-Frequency Cetaceans	$L_{E,24hr}$[1,3]	185	116	46	34
	$L_{p,pk}$[1,3]	230	11	-[5]	-[5]
Marine Mammal Behavior	L_p[2,4]	160	3,208	1,560	1,021

1 NOAA Fisheries 2018
2 NOAA Fisheries 2005
3 Level A Injury PTS
4 Level B Behavioral
5 The threshold level is greater than the source level; therefore, distances are not generated.

Table 6-5 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile Driving at P5 Location

Hearing Group	Metric	Threshold (dB)	Location P5		
			Hammer Energy – 1,380 kJ		
			Pile Diameter - 2.743 m		
			Attenuation (dB)		
			0	6	10
Low-Frequency Cetaceans	$L_{E,24hr}$[1,3]	183	4,558	2,249	1,353
	$L_{p,pk}$[1,3]	219	39	24	14
Mid-Frequency Cetaceans	$L_{E,24hr}$[1,3]	185	132	70	37
	$L_{p,pk}$[1,3]	230	12	-[5]	-[5]
Marine Mammal Behavior	L_p[2,4]	160	3,037	1,582	1,045

1 NOAA Fisheries 2018
2 NOAA Fisheries 2005
3 Level A Injury PTS
4 Level B Behavioral
5 The threshold level is greater than the source level; therefore, distances are not generated.

Table 6-6 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile Driving at P6 Location

Hearing Group	Metric	Threshold (dB)	Location P6		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 m		
			Attenuation (dB)		
			0	6	10
Low-Frequency Cetaceans	$L_{E,24hr}$[1,3]	183	3,908	1,887	1,176
	$L_{p,pk}$[1,3]	219	39	24	13
Mid-Frequency Cetaceans	$L_{E,24hr}$[1,3]	185	111	45	33
	$L_{p,pk}$[1,3]	230	11	-[5]	-[5]
Marine Mammal Behavior	L_p[2,4]	160	3,141	1,603	1,064

1 NOAA Fisheries 2018
2 NOAA Fisheries 2005
3 Level A Injury PTS
4 Level B Behavioral
5 The threshold level is greater than the source level; therefore, distances are not generated.

6.2 Estimate of Potential Project Impact Pile-Driving Takes by Harassment

Estimates of take are computed according to the following formula as provided by NOAA Fisheries (personal communication, November 24, 2015):

$$\text{Estimated Take} = D \times ZOI \times (d)$$

Where:

D = average highest species density (number per 100 km^2)
ZOI = maximum ensonified area to MMPA threshold for impulsive, intermittent noise (160 $\mathrm{dB}_{\mathrm{RMS}90\%}$ re 1 µPa)
d = number of days

The ensonified area specific to Level B harassment, as well as the projected duration of installation at each respective impact pile-driving location, was then used to produce the results of take calculations provided in Table 6-7. As described in Section 1.2, impact pile driving will take 3 days per site to complete during the months of May through August for a total of 9 days. The action is planned from May through August with monthly datasets available from NOAA SEFSC (2022) for the GOM (Table 6-7). 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 6-7 are the maximum number of animals that may be harassed during impact pile driving (i.e., the Applicant assumes that each exposure event is a different animal).

The data used as the basis for estimating species density for the Project Area are derived from data provided by NOAA SEFSC (2022). These datasets are a compilation of the best available marine mammal data (2003-2019). The NOAA SEFSC (2022) dataset was prepared in collaboration between NOAA SEFSC and the U.S. Fish and Wildlife Service ("FWS").

While impact pile driving is planned from May through August, monthly datasets are available for the GOM through the NOAA SEFSC (2022).Therefore, monthly data as reported by NOAA SEFSC (2022) were used for density calculations and take estimates for the GOM as these are the best available datasets for the GOM. Bottlenose dolphins are the only marine mammal species that resulted in calculated take; therefore, bottlenose dolphins are the only marine mammal species for which take is being requested. As the NOAA SEFSC (2022) dataset does not account for group size, the requested take was adjusted to account for a group size of 20 individuals per day over 3 days of construction for bottlenose dolphins(Maze-Foley and Mullin 2006).

Pantropical spotted dolphins, Atlantic spotted dolphins, and Risso's dolphins were considered in the analysis; however, as they are not expected to occur in the Project Area and calculated take was negligible or zero, take is therefore not requested. No Level A harassment takes are requested for any species during impact pile driving. Rice's whales and sperm whales were included in the analysis because they are ESA species, but as demonstrated by the analysis, no take is anticipated. Therefore, the Applicant is not requesting take of Rice's and sperm whales and there will be no impact to ESA listed species.

Table 6-7 Average Marine Mammal Densities Used in Exposure Estimates and Estimates of Calculated Takes by Level A and Level B Harassment due to Impact Pile Driving

Species	Stock	Average Seasonal Density[1] (No./100 km²)	P4		P5		P6	
			Calculated Take by Level A Harassment	Calculated Take by Level B Harassment	Calculated Take by Level A Harassment	Calculated Take by Level B Harassment	Calculated Take by Level A Harassment	Calculated Take by Level B Harassment
Atlantic Spotted Dolphin[3]	GOM	0.247	0.000	0.002	0.000	0.002	0.000	0.003
Bottlenose Dolphin[2]	GOM	149.159	0.018	14.654	0.022	15.353	0.018	15.917
Pantropical Spotted Dolphin[3]	GOM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rice's Whale[3]	GOM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Risso's Dolphin	GOM	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sperm Whale	GOM	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes:

1 Cetacean density values from the NOAA Southeast Fisheries Science Center (SEFSC 2022).

2 Bottlenose dolphin density values from the NOAA Southeast Fisheries Science Center (SEFSC 2022) reported as "bottlenose" and not identified to stock. Given the difficulty of visual identification in the field for bottlenose dolphins, it's been assumed that the calculated take could be accrued to either the GOM western coastal stock, the northern GOM continental shelf stock, or the northern GOM oceanic stock.

3 Density values from the NOAA Southeast Fisheries Science Center (SEFSC 2022) Rice's whale since NOAA has recently (2021) determined Rice's whale as a distinct species. As NOAA SEFSC (2022) does not account for group size, the estimated take was adjusted to account for one group size of 20 individuals per day for 9 days of construction for bottlenose dolphins (Maze-Foley and Mullin 2006)

GOM = Gulf of Mexico

6.3 Estimate of Numbers of Marine Mammals that Might be "Taken by Harassment"

Per NOAA Fisheries guidance for impulsive, intermitted sound sources, the zone of influence ("ZOI") was calculated according to the following formula (personal communication, November 24, 2015):

ZOI = maximum ensonified area around the sound source ×
the radius of the circle using the isopleth as the radius over a 24-hour period.

The data used as the basis for estimating cetacean density D for the Project Area are sightings per unit effort derived by NOAA SEFSC (2022).

The NOAA SEFSC (SEFSC 2022) cetacean and sea turtle spatial density models ("SDMs") derived from line-transect surveys were conducted during the Gulf of Mexico Marine Assessment Program for Protected Species ("GoMMAPPS") project and comparable prior year surveys. GoMMAPPS aerial surveys from seasonal surveys were conducted during 2011-2012 and 2017-2018 over the continental shelf, while GoMMAPPS vessel surveys were conducted in 2003, 2004, 2009, summer 2017, summer/fall 2018, and winter 2018 in oceanic waters.

While impact pile driving is planned from May through August, monthly datasets are available for the GOM as reported by NOAA SEFSC (2022) and were used for density calculations and take estimates in Table 6-8.

Due to the spatial distribution and transient nature of marine mammal species identified in the Project Area, and the implementation of the mitigation measures as described in Section 11.0, these activities are not expected to result in Level A harassment, and Level B harassment is expected only on the species identified in Table 6-7. The take estimates as provided in Section 6.1.2 are based on an overly conservative ZOI and therefore are likely a significant overestimate of the actual potential for take by Level B acoustic harassment.

Table 6-8 Average Marine Mammal Densities Used in Exposure Estimates and Estimates of Calculated Takes by Level A and Level B Harassment due to Impact Pile Driving

Species	Stock	Average Seasonal Density[1] (No./100 km²)	P4 Calculated Take Harassment Level		P5 Calculated Take Harassment Level		P6 Calculated Take Harassment Level		Total Requested Level B Take[4]	% Population
			Level A	Level B	Level A	Level B	Level A	Level B		
Atlantic Spotted Dolphin	GOM	0.247	0	0	0	0	0	0	0	0
Bottlenose Dolphin[2]	GOM	149.159	0	15	0	15	0	16	180	0.284
Bottlenose Dolphin[2]	Northern GOM, Continental Shelf	149.159	0	15	0	15	0	16	180	0.284
Bottlenose Dolphin[2]	GOM, Western Coastal	149.159	0	15	0	15	0	16	180	0.284
Bottlenose Dolphin[2]	Northern GOM, Oceanic	149.159	0	15	0	15	0	16	180	0.284
Pantropical Spotted Dolphin	GOM	0.000	0	0	0	0	0	0	0	0
Rice's Whale[3]	GOM	0.000	0	0	0	0	0	0	0	0
Risso's Dolphin	GOM	0.000	0	0	0	0	0	0	0	0
Sperm Whale	GOM	0.000	0	0	0	0	0	0	0	0

Table 6-8 Average Marine Mammal Densities Used in Exposure Estimates and Estimates of Calculated Takes by Level A and Level B Harassment due to Impact Pile Driving

Species	Stock	Average Seasonal Density[1] (No./100 km^2)	P4 Calculated Take Harassment Level		P5 Calculated Take Harassment Level		P6 Calculated Take Harassment Level		Total Requested Level B Take[4]	% Population
			Level A	Level B	Level A	Level B	Level A	Level B		

Notes:
1 Cetacean density values from NOAA SEFSC (2022).
2 Bottlenose dolphin density values from NOAA SEFSC (2022) reported for each bottlenose stock. Given that stock identification for bottlenose dolphins in the field is difficult, the percentage of Level B harassment take for the northern GOM continental shelf stock, western GOM coastal stock, and northern GOM oceanic stock are presented.
3 Density values from the NOAA SEFSC (2022) Bryde's whale since NOAA has recently (2021) determined Rice's whale as a distinct species. To account for group size, the requested take was adjusted to account for one group size of 20 individuals per day for 9 days of construction for bottlenose dolphins.
4 Group size adjustment values from Maze-Foley and Mullin (2006)
GOM = Gulf of Mexico

6.4 Estimate of Potential Project Pile-Driving Takes by Harassment

The parameters in Tables 6-4, 6-5, and 6-6 were used to estimate the potential take by incidental Level B harassment for impact pile driving that will govern the Level B ZOI determination during impact pile driving activities. Potential take calculations were based on annual species density within the maximum Project Area, given the dates during which impact pile driving will occur. Results of the take calculations by impact pile-driving activities are provided in Table 6-7 using the most recent NOAA SEFSC (2022) monthly dataset. Bottlenose dolphins are the only marine mammal species that resulted in calculated take; therefore, bottlenose dolphins are the only marine mammal species for which take is being requested. No Level A take is anticipated during impact pile driving. Rice's whales and sperm whales were included in the analysis because they are ESA species, but as demonstrated by the analysis no take is anticipated. Therefore, the Applicant is not requesting take of Rice's and sperm whales and there will be no impact to ESA listed species.

For bottlenose dolphin densities, the NOAA SEFSC (2022) does not differentiate by individual stock. Given the difficulty of bottlenose dolphin identification in the field, it has been assumed that the calculated take of bottlenose dolphins is accrued to the GOM western coastal stock, the northern GOM continental shelf stock, or the northern GOM oceanic stock. For requested take, the percentage of Level B take is shown for these three stocks (Table 6-8). For a full description of the proposed monitoring and exclusion zones and associated mitigations, please see Section 11.

Finally, to account for the potential of large groups of bottlenose dolphins, average pod size has been used as a multiplier to the calculated take, based on animal density (Maze-Foley 2006). Based on the most recent Stock Assessment Reports (Hayes et al. 2022) and cetacean density data (SEFSC 2022), bottlenose dolphins are very likely to be present during construction activities, whereas Atlantic spotted dolphins, pantropical spotted dolphins, and Risso's dolphins are not as likely. Due to the very high likelihood that bottlenose dolphins will be present during construction activities, one pod of bottlenose dolphins was assumed per 9 days of impact pile driving; therefore, the total number of days, 9, was multiplied by the average group size, 20 (Maze-Foley 2006). Each day of impact pile driving corresponds to each day of possible Level B exposure. These increases were applied to the initial calculated Level B harassment take request, as indicated in Table 6-7.

The NOAA SEFSC (2022) marine mammal density estimates for the GOM are the best available marine mammal data for the Project Area. The methodology employed to derive these data is described in NOAA SEFSC (2022). While construction is anticipated to occur from May through August, monthly datasets for the GOM are available in NOAA SEFSC (2022). Therefore, monthly data for the GOM are used to calculate density estimates for the Project Area from NOAA SEFSC (2022) (Table 6-8).

Assumptions regarding construction parameters are conservative and additional conservatism is built into the modeling scenarios for both acoustic modeling and exposure estimates, including the potentially most impactful pile driving scenario in terms of pile size and penetration depth. For impact pile driving, the maximum impact for all species (i.e., an assumption that impact driving would occur in highest density months for each species) was carried forward to the exposure estimates for P5 and P6. In addition, a hammer energy of 1,380 kJ was modeled; however, this is highly conservative given the available hammers.

7.0 ANTICIPATED IMPACTS OF THE ACTIVITY

Pile driving will temporarily increase underwater noise, and this increase in noise has the potential to impact marine mammals behaviorally and physiologically. Increased underwater noise is a concern for marine wildlife, particularly marine mammals, which use sound to forage, orient, socially interact with conspecifics, or detect and respond to predators. Marine mammals use sound for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding. The sound generated by impact pile installation during the Project would exceed the NOAA Fisheries in-water acoustic thresholds for Level B harassment. Therefore, these sound levels would be considered potentially behaviorally disturbing to marine mammals.

Most marine animals can perceive underwater sounds over a broad range of frequencies, from about 10 Hz to more than 10 kHz (Southall et al. 2009; Southall et al. 2019). Potential effects of anthropogenic noise to marine mammals can include behavioral modification (changes in foraging or habitat-use patterns), and masking (the prevention of marine mammals from hearing important sounds; Nowacek at al. 2007). Behavioral reactions can include avoidance of the sound source, avoidance of feeding habitat, and changes in breathing patterns (Malme et al. 1984; Richardson et al. 1995; Nowacek et al. 2007; Tyack 2009). Recent studies on behavioral responses to anthropogenic noise clearly indicate that animals will show variable responses to noise dependent on species, behavioral contexts, and likely the distance from animals to the sound source (Ellison et al. 2012). The proposed pile-driving activities are not expected to result in population-level effects and individuals will return to normal behavioral patterns after activities have ceased or after the animal has temporarily left the area.

Marine mammals are mobile and are expected to quickly leave an area when impact pile-driving 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. Acoustical disturbance of marine mammal species would therefore be temporary. Impact pile-driving activities are not anticipated to have an impact on recruitment or survival of any of the marine mammal stocks discussed in this application. Therefore, based on the best available information and the information provided in this application, Project-related pile installation activities are expected to have a negligible impact on the marine mammal species and stocks that could occur in the vicinity of the Project Area during pile driving.

8.0 ANTICIPATED IMPACTS ON SUBSISTENCE USES

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

9.0 ANTICIPATED IMPACTS ON HABITAT

9.1 Construction Impacts

Benthic and pelagic habitat will be temporarily disturbed by construction activities required for the Project, with the majority of potential disturbance caused by pipeline lay barge anchor placement and anchor chain drag during pipeline installation (see Table 9-1). The area of seafloor habitat impacted during impact pile driving will fall within the area temporarily impacted during pipeline installation. Pile driving will occur sequentially, resulting in localized areas of disturbance in any given time period. Marine mammals are highly mobile species and as such may avoid potential construction-related impacts by leaving the immediate area of activity. Marine mammals that may be present during construction-related habitat disturbances are not expected to be impacted from the temporary loss of habitat. Temporarily disturbed marine habitats are expected to return to pre-construction conditions following localized disturbances within a relatively short timeframe. Additionally, due to local habitat uniformity, ample suitable habitat is available in the vicinity of the Project Area. Temporarily displaced marine mammals will still have access to similar quality habitat in adjacent areas and are expected to return to the Project Area upon the completion of construction.

Construction activities will also temporarily impact prey species by increasing turbidity in the water column, disturbing benthic habitat, and generating underwater sound. Such impact-producing factors may provoke mobile prey species to leave the area of activity and/or cause injury or mortality in less mobile species. This may indirectly inhibit marine mammal foraging activities within the Project Area. Sound emitted by impact pile driving will be temporary and localized. Due to the relatively limited area of impact compared to the extensive available surrounding habitat, potential impacts from sound are anticipated to be negligible on marine mammal habitat. Project impacts to marine mammal prey species are expected to be minor and limited to short-term changes that may result in potential prey avoidance of the active portions of the Project Area during construction (BOEM and NOAA Fisheries 2021). Marine mammals and prey species impacted by impact pile-driving activities will return to normal behavior shortly after the conclusion of pile driving operations in that specific area, and areas of available habitat are in immediate proximity to the area around the impact pile-driving activities; therefore, impacts to habitat are considered negligible.

Table 9-1 Estimated Temporary Seafloor Disturbance From Project Construction

Project Component	Area (Acres)
Pipeline Laterals (Pipeline Trench) [1]	4.0
Pipeline Laterals (Lay Barge Impacts)	432
FLNG1 [1]	0.7
FLNG2 [1]	0.2
FSU Mooring Anchors and Chains	3.6
Construction Support Vessels	1.0
Total	**441.5**

1 Seafloor impacts from this component are entirely within the area potentially impacted by pipeline lateral lay barge anchors and anchor chains.

Marine mammals consume a variety of organisms including benthic invertebrates (e.g., cephalopods and crustaceans), copepods, krill, small schooling fish (e.g., capelin, herring, and mackerel), and squid. Foraging preferences vary by species and prey availability and foraging locations span benthic, coastal, and pelagic environments. Marine mammal species that exhibit preferences for benthic prey will be most impacted by seafloor impacts and associated prey mortality, while those that exhibit preferences for coastal or pelagic prey will be most impacted by predator evasion and displacement from construction sites. Copepods and other planktonic prey remain suspended in the water column and have limited mobility; they are unlikely to be affected by Project-related construction activities.

10.0 ANTICIPATED EFFECTS OF HABITAT IMPACTS ON MARINE MAMMALS

As described in Section 9, impacts to marine mammals from habitat impacts are expected to be temporary, with a return to pre-construction conditions within a relatively short time frame, or very minimal, and therefore insignificant.

Because of the small footprint of the piles and anchoring systems relative to available habitat, it is reasonable to conclude that effects to marine mammals from loss or modification of habitat will be insignificant or *de minimis*. Potential effects on Rice's whales and sperm whales were analyzed as demonstrated in Table 6-7. No take is anticipated and therefore no impacts to endangered species are anticipated. As discussed in Section 9, impacts on marine mammals from the loss or modification of habitat are considered to be negligible.

11.0 MITIGATION MEASURES

Project pile driving is anticipated to result in take by Level B behavioral harassment of small numbers of bottlenose dolphins.

The Applicant will develop an environmental training program that will be provided to all crew prior to the start of activities, and during any changes in crew such that all personnel are fully aware and understand the mitigation, monitoring, and reporting requirements. This training program will include vessel strike avoidance protocols (Section 11.1, Vessel Strike Avoidance Procedures). A briefing will be conducted between the supervisors and crews, the PSOs, 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. A lead PSO will be designated who will oversee the other PSOs and other monitoring related duties. The Applicant will employ a big bubble curtain with a minimum airflow rate of 0.3 cubic meter ("m^3")/min*meter to achieve noise reduction. In a big bubble curtain system, the entire construction site (installation vessel and foundation structure) is enveloped by a nozzle hose deployed in a complete circle at a specified distance from the site of pile driving on the sea floor. The hose is perforated through which air is forced creating an air bubble curtain that encloses the construction site (Bellmann et al. 2020). Available single bubble curtains are documented to achieve a minimum of 10 dB reduction in sound propagation (Bellmann et al. 2020). A single bubble curtain with an airflow rate of 0.3 m^3/min*meter can reliably achieve 8-14 dB reduction at 30-meter (98-foot) depth (Koschinski and Ludemann 2020). To be conservative in determination of take estimations, a 6 dB mitigation level was chosen for this application, although a higher level of sound attenuation may be achieved during construction. Note that given the rapid advancement in technologies and potential for additional attenuation as technology evolves, the Applicant will review suitable technologies available at the time of installation before selecting a final device.

11.1 Vessel Strike Avoidance Procedures

The Applicant will ensure that vessel operators and crew maintain a vigilant watch for cetaceans and pinnipeds during all impact pile-driving activities. 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 reduce vessel speed to 10 knots (<18.5 km/hour) or less when mother/calf pairs, pods, or larger assemblages of whales are observed near an underway vessel.
- All vessels will maintain a separation distance of 500 meters (1,640 feet) or greater from any sighted ESA-listed whale. If an ESA-listed species is sighted within the relevant separation distance, the vessel must steer a course away at 10 knots or less until the 500-meter (1,640-foot) separation distance has been established. If a whale is observed but cannot be confirmed as a species that is not ESA-listed, the vessel operator must assume that it is an ESA-listed species and take appropriate action.
- If underway, vessels must steer a course away from any sighted endangered species at 10 knots (<18.5 km/hour) or less until the 500-meter (1,640-foot) minimum separation distance has been established. If an endangered species is sighted in a vessel's path, or within 500 meters (1,640 feet) to an underway vessel, the underway vessel must reduce speed and shift the engine to neutral. Engines will not be engaged until the endangered species has moved outside of the vessel's path and beyond 500 meters (1,640 feet). If stationary, the vessel must not engage engines until the endangered species has moved beyond 500 meters (1,640 feet).
- All vessels will maintain a separation distance of 100 meters (328 feet) or greater from any sighted non-ESA baleen whale. If sighted, the vessel underway must reduce speed and shift the engine to neutral, and must not engage the engines until the whale has moved outside of the vessel's path and beyond 100 meters (328 feet). If a vessel is stationary, the vessel will not engage engines until the whale has moved out of the vessel's path and beyond 100 meters (328 feet).
- All vessels underway will not divert to approach any dolphin or pinniped and ensure that any vessel underway remains parallel to a sighted dolphin's or pinniped's course whenever possible. The vessel will not adjust course and speed until the dolphin or pinniped has moved beyond 50 meters (164 feet) or has moved abeam of the underway vessel. Any vessel underway will avoid excessive speed or abrupt changes in direction to avoid injury to the sighted dolphin or pinniped. All vessels will reduce vessel speed to 10 knots (18.5 km/hour) or less when pods (including mother/calf pairs) or large assemblages of dolphins are observed. The vessel will not adjust course and speed until the dolphins have moved beyond 50 meters (164 feet) or abeam of the vessel.
- All vessels will maintain a separation distance of 50 meters (164 feet) or greater from any sighted dolphins or pinnipeds.
- All vessels will employ a dedicated lookout during all operations (note this role will be filled by the PSO(s) as outlined below).

