Coastal Virginia Offshore Wind

Balance of Plant

Engineering, Procurement, Transportation and Installation Services

Sound Field Verification Plan

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Coastal Virginia Offshore Wind Commercial Project

Appendix E - Sound Field Verification Plan

Part of the Construction Mitigation & Monitoring Plan (CMMP)

JASCO Applied Sciences (USA) Inc.

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Contents

Figures

Tables

List of Acronyms, Symbols, and Abbreviations

μPa	micropascal
AMAR	Autonomous Multichannel Acoustic Recorders
ASFV	Abbreviated Sound Field Verification
BiOp	Biological Opinion
BOEM	Bureau of Ocean Energy Management
CMMP	Construction Mitigation & Monitoring Plan
COP	Construction and Operations Plan
CTD	conductivity, temperature, dissolved oxygen
CVOW-C	Coastal Virginia Offshore Wind Commercial Project
dB	decibel
DBBC	Double Big Bubble Curtain plan
DEME	DEME Offshore US LLC, part of the DEME Group
ESP	electrical service platform
GARFO	Greater Atlantic Regional Fisheries Office
GPS	Global Positioning System
HSD	Hydro-Sound-Damper
HSE	health safety and environment
ISO	International Organization for Standardization
LOA	Letter of Authorization
MP	monopile
NAS	noise attenuation system
NCEI	NOAA's National Centers for Environmental Information
NOTMA	notice to mariners through US Coast Guard
NMFS	National Marine Fisheries Service
OCS	outer continental shelf
ONR	Office of Naval Research
OSS	offshore substation
PAM	Passive acoustic monitoring
PDMP	Pile Driving Monitoring, Mitigation and Management Plan
PM	Project Manager
PSD	power spectral density
PSO	Protected species observer
QA/QC	quality assurance/quality control
QMA	qualified marine archaeologist
rms	root-mean-square
SEL	sound exposure level
SFV	Sound Field Verification
SPL	sound pressure level
SSV	Sound Source Verification
SVP	Sound velocity profile

T&C	Terms and Conditions
TSFV	Thorough Sound Field Verification
USACE	United States Army Corps of Engineers
WDA	wind development area
WM	Works Manager
WTG	wind turbine generator

1. Introduction

1.1. Project Overview

Virginia Electric and Power Company doing business as Dominion Energy Virginia (Dominion Energy) is proposing to construct, own, and operate the Coastal Virginia Offshore Wind Commercial (CVOW-C) Project (Project) in the Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf (OCS) Offshore Virginia (OCS-A-0483, the Lease Area). To this end, the Proponent has submitted a Construction and Operations Plan (COP) to the Bureau of Ocean Energy Management (BOEM), a request for a Letter of Authorization (LOA) to the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS), and a request for a Biological Opinion (BiOp) issued by NMFS Greater Atlantic Regional Fisheries Office (GARFO); each are required to conduct activities in the Lease Area.

DEME Offshore US LLC, part of the DEME Group (DEME) has been contracted to transport and install the Project's monopile (MP) and jacket foundations for wind turbine generators (WTGs) and offshore substations (OSSs) using pile driving equipment, which will be subject to monitoring and mitigation conditions outlined in the project permits. The Project consists of up to 176 WTGs on MP foundations and three OSSs on jacket foundations, with installation beginning in May 2024. As a minimum, Thorough Sound field verification (TSFV) for installation of the first three WTG foundations and the three OSS jacket foundations (each with 4 piles, 12 piles in total) is required for the Project. In addition, abbreviated sound field verifications (ASFV), with measurement at one location relative to a monopile, is required for all monopile foundation installations for which a thorough SFV is not conducted.

During an SFV, the sound levels produced during pile driving are measured and compared to the sound levels predicted for the operations. This is done to ensure that the sound fields produced are in compliance within the modeled ranges assuming 10 dB of attenuation. For this project, WTG and OSS foundations will be installed with a combination of vibratory and impact pile driving, and in alignment with the Proposed Rule (50 CFR Part 217; May 4, 2023) the Project will employ a double big bubble curtain (DBBC), or other technology, capable of achieving a 10-decibel (dB) reduction in sound level.