11.2 Seasonal Operating Requirements

There are no seasonal requirements for this Project.

11.3 Pile Driving Weather and Time Restrictions

Pile driving will commence only during daylight hours no earlier than one hour after (civil) sunrise. Pile driving will not be initiated later than 1.5 hours before (civil) sunset. Pile driving may continue after dark when the installation of the same pile began during daylight (1.5 hours before [civil] sunset), when visual Clearance zones were fully visible for at least 60 minutes and must proceed for human safety or installation feasibility reasons. Pile driving will not be initiated in times of low visibility when the visual Clearance zones (Section 11.6) cannot be visually monitored, as determined by the lead PSO on duty.

11.4 Visual Monitoring Program

Visual monitoring of the established shutdown zones and monitoring zones will be performed by qualified and NOAA Fisheries–approved third-party PSOs. A visual observer team comprising NOAA Fisheries–approved PSOs, operating in shifts, will be stationed aboard either the respective Project vessel and a dedicated PSO vessel. PSO qualifications will include a science degree and direct field experience on a marine mammal/sea turtle observation vessel and/or aerial surveys in the Atlantic Ocean/GOM. All PSOs will work in shifts such that no one monitor will work more than 4 consecutive hours without a consecutive 2-hour break or longer than 12 hours during any 24-hour period.

PSOs will be responsible for visually monitoring and identifying marine mammals approaching or entering the established shutdown zones during survey activities. It will be the responsibility of the Lead PSO on duty to communicate the presence of marine mammals as well as to communicate and enforce the action(s) that are necessary to ensure mitigation and monitoring requirements are implemented as appropriate. Observations from other PSOs will be communicated to the Lead PSO on duty, who will then be responsible for implementing the necessary mitigation procedures.

The PSOs will be equipped with binoculars and have the ability to estimate distances to marine mammals located in proximity to their established zones using range finders. Reticulated binoculars will also be available to PSOs for use as appropriate based on conditions and visibility to support the sighting and monitoring of marine species.

Data on all PSO observations will be recorded based on standard PSO collection requirements. This will include dates and locations of survey 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). The data sheet will be provided to both NOAA Fisheries and the Bureau of Ocean Energy Management (“BOEM”) for review and approval prior to the start of survey activities. In addition, prior to initiation of Project activities, all crew members will undergo environmental training, a component of which will focus on the procedures for sighting and protection of marine mammals. A briefing will also be conducted between the survey supervisors and crews, the PSOs, and the Applicant. 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.

During impact pile driving visual monitoring will occur as follows:

- A minimum of two PSOs must be on active duty at the pile-driving vessel/platform from 60 minutes before, during, and for 30 minutes after all pile installation activity; and
- A minimum of two PSOs must be on active duty on a dedicated PSO vessel from 60 minutes before, during, and for 30 minutes after all pile installation activity. The dedicated PSO vessel must be located at the best vantage point in order to observe and document marine mammal sightings in proximity to the Clearance/Shutdown zones.

11.5 Pre-Start Clearance

For impact pile driving, the Applicant will implement a 60-minute clearance period of the Clearance zones (Section 11.6). Pile driving will not be initiated if any marine mammal is observed within its respective clearance zone. If a marine mammal is observed within a Clearance zone during the pre-clearance period, pile driving may not begin until the animal(s) has been observed exiting its respective zone, or until an additional time period has elapsed with no further sightings (i.e., 15 minutes for small odontocetes and pinnipeds and 30 minutes for all other species).

Pile driving will not be initiated if the clearance zones cannot be adequately monitored (i.e., if they are obscured by fog, inclement weather, poor lighting conditions) for a 60-minute period prior to the commencement of soft-start for impact pile driving, as determined by the lead PSO. If light is insufficient, the lead PSO will call for a delay until the Clearance zone is visible in all directions). If pile driving has been initiated before the onset of inclement weather, activities may continue through these periods if deemed necessary to ensure human safety and/or the integrity of the Project.

11.6 Clearance and Shutdown Zones

Clearance and Shutdown zones will be established and continuously monitored during impact pile driving to minimize impacts to marine mammals (Table 11-1). The Applicant proposes the following Clearance and Shutdown zones for impact pile driving:

Table 11-1 Clearance and Shutdown Zones (Impact Pile Driving)

Species	Clearance Zone (meters [m])	Shutdown Zone (m)	Explanation of Zone Sizes
Rice’s and sperm whales	2,500	2,500	Clearance and Shutdown zones based on the buffered PTS distance of 2,492 m
Dolphins	1,700	500	Clearance zone based on the buffered behavioral distance of 1,603 m; Shutdown zone based on the buffered PTS distance of 77 m and inclusive of additional buffer area to decrease likelihood of direct interaction of marine mammals and equipment

Note:
Take of Rice’s and sperm whales is not anticipated but Clearance and Shutdown zones will be implemented as a precautionary measure.

These proposed mitigation zones have been based on distances to NOAA Fisheries harassment criteria. These zones will be monitored as described in Section 11.4 (Visual Monitoring) and mitigation enacted as described in Section 11.8 (Shutdown and Power-Down Procedures).

11.7 Soft-Start Procedures

A soft start will occur at the beginning of the impact pile driving of each pile and at any time following the cessation of impact pile driving of 30 minutes or longer. The soft start requires an initial 30 minutes using a reduced hammer energy for pile driving.

11.8 Shutdown and Power-Down Procedures

The Shutdown zones around the pile-driving activities will be maintained, as previously described, by PSOs for the presence of marine mammals before, during, and after pile-driving activity. For pile driving, from an engineering standpoint, any significant stoppage of driving progress may allow time for displaced sediments along the pile surface areas to consolidate and bind. Attempts to restart the driving of a stopped pile may be unsuccessful and create a situation where a pile 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 a marine mammal is observed entering or within the respective zones after pile driving has commenced, a shutdown of pile driving will occur when practicable as determined by the lead engineer on duty, who must evaluate the following to determine whether shutdown is safe and practicable:

- Use of site-specific soil data and real-time hammer log information to judge whether a stoppage would risk causing pile refusal at restart of pile;
- Confirmation that pile penetration is deep enough to secure pile stability in the interim situation, taking into account weather statistics for the relevant season and the current weather forecast; and
- Determination by the lead engineer on duty will be made for each pile as the installation progresses and not for the site as a whole. If a shutdown is called for but the lead engineer determines shutdown is not practicable due to an imminent risk of injury or loss of life to an individual, or risk of damage to a vessel that creates risk of injury or loss of life for individuals, reduced hammer energy (power down) will be implemented, when the lead engineer determines it is practicable.

Subsequent restart/increased power of the equipment can be initiated if the animal has been observed exiting its respective zone within 30 minutes of the shutdown, or, after an additional time period has elapsed with no further sighting of the animal that triggered the shutdown (i.e., 15 minutes for small odontocetes and 30 minutes for all other species).

If pile driving shuts 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 a soft start, if PSOs have maintained constant observation and no detections of any marine mammal have occurred within the respective zones.

12.0 MITIGATION MEASURES TO PROTECT SUBSISTENCE USE

This section is not applicable. Given that the Project Area is not located in Arctic waters, the Applicant’s construction activities will not have an adverse effect on the availability of marine mammals for subsistence use allowable under the MMPA.

13.0 MONITORING AND REPORTING

13.1 Monitoring

Visual monitoring protocols are described in Section 11.4, Visual Monitoring Program.

13.2 Reporting

The Applicant will provide the following reporting as necessary during active pile-driving activities:

- The Applicant will contact NOAA Fisheries within 24 hours of the commencement of pile-driving activities and again within 24 hours of the completion of the activity;
- During pile driving, weekly reports briefly summarizing sightings, detections, and activities will be provided to NOAA Fisheries and BOEM on the Wednesday following a Sunday-Saturday period.
- The Applicant will report any observed injury or mortality as soon as feasible and in accordance with NOAA Fisheries' standard reporting guidelines. Reports will be made by phone (866-755-6622) and by email (nmfs.gar.stranding@noaa.gov and PR.ITP.MonitoringReports@noaa.gov) and will include the following:
    1. Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);
    2. Species identification (if known) or description of the animal(s) involved;
    3. Condition of the animal(s) (including carcass condition if the animal is dead);
    4. Observed behaviors of the animal(s), if alive;
    5. If available, photographs or video footage of the animal(s); and
    6. General circumstances under which the animal was discovered.

An annual report summarizing the prior year's activities 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 Project pile driving, and provides an interpretation of the results and effectiveness of all monitoring tasks. The annual draft report will be provided no later than 90 days following completion of construction activities. Any recommendations made by NOAA Fisheries will be addressed in the final report, due after the IHA expires and including a summary of all monitoring activities, prior to acceptance by NOAA Fisheries. Final reports will follow a standardized format for PSO reporting from activities requiring marine mammal mitigation and monitoring.

All PSOs will use a standardized data entry format as shown in Appendix B.

14.0 SUGGESTED MEANS OF COORDINATION RESEARCH

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

15.0 REFERENCES

Balthis, W. L., J. L. Hyland, C. Cooksey, M. H. Fulton, and E. F. Wirth. 2013. Ecological Condition of Coastal Ocean Waters of the Western Gulf of Mexico: 2011. NOAA Technical Memorandum NOS NCCOS 171, NOAA National Ocean Service, Charleston, SC 29412-9110. 63 pp.

Bellmann, M. A., A. May, T. Wendt, S. Gerlach, P. Remmers, and J. Brinkmann. 2020. Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

BOEM (Bureau of Ocean Energy Management) and NOAA Fisheries (National Oceanic and Atmospheric Administration National Marine Fisheries Service). 2021. Offshore wind Site Assessment Programmatic ESA Consultation. Initially published June 29, 2021 with later updates to the PDCs and BMPs in November, 2021.

Bryant, W.R., J. Lugo, C. Cordova, and A. Salvador. 1991. Physiography and bathymetry. In: *The Gulf of Mexico Basin, Boulder, Colorado,* A. Salvador A (ed)., 13–30. Geological Society of America. Boulder, CO. Available online at: https://doi.org/10.1130/DNAG-GNA-J.

DWH MMIQT (Deepwater Horizon Marine Mammal Injury Quantification Team). 2015. Models and analyses for the quantification of injury to Gulf of Mexico cetaceans from the Deepwater Horizon Oil Spill. DWH Marine Mammal NRDA Technical Working Group Report. Washington, DC: U.S. Department of the Interior. Accessed at: https://www.fws.gov/doiddata/dwh-ar-documents/876/DWHAR0105866.pdf

CWPPRA (Coastal Wetland Planning, Protection and Restoration Act). 2022. The Atchafalaya Basin. Available online at: https://lacoast.gov/new/about/basin_data/at/default.aspx

Coogan, J., Dzwonkowski, B.;Park, K.;Webb, B. 2019. Observations of Restratification after a Wind Mixing Event in a Shallow Highly Stratified Estuary. *Estuaries and Coasts* 43:1–30. https://doi.org/10.1007/s12237-019-00689-w

Ellison, W. T., B. L. Southall, C. W. Clark, and A. S. Frankel. 2012. A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conserv. Biol.* 26(1):21-8. doi: 10.1111/j.1523-1739.2011.01803.x.

EPA (U.S. Environmental Protection Agency). 2019. Second Report on Point Source Progress in Hypoxia Task Force States. October 2019. Available at: https://www.epa.gov/sites/default/files/2019-10/documents/2019_htf_point_source_progress_report_final_508.pdf.

Farmer, N.A., D.P. Noren, E.M. Fougeres, A. Machernis, and K. Baker. 2018. Resilience of the endangered sperm whale Physeter macrocephalus to foraging disturbance in the Gulf of Mexico, USA: A bioenergetic approach. *Marine Ecology Progress Series* 589:241–261.

Garrison, L.P., J. Ortega-Ortiz and G. Rappucci. 2020. Abundance of marine mammals in the waters of the U.S. Gulf of Mexico in the summer of 2017 and 2018. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, 75 Virginia Beach Dr., Miami, Florida 33140. PRBD Contribution # PRBD-2020-07. 55pp. Available from: https://repository.library.noaa.gov/view/noaa/26505

Garrison, L.P., and L. Stokes. 2021. Estimated bycatch of marine mammals and sea turtles in the U.S. Atlantic pelagic longline fleet during 2019. NOAA Tech. Memo. NMFS-SEFSC-750. 59 pp.

Hansen, L.J., K.D. Mullin, T.A. Jefferson and G.P. Scott. 1996. Visual surveys aboard ships and aircraft. Pages 55– 132 in: R.W. Davis and G.S. Fargion (Eds.). Distribution and abundance of marine mammals in the northcentral and western Gulf of Mexico: Final report. Volume II: Technical report. OCS Study MMS 96-0027. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P. Rosel (eds.). 2021. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2020*. NOAA Technical Memorandum NMFS-NE-271. Available online at: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports. Accessed 21 August 2022.

Hayes, S.A., E. Josephson, K. Maze-Foley, and P. Rosel (eds.). 2022. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2021*. NOAA Technical Memorandum NMFS-NE-271. Available online at: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports. Accessed 21 August 2022.

Jacques, J., and H. Clegg. 2002. Late Jurassic Source Rock Distribution and Quality in the Gulf of Mexico: Inferences from Plate Tectonic Modelling. *Gulf Coast Association of Geological Societies, Transactions* 52:429–440.

Jefferson, T.A., Webber, M.A. and Pitman, R.L. 2015. *Marine Mammals of the World: A Comprehensive Guide to their Identification*. Elsevier. 2nd edition. Available online at: https://www.elsevier.com/books/marine-mammals-of-the-world/jefferson/978-0-12-409542-7. Accessed 8 Dec 2020.

Koschinski, S., and K. Ludemann. 2020. Noise mitigation for the construction of increasingly large offshore wind turbines: Technical options for complying with noise limits. Report commissioned by the Federal Agency for Nature Conservation, Isle of Vilm, Germany.

Knockaert, C. 2021: Possible consequences of eutrophication. Available online at: http://www.coastalwiki.org/wiki/Possible_consequences_of_eutrophication

LDEQ (Louisiana Department of Environmental Quality). 2014. Water Quality Management Plan: Vol. 4 Basin and Subsegment Boundaries. Available online at: https://www.deq.louisiana.gov/assets/docs/Water/WQMPVolume4_9-9-14_final.pdf

Litz, J.A., E.I. Ronje, H.R. Whitehead, and L.P. Garrison. 2019. Updated abundance estimates for common bottlenose dolphins (*Tursiops truncatus*) inhabiting West Bay, Texas. *Wiley Online Library* 29(11):1959-1970. https://doi.org/10.1002/aqc.3195

Lybolt, T. 2022. Turbidity caused by seiving surface sediment grab samples in the 50-gallon tub settled-out in less than 12 hours, generally less than 8 hours. Personal communication in person from T. Lybolt to L. Maddux, Cruise Leader, Tetra Tech, Inc. May 5, 2022.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and E.J. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 586. Rep form Bolt, Beranek & Newman, Inc. Cambridge, MA, for U.S. Minerals Management Serv., Anchorage, AK.

Maze-Foley, K., and K.D. Mullin. 2006. Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. *Journal of Cetacean Research and Management* 8(2):203–213.

MBARI (Monterey Bay Aquarium Research Institute). 2019. How risso's dolphins striek a balance between holding their breath and finding food. Available online at: www.mbari.org/rissos-dolphin-foraging/

MMC (Marine Mammal Commission). 2022. Rice's Whale. Available online at: https://www.mmc.gov/priority-topics/species-of-concern/rices-whale/

MMS (Minerals Management Service). 1992. Gulf of Mexico Sales 142 and 143: Central and Western Planning Areas. Final Environmental Impact Statement. MMS 92-0007.

Mullin, K.D., and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships. In: *Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations. Volume II: Technical report,* W. Davis, W.E. Evans and B. Würsig (Eds.), 111–172. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana. OCS Study MMS 96-0027.

NOAA Fisheries (National Oceanic and Atmospheric Administration National Marine Fisheries Service). 2005. Endangered fish and wildlife: Notice of intent to prepare an environmental impact statement. *Federal Register* 70(7):1871–1875. http://www.nmfs.noaa.gov/pr/pdfs/fr/fr70-1871.pdf

NOAA Fisheries. 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts.* NOAA Technical Memorandum NOAA-OPR-55. Jul 2016.

NOAA Fisheries. 2018. *2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NOAA-OPR-59, 167 p. Available online at: https://www.fisheries.noaa.gov/resource/document/technical-guidance-assessing-effects-anthropogenic-sound-marine-mammal-hearing. Accessed 10 Dec 2020.

NOAA Fisheries. 2021a. Glossary: Marine Mammal Protection Act. Available online at: https://www.fisheries.noaa.gov/laws-and-policies/glossary-marine-mammal-protection-act

NOAA Fisheries. 2021b. Atlantic Spotted Dolphin. Available online at: https://www.fisheries.noaa.gov/species/atlantic-spotted-dolphin

NOAA Fisheries. 2021c. Sperm Whale. Available online at: https://www.fisheries.noaa.gov/species/ species/sperm-whale

NOAA Fisheries. 2022. Pantropical Spotted Dolphin. Available online at: https://www.fisheries.noaa.gov/species/ species/pantropical-spotted-dolphin

NOAA Satellite and Information Service. 2020. *U.S. Coastal Relief Model. 1999 to 2005.* Available online at: https://www.ngdc.noaa.gov/mgg/coastal/crm.html. Accessed December 13, 2020.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Wiley Online Library (37)2.

OBIS (Ocean Biodiversity Information System). 2023. Available at: https://obis.org/. Accessed January 25, 2023.

Rabalais, N.N., and R.E. Turner. 2019. Gulf of Mexico Hypoxia: Past, Present, and Future. *Limnology and Oceanography Bulletin* 28:117–124. https://doi.org/10.1002/lob.10351

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. *Guide to Marine Mammals of the World*. National Audubon Society.

Reeves, R.R., J.N. Lund, T.D. Smith, and E.A. Josephson. 2011. Insights from whaling logbooks on whales, dolphins, and whaling in the Gulf of Mexico. *Gulf of Mexico Science* 29(1):41–67.

Richardson, W.J., C.R. Greene, C.I. Malme, and D.H. Thomson. 1995. *Marine Mammals and Noise*. Academic Press, San Diego, CA.

Roberts, J.J., L. Mannocci, and P.N. Halpin. 2016. Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico (2015 Version). Marine Geospatial Ecology Laboratory/Duke University. Available online at: https://seamap.env.duke.edu/models/Duke-EC-GOM-2015/

Rosel, P.E., Wilcox, L.A., Yamada, T.K., Mullin, K.D. 2021. A new species of baleen whale (Balaenoptera) from the Gulf of Mexico, with a review of its geographic distribution. *Marine Mammal Science* 37: 577−610.

Sawyer, D.S., R.T. Buffler, and R.H. Pilger Jr. 1991. The Crust under the Gulf of Mexico basin. In: *Volume J, The Gulf of Mexico Basin,* A. Salvador. Geological Society of America. https://doi.org/10.1130/DNAG-GNA-J.53

Sassen, R., J.M. Brooks, M.C. Kennicutt II, J.R. MacDonald, and N.L. Guinasso, Jr. 1993a. How Oil Seeps, Discoveries Relate in Deepwater Gulf of Mexico. *Oil and Gas Journal* 91(16):64–69 p. https://www.osti.gov/biblio/6490937-how-oil-seeps-discoveries-relate-deepwater-gulf-mexico.

Sassen, R., J. Brooks, I. MacDonald, M. Kennicutt II, and N. Guinasso. 1993b. Association of Oil Seeps and Chemosynthetic Communities with Oil Discoveries, Upper Continental Slope, Gulf of Mexico. *Bulletin of the American Association of Petroleum Geologists* 77:1599. https://www.osti.gov/biblio/6917183-association-oil-seeps-chemosynthetic-communities-oil-discoveries-upper-continental-slope-gulf-mexico

Soldevilla, M.S., J.A. Hildebrand, K.E. Frasier, L. Aichinger Dias, A. Martinez, K.D. Mullin, P.E. Rosel, and L.P. Garrison. 2017. Spatial distribution and dive behavior of Gulf of Mexico Bryde’s whales: potential risk of vessel strikes and fisheries interactions. *Endangered Species Research* 32:533–550.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2009. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. *The Journal of the Acoustical Society of America.*125(4):2517. DOI: 10.1080/09524622.2008.9753846. Accessed December 10, 2020.

Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., Tyack, P.L. 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2):125–232.

Tetra Tech. 2022. Environmental Baseline Survey and Geotechnical Field Report WD-38, WD-39, WD-68 Gulf of Mexico. Appendix C in New Fortress Energy Louisiana FLNG LLC Deepwater Port Application, Volume II. Prepared for New Fortress Energy. 162 pp.

Transportation Research Board and National Research Council. 2003. Oil in the Sea III: Inputs, Fates, and Effects. Washington, DC: The National Academies Press. Available online at: https://doi.org/10.17226/10388

Turner, R. E., E. B. Overton, N. N. Rabalais, and B. K. Sen Gupta (eds.). 2003. Historical reconstruction of the contaminant loading and biological responses in the Central Gulf of Mexico shelf sediments. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-063. 140 p. Available online at: https://digital.library.unt.edu/ark:/67531/metadc955359/m2/1/high_res_d/3037.pdf.

Tyack, P. L. 2009. Human-generated sound and marine mammals. *Physics Today* 62(11):39-44.

USACE. 2015. Dredging and Dredged Material Management. (pp. 920). Washington, DC: U.S. Army Corps of Engineers (USACE) Publications. Available from http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-5025.pdf

Viricel, A., and P. E. Rosel. 2014. Hierarchical population structure and habitat differences in a highly mobile marine species: the Atlantic spotted dolphin. *Molecular Ecology* 23(20):5018–5035.

Ward, C.H. 2017. Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill. Springer, New York, NY. Available online at: https://doi.org/10.1007/978-1-4939-3456-0.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel (eds.). 2010. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2010. NOAA Technical Memorandum NOAA-NE-219. Available online at: https://repository.library.noaa.gov/view/noaa/3831. Accessed December 10, 2020.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel. 2013. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments – 2012. NOAA Technical Memorandum NMFS-NE-223. 419 pp.

WDC (Whale and Dolphin Conservation USA). 2022. Rice's Whale. Available at: https://us.whales.org/whales-dolphins/species-guide/rices-whale/

Wells, R.S. and M.D. Scott. 2002. "Bottlenose Dolphins *Tursiops truncates* and *T. aduncus*". In *Encyclopedia of Marine Mammals,* 122–128, W.F. Perrin, B. Wursig, and J.G.M. Thewissen (eds.). Academic Press, San Francisco, CA.

Wells, R.S., L.H. Schwacke, T.K. Rowles, B.C. Balmer, E. Zolman, T. Speakman, F.I. Townsend, M.C. Tumlin, A. Barleycorn and K.A. Wilkinson. 2017. Ranging patterns of common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the Deepwater Horizon oil spill. *Endangered Species Research* 33:159–180.

Würsig, B. 2017. Marine Mammals of the Gulf of Mexico. In: *Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill,* Volume 2, C. Ward (ed.), 1489–1587. New York, NY: Springer. https://doi.org/10.1007/978-1-4939-3456-0_5

Appendix A
Underwater Acoustic Assessment

New Fortress Energy Louisiana FLNG Project

Underwater Acoustic Assessment

New Fortress Energy
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September 2022, Revised February 2023

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APPENDICES

Appendix A Acoustic Distances for Impact Pile Driving
Appendix B Underwater Sound Propagation Modeling Inputs
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ACRONYMS AND ABBREVIATIONS

ρ	physical density
λ	wavelength
°C	degree Celsius
°F	degree Fahrenheit
§	section
Bcf/d	billion cubic feet per day
Bcf/y	billion cubic feet per year
dB	decibel
dB re 1 µPa	decibels referenced at one micropascal
dB re 1 $\mu Pa^2 \cdot s$	decibels referenced at one squared micropascal-second
dBSea	Software for the prediction of underwater noise in a variety of environments
dB/km	decibels per kilometer
DOE	U.S. Department of Energy
DP	dynamic positioning
DWP	deepwater port
DWPA	Deepwater Port Act of 1974, as amended
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FSU	Floating LNG Storage Unit
GARFO	Greater Atlantic Regional Fisheries Office
HF	high-frequency
Hz	hertz
kHz	kilohertz
kJ	kilojoule
Kinetica	Kinetica Energy Express, LLC
km	kilometers
LF	low-frequency
LNG	liquefied natural gas
LNGC	liquefied natural gas carrier
Lpk	peak sound pressure
m/s	meters per second
MARAD	Maritime Administration
MF	mid-frequency
MMPA	Marine Mammal Protection Act
MTPA	million metric tonnes per annum
NFE	New Fortress Energy
NGDC	National Geophysical Data Center

nm	nautical mile
NOAA Fisheries	National Oceanic and Atmospheric Administration’s National Marine Fisheries Service
ppt	part per thousand
Project	New Fortress Energy Louisiana FLNG Project
Project Study Area	The area where the Project facilities are physically located
PTS	permanent threshold shift
rms	root-mean-square
SEL	sound exposure level
SEL_{cum}	cumulative sound exposure level
SPL	sound pressure level
TBtu	trillion British thermal units
Tetra Tech	Tetra Tech, Inc.
TTS	temporary threshold shift
U.S.C.	United States Code
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
WD-38	West Delta Lease Block 38

1.0 INTRODUCTION

New Fortress Energy Louisiana FLNG LLC is proposing to construct, own, and operate the New Fortress Energy (hereinafter referred to as NFE) Louisiana FLNG Project (hereinafter referred to as the Project), a deepwater port ("DWP") export terminal approximately 16 nautical miles ("nm") off the southeast coast of Grand Isle, Louisiana. The Project will provide a safe and reliable source of much needed natural gas supplies to global markets in the form of liquefied natural gas ("LNG"). The Project is consistent with the Applicant's commitment to make clean, affordable energy available to markets around the world. The Applicant is filing an application for a license to construct, own, and operate the DWP export terminal pursuant to the Deepwater Port Act of 1974, as amended ("DWPA"), and in accordance with the U.S. Coast Guard's ("USCG") and the Maritime Administration's ("MARAD") implementing regulations.

The Project will involve the installation of two nominal 1.4 million metric tonnes per annum ("MTPA") liquefaction systems (FLNG1 and FLNG2) installed in the West Delta Lease Block 38 ("WD-38") in approximately 30 meters (98 feet) of water. Each system will contain three platforms consisting of natural gas processing, natural gas liquefaction, and utilities and accommodations. FLNG1 will incorporate self-elevating platforms, and FLNG2, which will be located adjacent to FLNG1, will utilize fixed platform structures. The feed gas supply to the Project will be transported to the WD-38 site via the existing Kinetica Energy Express, LLC ("Kinetica") offshore natural gas pipeline system and two, newly constructed, pipeline laterals connecting the Kinetica pipeline system to the Project. The northern lateral will be 24-inches in diameter and the southern lateral 20 inches in diameter. Both FLNG1 and FLNG2 will be connected to a single Floating LNG Storage Unit ("FSU") via a flexible, partially submerged, 220-meter cryogenic hose transfer system. The FSU will be positioned approximately 107 meters (350 feet) from the FLNGs. LNG carriers ("LNGCs") will call on the Project approximately 40 times per year. Other than temporary construction staging areas, there are no onshore facilities associated with the Project. Staging for construction, if needed, will utilize existing staging, laydown and warehouse space near Port Fourchon, Port Sulphur, or Venice, Louisiana. The general Project location is shown on Figure 1-1.

The Project is designed using a modular approach to create liquefaction capacity more quickly, and rapidly address the global shortage in available LNG. Each FLNG will be capable of producing 1.4 MTPA for a total nominal capacity of 2.8 MTPA. Each FLNG is expected to consume 71 trillion British thermal units ("TBtu") of natural gas per annum and produce 63 TBtu of LNG per annum (all figures are calculated on a higher heating value basis and assumes a 95 percent capacity factor). The difference between consumption and production is due primarily to (a) power generation feed gas consumption, and (b) process gas loss during the pretreatment process.

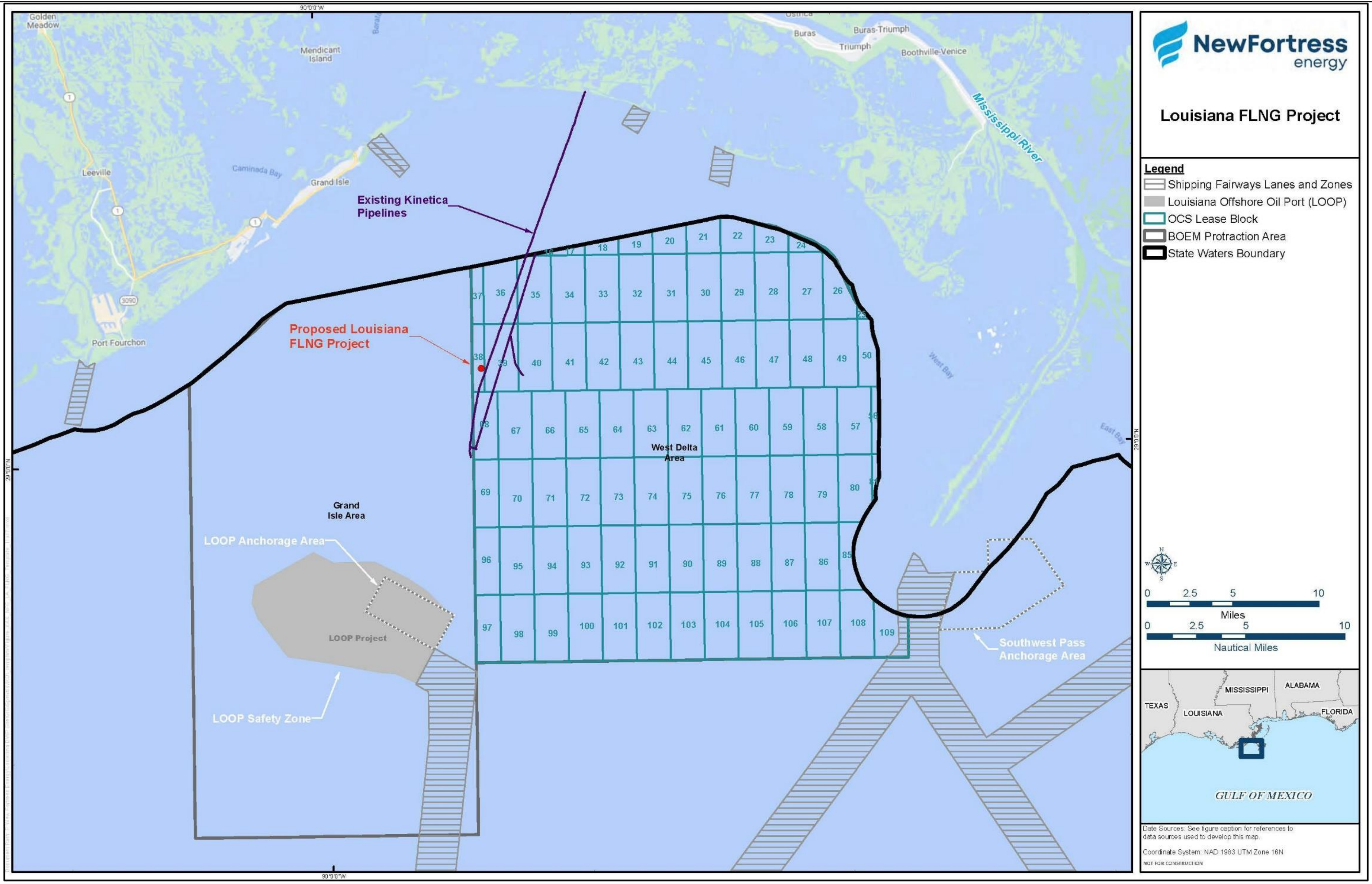

Figure 1-1 Project Study Area

This Underwater Acoustic Assessment report has been prepared in support of the Project DWPA. As discussed in the DWPA, construction and operation of the Project have the potential to cause acoustic harassment to marine species, in particular, marine mammals, sea turtles, and fish populations. This report presents the acoustic modeling methodologies, as applied, to estimate the expected underwater noise levels generated during construction of the Project. The objective of this modeling study was to predict the ranges to acoustic thresholds that could result in injury (Level A Take) or behavioral disruption (Level B Take) of marine mammals, sea turtles, and fish during construction and operation of the Project. Primary noise-generating activities have been identified during construction as impact pile driving associated with the three permanently fixed jacket platforms, consisting of three piles per jacket, associated with FLNG2:

- FLNG2 Gas Treating (“P4”),
- FLNG2 Liquefaction (“P5”), and
- FLNG2 Utilities (“P6”).

The potential noise impacts associated with pile-driving activities were analyzed and results were compared to the relevant underwater noise regulations.

1.1 ACOUSTIC CONCEPTS AND TERMINOLOGY

This section outlines some of the relevant concepts in acoustics to help the non-specialist reader best understand the modeling assessment and results presented in this report. Sound is the result of mechanical vibrations traveling through a fluid medium such as air or water. These vibrations constitute waves that generate a time-varying pressure disturbance oscillating above and below the ambient pressure.

It is important to note that underwater sound levels are not equivalent to in-air sound levels, with which most readers would be more familiar. An underwater sound pressure level (SPL or L_p) of 150 decibels (dB) referenced to 1 micropascal (re 1 μPa) is not equivalent to an in-air sound pressure level of 150 dB re 20 μPa due to the differences in density and speed of sound between water and air, and the different reference pressures that are used to calculate the dB levels, i.e., 1 μPa for water and 20 μPa for air. Underwater sound levels can be presented either as overall broadband levels or as frequency-dependent levels showing the frequency content of a source. Broadband values present the total sound pressure level of a given sound source within a specified frequency bandwidth. Sometimes it is preferable to use frequency-dependent sound levels to characterize spectral content of a sound source and/or identify narrowband sources such as one-third octave band levels, which are one-third of an octave wide, wherein octave refers to a factor 2 increase in sound frequency.

The sound level estimates presented in this modeling study are expressed in terms of several metrics and apply the use of exposure durations to allow for interpretation relative to potential biological impacts on marine life. The National Oceanic and Atmospheric Administration National Marine Fisheries Service (“NOAA Fisheries”) issued a Technical Guidance that provides acoustical thresholds and defines the threshold metrics (NOAA Fisheries 2018). The ISO 18405 Underwater Acoustics – Terminology (ISO 2017) provided a dictionary of underwater bioacoustics for standardized terminology. Table 1-1 provides a summary of the relevant metrics from both NOAA Fisheries (2018) and ISO (2017) that are used within this report.

Table 1-1 Summary of Acoustic Terminology

Metric	NOAA Fisheries (2018)	ISO (2017)		Reference Value
		Main Text	Equations and Tables	
Sound Pressure Level	SPL	SPL	L_p	dB re 1 µPa
Peak Sound Pressure Level	PK	Lpk	$L_{p,pk}$	dB re 1 µPa
Cumulative Sound Exposure Level	SEL_{cum} [1]	SEL	L_E	dB re 1 µPa^2·s

Note:
1 NOAA Fisheries (2018) describes the cumulative sound exposure level (“SEL_{cum}”) metric over an accumulation period of 24-hour period. Following the ISO standard, this will be identified as SEL in the text and LE will be used in tables and equations of this report with the accumulation period identified.

This report follows the ISO (2017) standard terminology and symbols for the sound metrics unless stated otherwise. Below are descriptions of the relevant metrics and concepts that should help frame the discussion of acoustics in this document. The majority of the information in the following sections provides further insight into how data and modeling results have been presented in accordance with regulatory reporting requirements and established criteria.

Peak sound pressure (Lpk or $L_{p,pk}$; dB re 1 µPa) is the maximum instantaneous noise level over a given event and is calculated using the level of the squared sound pressure from zero-to-peak within the wave. The peak sound pressure level is commonly used as a descriptor for impulsive sound sources. At high intensities, the Lpk can be a valid criterion for assessing whether a sound is potentially injurious; however, since it does not take into account the pulse duration or bandwidth of a signal, it is not a good indicator of loudness or potential for masking effects. The Lpk can be calculated using the formula below. Impulses are 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.

$$L_{p,pk} = 10\,log_{10}\left[\frac{max(|p^2(t)|)}{p_0^2}\right]\ dB \tag{1}$$

Sound pressure level (“SPL or L_p”; dB re 1 µPa) is the root-mean-square (rms) sound pressure level in a stated frequency band over a specified time window. It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure. The 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 SPL 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 from a given sound source, the SPL is computed according to the following formula where p^2 is the mean squared sound pressure and p_0^2 is the reference value of mean-square sound pressure, which is 1 µPa^2.

$$L_p = 10\,log_{10}\left(\frac{1}{T}\int_T p^2(t)dt/p_0^2\right)\ \ dB \tag{2}$$

Sound exposure level (“SEL or L_E”; dB re 1 µPa^2·s) is similar to the SPL but further specifies the sound pressure over a specified time interval or event, for a specified frequency range. The SEL for a single event is calculated by taking the time-integral of the squared sound pressure, E_p, over the full event duration:

$$L_E = 10\,log_{10}\left(\int_{T_{100}} p^2(t)dt/T_0p_0^2\right)\ \ dB \tag{3}$$

The SEL represents the total acoustic energy received at a given location. Unless otherwise stated, SELs for impulsive noise sources presented in this report, i.e., impact hammer pile-driving, refer to a single pulse. In addition, 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 1 second and can be expanded to represent the summation of energy from multiple pulses. The latter is written $\mathrm{SEL_{cum}}$ denoting that it represents the cumulative sound exposure level. Sound exposure level is often used in the assessment of marine mammal and fish injury/physiological impacts over a 24-hour time period. The $\mathrm{SEL_{cum}}$ (dB re 1 μPa^2·s) can be computed by summing (in linear units) the SEL of N individual events:

$$L_{E,N} = 10\, log_{10}\left(\sum_{i=1}^{N} 10^{\frac{\mathrm{SEL}_i}{10}}\right)\ dB \tag{4}$$

1.1.1 Sound Propagation in Shallow Waters

Seawater Absorption

Absorption in the underwater environment involves 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 absorption of sound energy by water linearly reduces the sound level with range and is given by an absorption coefficient in units of decibels per kilometer (“dB/km”). The attenuation coefficient is calculated from empirical equations and increases with the square of frequency. For example, for typical open-ocean values (temperature of 50 degrees Fahrenheit (“°F”) [10 degrees Celsius (“°C”)], pH of 8.0, and a salinity of 35 practical salinity units, the equations presented by Francois and Garrison (1982a and 1982b) yield the following values for attenuation due to seawater absorption: 0.001 dB/km at 100 hertz (“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. Seawater absorption was accounted for in the acoustic modeling according to the Fisher and Simmons (1977) calculation methodology. Site-specific sound speed profile information was used, resulting in a site-specific sound attenuation rate.

Scattering and Reflection

Scattering of sound from the surface and bottom boundaries, and from other objects, is difficult to quantify as it is site-specific. However, it is valuable 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 propagation loss, even in relatively calm waters. If boundaries are present, whether “real” like the surface of the sea or “internal” like changes in the physical characteristics of the water, sound propagation is affected. The received acoustic intensity 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 sea floor and the sea surface, resulting in constructive and/or destructive interference patterns. Reflections occurring between the sea floor and sea surface are accounted for in the Project acoustic modeling analysis. The model is described further in Section 4.1, Sound Propagation Model.

Changes in direction of the sound due to variation in sound speed 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 greatest impact on sound velocity is temperature. The change in the direction of the sound wave due to changes in sound speed can produce many complex sound paths. When there is a negative temperature gradient, sound speed decreases with depth, and sound rays bend sharply downward. At some horizontal distance from the sound source, there are regions of low sound intensity where sound rays do not reach, which are known as shadow zones. Variability in sound speed can also produce surface ducts and sound channels that can trap acoustic energy and enable long-distance propagation with minimal losses; for example, the Sound Fixing and Ranging channel, also known as the deep sound channel, acts as an acoustic waveguide and has been used for ocean surveillance and attributed toward increased communication ranges for marine mammals such as fin whales.

Since the inhomogeneities in water are very small compared to the wavelength of the sound signals, 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 becomes somewhat less important than other factors. Also, scattering loss occurring at the surface due to wave action increases at higher sea states. For reflection from the sea surface, it is assumed that the surface is smooth. While a rough sea surface would increase scattering and transmission loss at higher frequencies, the scale of surface roughness is insufficient to have a significant effect on sound propagation in the near field relative to the source.

Seabed Absorption

Seabed sediment characteristics influence propagation loss in shallow water due to the repeated reflections and scattering at the water/sea floor interface. For underwater acoustic analysis, shallow water is typically defined as water depths less than 656 feet (200 meters). Depending on the sediment properties, sound may be absorbed or reflected. For example, fine-grained silt and clay absorb sound efficiently, while sand, gravel, and bedrock are more reflective. To model these effects, the most important parameters to consider are the sediment density, sound speed, and acoustic attenuation.

The acoustic properties of different sediment types display a much greater range of variation than the acoustic properties of seawater. A good understanding of these properties and their spatial variation is useful for accurate modeling. Oftentimes it is challenging to obtain site-specific data characterizing the sea floor; however, the West Delta LNG Liquefaction Facility – Geohazards Assessment performed by NFE provided preliminary sediment data for the Project area, which was used in the modeling analysis up to a depth of approximately 220 feet (67 meters). Further details pertaining to sediment characteristics are provided in Section 4.2.2, Sediment Characteristics, and in Appendix A, Underwater Sound Propagation Modeling Methodology.

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 can also be calculated if the speed of sound in the sediment ($C_{sediment}$) is known (Au and Hastings 2008) and seasonal temperature variation of the speed of sound of the seawater (C_{water}) is known using the following equation:

$$f_c = \frac{C_{water}}{4h} / \sqrt{1 - (C_{water})^2 / (C_{sediment})^2} \qquad (5)$$

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

The speed of sound in sediment is higher than in water. In water, it is approximated at 1,500 meters/second ("m/s"). Values for speed of sound in sediment in the Project Study Area range from 1,470 m/s in clay, 1,515 m/s in clayey silt, to 1,680 m/s in sandy areas. Sound traveling in shallower regions of the Project Study Area will be subject to a higher cutoff frequency and a greater attenuation rate than sound propagating in deeper regions.

Figure 1-2 graphically presents the cut-off frequency for different bottom material types (represented as separate lines on the figure) plotted as a function of water depth (x-axis) and cut-off frequency (y-axis). As shown, at an approximate water depth of 92 feet (24 meters) and a sea bottom consisting of predominantly clay, which represents the deeper region of the Lease Area, the cut-off frequency would be expected to occur at approximately 0.08 kHz. Greater low-frequency attenuation rates would occur at shallower locations within the Lease Area. For the Project acoustic modeling analysis, the concept of cut-off frequency is incorporated into the modeling calculations through the characterization of sediment properties within the seabed.