This plan presents the technical approach to perform the thorough SFVs in accordance with the International Organization for Standardization (ISO) recommendations of measurement procedures from percussive pile driving (ISO 18406:2017[E]), the *BOEM Recommendations for Offshore Wind Project Pile Driving Sound Exposure Modeling and Sound Field Measurement* (https://www.boem.gov/renewable-energy/boemoffshorewindpiledrivingsoundmodelingguidance), the *BOEM Nationwide Recommendations for Impact Pile Driving Sound Field Measurement for Offshore Wind Construction and Operations Plans* (https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/Nationwide%20Recommendations%20for%20Impact%20Pile%20Driving%20Sound%20Exposure%20Modeling%20and%20Sound%20Field%20Measurement.pdf), and to satisfy the requirements and proposed requirements listed in the NMFS' BiOp (Published on September 18, 2023; Appendix C), Proposed Rule (50 CFR Part 217, May 4, 2023; Appendix A), and the USACE Individual Permit (issued on 30 January 2024), respectively.

1.2. Project Objectives

- Measure, plot, and validate sound levels produced during pile driving.
- Determine the isopleth ranges to Level A and Level B harassment for marine mammals and injury and behavioral disturbance zones for sea turtles and Atlantic Sturgeon.
- Compare field-measured levels to predicted (modeled) sound fields.

1.3. Compliance Requirements and Recommendations

The SFV requirements and recommendations during construction are described in the LOA (section C 15), and the Conditions of COP Approval, USACE Individual Permit and the NMFS Biological Opinion (NMFS BiOp). The COP T&C was issued on 28 January 2024 the NMFS BiOp was issued on September 18, 2023; The USACE Individual Permit was issued on 30 January 2024; and the LOA on 5 February 2024. The BiOp, early documentation of proposed requirements, and lessons-learned on similar projects were used to inform the basic measures that will be required by lead federal agencies by the time that pile driving is expected to begin. The following describes permit stipulations that Dominion Energy will need to comply with.

Permitting requirements stipulate that the sound field produced during installation of the first three MP foundations and all three jacket foundations be completely verified, and that the selected “thorough” SFV sites for MPs be representative of the subsequent MP foundations. If larger piles or a larger hammer are later used, a thorough SFV must be performed for these subsequent piles or greater hammer energy. The effectiveness of the sound attenuation must be evaluated, based on SFV measurements, which will be completed by comparing measurement data with modeling results. If reductions to the clearance and shutdown zones are requested, measurement data may be required on more than the first three MP foundations. Measurements must not exceed minimum seasonal distances for threatened and endangered species specified in the BiOp. Initial results of the field measurements must be provided to NMFS, BOEM, and the United States Army Corp of Engineers (USACE) as soon as they are available.

Following the completion of the thorough SFV monitoring of the first three MPs and all three OSS foundations, an “abbreviated” SFV (ASFV) effort is required. ASFV monitoring consists of a single acoustic recording at a predetermined distance from each pile, which must be performed on all foundation installations for the Project that are not captured in the thorough SFV. The objective of the abbreviated monitoring (ASFV) is to collect data for Dominion Energy and federal agencies to identify if harassment threshold distances or injury or behavioral disturbance distances were exceeded.

The SFV must empirically determine ranges to Level A and Level B harassment thresholds for marine mammals and to the injury and behavioral disturbance zones for sea turtles and Atlantic Sturgeon. Ranges to the modeled distances assuming 10 dB of attenuation can be extrapolated from in situ measurements conducted at several distances from the driven pile. Modeled distances assuming 10 dB of attenuation, from the BiOp, are shown in Tables 1 - 3. Expected received levels at 750 m are shown in Table 4. If the initial acoustic field measurements indicate that distances to the Level A and Level B are greater than the distances predicted by modeling, Dominion Energy must implement additional sound attenuation measures, and enhance shutdown zones and clearance zones prior to conducting additional pile driving. NMFS may further expand the relevant clearance and shutdown zones if initial acoustic field measurements indicate greater Level A and Level B distances to relevant thresholds. Results of SFV of pile driving must be submitted to BOEM, NMFS and USACE as soon as possible but no later than 90 days following completion of acoustic monitoring.

Table 1. BiOp marine mammal acoustic ranges ($R_{95\%}$, m) to Level A and Level B harassment thresholds for foundation installation scenarios assuming 10 dB of attenuation (modified from Table 34 of the BiOp).