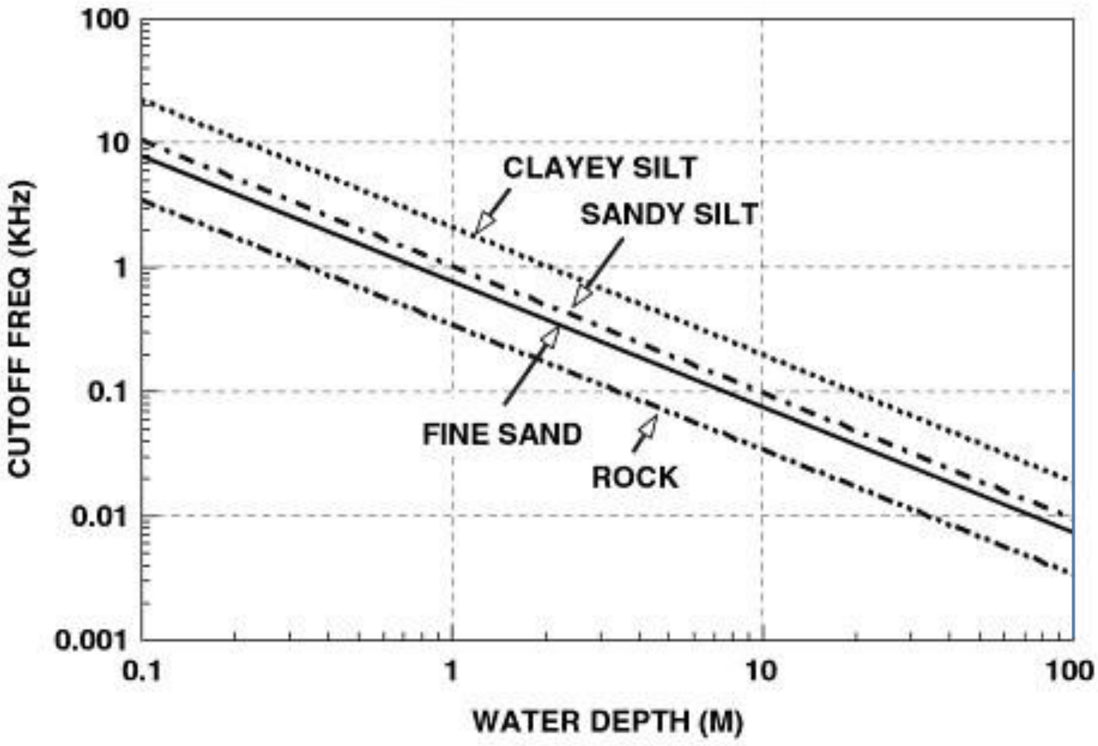

Figure 1-2 Cut-off Frequencies for Different Bottom Materials (Au and Hastings 2008)

2.0 REGULATORY CRITERIA AND SCIENTIFIC GUIDELINES

2.1 UNDERWATER ACOUSTIC CRITERIA

The Marine Mammal Protection Act ("MMPA") of 1972 provides for the protection of all marine mammals. The MMPA prohibits, with certain exceptions, the "take" of marine mammals. The term "take," as defined in Section 3 (16 United States Code ["U.S.C."] section ["§"] 1362 (13)) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal". NOAA Fisheries has jurisdiction for overseeing the MMPA regulations as they pertain to most marine mammals; however, the U.S. Fish and Wildlife Service ("USFWS") has jurisdiction over a select group of marine mammals including manatees, otters, walruses, and polar bears. Since manatees are present within the Project Study Area, the USFWS's jurisdiction over manatees is pertinent to the Project; however, manatee presence offshore is considered rare. Generally, NOAA Fisheries is responsible for issuing take permits under MMPA, upon a request, for authorization of incidental but not intentional "taking" of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. The USFWS issues take permits for manatees, but criteria evaluating potential acoustic impacts to manatees has not yet been developed by the agency. "Harassment" was further defined in the 1994 amendments to the MMPA, with the designation of two levels of harassment: Level A and Level B. By definition, Level A harassment is any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock, while Level B harassment is any act of pursuit, torment, or annoyance which 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. NOAA Fisheries defines the threshold level for Level B harassment at 160 dB SPL for impulsive/intermittent sound, averaged over the duration of the signal and at 120 dB SPL for non-impulsive sound, with no relevant acceptable distance specified.

NOAA Fisheries provided guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, which includes whales, dolphins, porpoises, seals, and sea lions, and updated this guidance in 2018 (NOAA Fisheries 2018). The guidance specifically defines marine mammal hearing groups; develops auditory weighting functions; and identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift ["PTS"] or temporary threshold shift ["TTS"]) for acute, incidental exposure to underwater sound. Under this guidance, any occurrence of PTS constitutes a Level A, or injury, take. The sound emitted by man-made sources may induce TTS or PTS in an animal in two ways: (1) peak sound pressure levels (Lpk) may cause damage to the inner ear, and (2) the accumulated sound energy the animal is exposed to (SEL) over the entire duration of a discrete or repeated noise exposure has the potential to induce auditory damage if it exceeds the relevant threshold levels.

Research showed that the frequency content of the sound would play a role in causing damage. Sound outside the hearing range of the animal would be unlikely to affect its hearing, while the sound energy within the hearing range could be harmful. Under the NOAA Fisheries (2018) guidance, recognizing that marine mammal species do not have equal hearing capabilities, five hearing groups of marine mammals are defined as follows:

- Low-frequency ("LF") Cetaceans—this group consists of the baleen whales (mysticetes) with a collective generalized hearing range of 7 Hz to 35 kHz;

- Mid-frequency ("MF") Cetaceans—includes most of the dolphins, all toothed whales except for Kogia spp., and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz (renamed High-frequency cetaceans by Southall et al. [2019] because their best hearing sensitivity occurs at frequencies of several tens of kHz or higher);
- High-frequency ("HF") Cetaceans—incorporates all the true porpoises, the river dolphins, plus Kogia spp., Cephalorhynchid spp. (genus in the dolphin family Delphinidae), and two species of Lagenorhynchus (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz (renamed very high-frequency cetaceans by Southall et al. [2019] since some species have best sensitivity at frequencies exceeding 100 kHz);
- Phocids Underwater—consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz (renamed Phocids carnivores in water by Southall et al. [2019]); and
- Otariids Underwater —includes sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz (termed "other marine carnivores" in water by Southall et al. [2019]) and includes otariids, as well as walrus [Family Odobenide], polar bear [*Ursus maritimus*], and sea and marine otters [Family Mustelidae]).

Within these generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (NOAA Fisheries 2018; Southall et al. 2019). To reflect higher noise sensitivities at specific frequencies, auditory weighting functions were developed for each functional hearing group that reflected the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency (NOAA Fisheries 2018). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing (Figure 2-1).

NOAA Fisheries (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each hearing group for impulsive and non-impulsive signals (Table 2-1), which are presented in terms of dual metrics: SEL and Lpk. The Level B harassment thresholds are also provided in Figure 2-1.

NOAA Fisheries anticipates behavioral response for sea turtles from impulsive sources such as impact pile-driving to occur at SPL 175 dB, which has elicited avoidance behavior of sea turtles (Table 2-2; Blackstock et al. 2017). There is limited information available on the effects of noise on sea turtles, and the hearing capabilities of sea turtles are still poorly understood. In addition, the U.S. Navy introduced a weighting filter appropriate for sea turtle impact evaluation in their 2017 document titled *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III).* The U.S. Navy weighting has been applied to impulsive criterion for PTS (204 dB SEL and 232 dB Lpk), impulsive criterion for TTS (189 dB SEL and 226 dB L_{pk}), and non-impulsive criteria for TTS (200 dB SEL) and PTS (220 dB SEL). The weighting for sea turtles is presented in Figure 2-1.

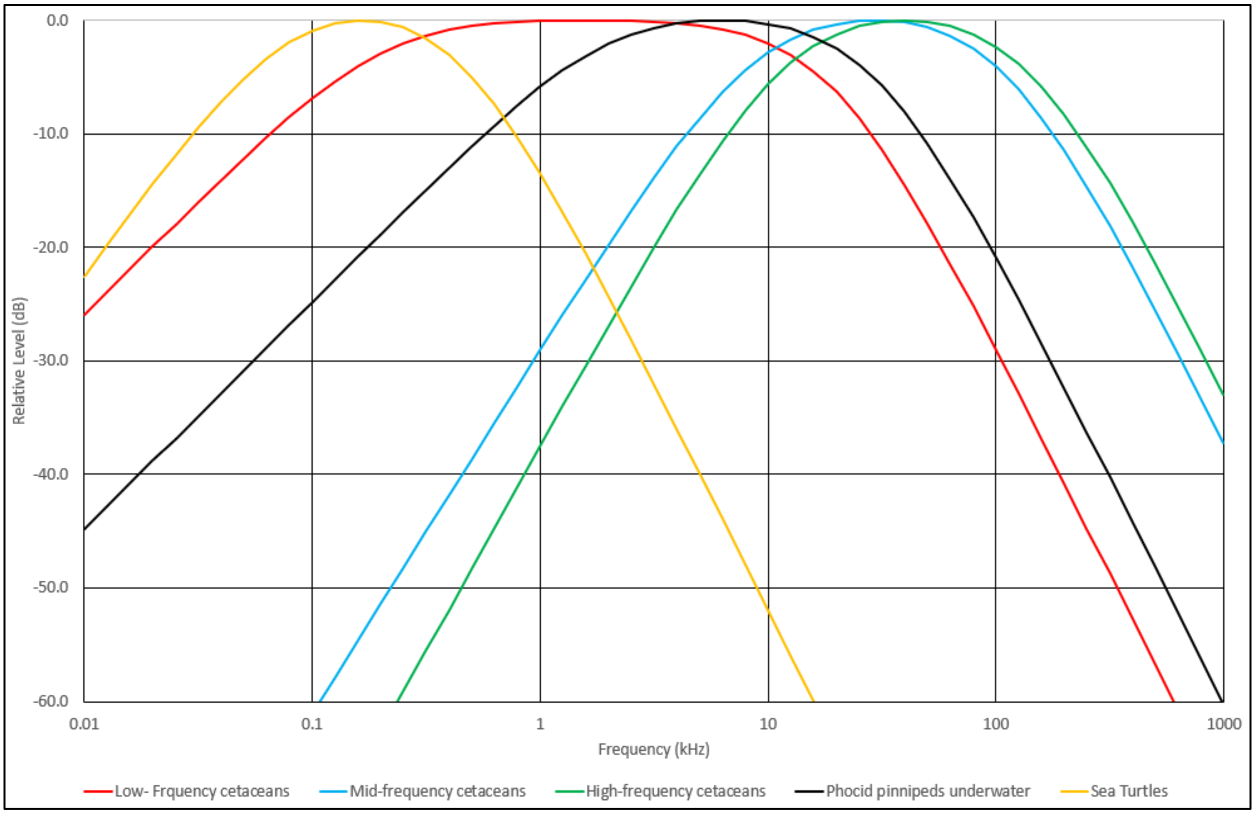

Figure 2-1 Auditory Weighting Functions for Cetaceans (Low-frequency, Mid-frequency, and High-frequency Species), Pinnipeds in water (PW), and Sea Turtles (NOAA Fisheries 2018; U.S. Navy 2017)

In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury to fishes exposed to pile-driving sounds. These noise injury thresholds have been established by the Fisheries Hydroacoustic Working Group, which was assembled by NOAA Fisheries with thresholds subsequently adopted by NOAA Fisheries. The NOAA Fisheries Greater Atlantic Regional Fisheries Office (“GARFO”) has applied these standards for assessing the potential effects of Endangered Species Act (“ESA”)-listed fish species exposed to elevated levels of underwater sound produced during pile-driving, which were just recently updated (NOAA Fisheries 2019). The 183 dB and 187 dB cumulative sound exposure level thresholds for fish species are based on mass. These noise thresholds have been adopted by GARFO and are based on sound levels that have the potential to produce injury or illicit a behavioral response from fishes (Table 2-2).

A Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, also developed sound exposure guidelines for fish and sea turtles (Table 2-3; Popper et al. 2014). They identified three types of fishes depending on how they might be affected by underwater sound. The categories include fishes with no swim bladder or other gas chamber (e.g., flounders, dab, and other flatfishes); fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids); and fishes with a swim bladder that is involved in hearing (e.g., channel catfish).

Table 2-1 Acoustic Threshold Levels for Marine Mammals

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds		
	Permanent Threshold Shift Onset	**Temporary Threshold Shift Onset**	**Behavior**	**Permanent Threshold Shift Onset**	**Temporary Threshold Shift Onset**	**Behavior**
Low-frequency cetaceans	219 dB ($L_{p,pk}$) 183 ($L_{E,\ LF,\ 24h}$)	213 dB ($L_{p,pk}$) 168 dB ($L_{E,\ LF,\ 24h}$)	160 dB (L_p)	199 dB ($L_{E,\ LF,\ 24h}$)	179 dB ($L_{E,\ LF,\ 24h}$)	120 dB (L_p)
Mid-frequency cetaceans	230 dB ($L_{p,pk}$) 185 dB ($L_{E,\ MF,\ 24h}$)	224 dB ($L_{p,pk}$) 170 dB ($L_{E,\ MF,\ 24h}$)		198 dB ($L_{E,\ MF,\ 24h}$)	178 dB ($L_{E,\ MF,\ 24h}$)	
High-frequency cetaceans	202 dB ($L_{p,pk}$) 155 dB ($L_{E,\ HF,\ 24h}$)	196 dB ($L_{p,pk}$) 140 dB ($L_{E,\ HF,\ 24h}$)		173 dB ($L_{E,\ HF,\ 24h}$)	153 dB ($L_{E,\ HF,\ 24h}$)	
Phocid pinnipeds underwater	218 dB ($L_{p,pk}$) 185 dB ($L_{E,\ PW,\ 24h}$)	212 dB ($L_{p,pk}$) 170 dB ($L_{E,\ PW,\ 24h}$)		201 dB ($L_{E,\ PW,\ 24h}$)	181 dB ($L_{E,\ PW,\ 24h}$)	

Sources: Southall et al. 2019; NOAA Fisheries 2018, NOAA Fisheries 2005
$L_{E,\ 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)

Table 2-2 Acoustic Threshold Levels for Fishes and Sea Turtles

Hearing Group	Impulsive Signals		Non-Impulsive Signals		Behavior (Impulsive and Non-impulsive)
	Injury	**Temporary Threshold Shift Onset**	**Injury**	**Temporary Threshold Shift Onset**	
Fishes	206 dB ($L_{p,pk}$) 187 dB ($L_{E,\ 24h}$) (fish mass ≥ 2 g) 183 dB ($L_{E,\ 24h}$) (fish mass < 2 g)	--	--	--	150 dB (L_p)
Sea turtles	232 dB ($L_{p,pk}$) 204 dB ($L_{E,\ TUW,\ 24h}$)	226 dB ($L_{p,pk}$) 189 dB ($L_{E,\ TUW,\ 24h}$)	220 dB ($L_{E,\ TUW,\ 24h}$)	200 dB ($L_{E,\ TUW,\ 24h}$)	175 dB (L_p)

Sources: Stadler and Woodbury 2009; NOAA Fisheries 2019; NOAA Fisheries 2005; Blackstock et al. 2017; Department of the Navy 2017
$L_{E,\ 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)

Table 2-3 Acoustic Threshold Levels for Fishes and Sea Turtles

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds	
	Mortality and Potential Mortal Injury	**Recoverable Injury**	**Temporary Threshold Shift**	**Recoverable Injury**	**Temporary Threshold Shift**
Fishes without swim bladders	> 213 dB ($L_{p,pk}$) > 219 dB ($L_{E, 24h}$)	> 213 dB ($L_{p,pk}$) > 216 dB ($L_{E, 24h}$)	> 186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder not involved in hearing	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	> 207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	> 186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder involved in hearing	207 dB ($L_{p,pk}$) 207 dB ($L_{E, 24h}$)	> 207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	186 dB ($L_{E, 24h}$)	170 dB (L_p)	158 dB (L_p)
Sea turtles	> 207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	(N) High (I) Low (F) Low	(N) Moderate (I) Low (F) Low	--	--
Eggs and larvae	> 207 dB ($L_{p,pk}$) > 210 dB ($L_{E, 24h}$)	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	--	--

Sources: Popper et al. 2014
$L_{E, 24h}$ = cumulative sound exposure over a 24-hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)
PTS = permanent threshold shift;
N = near (10s of meters);
I = intermediate (100s of meters);
F = far (1000s of meters);
-- = not applicable

3.0 EXISTING AMBIENT SOUND CONDITIONS

Noise in the ocean associated with natural sources is generated by physical and biological processes and non-natural sources such as shipping. 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. The ambient noise for frequencies above 1 kHz is due largely to waves, wind, and heavy precipitation (Simmonds et al. 2004). Surface wave interaction and breaking waves with spray have been identified as significant sources of noise. Wind-induced bubble oscillations and cavitation are also near-surface noise sources. Major storms can give rise to noise in the 40 Hz to 50 kHz frequency band due to intense wind forcing, which can propagate over long distances at low frequencies, and comparable to noise from distant shipping (Zhao et al. 2014; Wilson and Makris 2008). At areas within distances of 4 to 5 nm (8 to 10 kilometers [“km”]) of the shoreline, surf noise will be prominent in the frequencies ranging up to a few hundred Hz (Richardson et al. 2013).

A considerable amount of background noise may also be caused by biological activities. Aquatic animals generate sounds for communication, echolocation, prey manipulation, and as byproducts 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 SPL. 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). Typical underwater noise levels show a frequency dependency in relation to different noise sources; the classic curves are given in Wenz (1962).

Anthropogenic noise sources can consist of contributions related to industrial development, offshore oil industry activities, naval or other military operations, and marine research. A predominant contributing anthropogenic noise source is generated by commercial ships and recreational watercraft. Noise from these vessels dominates coastal waters and emanates from the ships’ propellers and other dynamic positioning (“DP”) propulsion devices such as thrusters. The sound generated from main engines, gearboxes, and 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. Typically, shipping vessels produce frequencies below 1 kHz, although smaller vessels such as fishing, recreational, and leisure craft may generate sound at somewhat higher frequencies (Simmonds et al. 2004).

There is limited publicly available site-specific ambient sound information collected within the Project Study Area. NOAA’s SoundMap (NOAA Fisheries 2012), which is a mapping tool that provides maps of the temporal, spatial, and frequency characteristics of man-made underwater noise resulting from various activities, was consulted. Pressure fields associated with different contributors of underwater sound (i.e., shipping and passenger vessels) were summed and the sound pressure level values at frequencies ranging from 50 to 800 Hz were presented for various water column depths. Within the lower 50 Hz frequency range, underwater sound pressure levels were greatest, varying between approximately 80 to 100 dB depending on water depth and proximity to the coastline. The sound contribution and magnitude decreases with increasing frequency, indicating that the noise from shipping and passenger vessels is largely focused within the LF range.

4.0 ACOUSTIC MODELING METHODOLOGY

Underwater acoustic model simulations were conducted for primary noise-generating activities occurring during Project construction and operation. The following subsections describe the modeling calculations approach, modeled scenarios, and model input values. Please refer to Appendix A for additional details on the modeling principles and assumptions.

4.1 SOUND PROPAGATION MODEL

Underwater sound propagation modeling was completed using dBSea, a software developed by Marshall Day Acoustics for the prediction of underwater noise in a variety of environments. The 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. Noise mitigation methods may also be included. The user has control over the seabed and water properties including sound speed profile, temperature, salinity, and current. Noise levels are calculated to the extent of the bathymetry area. 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 calculation area. Levels are calculated in third octave bands from 12.5 Hz to 20 kHz. Please refer to Appendix B for additional details on the modeling principles and assumptions.

4.2 MODELING ENVIRONMENT

The accuracy of underwater noise modeling results is largely dependent on the sound source characteristics and the accuracy of the intrinsically dynamic data inputs and assumptions used to describe the medium between the path and receiver, including sea surface conditions, water column, and sea bottom. Depending on the sound source under review, it was approximated as a point source or a line source, composed of multiple points, extending downward into the water column. Furthermore, determining sound emissions for the various sources are based on a combination of factors, including known properties (e.g., hammer energy) as well as consulting empirical data. 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 in the following subsections.

4.2.1 Bathymetry

Bathymetry data represent the three-dimensional nature of the subaqueous land surface and were obtained from the National Geophysical Data Center (“NGDC”) and a U.S. Coastal Relief Model (NOAA Satellite and Information Service 2020); the horizontal resolution of this dataset is 3 arc seconds (90 meters). NGDC’s 3 arc-second U.S. Coastal Relief Model 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 Coastal Relief Model 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 is an interactive database management system developed by the NGDC for use in the assimilation, storage, and retrieval of geophysical data. Geographical Data System software manages several types of data including marine trackline geophysical data, hydrographic survey data, aeromagnetic survey data, and gridded bathymetry/topography. The bathymetry is imported into the model and sets the extents for displaying modeled received sound levels; therefore, prior to selecting the bathymetry, coverage test model runs are conducted to determine the anticipated distance to the lowest relevant underwater acoustic threshold values. Additional information regarding bathymetry can be found in Appendix B.

4.2.2 Sediment Characteristics

Sediment type (e.g., hard rock, sand, mud, clay) directly impacts the speed of sound since it is a part of the medium in which the sound propagates. For the immediate Project Study. the sea floor is expected to be predominantly clay. The geoacoustic properties with information on the compositional data of the surficial sediments were informed by estimated geophysical and geotechnical data. The sediment layers and the geoacoustic properties used in the modeling analysis of the impact piling are defined in Table 4-1. The term "compressional" refers to the fact that particle motion of the sound wave is in the same direction as propagation. The term "compressional sound speed" refers to the speed of sound in the sediment along the direction of acoustic propagation. The term "compressional attenuation" refers to how much sound (dB) is lost per wavelength ("λ") of the signal. Finally, density is the physical density ("ρ") of the sediment. Ranges are provided for the different geoacoustic properties because the values vary depending on the location specifically being modeled for a given scenario.

Table 4-1 Geoacoustic Properties of Sub-bottom Sediments as a Function of Depth

Seabed Layer (meters)	Material	Geoacoustic Properties
0 to 19	Clay	Cp = 1470 m/s; αs (dB/λ) = 0.1 dB/ λ; ρ = 1200 kg/m^3
19 to 54	Clay-Silt	Cp = 1515 m/s; αs (dB/λ) = 0.2 dB/ λ; ρ = 1500 kg/m^3
54	Sand	Cp = 1680 m/s; αs (dB/λ) = 1.0 dB/ λ; ρ= 1900 kg/m^3

4.2.3 Seasonal Sound Speed Profiles

The speed of sound in sea water depends on the temperature T (°C), salinity S (parts per thousand ["ppt"]), and depth D (meters), and can be described using sound speed profiles. 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 downward, 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 upward, which can aid in long-distance sound propagation. Pile-driving will take place in the daytime. For the construction modeling scenarios, the December sound speed profile was used in the model based on a sensitivity analysis, as it exhibited maximum case characteristics for long-range noise propagation effects. The speed of sound profile information was obtained using the NOAA Sound Speed Manager software incorporating the World Ocean Atlas 2009 extension algorithms. Additional details pertaining to the sound speed profile sensitivity analysis conducted for the Project can be found in Appendix B.

4.2.4 Threshold Range Calculations

To determine the ranges to the defined threshold isopleths a maximum received level-over-depth approach was used. This approach uses the maximum received level that occurs within the water column at each horizontal sampling point. Both the R_{max} and the $R_{95\%}$ ranges were calculated for each of the regulatory thresholds. The R_{max} is the maximum range in the model at which the sound level calculated. The $R_{95\%}$ is the maximum range at which a sound level was calculated excluding 5% of the R_{max}. The

$R_{95\%}$ excludes major outliers or protruding areas associated with the underwater acoustic modeling environment. Regardless of shape of the calculated isopleths the predicted range encompasses at least 95 percent of the horizontal area that would be exposed to sound at or above the specified level. All ranges to injury thresholds presented in the Underwater Acoustic Assessment Report are presented in terms of the $R_{95\%}$ range.

5.0 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 scenarios modeled were ones where potential underwater noise impacts of marine species were anticipated, including impact pile-driving for a fixed-jacket design associated with the FLNG2, liquefaction, and utilities platforms which are referred to as the platform 4 (P4), platform 5 (P5), and platform 6 (P6) locations, respectively. The Project Area showing the modeled pile-driving locations at P4, P5, and P6 and bathymetry are displayed in Figure 5-1.