Scenario	Installation Method	Marine Mammal Hearing Group											
		LFC			MFC			HFC			PPW		
		PTS (SEL_{24h})	PTS (Lpk)	Behavior (SPL)	PTS (SEL_{24h})	PTS (Lpk)	Behavior (SPL)	PTS (SEL_{24h})	PTS (Lpk)	Behavior (SPL)	PTS (SEL_{24h})	PTS (Lpk)	Behavior (SPL)
WTG Monopile 1 Standard Installation	Impact	4,396	132	6,182	170	29	6,182	2,139	663	6,182	1,267	141	6,182
	Vibratory	141	NA	8,866	0	NA	8,866	103	NA	8,866	12	NA	8,866
WTG Monopile 2 Hard-to-drive Installation	Impact	4,980	132	6,182	187	29	6,182	2,304	663	6,182	1,358	141	6,182
	Vibratory	113	NA	8,866	0	NA	8,866	87	NA	8,866	3	NA	8,866
WTG Monopile 3 One Standard and One Hard-to-drive Installation	Impact	5,663	132	6,182	226	29	6,182	2,884	663	6,182	1,756	141	6,182
	Vibratory	158	NA	8,866	0	NA	8,866	125	NA	8,866	31	NA	8,866
OSS Foundation	Impact	2,680	0	2,172	48	0	2,172	1,435	197	2,172	1,283	0	2,172
	Vibratory	75	NA	3,601	0	NA	3,601	68	NA	3,601	0	NA	3,601

dB = decibel; LFC = low-frequency cetacean; Lpk = peak sound pressure level in units of dB referenced to 1 micropascal; MFC = mid-frequency cetacean; HFC = high-frequency cetaceans; PPW= phocid pinnipeds in water; NA = not applicable for this installation method; OSS = offshore substation; PTS = permanent threshold shift; SEL_{24h} = sound exposure level over 24 hours in units of dB referenced to 1 micropascal squared second; SPL = root-mean-square sound pressure level in units of dB referenced to 1 micropascal; WTG = wind turbine generator.

Table 2. BiOp sea turtle acoustic ranges ($R_{95\%}$, m) to injury and behavioral response thresholds for foundation installation scenarios assuming 10 dB of attenuation (Table 34 of the BiOp).

Scenario	Installation Method	PTS (Lpk)	PTS (SEL_{24h})	TTS (Lpk)	TTS (SEL_{24h})	Behavior (SPL)
WTG Monopile 1 Standard Installation	Impact	10	1,044	67	3,575	2,146
	Vibratory	NA	6	NA	179	82
WTG Monopile 2 Hard-to-drive Installation	Impact	10	1,142	67	3,902	2,146
	Vibratory	NA	0	NA	132	82
WTG Monopile 3 One Standard and One Hard-to-drive Installation	Impact	10	1,410	67	4,812	2,146
	Vibratory	NA	8	NA	200	82
OSS Foundation	Impact	0	653	0	2,303	742
	Vibratory	NA	0	NA	94	7

dB = decibel; Lpk = peak sound pressure level in units of dB re 1 micropascal; OSS = offshore substation; PTS = permanent threshold shift; SEL_{24h} = sound exposure level over 24 hours in units of dB referenced to 1 micropascal squared second; SPL = root-mean square sound pressure level in units of dB referenced to 1 micropascal; TTS = temporary threshold shift; WTG = wind turbine generator.

Table 3. BiOp fish acoustic ranges ($R_{95\%}$, m) to injury and behavioral response thresholds for foundation installation scenarios assuming 10 dB of attenuation (Table 40 of the BiOp).

Scenario	Installation Method	Injury (Lpk)	Injury (SEL_{12h})	Behavior (SPL)
WTG Monopile 1 - Standard Installation	Impact	445	4,501	15,010
	Vibratory	NA[1]	NA[1]	903
WTG Monopile 2 – Hard-to-drive Installation	Impact	445	5,085	15,010
	Vibratory	NA[1]	NA[1]	903
WTG Monopile 3 – One Standard and One Hard-to-drive	Impact	445	5,880	15,010
	Vibratory	NA[1]	NA[1]	903
OSS Foundation	Impact	94	2,959	5,530
	Vibratory	NA[1]	NA[1]	393

dB = decibel; Lpk = peak sound pressure level in units of dB referenced to 1 micropascal; OSS = offshore substation; SEL_{12h} = sound exposure level over 12 hours in units of dB referenced to 1 micropascal squared second; SPL = root-mean-square sound pressure level in units of dB referenced to 1 micropascal; WTG = wind turbine generator. NA = Not Applicable.
[1] NMFS does not have physical injury thresholds for non-impulsive sources, except tactical sonar.

Table 4. CVOW-C predicted single strike (impact driving) and 1 s (vibratory driving) received levels at 750 m from the pile. The received levels are for maximum impact hammering energy, 4000 kJ, and apply to standard and hard to drive piles.

Source Type	Pile Type	Reduction	Maximum Modeled Sound Level at 750 meters (dB)		
			Peak Sound Level ($L_{p,pk}$)	Sound Pressure Level (L_p)	Sound Exposure Level ($L_{E\ ss}$)
Impact Hammer	Monopile Foundation	Unmitigated	215	204	192 $L_{E\ ss}$
		10 dB	205	194	182 $L_{E\ ss}$
Vibratory Hammer	Monopile Foundation	Unmitigated	N/A	166	170 $L_{E\ 1sec}$
		10 dB	N/A	156	160 $L_{E\ 1sec}$
Impact Hammer	Piled Jacket Foundation	Unmitigated	202	186	174 $L_{E\ ss}$
		10 dB	192	176	164 $L_{E\ ss}$
Vibratory Hammer	Piled Jacket Foundation	Unmitigated	N/A	155	155 $L_{E\ 1sec}$
		10 dB	N/A	145	145 $L_{E\ 1sec}$

2. Methodological Processes

2.1. Pile Installation Overview

MP installation for the Project is expected to start in May 2024 and end in October of the same year. Installation of MPs will resume in May 2025 and be completed in October 2025. Jacket installation is expected to occur in August 2024 (Tetra Tech 2023). The LOA requires that an SFV be completed when conditions change. Pile driving is expected to be completed by 31 October of 2024 and 2025, seasonality was not considered in this measurement plan because variability in the sound speed profiles expected in this area are not likely to be directly attributable to spring, summer, and fall.

Reference is made to the Appendix C - Pile Driving Monitoring, Mitigation and Management Plan (PDMP) of the CMMP for more detailed information on pile installation.

A double big bubble curtain will be deployed, tested, and activated by a support vessel prior to the foundation installation vessel arriving at the foundation position. The support vessel will deploy the bubble curtain hose in a pre-determined ring around the foundation position and then test the bubble curtain. The support vessel will remain onsite until the foundation installation vessel arrives. The vessel will activate the bubble curtain prior to pile driving and will recover the bubble curtain once pile driving is complete.

Reference is made to the Appendix G – Double Big Bubble Curtain plan (DBBC) of the CMMP for more detailed information.

Before pile driving begins, the acoustic recording systems for TSFV will be deployed. The recorders will be deployed by two acousticians from an support vessel and will be in place at least one hour prior to the commencement of pile driving activities.

To minimize the risk of pile run, both MPs and pin piles would first be installed using a vibratory hammer, followed by an impact hammer. Vibratory hammers are hydraulically operated mechanical pile driving tools that clamp onto and oscillate a pile into the soil. The vibratory hammer is lifted (clamped together with the pile), operated, and controlled by the crane of an offshore installation vessel. First, the pile is upended from the main installation vessel using the vibratory hammer. The vibratory hammer itself thus also functions as pile lifting tool. The pile is lowered to the seabed, under control of the vibratory hammer, and its self-weight penetration is controlled by line-pull force in the crane depending on soil conditions. The pile is vibrated into the soil in a controlled manner and is stopped when a pre-defined penetration depth is reached, ensuring the pile is self-stable and the pile run risk is overcome (Tetra Tech 2022).

While the vessel remains on position, and directly following retrieval of the vibratory hammer, the impact hammer is lowered onto the partially driven pile. Impact pile driving will begin with a "soft-start" to ensure that the pile remains vertical and allow any motile marine life to leave the area before the pile driving intensity is increased. The intensity (i.e., hammer energy level) will be gradually increased based on the resistance that is experienced from the soil conditions encountered at each location. Impact hammering proceeds until the pile is lowered to its final penetration depth. After pile driving is completed, the impact hammer is retrieved to the deck of the installation vessel.

Reference is made to the CMMP Appendix C - Pile Driving Monitoring, Mitigation and Management Plan (PDMP), for more detailed information on pile installation At maximum for a standard to drive single MP a day, it is expected that vibratory hammering may be needed for approximately 60 minutes per MP before impact piling can begin. Impact pile driving for each MP foundation is expected to take no more than 3.5 hours to achieve the target penetration depth (Tetra Tech 2022). The transition time between vibratory and impact activities may take about 1.2 hours on average. During MP installation, acoustic recording will continue uninterrupted throughout its installation, regardless of the transition time in between the vibratory and impact hammer changeover. After a minimum of 30 minutes have passed following the completion of MP installation, acoustic recording equipment will be retrieved, and the data will be processed after all locations have been downloaded. The WTG MP foundations will be installed at a maximum rate of two MPs per day.