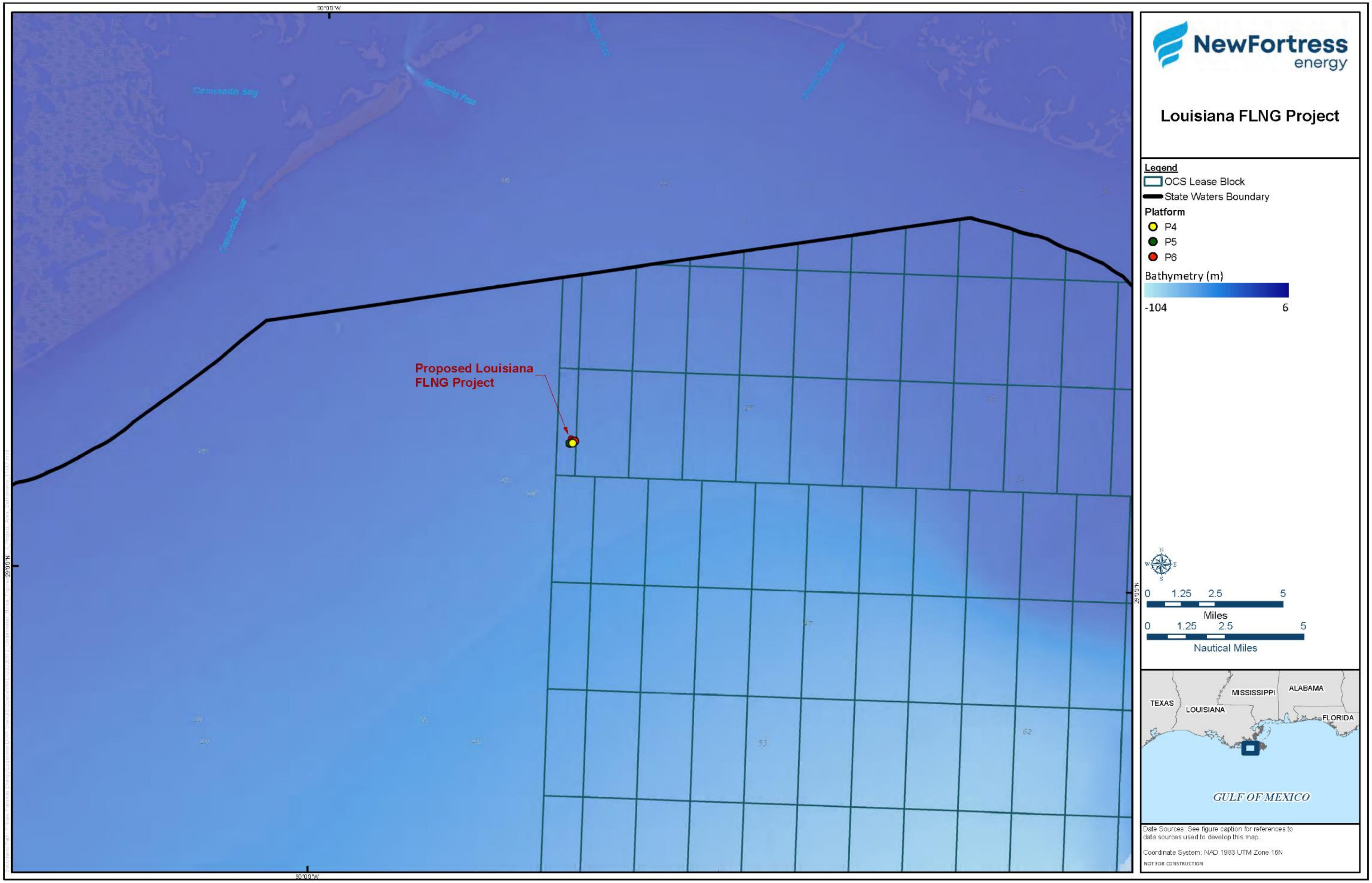

Figure 5-1 Project Study Area and Bathymetry

Modeling requires understanding of the sound source level or theoretical sound level. Tetra Tech, Inc. (Tetra Tech) developed its empirical model based on literature, engineering guidelines, and underwater source measurements and acoustic modeling assessments of similar equipment and activities. The empirical model calculation methodology is described in detail in Appendix C, Pile Driving Sound Source Development, for impact piling, and that methodology was used to determine the Lpk and SEL sound source levels for the scenarios including impact piling activities.

A summary of construction scenarios included in the underwater acoustic modeling analysis is provided in Table 5-1. The model accounts for differences in hammer energy, number of strikes, installation duration, sound source level, and pile progression as appropriate for the fixed jacket piles. The pile diameters selected for the pile-driving modeling scenarios were based on the proposed Project Design Envelope considerations provided by NFE. The subsections that follow provide more detailed information about the parameters used to model the noise sources associated with each scenario, which refer to the P4, P5, and P6 platform locations.

The pile-driving installation scenarios including the broadband sound source levels are summarized in Table 5-1. A summary of the scenarios is bulleted below:

P4 – A total of 12 jacket piles will be installed in 3 days.

- This analysis evaluated 4 piles installed per day.

P5 – A total of 8 jacket piles will be installed in 3 days.

- Day 1 – segment 1 for all 8 piles will be installed.
- Day 2 – segment 2 for all 8 piles will be installed (segment 1 + segment 2).
- Day 3 – segment 3 for all 8 piles will be installed (segment 1 + segment 2 + segment 3).
    - This analysis evaluates day 3 for this location.

P6 – A total of 6 jacket piles will be installed in 3 days.

- Day 1 – segment 1 for all 6 piles will be installed.
- Day 2 – segment 2 for all 6 piles will be installed (segment 1 + segment 2).
- Day 3 – segment 3 for all 6 piles will be installed (segment 1 + segment 2 + segment 3).
    - This analysis evaluates day 3 for this location.

For all of the impact piling scenarios, it was assumed that the maximum rated hammer energy of 1,380 kilojoules (“kJ”) would be employed; however, that hammer energy assumption is considered conservative. The actual transferred energy to the pile during installation will be less than the maximum rated hammer energy, with losses in energy from sources such as heat and friction.

Table 5-1 Underwater Acoustic Modeling Scenarios

Platform	Activity Description	Maximum Hammer Energy (kilojoules)	Duration of Pile Installation (minutes)[2]	Total Hammer Blows[1]	Location (UTM Coordinates) for Modeling Locations	Sound Source Level (No Attenuation)
P4	108” Pile (includes 4 piles per day): 2.743 meters (m)	Impact Pile Driving: 1,380	189.5	5,684	223049 m, 3219466 m	236 $L_{p,pk}$ 210 $L_{E,\ 1sec}$ 220 L_p
P5	108” Pile (includes 8 pile segments per day): 2.743 m	Impact Pile Driving: 1,380	238.13	7,144	222890 m, 3219450 m	236 $L_{p,pk}$ 210 $L_{E,\ 1sec}$ 220 L_p
P6	108” Pile (includes 6 pile segments per day): 2.743 m	Impact Pile Driving: 1,380	122.2	5,358	223176 m, 3219585 m	236 $L_{p,pk}$ 210 $L_{E,\ 1sec}$ 220 L_p

1 Total hammer blows are based on the total piles per day.

2 Duration provided for all piles within a 24-h period.

5.1 IMPACT PILE-DRIVING FOR PLATFORM INSTALLATION

Impact pile driving involves weighted hammers that pile drive foundations into the sea floor. Different methods for lifting the weight associated with the pile driver include hydraulic, steam, or diesel. The acoustic energy is created upon impact; the energy 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 traveling 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 ground, traveling through the ground and radiating back into the water. Near the pile, acoustic energy arrives from different paths with different associated stage and time lags, which creates a pattern of destructive and constructive interference. Further away from the pile, the water- and seafloor-born energy are the dominant pathways. The underwater noise generated by a pile-driving strike depends primarily on the following factors:

- The impact energy and type of pile-driving hammer;
- The size and type of the pile;
- Water depth; and
- Subsurface hardness in which the pile is being driven.

As indicated in Table 5-1, three platform locations were modeled within the Project Study Area. It is expected that by modeling these three locations, the range of anticipated sound fields resulting from pile driving will be represented. Propagation modeling was conducted using the maximum projected blow energy to calculate Lpk and SPL; however, a soft start and pile progression were also incorporated into the model to calculate SEL for each pile scenario as shown in Table 5-2. For Platforms P5 and P6, only Day 3 (P1+P2+P3) was modeled, which was projected to have the greatest impact and includes the potential impacts from Day 1 (P1) and Day 2 (P1+P2). The choice of Day 3 as the worst-case scenario was due to the total number of blows per day being highest as well as due to propagation conditions. As described in Appendix B, the SPL is related to the SEL by an average pulse duration of 0.09 seconds.

Table 5-2 Pile-Driving Progression Summary

Platform	Pile Segment	Hammer Energy %	Hammer Energy	Duration (minutes)[2]	Blows per Minute	Total Number of Blows per Hammer Energy[1]	Total Number of Blows per Day
P4	P1	20	460	36.53	30	1,096	5,684
		40	920	42.93	30	1,288	
		60	1,380	110.0	30	3,300	
P5	Day 1: P1	20	460	85.6	30	2,568	5,256
		40	920	89.6	30	2,688	
	Day 2: P1+P2	20	460	17.07	30	512	6,736
		40	920	22.67	30	680	
		60	1,380	184.8	30	5,544	
	Day 3: P1+P2+P3	20	460	52.8	30	1,584	7,144
		40	920	22.4	30	672	
		60	1,380	162.93	30	4,888	
P6	Day 1: P1	20	460	64.2	30	1,926	3,942
		40	920	6.2	30	2,016	
	Day 2: P1+P2	20	460	12.8	30	384	5,052
		40	920	17	30	510	
		60	1,380	138.6	30	4,158	
	Day 3: P1+P2+P3	20	460	39.6	30	1,188	5,358
		40	920	16.8	30	504	
		60	1,380	122.2	30	3,666	

1 Total number of blows are based on the total number of piles installed per day.
2 Duration provided for all piles within a 24-h period.

Third octave band center frequencies from 12.5 Hz up to 20 kHz were used in the modeling. The spectra used in the modeling are shown in Figure 5-2. Additional detail pertaining to how the pile spectral source levels were calculated is provided in Appendix B.

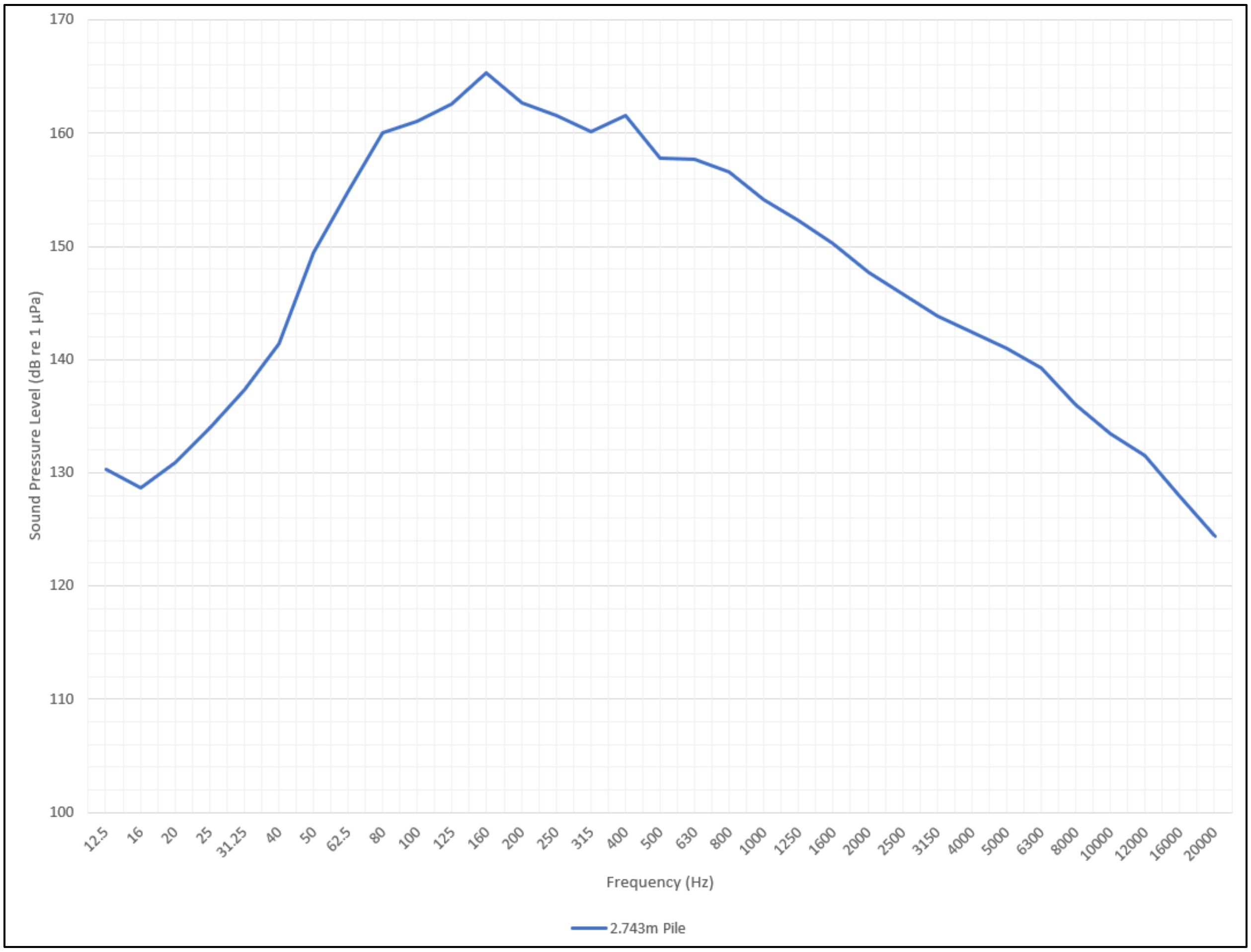

Figure 5-2 2.743-Meter Pile Spectral Source Levels

6.0 NOISE MITIGATION

As discussed in this report, NFE is considering the use of impact pile driving to install the FLNG2 Gas Treating Platform (P4), Liquefaction Platform (P5), and Utilities Platform (P6). The relevant noise mitigation strategies are discussed.

6.1 IMPACT PILE DRIVING

With regard to impact pile driving and, as detailed in Section 5.1, NFE intends to implement noise mitigation in the form of the “soft-start” technique when impact piling with the maximum hammer energy limited to 60 percent. The soft start technique involves initially driving a pile using a low hammer energy. As the pile is driven further into the soil, the hammer energy is increased as necessary to achieve soil penetration. This technique gives fish and marine mammals an opportunity to move out of the area before full-powered impact pile-driving begins. The intended pile progressions for the pile installation are presented in Table 5-2.

In addition to the application of the soft-start technique, other devices may be considered to mitigate impact pile-driving sound levels. There are several types of sound attenuation devices including bubble curtains, noise mitigation screen (cofferdam type), Hydro Sound Dampers, and the AdBm noise mitigation system. The commonly considered mitigation strategy is the use of bubble curtains. Bubble curtains create a column of air bubbles rising around a pile from the substrate to the water surface. Because air and water have a substantial impedance mismatch, the bubble curtain acts as a reflector. In addition, the air bubbles absorb and scatter sound waves emanating from the pile, thereby reducing the sound energy. Bubble curtains may be confined or unconfined. These systems may be deployed in series, such as a double bubble curtain with two rings of bubbles encircling a pile. Attenuation levels also vary by type of system, frequency band, and location. Small bubble curtains have been measured to reduce sound levels from approximately 10 dB to more than 20 dB but are highly dependent on depth of water and current, and configuration and operation of the curtain (Koschinski and Lüdemann 2013; Bellmann 2014; Austin et al. 2016). Larger bubble curtains tend to perform better and are more reliable when deployed with two rings. Encapsulated bubble systems and Hydro Sound Dampers are effective within their targeted frequency ranges, e.g., 100 to 800 Hz, and when used in conjunction with bubble curtains, reduced impact energy by increasing the blow rate, or prolonged pulse duration by use of hydraulic hammers, can further reduce noise (Koschinski and Lüdemann 2020).

Effectiveness of bubble curtains is variable and depends on many factors, including the bubble layer thickness, the total volume of injected air, the size of the bubbles relative to the sound wavelength, and whether the curtain is completely closed. Decreased noise reduction has been found in cases of strong currents or sub-optimal configuration (Bellmann et al. 2017). As water depth increases, the opportunity for current-based disruption of the bubble curtain increases. In general, bubble curtain effectiveness decreases as the water depth increases (Bellmann et al. 2017). With studies reporting variable achievable attenuation rates for bubble curtains, to represent the use of bubble curtains as a mitigation option in the modeling, a range of potential sound reduction was applied to the modeled sound fields associated with impact pile-driving. Attenuation factors of 6 dB and 10 dB were applied to all impact pile-driving scenarios to evaluate potential mitigated underwater noise impacts. The 6 dB and 10 dB attenuation factors have been incorporated into the underwater acoustic analysis based on guidance from NOAA Fisheries but can be considered conservative based on measurement results documenting the effectiveness of bubble curtains in other in-water environments (Koschinski and Lüdemann 2020).

7.0 RESULTS

As stated earlier, using dBSea and site-specific parameters related to the marine environment and Project sound source characteristics, acoustic modeling was completed to assess distances to the various acoustic threshold levels identified in Section 2.1, Underwater Acoustic Criteria. The modeling scenarios analyzed are described in Table 5-2 and include the following:

- P4: Jacket pile installation, which includes impact pile-driving four piles per day with a diameter of 8.9 feet (2.743 meters);
- P5: Jacket pile installation, which includes impact pile-driving eight piles per day with a diameter of 8.9 feet (2.743 meters);
- P6: Jacket pile installation, which includes impact pile-driving six piles per day with a diameter of 8.9 feet (2.743 meters);

The results for the modeling scenarios are provided in subsections 7.1, 7.2, and 7.3 for the three platform locations. Results are presented without mitigation and with two different levels of mitigation: a 6 dB reduction and a 10 dB reduction. Noise mitigation requirements and methods have not been finalized at this stage of Project design; therefore, these two levels of reduction were applied to potentially mimic the use of noise mitigation options, such as bubble curtains. Appendix A summarizes the R95 distances for the Lpk, SPL, and SEL metrics. The results of the analysis will be used to inform development of evaluation and mitigation measures that will be applied during construction and operation of the Project, in consultation with NOAA Fisheries and any additional appropriate regulatory agencies. The Project will obtain necessary permits to address potential impacts to marine mammals, sea turtles, and fisheries resources from underwater noise and will establish appropriate and practicable mitigation and monitoring measures through discussions with regulatory agencies. Figure 7-1. Figure 7-2, Figure 7-3 show the unweighted and unmitigated underwater received sound pressure levels for the 8.9 ft (2.743 m) jacket piles at each of the platform locations. Underwater sound pressure level ranges are displayed in 5 dB increments and sound propagation characteristics are shown throughout the Lease Area and beyond, as applicable.

7.1 MARINE MAMMAL INJURY AND BEHAVIORAL ONSET RESULTS

The results for marine mammal injury and behavioral onset for platforms P4, P5, and P6 are shown in Table 7-1, Table 7-2, and Table 7-3 for the applicable SEL, Lpk, and SPL metrics. The results display trends that are expected including increasingly reduced distances as greater levels of noise mitigation are applied. In addition, the smallest distances to thresholds are evaluated for the Lpk acoustic thresholds while the largest distances were observed for the 183 dB SEL LF cetacean, 155 dB SEL HF cetacean, and 160 dB SPL Marine Mammal criteria. The calculated values for all platforms were all comparable, which is expected since they are positioned in proximity to one another and therefore are at similar water depths and experience similar effects of bathymetry and SSP. The largest distance was determined to be 4,558 meters corresponding to the 183 dB SEL LF cetacean criterion without mitigation at P5.

7.2 FISH INJURY AND BEHAVIORAL ONSET RESULTS

The results for fish injury and behavioral onset results for fish with no swim bladder, fish with a swim bladder not involved in hearing, fish with swim bladder involved in hearing, eggs and larvae, small fish, and large fish are shown in Table 7-4, Table 7-5, and Table 7-6. All distance to threshold values were fairly low (i.e., less than 400 meters) except for the distances to the 187 dB SEL and 183 dB SEL injury and 150 dB SPL behavioral thresholds with the largest distance of 8,284 meters occurring at P6 for the unmitigated distance to the 150 dB SPL acoustic threshold.

7.3 SEA TURTLE INJURY AND BEHAVIORAL ONSET RESULTS

The results for the applicable sea turtle criteria are shown in Table 7-7, Table 7-8, and Table 7-9. Distances to all relevant acoustic thresholds remain below 1,500 meters for all criterion values. The largest distances were observed for the TTS impulsive criterion for turtles of 189 dB SEL without mitigation, ranging from 1,155 meters from P4 to 1,332 meters from P5.

Table 7-1 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P4 Location

			Location P4		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Hearing Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Low-frequency cetaceans	$L_{E,24hr}$ [1,3]	183	3,929	2,010	1,238
	$L_{p,pk}$ [1,3]	219	39	23	13
Mid-frequency cetaceans	$L_{E,24hr}$ [1,3]	185	116	46	34
	$L_{p,pk}$ [1,3]	230	11	-[5]	-[5]
High-frequency cetaceans	$L_{E,24hr}$ [1,3]	155	3,133	1,692	993
	$L_{p,pk}$ [1,3]	202	235	106	84
Phocid pinnipeds	$L_{E,24hr}$ [1,3]	185	1,448	524	311
	$L_{p,pk}$ [1,3]	218	41	26	16
Marine Mammal Behavior	L_p [2,4]	160	3,208	1,560	1,021

1 NOAA Fisheries 2018
2 NOAA Fisheries 2005
3 Level A Injury PTS
4 Level B Behavioral (Impulsive/Intermittent)
5 The threshold level is greater than the source level; therefore, distances are not generated.

Table 7-2 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P5 location

			Location P5		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Hearing Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Low-frequency cetaceans	$L_{E,24hr}$ [1,3]	183	4,558	2,249	1,353
	$L_{p,pk}$ [1,3]	219	39	24	14
Mid-frequency cetaceans	$L_{E,24hr}$ [1,3]	185	132	70	37
	$L_{p,pk}$ [1,3]	230	12	-[5]	-[5]
High-frequency cetaceans	$L_{E,24hr}$ [1,3]	155	3,739	1,951	1,165
	$L_{p,pk}$ [1,3]	202	236	105	84
Phocid pinnipeds	$L_{E,24hr}$ [1,3]	185	1,774	660	367
	$L_{p,pk}$ [1,3]	218	41	27	17
Marine Mammal Behavior	L_p [2,4]	160	3,037	1,582	1,045

1 NOAA Fisheries 2018

2 NOAA Fisheries 2005

3 Level A Injury PTS

4 Level B Behavioral (Impulsive/Intermittent)

5 The threshold level is greater than the source level; therefore, distances are not generated.

Table 7-3 Marine Mammal Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P6 Location

Hearing Group	Metric	Threshold (dB)	Location P6 Hammer Energy - 1380 kJ Pile Diameter - 2.743 meters Attenuation (dB)		
			0	6	10
Low-frequency cetaceans	$L_{E,24hr}$ [1,3]	183	3,908	1,887	1,176
	$L_{p,pk}$ [1,3]	219	39	24	13
Mid-frequency cetaceans	$L_{E,24hr}$ [1,3]	185	111	45	33
	$L_{p,pk}$ [1,3]	230	11	-[5]	-[5]
High-frequency cetaceans	$L_{E,24hr}$ [1,3]	155	3,149	1,664	1,008
	$L_{p,pk}$ [1,3]	202	241	107	85
Phocid pinnipeds	$L_{E,24hr}$ [1,3]	185	1,389	508	315
	$L_{p,pk}$ [1,3]	218	41	26	16
Marine Mammal Behavior	L_p [2,4]	160	3,141	1,603	1,064

1 NOAA Fisheries 2018
2 NOAA Fisheries 2005
3 Level A Injury PTS
4 Level B Behavioral (Impulsive/Intermittent)
5 The threshold level is greater than the source level; therefore, distances are not generated.

Table 7-4 Fish Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P4 Location

			Location P4		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Fish: no swim bladder	$L_{E,24hr}$ [1,2]	219	93	47	36
	$L_{p,pk}$ [1,2]	213	79	39	29
Fish: swim bladder is not involved in hearing	$L_{E,24hr}$ [1,2]	210	214	110	89
	$L_{p,pk}$ [1,2]	207	117	79	44
Fish: swim bladder involved in hearing	$L_{E,24hr}$ [1,2]	207	342	144	104
	$L_{p,pk}$ [1,2]	207	117	79	44
Eggs and larvae	$L_{E,24hr}$ [1,2]	210	214	110	89
	$L_{p,pk}$ [1,2]	207	117	79	44
Small fish	$L_{E,24hr}$ [3,4]	183	3,968	2,062	1,333
	$L_{p,pk}$ [3,4]	206	131	84	46
	L_p [5]	150	7,919	4,566	3,208
Large fish	$L_{E,24hr}$ [3,4]	187	2,475	1,333	858
	$L_{p,pk}$ [3,4]	206	131	84	46
	L_p [5]	150	7,919	4,566	3,208

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 Stadler and Woodbury 2009
4 Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger.
5 GARFO 2016

Table 7-5 Fish Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P5 Location

			Location P5		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Fish: no swim bladder	$L_{E,24hr}$ [1,2]	219	99	69	38
	$L_{p,pk}$ [1,2]	213	79	39	29
Fish: swim bladder is not involved in hearing	$L_{E,24hr}$ [1,2]	210	251	122	93
	$L_{p,pk}$ [1,2]	207	116	79	44
Fish: swim bladder involved in hearing	$L_{E,24hr}$ [1,2]	207	362	177	111
	$L_{p,pk}$ [1,2]	207	116	79	44
Eggs and larvae	$L_{E,24hr}$ [1,2]	210	251	122	93
	$L_{p,pk}$ [1,2]	207	116	79	44
Small fish	$L_{E,24hr}$ [3,4]	183	4,647	2,275	1,479
	$L_{p,pk}$ [3,4]	206	130	84	46
	L_p [5]	150	7,888	4,654	3,037
Large fish	$L_{E,24hr}$ [3,4]	187	2,974	1,479	993
	$L_{p,pk}$ [3,4]	206	130	84	46
	L_p [5]	150	7,888	4,654	3,037

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 Stadler and Woodbury 2009
4 Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger.
5 GARFO 2016

Table 7-6 Fish Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P6 Location

			Location P6		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Fish: no swim bladder	$L_{E,24hr}$ [1,2]	219	92	46	35
	$L_{p,pk}$ [1,2]	213	79	39	29
Fish: swim bladder is not involved in hearing	$L_{E,24hr}$ [1,2]	210	225	111	88
	$L_{p,pk}$ [1,2]	207	146	79	44
Fish: swim bladder involved in hearing	$L_{E,24hr}$ [1,2]	207	350	164	103
	$L_{p,pk}$ [1,2]	207	146	79	44
Eggs and larvae	$L_{E,24hr}$ [1,2]	210	225	111	88
	$L_{p,pk}$ [1,2]	207	146	79	44
Small fish	$L_{E,24hr}$ [3,4]	183	3,920	2,033	1,291
	$L_{p,pk}$ [3,4]	206	158	85	46
	L_p [5]	150	8,284	4,490	3,141
Large fish	$L_{E,24hr}$ [3,4]	187	2,523	1,291	881
	$L_{p,pk}$ [3,4]	206	158	85	46
	L_p [5]	150	8,284	4,490	3,141

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 Stadler and Woodbury 2009
4 Small fish are fish less than 2 grams in weight. Large fish are 2 grams or larger
5 GARFO 2016

Table 7-7 Sea Turtle Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P4 Location

			Location P4		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Sea turtles	$L_{E,24hr}$ [1,2]	210	214	110	89
	$L_{p,pk}$ [1,2]	207	117	79	44
	$L_{E,24hr}$ [3,4]	204	375	190	120
	$L_{p,pk}$ [3,4]	232	6	-[8]	-[8]
	$L_{E,24hr}$ [3,5]	189	1,155	748	497
	$L_{p,pk}$ [3,5]	226	21	6	-[8]
	L_p [6,7]	175	590	356	205

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 NOAA Fisheries 2018
4 PTS Shift
5 TTS Shift
6 Behavioral (NOAA 2005)
7 Blackstock 2018
8 The threshold level is greater than the source level; therefore, distances are not generated.

Table 7-8 Sea Turtle Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P5 Location

			Location P5		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Sea turtles	$L_{E,24hr}$ [1,2]	210	251	122	93
	$L_{p,pk}$ [1,2]	207	116	79	44
	$L_{E,24hr}$ [3,4]	204	395	203	130
	$L_{p,pk}$ [3,4]	232	7	-[8]	-[8]
	$L_{E,24hr}$ [3,5]	189	1,332	804	586
	$L_{p,pk}$ [3,5]	226	22	7	-[8]
	L_p [6,7]	175	596	347	202

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 NOAA Fisheries 2018
4 PTS Shift
5 TTS Shift
6 Behavioral (NOAA 2005)
7 Blackstock 2018
8 The threshold level is greater than the source level; therefore, distances are not generated.

Table 7-9 Sea Turtle Injury and Behavioral Onset Criteria Threshold Distances (meters) for Pile-Driving at P6 Location

			Location P6		
			Hammer Energy - 1380 kJ		
			Pile Diameter - 2.743 meters		
			Attenuation (dB)		
Group	**Metric**	**Threshold (dB)**	**0**	**6**	**10**
Sea turtles	$L_{E,24hr}$ [1,2]	210	225	111	88
	$L_{p,pk}$ [1,2]	207	146	79	44
	$L_{E,24hr}$ [3,4]	204	389	188	117
	$L_{p,pk}$ [3,4]	232	6	-[8]	-[8]
	$L_{E,24hr}$ [3,5]	189	1,180	768	565
	$L_{p,pk}$ [3,5]	226	21	6	-[8]
	L_p [6,7]	175	647	376	213

1 Popper et al. 2014
2 Mortality and Potential Mortal Injury
3 NOAA Fisheries 2018
4 PTS Shift
5 TTS Shift
6 Behavioral (NOAA 2005)
7 Blackstock 2018
8 The threshold level is greater than the source level; therefore, distances are not generated.

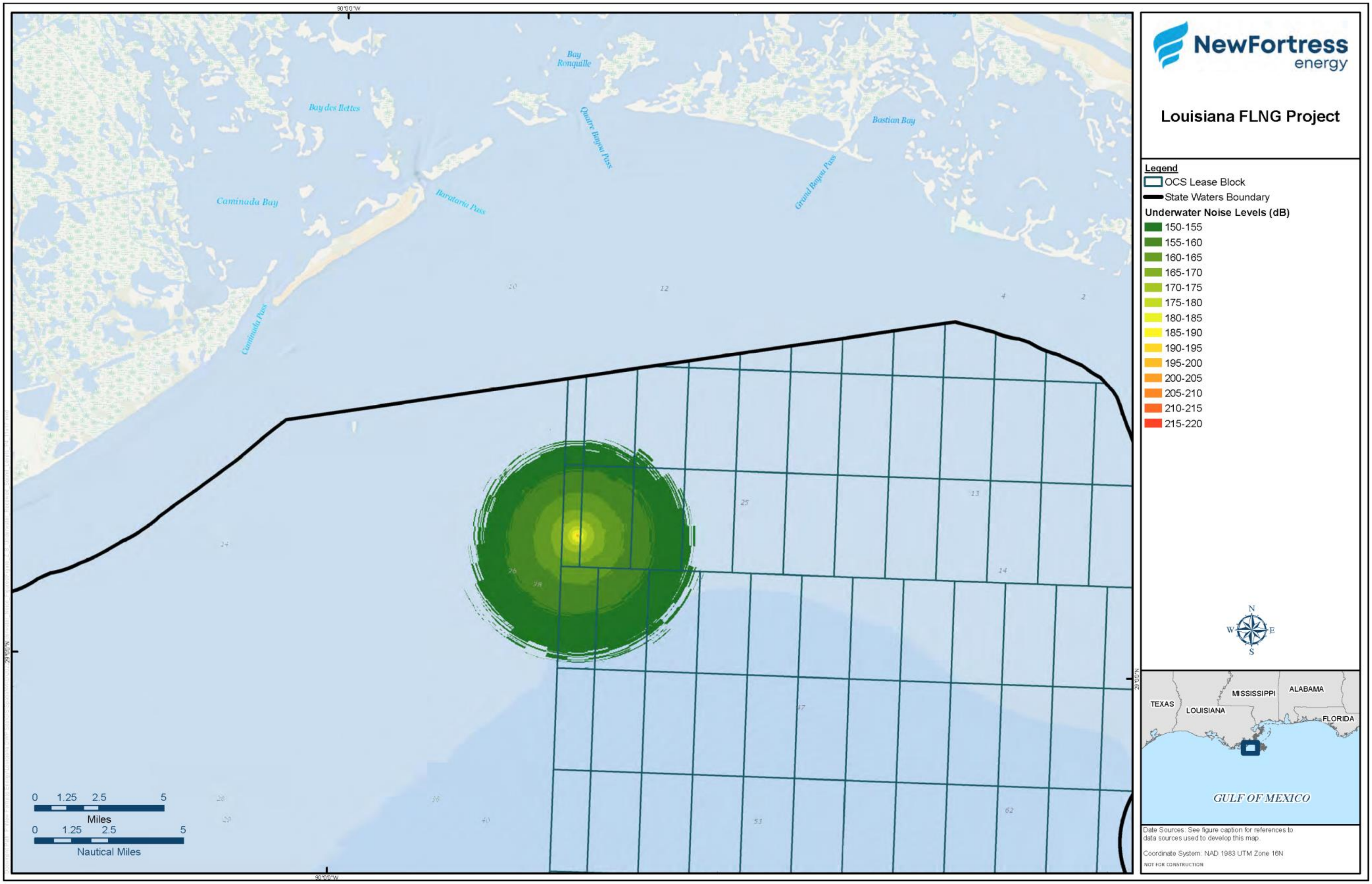

Figure 7-1 Underwater Received Sound Levels: P4 Impact Pile Driving, Unmitigated (SPL)

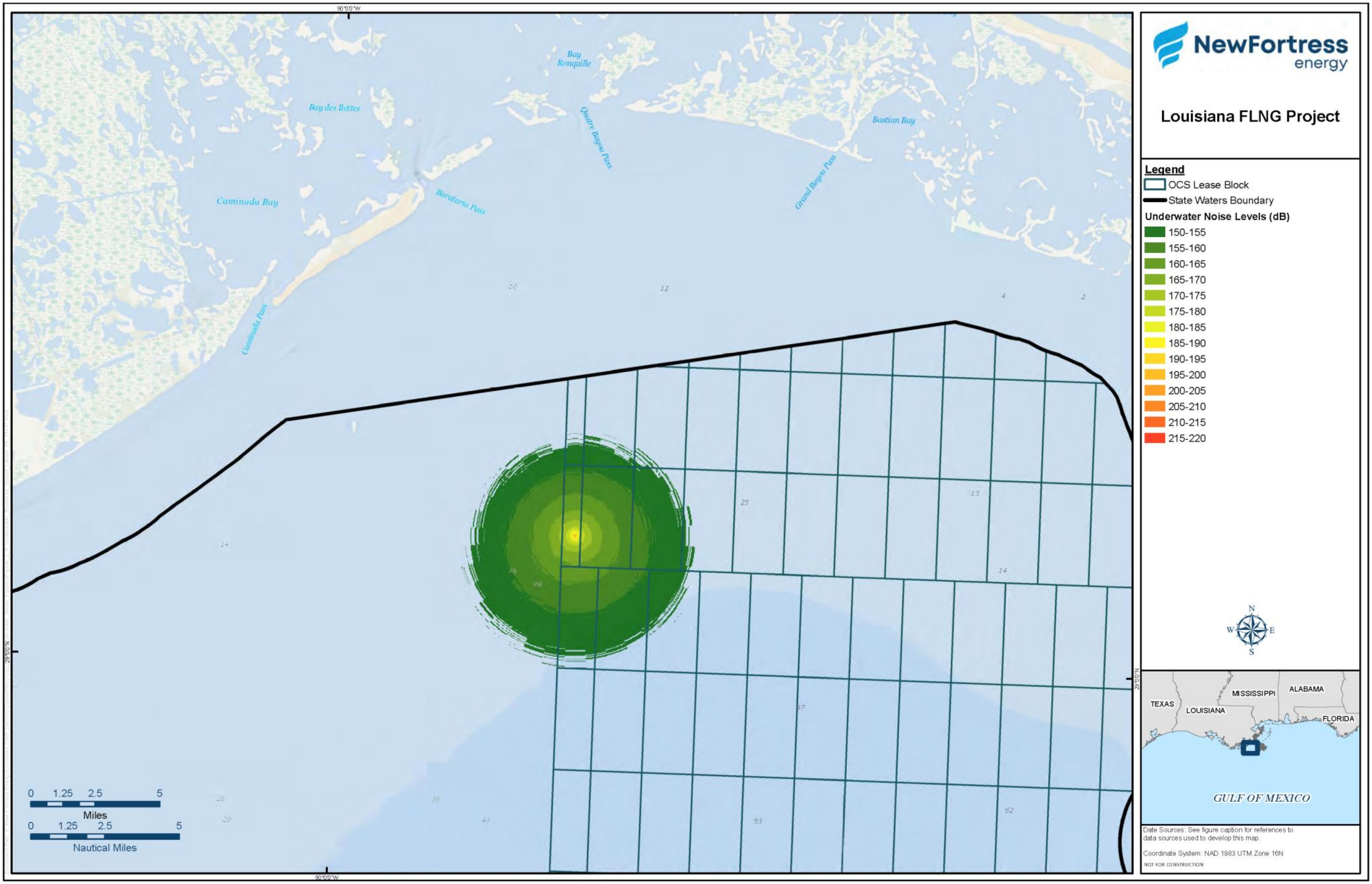

Figure 7-2 Underwater Received Sound Levels: P5 Impact Pile Driving, Unmitigated (SPL)

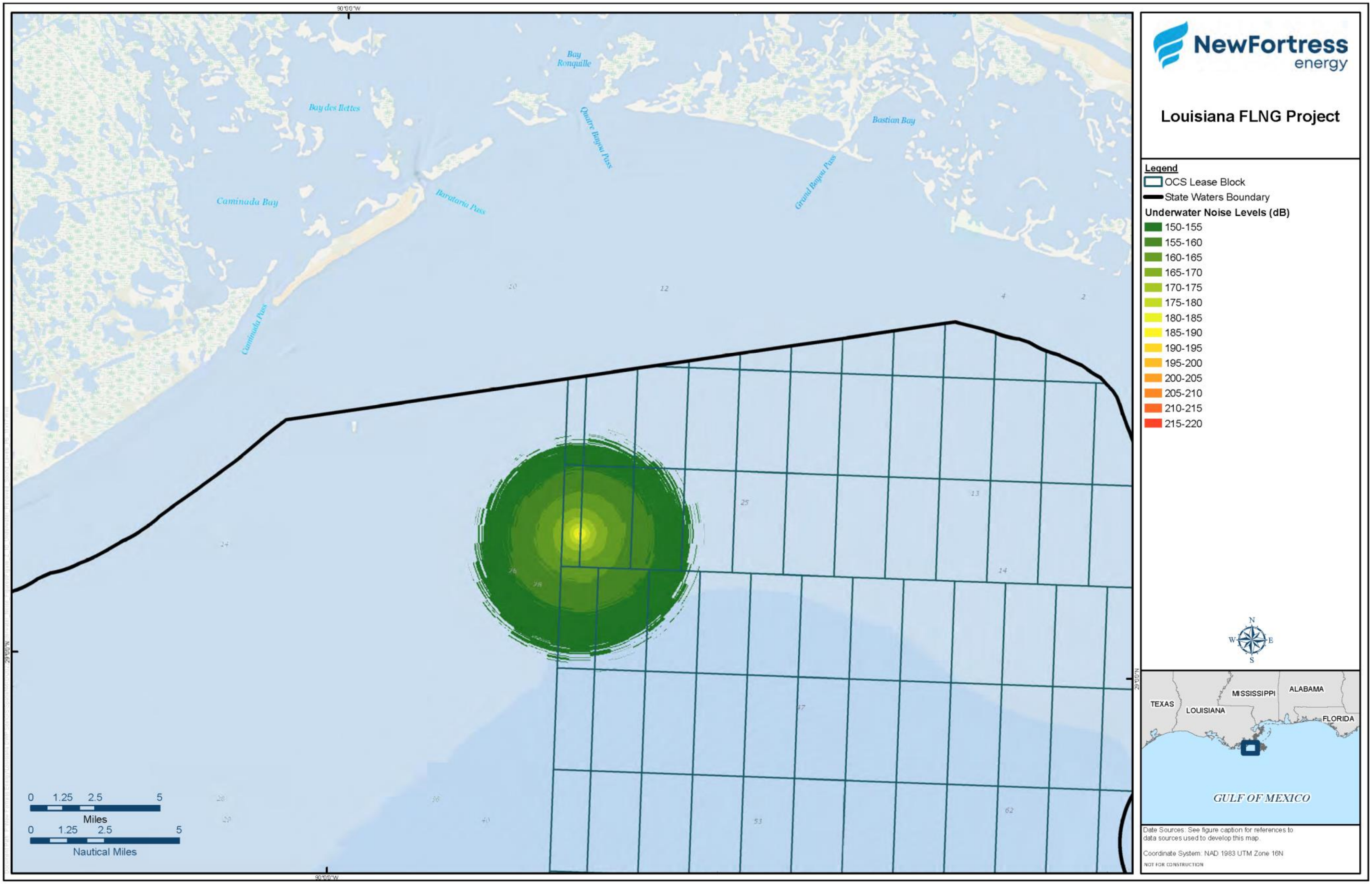

Figure 7-3 Underwater Received Sound Levels: P6 Impact Pile Driving, Unmitigated (SPL)

8.0 REFERENCES

Au, Whitlow. and M. Hastings. 2008. “Principles of Marine Bioacoustics”. *Springer Science & Business Media, New York, New York*. Available online at: https://link.springer.com/book/10.1007%2F978-0-387-78365-9. Accessed December 14, 2020.

Austin, M., S. Denes, J. MacDonnell, and G. Warner. 2016. *Hydroacoustic Monitoring Report: Anchorage Port Modernization Project Test Pile Program. Version 3.0*. Technical report by JASCO Applied Sciences for Kiewit Infrastructure West Co.

Bellman, M.A. 2014. Overview of existing Noise Mitigation Systems for Reducing Pile-Driving Noise. Inter-Noise 2014, Sydney, Australia.

Bellman, M.A., J. Schuckenbrock, S. Gündert, M. Müller, H. Holst, P. Remmers. 2017. “Is There a State-of-the-Art to Reduce Pile-Driving Noise?” *Wind Energy and Wildlife Interactions*. Available online at: https://link.springer.com/chapter/10.1007/978-3-319-51272-3_9. Accessed December 14, 2020.

Blackstock, S.A., J.O. Fayton, P.H. Hulton, T.E. Moll, K.K. Jenkins, E. Henderson, S. Rider, C. Martin, and V. Bowman. 2017. *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase III Training and Testing*. Naval Undersea Warfare Center Division, Newport United States.

Department of the Navy. 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). U.S. Navy SSC Pacific.

Fisher, F.H., and V.P. Simmons. 1977. Sound absorption in seawater. *Journal of the Acoustical Society of America* 62(3):558–564.

Francois, R.E., and G.R. Garrison. 1982a. Sound absorption based on ocean measurements. Part I: Pure water and magnesium sulphate contributions. *Journal of the Acoustical Society of America* 72(3): 896–907.

Francois, R.E., and G.R. Garrison. 1982b. Sound absorption based on ocean measurements. Part II: Boric acid contribution and equation for total absorption. *Journal of the Acoustical Society of America* 72: 1879–1890.

ISO (International Organization for Standardization). 2017. Underwater acoustics – Terminology. https://www.iso.org/obp/ui/#iso:std:iso:18405:ed-1:v1:en

Koschinski, S. and K. Lüdemann. 2013. Development of noise mitigation measures in offshore wind farm construction. *Federal Agency for Nature Conservation.* Available online at: https://www.bfn.de/fileadmin/BfN/meeresundkuestenschutz/Dokumente/Noise-mitigation-for-the-construction-of-increasingly-large-offshore-wind-turbines.pdf. Accessed December 14, 2020.

Koschinski, S. and K. Lüdemann. 2020. Noise mitigation for the construction of increasingly large offshore wind turbines. [German] *Federal Agency for Nature Conservation.*

NOAA Fisheries (National Oceanic and Atmospheric Administration’s National Marine Fisheries Service). 2005. *Endangered fish and wildlife: Notice of intent to prepare an environmental impact statement*. Federal Register 70(7):1871–1875. http://www.nmfs.noaa.gov/pr/pdfs/fr/fr70-1871.pdf.

NOAA Fisheries. 2012. Cetacean & Sound Mapping. Available online at: https://cetsound.noaa.gov/sound_data . Accessed December 2021.

NOAA Fisheries. 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

NOAA Fisheries. 2019. "GARFO Acoustics Tool: Analyzing the effects of pile driving on ESA-listed species in the Greater Atlantic Region". https://www.fisheries.noaa.gov/new-england-mid-atlantic/consultations/section-7-consultation-technical-guidance-greater-atlantic

NOAA Satellite and Information Service. 2020. *U.S. Coastal Relief Model. 1999 to* 2005. Available online at: https://www.ngdc.noaa.gov/mgg/coastal/crm.html. Accessed December 13, 2020.

Popper, A., A. Hawkins, R. Fay, D. Mann, and S. Bartol. 2014. Sound Exposure Guidelines. ASA S3/SC14 TR-2014 Sound Exposure Guidelines for Fish and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. p. 33-51.

Richardson, W.J., C.R. Greene Jr., C.I. Malme, and D.H. Thomson. 2013. *Marine Mammals and Noise.* Academic Press, New York.

Simmonds, M., S. Dolman, and L. Weilgart. 2004. *Oceans of Noise: A WDCS Science Report*. https://au.whales.org/wp-content/uploads/sites/3/2018/08/Oceans-of-Noise.pdf

Southall, B.L., J.J. Finneran, C. Reichmuth, P.E. Nachtigall, D.R. Ketten, A.E. Bowles, W.T. Ellison, D.P. Nowacek, and P.L. Tyack. 2019. “Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects.” *Aquatic Mammals* 45, 125-232.

Stadler, J.H., and D.P. Woodbury. 2009. Assessing the effects to fish from pile driving: Application of new hydroacoustic criteria.

Wahlberg, M. 2012. “Contribution of Biological Sound Sources to Underwater Ambient Noise Levels.” *Bioacoustics* 17: 30-32.

Wenz, G. 1962. Acoustic ambient noise in the ocean: Spectra and Sources. *Journal of the Acoustic Society of America* 34:1936.

Zhao, Z., , E.A. D’Asaro, & , J.A. Nystuen. 2014. The Sound of Tropical Cyclones. *Journal of Phys. Ocean.* 44(10):2763–2778. https://doi.org/10.1175/jpo-d-14-0040.1

APPENDIX A
ACOUSTIC DISTANCES FOR IMPACT PILE DRIVING

PEAK SOUND PRESSURE THRESHOLDS

Table A-1 Summary of $R_{95\%}$ ranges (in meters) to Lpk due to impact pile driving at P4 location

NFE Louisiana - P4- 108" Pile Impact - $L_{p,pk}$

Attenuation (dB)	232	230	226	220	219	218	213	210	207	206	202	200
0	6	11	21	36	39	41	79	95	117	131	235	332
6	0	0	6	21	23	26	39	46	79	84	106	131
10	0	0	0	11	13	16	29	36	44	46	84	95

Table A-2 Summary of $R_{95\%}$ ranges (in meters) to Lpk due to impact pile driving at P5 location

NFE Louisiana - P5 - 108" Pile Impact - $L_{p,pk}$

Attenuation (dB)	232	230	226	220	219	218	213	210	207	206	202	200
0	7	12	22	36	39	41	79	94	116	130	236	328
6	0	0	7	22	24	27	39	46	79	84	105	130
10	0	0	0	12	14	17	29	36	44	46	84	94

Table A-3 Summary of $R_{95\%}$ ranges (in meters) to Lpk due to impact pile driving at P6 location

NFE Louisiana - P6 - 108" Pile Impact - $L_{p,pk}$

Attenuation (dB)	232	230	226	220	219	218	213	210	207	206	202	200
0	6	11	21	36	39	41	79	96	146	158	241	335
6	0	0	6	21	24	26	39	46	79	85	107	158
10	0	0	0	11	13	16	29	36	44	46	85	96

SPL THRESHOLDS

Table A-4 Summary of $R_{95\%}$ ranges (in meters) to SPL due to impact pile driving at P4 location

NFE Louisiana - P4 - 108" Pile Impact - L_p

Attenuation (dB)	210	200	190	180	175	170	160	150	140
0	18	45	115	381	590	1,021	3,208	7,919	16,618
6	2	29	81	187	356	524	1,560	4,566	10,770
10	0	18	45	115	205	381	1,021	3,208	7,919

Table A-5 Summary of $R_{95\%}$ ranges (in meters) to SPL due to impact pile driving at P5 location

NFE Louisiana – P5 – 108” Pile Impact – L_p									
Attenuation (dB)	**210**	**200**	**190**	**180**	**175**	**170**	**160**	**150**	**140**
0	18	45	114	370	596	1,045	3,037	7,888	17,267
6	2	29	80	184	347	526	1,582	4,654	10,770
10	0	18	45	114	202	370	1,045	3,037	7,888

Table A-6 Summary of $R_{95\%}$ ranges (in meters) to SPL due to impact pile driving at P6 location

NFE LA - P6 - 108" Pile Impact – SPL									
Attenuation (dB)	**210**	**200**	**190**	**180**	**175**	**170**	**160**	**150**	**140**
0	18	45	142	397	647	1,064	3,141	8,284	17,226
6	2	29	81	188	376	591	1,603	4,490	10,930
10	0	18	45	142	213	397	1,064	3,141	8,283

SEL THRESHOLDS (UNWEIGHTED)

Table A-7 Summary of $R_{95\%}$ ranges (in meters) to unweighted Cumulative SEL due to impact pile driving at P4 location

NFE LA - P4 - 108" Pile Impact - $L_{E,24hr}$								
Attenuation (dB)	**220**	**219**	**210**	**207**	**200**	**187**	**183**	**180**
0	89	93	214	342	632	2,475	3,968	5,269
6	44	47	110	144	369	1,333	2,062	2,970
10	33	36	89	104	214	858	1,333	1,893

Table A-8 Summary of $R_{95\%}$ ranges (in meters) to unweighted Cumulative SEL due to impact pile driving at P5 location

NFE LA - P5 - 108" Pile Impact - $L_{E,24hr}$								
Attenuation (dB)	**220**	**219**	**210**	**207**	**200**	**187**	**183**	**180**
0	93	99	251	362	706	2,974	4,647	6,003
6	46	69	122	177	392	1,479	2,275	3,310
10	36	38	93	111	251	993	1,479	2,098

Table A-9 Summary of $R_{95\%}$ ranges (in meters) to unweighted Cumulative SEL due to impact pile driving at P6 location

NFE LA - P6 - 108" Pile Impact - $L_{E,24hr}$								
Attenuation (dB)	220	219	210	207	200	187	183	180
0	88	92	225	350	676	2,523	3,920	5,310
6	44	46	111	164	384	1,291	2,033	2,908
10	33	35	88	103	225	881	1,291	1,828

SEL THRESHOLDS (WEIGHTED)

Table A-10 Summary of $R_{95\%}$ ranges (in meters) to Cumulative SEL for marine mammal functional hearing groups due to impact pile driving at P4 location.

NFE LA – P4 – 108” Pile Impact – $L_{E,24hr}$ Weighted						
Attenuation (dB)	LF 183	MF 185	HF 155	PP 185	TU 204	TU 189
0	3,929	116	3,133	1,448	375	1,155
6	2,010	46	1,692	524	190	748
10	1,238	34	993	311	120	497

Table A-11 Summary of $R_{95\%}$ ranges (in meters) to Cumulative SEL for marine mammal functional hearing groups due to impact pile driving at P5 location.

NFE LA - P5 - 108" Pile Impact - $L_{E,24hr}$ Weighted						
Attenuation (dB)	LF 183	MF 185	HF 155	PP 185	TU 204	TU 189
0	4,558	132	3,739	1,774	395	1,332
6	2,249	70	1,951	660	203	804
10	1,353	37	1,165	367	130	586

Table A-12 Summary of $R_{95\%}$ ranges (in meters) to Cumulative SEL for marine mammal functional hearing groups due to impact pile driving at P6 location.

NFE LA - P6 - 108" Pile Impact - $L_{E,24hr}$ Weighted						
Reduction (dB)	LF 183	MF 185	HF 155	PP 185	TU 204	TU 189
0	3,908	111	3,149	1,389	389	1,180
6	1,887	45	1,664	508	188	768
10	1,176	33	1,008	315	117	565

APPENDIX B
UNDERWATER SOUND PROPAGATION MODELING

UNDERWATER SOUND PROPAGATION MODELING METHODOLOGY

Tetra Tech has developed a reliable and effective approach to evaluating underwater acoustic impacts from pile driving as well as other in-water activities. The underwater noise modeling methodology used to evaluate the Project pile driving activities is described below.

Underwater Sound Propagation Modeling

Tetra Tech uses dBSea for underwater sound propagation modeling. dBSea is a software program developed by Marshall Day Acoustics for the prediction of underwater noise. The three-dimensional 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. Noise mitigation methods may also be included. The user has control over the seabed and water properties including sound speed profile ("SSP"), temperature, salinity, and current.

Noise levels are calculated throughout the entire Offshore Project Area and displayed in three dimensions. Levels are calculated in third octave bands. For the Project, two different solvers are used for the low- and high-frequency ranges:

- dBSeaPE (Parabolic Equation Method): The dBSeaPE solver makes use of the range-dependent acoustic model ("RAM") 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.

Calculation Grid and Source Solution Setup

The calculation grid and source solution setup are based on the resolution and extents of the bathymetry data. The calculations within dBSea are made along each radial for each range point and depth point. Radials are generated from the source location out to the extent of the bathymetry area. The range points are generated along each radial and are evenly spaced out (range step). However, this spacing does not change if the source is moved. The number of "Radial slices" and "Range points" are entered, which represents the number of radial solution slices for each source and the evaluation range points along those slices (Figure B-1). The range points are determined based on the width and length of the modeled area as well as the required range step resolution (Equation 1).

$$Range\ Points = \frac{\sqrt{Width^2 + length^2}}{\text{Range Step}} \tag{6}$$

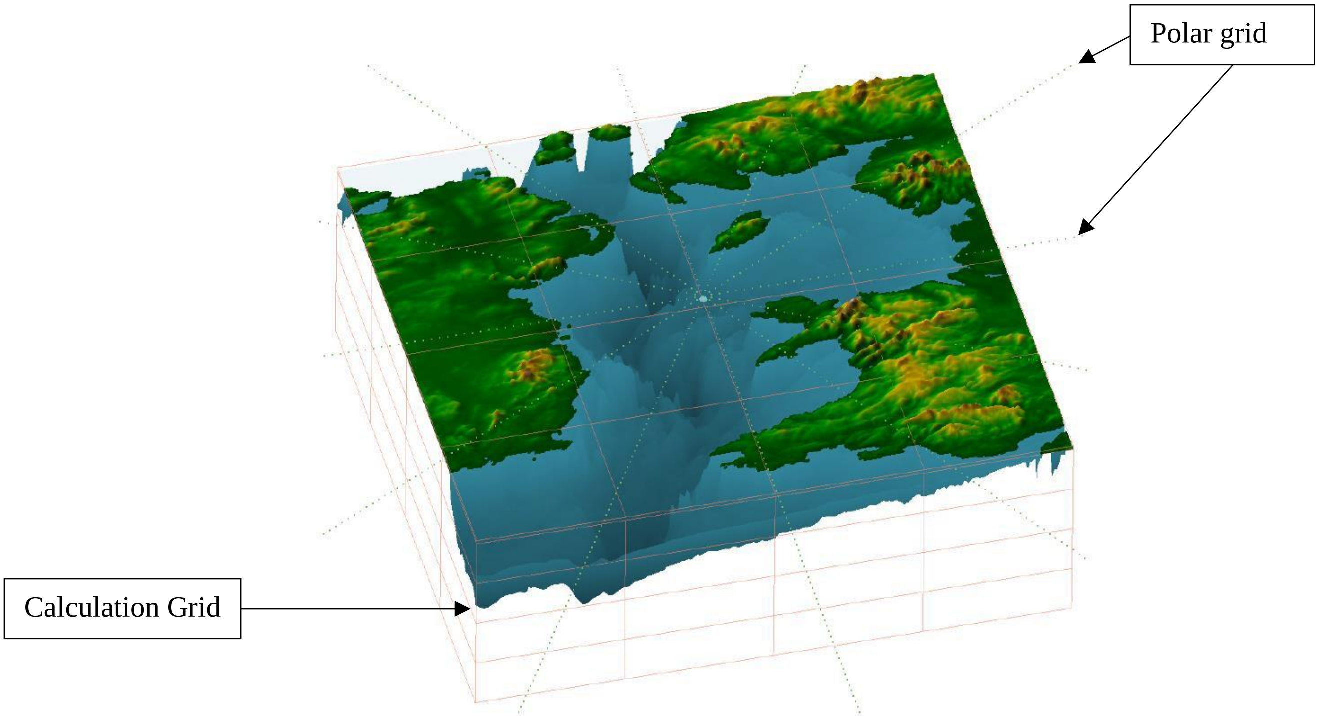

Figure B-1 Example Radial Solution Points

dBSea source solution calculations are completed along the radials (polar grid) based on the defined range and depth points. The calculation grid (cartesian) is filled from the polar grid using the nearest neighbor sampling, i.e., a point in the calculation results grid takes the value of the closest point in the polar grid. The calculation steps in dBSea are summarized below:

- Calculations are done in the polar grid (radials) at multiple depths, which are the same depths as the (cartesian) calculation grid.
- The calculation of the polar grid is smoothed with a triangular kernel, the width of which is selected by the user.
- The results of the cartesian grid is filled by the nearest neighbor sampling from the calculated polar grid using an inverse distance.

The more radials and range points used, the less interpolation needed for the cartesian grid. Because the calculation happens in the polar grid, while the results grid is cartesian, every point in the cartesian grid is “filled” depending on what point of the polar grid it is closest to (Figure B-2).

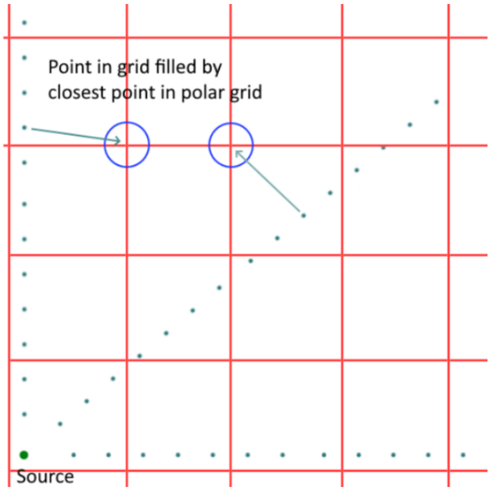

Figure B-2 Example Cartesian Grid Calculation

The underwater acoustic modeling analysis for the Project used a split solver, with dBSeaPE evaluating the 12.5 Hz to 800 Hz range and dBSeaRay addressing the 1 kHz to 20 kHz range. The radial resolution was 10-degree intervals to the extent of the bathymetry. The specific parameters used in the modeling analysis are described below.

Bathymetry

Bathymetry data were obtained from the National Geophysical Data Center and a U.S. Coastal Relief Model (NOAA Satellite and Information Service 2020), and the horizontal resolution of this dataset is 3 arc seconds (90 meters). The bathymetry data covered 58 kilometers (“km”) by 53 km total area with a maximum depth of 67 meters. The sound sources were placed near the middle of the bathymetry area and had a maximum depth of 28 meters at the source location.

Sediment Characteristics

Seafloor properties were obtained through core samples collected in the Project Study Area as documented in Topic Report 3 of the Deepwater Port Application. This data was used to develop a sediment profile for the overall modeled area. The sediment profile is presented in Table B-1. The geoacoustic properties given in Table B-1 were directly input into dBSea for each defined sediment layer. Each sediment layer is entered directly into dBSea. The parameters entered for each sediment layer is bulleted below:

- Sediment layer depth (provided by the client)
- Material name (provide by the client)
- Speed of sound (meters/second)
- Density (kilograms per cubic meter)
- Attenuation (dB/wavelength)

The acoustic parameters (speed of sound, density, and attenuation) are typically taken from Jensen et al. (2011), Hamilton (1976, 1982), and Hamilton and Bachman (1982).

Table B-1 Geoacoustic Properties of Sub-bottom Sediments as a Function of Depth

Depth	Speed of Sound	Geoacoustic Properties
0 to 19	Clay	Cp = 1470 m/s αs (dB/λ) = 0.1 dB/ λ ρ = 1200 kg/m3
19 to 54	Clay-Silt	Cp = 1515 m/s αs (dB/λ) = 0.2 dB/ λ ρ = 1500 kg/m3
54	Sand	Cp = 1680 m/s αs (dB/λ) = 1.0 dB/ λ ρ= 1900 kg/m3

Speed of Sound Profile

Sound speed profile information for the year was obtained per month, and a sensitivity analysis was conducted to determine the sound speed profile that would yield the most conservative sound modeling results. The speed of sound profile was obtained using the NOAA Sound Speed Manager software incorporating the World Ocean Atlas 2009 extension algorithms. Pile-driving will take place from November to May, and only taking place in the daytime. For the construction modeling scenarios, after completing a sensitivity analysis, the December sound speed profile was selected as it exhibited maximum case characteristics for long-range noise propagation effects. The December sound speed profile was directly inputted into the dBSea model, and the input is shown in Figure B-3.

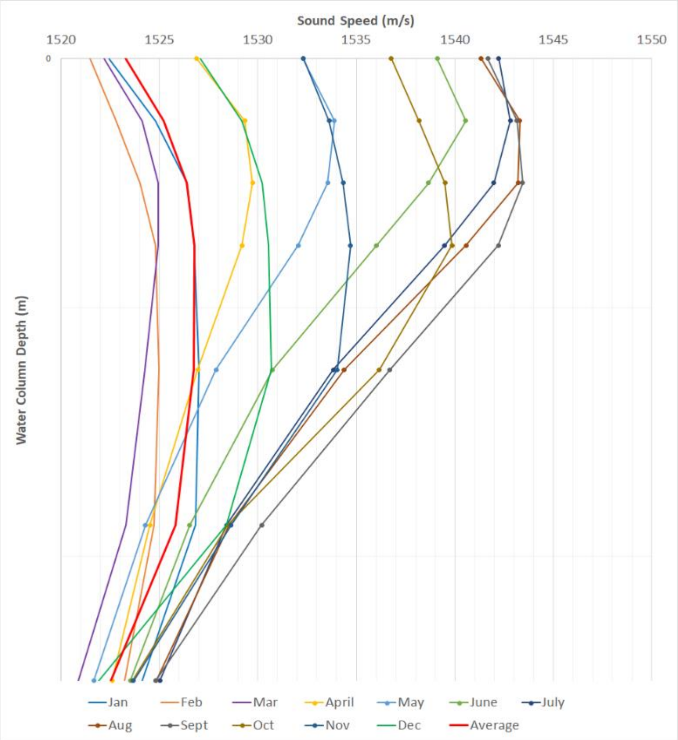

Figure B-3 Average Sound Speed Profile

Pile-driving Sound Source Characterization

The pile-driving sound source level was represented using three different metrics: peak sound level (“Lpk”), sound exposure level (“SEL”), and sound pressure level (“SPL”). The sound source spectrum is entered for each one-third octave band from 12.5 Hz to 20kHz based on Tetra Tech’s empirical model.

For the Lpk underwater acoustic modeling scenario, the pile-driving sound source was represented as a point source at mid-water depth. The Lpk scenario evaluates a single pile-driving strike.

For the SEL underwater acoustic modeling scenario, the pile-driving sound source was represented by a moving source, which accounts for the speed of sound of steel for the pile itself. The pile-driving scenarios were modeled using a vertical array of point sources spaced at 1-meter intervals. Using the SEL level calculated by the empirical model, the SEL sound source is calculated using the following equation to distribute the sound emissions across the vertical array:

$$L_{E,N} = L_{E,\,1\,strike} + 10Log(N) \tag{7}$$

Where: N is the number strikes

$L_{E,\,1\,strike}$ is obtained from the Tetra Tech, Inc. empirical model

The SPL underwater acoustic modeling scenario is set up identical to the SEL underwater acoustic modeling scenario. The difference regarding the SPL underwater acoustic modeling scenario is that the total number of anticipated pile-driving blows in the 24-hour assessment period is not incorporated into the calculation. For the SPL underwater acoustic modeling scenario, only a single pile-driving strike is evaluated.

Time Domain Considerations

Tetra Tech also recognizes the effect time has on pile-driving sound. As Bellman et al. (2020) reports, the noise of a single strike is thus temporally stretched with increasing distance. Additionally, the amplitude decreases steadily with the distance to the source, so that the signal-to-noise-ratio continuously decreases. Figure B-4 from Bellman et al. (2020) illustrates the change in signal over time.

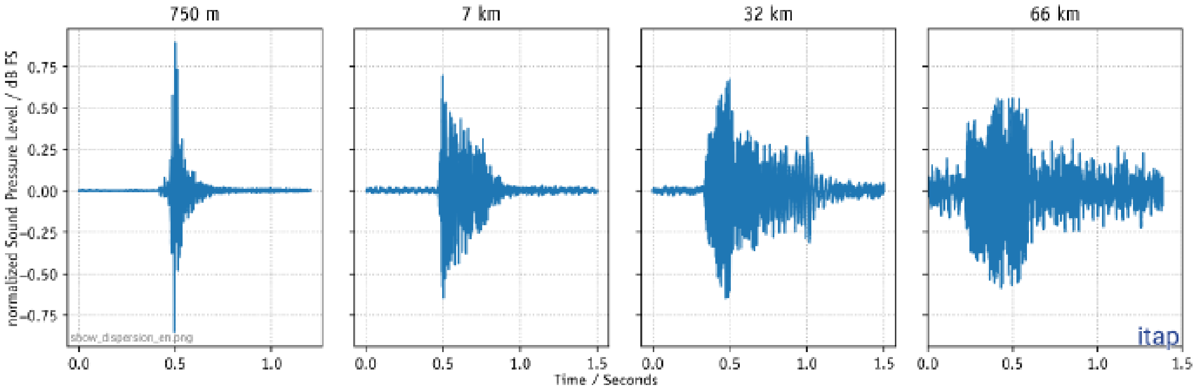

Figure B-4 Time Signal of a Single Strike, Measured in Different Distances to the Pile-driving Activity (Bellman et al. 2020)

The L_{PK} levels tend to decrease faster than the SEL sound levels as the propagation occurs. There are mixed views on whether the impulsivity of signals decrease over time, suggesting that non-impulsive limits should be applied to assess underwater acoustic impacts. While impulsivity may decrease, it is still observed that the rise times associated with impulsive signals are maintained (Martin et al. 2020). This is especially true when considering the narrow temporal windows (high temporal resolution) of many cetaceans and after application of weightings, excluding lower frequencies.

dBSea can account for the effects of the time domain using two different mechanisms. If time series information is available for use in the modelling analysis, it can be directly loaded into dBSea and used as sound source. The gaussian beam raytracer (dBSeaRay) will calculate the paths and arrival times from the source to all receiver points in the scenario for all the rays emitted from the source. At every receiver point, the transmission loss, phase inversion from the surface, loss to the sediment, and time of arrival is stored. This information is used to convolve all ray-arrivals into a single signal at that point. This means that each receptor point will receive a signal from many perceived origins and at various arrival times (depending on the length of the path travelled). This tends to "smooth" out and stretch the received signal at greater ranges or with more reflections.

Alternatively, if time series data are not known or available, dBSea can include a crest factor, which is a way to incorporate impulsiveness information into the source. The crest factor indicates the dB level above the rms level of the highest peak in the signal. It is applied when assessing peak levels and is applied to all frequency bands. Application of the crest factor is generally expected to yield more conservative results relative to using a time series for characterizing pile-driving sound source levels. Since time series data for the Project's pile-driving activities were not available at the time of the modelling analysis, Tetra Tech used the conservative crest application methodology.

References

Bellman, M.A., A. May,, T. Wendt, S. Gerlach, P. Remmers, and J. Brinkmann. 2020. Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values. ERa Report.

Hamilton, E.L. 1976. Geoacoustic modeling of the sea floor. *Journal of the Acoustical Society of America*, 68, 1313-1340.

Hamilton, E.L. 1982. Compressional Waves in marine sediments. *Geophysics*, 37 620-646.

Hamilton, E.L. and Bachman, R.T. 1982. Sound velocity and related properties of marine sediments. Journal of the Acoustical Society of America, 72, 1891-1904.

Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. 2011. Computational Ocean Acoustics, 2nd edition, Springer.

Martin, B., K. Lucke, and D. Barclay. 2020. Techniques for distinguishing between impulsive and non-impulsive sound in context of regulating sound exposure for marine mammals. *The Journal of the Acoustical Society of America* 147, 2159.

NOAA Satellite and Information Service. 2020. U.S. Coastal Relief Model. 1999 to 2005. Available online at: https://www.ngdc.noaa.gov/mgg/coastal/crm.html. Accessed December 13, 2020.

World Ocean Atlas. 2009. NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C. *Available online at:* https://www.ngdc.noaa.gov/mgg/coastal/crm.html.

APPENDIX C
PILE DRIVING SOUND SOURCE DEVELOPMENT

Impact Pile-Driving Sound Source Development

Tetra Tech, Inc. (“Tetra Tech”) has developed a reliable and effective approach for evaluating underwater acoustic impacts due to offshore liquefied natural gas (“LNG”) facility construction as well as other in-water activities. For offshore LNG facility construction, pile driving is typically the loudest activity, and therefore, analysis of pile driving impacts is critical during the permitting process. This technical memo describes how we derive pile-driving sound source levels.

Pile Driving Broadband Sound Source Development (L_{PK} and SEL)

Impact pile driving during construction of offshore energy facilities involve piles of larger diameters and use of greater hammer forces where previously collected comparable measurement data are not widely available. For that reason, Tetra Tech has developed an empirical modeling approach where source levels are derived based on a literature review of pile driving measurement reports, theoretical modeling reports, and peer-reviewed research papers (see the References section below). The data points from the cited references were obtained from piles of varying diameter, driven with hammers operated at various energies, and collected or analyzed at various ranges from the pile, as shown in Figures C-1 and C-2. To determine the source level for impact pile driving, Tetra Tech uses the following steps:

1. The first step involves normalizing the received sound pressure levels in the empirical model database assuming transmission loss associated with 15 times the common logarithm (logarithm base 10) of the distance between the source and receiver to obtain source levels associated with the scenario:

$$TL = 15*\log_{10}(D/D_{ref}) \qquad (8)$$

   Where: *TL = Transmission loss (dB)*

   D = Distance (m)

   D_{ref} *= Reference distance (m)*

2. The second step involves normalizing the source level assuming a relationship between hammer energy and radiated sound as 10 times the common logarithm of the hammer energy:

$$SL_{(D)} = SL_{ref} + 10\log_{10}(E/E_{ref}) \qquad (9)$$

   Where: $SL_{(D)}$ *= Sound source level for a given pile diameter (dB)*

   SL_{ref} *= Sound source level at reference distance (dB)*

   E = Hammer energy (kJ)

   E_{ref} *= Reference hammer energy (kJ)*

3. The third step consists of calculating a regression of the normalized source level (normalized for range and hammer energy given as SL(D)) to the logarithm of the diameters of the piles to predict the broadband SEL and peak sound levels:

$$SL = \text{Intercept} + N*\log_{10}(D) \qquad (10)$$

   Where: *SL = Sound source level for the Project (dB)*

   Intercept = Factor determined from regression analyses

   N = Factor determined from regression analyses

   D = Pile diameter (m)

Figures C-1 and C-2 below illustrate the L_{PK} and SEL values documented from a number of reference sources incorporating both measurement and theoretical modeling (y-axis) plotted versus pile diameter (x-axis). These plots also illustrate the normalized values for both range and energy.

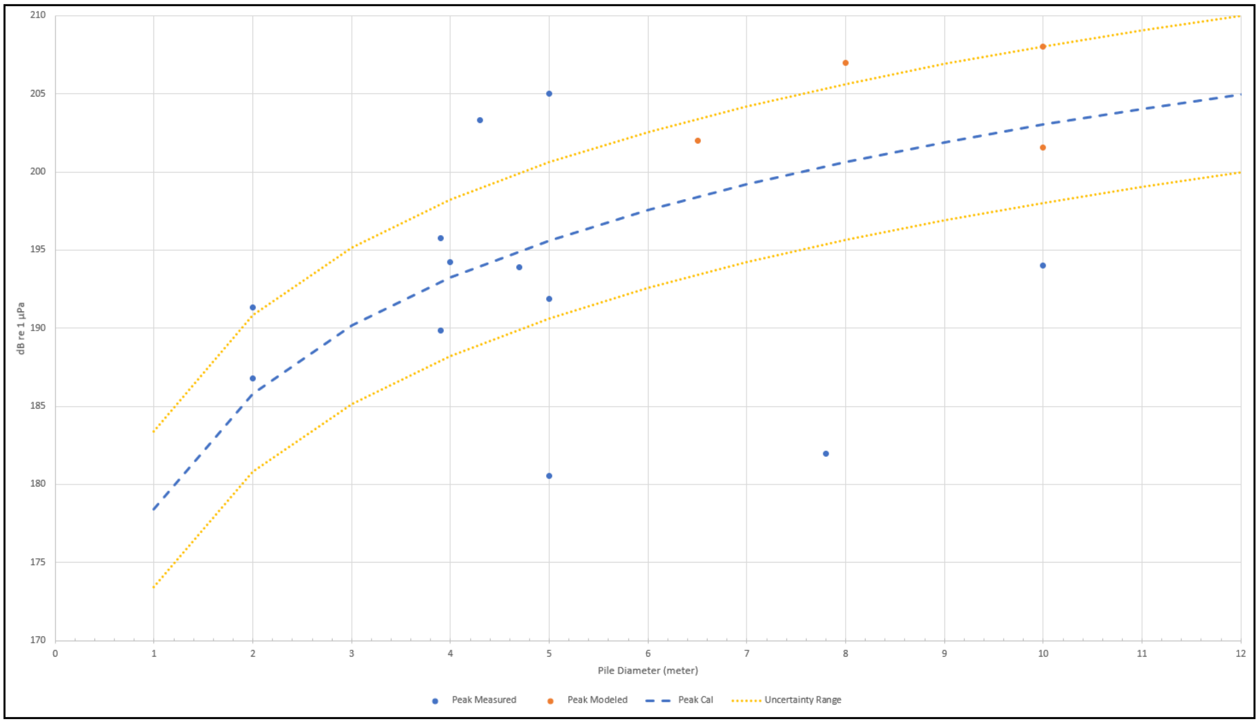

Figure C-1 Measured and Modeled Peak Levels Versus Pile Diameter at 750 meters

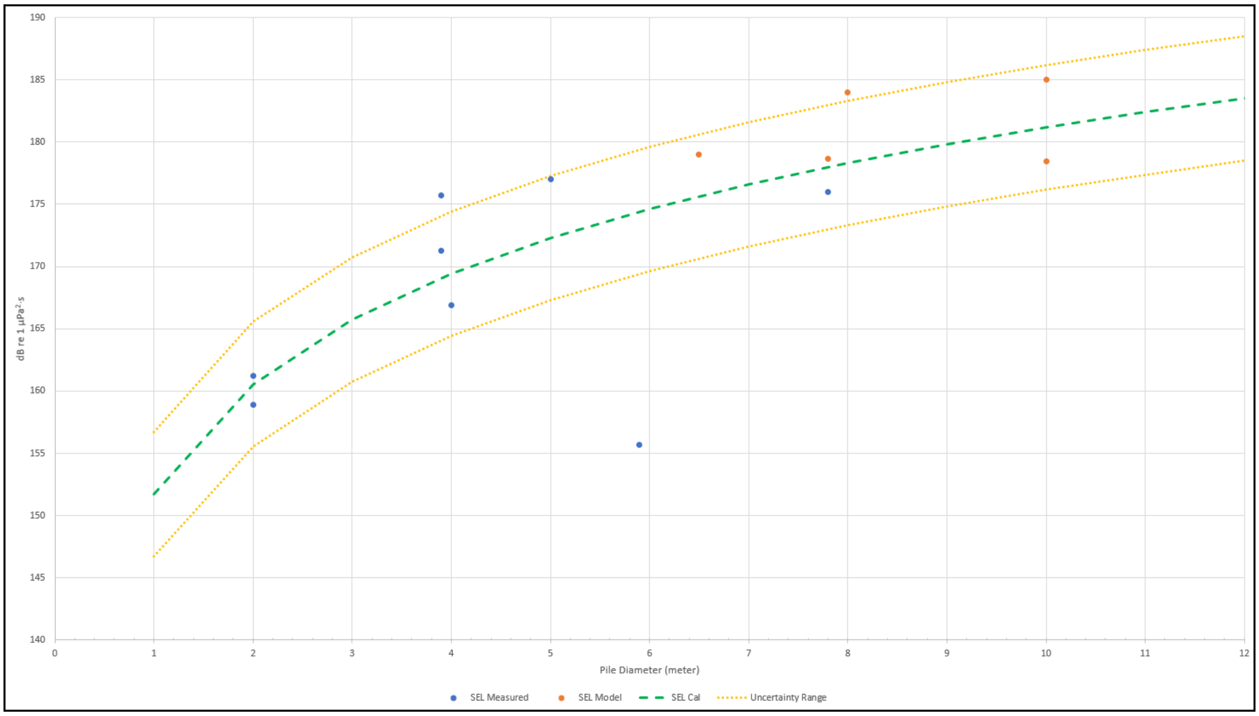

Figure C-2 Measured and Modeled SEL_{SS} Levels Versus Pile Diameter at 750 meters

The development of the empirical model assumes that the applied hammer energy takes into account the appropriate force needed to accommodate for site-specific soil properties and penetration rate. It is Tetra Tech's understanding that the dominant factor affecting pile-driving noise and potential underwater acoustic impacts is hammer energy. Bellman et al. (2020) state that "apart from the correlation between applied blow energy and measured noise level values, however, no significant correlation between acoustic measurement data and different soil layers, nor between acoustic measurement data and soil resistances could be identified."

Pile-driving Broadband SPL Sound Source Development

Based on the research completed for the empirical model, there were only three data points to calculate the regression curve for the sound pressure level (SPL) metric where the SEL and Lpk levels contained 13 to 16 data points. Because of the lack of data points for the SPL metric, the SPL was derived assuming a relationship between the SEL and SPL as 10 times the common logarithm of the pulse duration (see equation 4). A pulse duration of 0.09 second was used for the Project based on the average pulse duration of the source level reference studies.

$$L_p\ (\mathrm{dB}) = L_{Ess}+10\log(nT_0/T) \qquad (11)$$

Where: n = *number of sound events*

T_0 = *1 second*

T = *duration of the events*

This equation shows that the single event SPL is approximately 10 dB greater than the SEL value (Bellman et al. 2020).

Applied Safety Factor

The uncertainty range for this developed empirical model is +/- 5 dB. This uncertainty range is based on the scatter of the referenced data (Figures C-1 and C-2) as well as comparison to data collected by Tetra Tech for impact pile-driving activities. Therefore, 5 dB is added to the source level when entered into dBSea.

Deriving Impact Pile-driving Sound Spectrum Data

The spectrum data for the pile modeling scenarios are also derived using the empirical model, which includes published data from recent project applications that incorporated similar pile diameters. The spectrum for the pile driving activities is based on pile diameters between 94.5 to 157.5 inches (2.4 to 4 meters).

Using a process that is consistent with how the broadband levels were reviewed, the spectrum information collected for the empirical model was first normalized. The third octave band levels of the spectrum were normalized to both range and energy level. To ensure that the effect of the source data with the most acoustic energy (spectra for the largest pile driven at the highest hammer rating) does not contribute disproportionately to the spectral shape, the maximum value of each reference spectrum is subtracted from that spectrum so that maximum value is zero. The calculated broadband level is then added so that the peaks of all spectrums are the same. The mean of these normalized spectrums is then calculated to estimate the spectral shape. The reference spectrums for the impact pile are presented in Figure C-3 in terms of dB/third octave band.

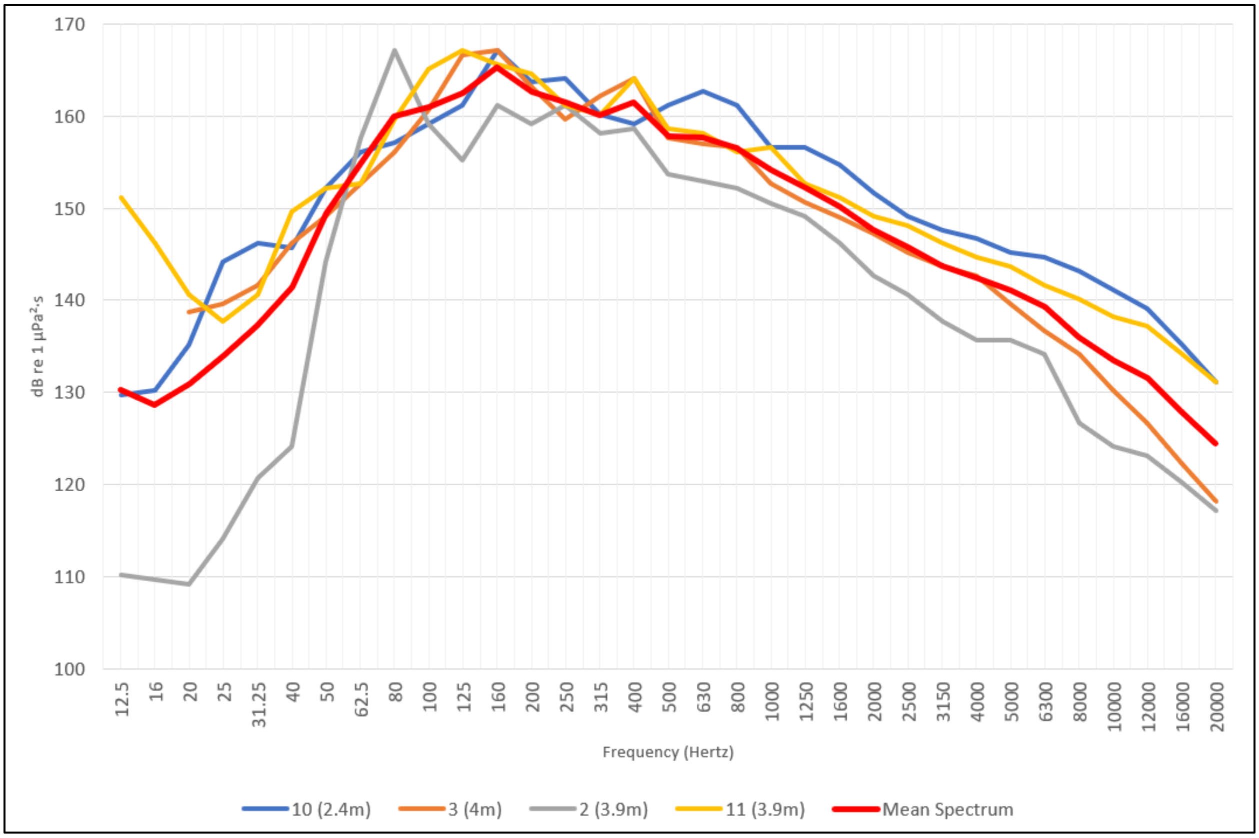

Figure C-3 Model Pile Spectrum

Please refer to the references section for the supporting documentation that has been used to support the development of the pile-driving sound source empirical model. References are numbered in the references section and in Figure C-3 so that data can be more easily correlated to its source.

References

1. Bellman, M.A., A. May, T. Wendt, S. Gerlach, P. Remmers, and J. Brinkmann. 2020. Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values. ERa Report.

2. Brandt, M.J., A. Diederichs, K. Betke, and G. Nehls. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series* 421:205–216.

3. De Jong, C.A.F., and M.A. Ainslie. 2008. Underwater radiated noise due to the piling for the Q7 Offshore Wind Park. *Journal of the Acoustical Society of America* 123:2987.

4. itap Gmbh. 2019. Offshore Wind Farm "Baltic Eagle" Prognosis of the expected underwater sound emissions during pile-driving work. January 2019.

5. JASCO Applied Sciences Inc. 2021. Turbine Foundation and Cable Installation at South Fork Wind Farm Acoustic Modeling of Construction.

6. Kuhler, R.M. and M.A. Bellmann. 2019. Offshore Wind Farm "Kaskasi II" Forecast of expected underwater noise emissions during possible pile driving in Offshore Wind Farm Kaskasi II (fall-back scenario).

7. Marine Acoustics Inc. 2020. Underwater Acoustic Assessment of Construction and Operation Activities at the Bay State Wind Offshore Wind Farm.

8. Mikaelsen, M.A. 2015. Kriegers Flak Offshore Wind Farm - Underwater noise modelling EIA - Technical Report. Aarhus, January 2015: Energinet.dk.

9. Nedwell, J.R., S.J. Parvin, B. Edwards, R. Workman, A.G. Brooker, and J.E. Kynoch. 2007. Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. Report for COWRIE, Newbury, UK.

10. Nehls, G. and M. Bellmann. 2016. Weiterentwicklung und Erprobung des „Großen Blasenschleiers“zur Minderung der Hydroschallemissionen bei Offshore-Rammarbeiten. Husum: ITAP.

11. Norro, A., J. Haelters, B. Rumes, and S. Degraer. 2010. Underwater noise produced by the piling activities during the construction of the Belwin offshore wind farm.

12. Robinson, S.P., P. Lepper, and J. Ablitt. 2007. “The measurement of the underwater radiated noise from marine piling including characterisation of a" soft start" period.” In Oceans 2007-Europe (pp. 1-6). IEEE.

13. Robinson, S.P., P.D. Theobald, and P.A. Lepper. 2012. Underwater sound from marine pile driving. *Proceedings of Meetings on Acoustics Acoustical Society of America* 17(1).

14. Tougaard, J., J. Carstensen, J. Teilmann, H. Skov, and P. Rasmussen. 2009. Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (Phocoena (L.)). *The Journal of the Acoustical Society of America* 126:11–14.

15. Von Pein, J., S. Lippert, and O. von Estorff. 2021. Validation of a finite element modelling approach for mitigated and unmitigated pile driving noise prognosis. *Journal of the Acoustical Society of America* 149:1737.

16. Yang, L., X. Xu, Z. Huang, and X. Tu. 2015. Recording and Analyzing Underwater Noise During Pile Driving for Bridge Construction. *Acoustics Australia* 43:159–167.

Appendix B
PSO Standardized Data Entry

Monitoring Effort Information:

Data Needed	Details
Date (YYYY-MM-DD)	
Source status at time of observation (on/off)	
Number of PSOs on duty	
Start time of observations for each shift in Universal Coordinated Time (“UTC”) (HH:MM)	
End time of observations for each shift in UTC(HH:MM)	
Duration of visual observations of protected species	
Wind speed (knots), from direction	
Swell (meters)	
Water depth (meters)	
Visibility (km)	
Glare severity	
Block name and number	
Location: Latitude and Longitude	
Time pre-clearance visual monitoring began in UTC (HH:MM)	
Time pre-clearance monitoring ended in UTC (HH:MM)	
Duration of pre-clearance visual monitoring	
Time of day of pre-clearance (day/night)	
Time power-up/ramp-up began (if applicable)	
Time equipment full power was reached (if applicable)	
Duration of power-up/soft-start (if conducted)	
Time activity began	
Time activity ended	
Activity duration	
Did a shutdown/power-down occur?	
Time shutdown was called for (UTC)	
Time equipment was shut down (UTC)	
Vessel location (latitude/longitude, decimal degrees)	
Habitat or prey observations	

Detection Information:

Data Needed	Details
Date (YYYY-MM-DD)	
Sighting ID (multiple sightings of the same animal or group should use the same ID)	
Time at first detection in UTC (YY-MMDDT HH:MM)	
Time at last detection in UTC (YY-MM-DDT HH:MM)	
PSO location	
Activity at time of sighting	
PSO name(s) on duty (Last, First)	
Effort (e.g., ON=Hammer On; OFF=Hammer Off)	
Start time of observations	
End time of observations	
Compass heading of vessel (degrees, if applicable)	
Beaufort scale	
Precipitation	
Cloud coverage (%)	
Sightings including common name and scientific name	
Certainty of identification	
Number of adults	
Number of juveniles	
Total number of animals or estimated group size	
Bearing to animal(s) when first detected (ship heading+ clock face)	
Distance determination method	
Distance from vessel (e.g., reticle distance in meters)	
Distance from pile being driven	
Description of unidentified animals (include features such as overall size; shape of head; color and pattern; size, shape, and position of dorsal fin; height, direction, and shape of blow, etc.)	
Detection narrative (note behavior, especially changes in relation to activity and distance from source vessel/platform)	
Direction of travel/first approach (relative to vessel/platform)	
Behaviors observed: indicate behaviors and behavioral changes observed in sequential order (use behavioral codes)	
If any bow-riding behavior observed, record total duration during detection (HH:MM)	
Initial heading of animal(s) (degrees)	
Final heading of animal(s)(degrees)	
Shutdown zone size during detection (meters)	
Was the animal inside the Shutdown zone? (Y/N)	
Closest distance to vessel (reticle distance in meters)	
Time at closest approach (UTC HH:MM)	
Time animal entered Shutdown zone (UTC HH:MM)	
Time animal left Shutdown zone (UTC HH:MM)	

Data Needed	Details
If observed/detected during ramp-up/power-up: first distance (reticle distance in meters), closest distance(reticle distance in meters), last distance (reticle distance in meters), behavior at final detection	
Mitigation Implemented	
Did a shutdown/power-down occur? (Y/N)	
Time shutdown was called for (UTC)	
Time equipment was shut down (UTC)	