The OSS jacket foundations are expected to be pre-piled, whereby the pin piles are driven into the seabed first, then the jacket is placed over the pin piles and onto the seafloor. For each OSS pin pile, it is expected that the maximum duration of vibratory hammering that may be needed is 2 hours. Subsequent impact pile driving for one pin pile is expected to take no more than 7 hours to achieve the pile's target penetration depth (Tetra Tech 2022). During jacket installation, acoustic recording will continue uninterrupted throughout its installation, regardless of handling time in between pile driving events for each pin pile and between vibratory and impact hammer changeover. After a- minimum of 30 minutes have passed following the completion jacket pile driving, two acousticians will retrieve the acoustic recording equipment. The OSS jacket foundations require a total of four pin piles, but pin piles will be installed at a maximum rate of 2 pin piles per day.

2.2. Foundations to be Monitored

Dominion Energy will perform a thorough SFV on the first three MP installations and on all three OSS jacket foundations (Table 8), and see Figures 7 and 8 of the PDMP for a plan view of pile identifiers and anticipated installation sequence). All piles for which a thorough SFV is not performed, an abbreviated SFV (ASFV) will be done. All MPs are tapered and will be no larger than 9.5-m in diameter, representing the larger end of the MP design. MPs will be installed using the same size impact hammer and will not exceed 4,000 kilojoules (kJ) maximum hammer energy. All OSS jacket foundations will be completely monitored over its entire installation duration. All pin piles will be no larger than 2.8-m diameter and will be installed using the same size hammer (different anvil) that will not exceed 3,000 kJ maximum hammer energy.

The first three piles are standard to drive but represent both shallow and deep-water scenarios (see PDMP Sect 4.1 and 4.2). Thorough SFVs on the first three piles will measure the sound production characteristics (at 750 m) and propagation in shallow and deep water. With this information, range estimates for other scenarios can be obtained from the single ASFV measurements (at 750 m), including hard to drive piles and two monopiles installed in one day – see Section 2.7 for explanation of ASFV methods. For these reasons additional thorough SFVs may not be needed. Results from the first thorough SFV campaign on standard to drive piles and subsequent ASFVs will be used to determine if additional thorough SFVs are required and on which piles to perform them.

Reference is made to the Appendix C – Pile Driving Monitoring, Mitigation and Management Plan (PDMP) of the CMMP for more detailed information on the total energy analysis.

2.3. Recording Systems

2.3.1. Deployed recording systems

To measure sound levels generated during pile driving, JASCO will supply autonomous monitoring equipment that will be deployed at multiple fixed locations. The proposed physical equipment for the SFV includes a subsea mooring with an AMAR G4 equipped with two hydrophones, one placed ~1.5 m from the seafloor and one near mid-water column depth (Figure 1). The mooring plate assembly that contacts the seabed is ~1 m^2 and the small anchor for the top-float assembly is ~0.25 m^2, both are expected to penetrate the bottom no more than a few centimeters.

Acoustic measurements will be performed with five AMARs for thorough SFV and one AMAR for ASFV, each fitted with two GeoSpectrum M36 hydrophones configured to sample continuously at 256 ksps (10 Hz to 128 kHz recording bandwidth) with 24-bit resolution. The recording bandwidth of the hydrophones is expected to sufficiently cover the frequency range of pile driving activity (see Attachment E-1). Hydrophone sensitivity was chosen to ensure that maximum expected received levels remain below the saturation level of the systems (-210 dB re 1V/µPa at 750 m, -200 dB re 1V/µPa at 3000, 6000, and 9000 m, and -165 dB re 1V/µPa at 15,000 m) and spare equipment for reasonably foreseeable situations included.

As part of the JASCO Canada LTD ISO 9001 certified Quality Management System, JASCO tracks equipment retrieval rates. JASCO has achieved a 99.8% retrieval rate and 99.2% data return rate throughout more than 500 deployments since 2016 (Figure 2). While data loss is not expected during this project, failures may occur. If, during thorough SFV monitoring, one recorder fails along the primary measured radius, then range estimates would still be possible because the remaining three measurement points are sufficient for defining the transmission loss fit.

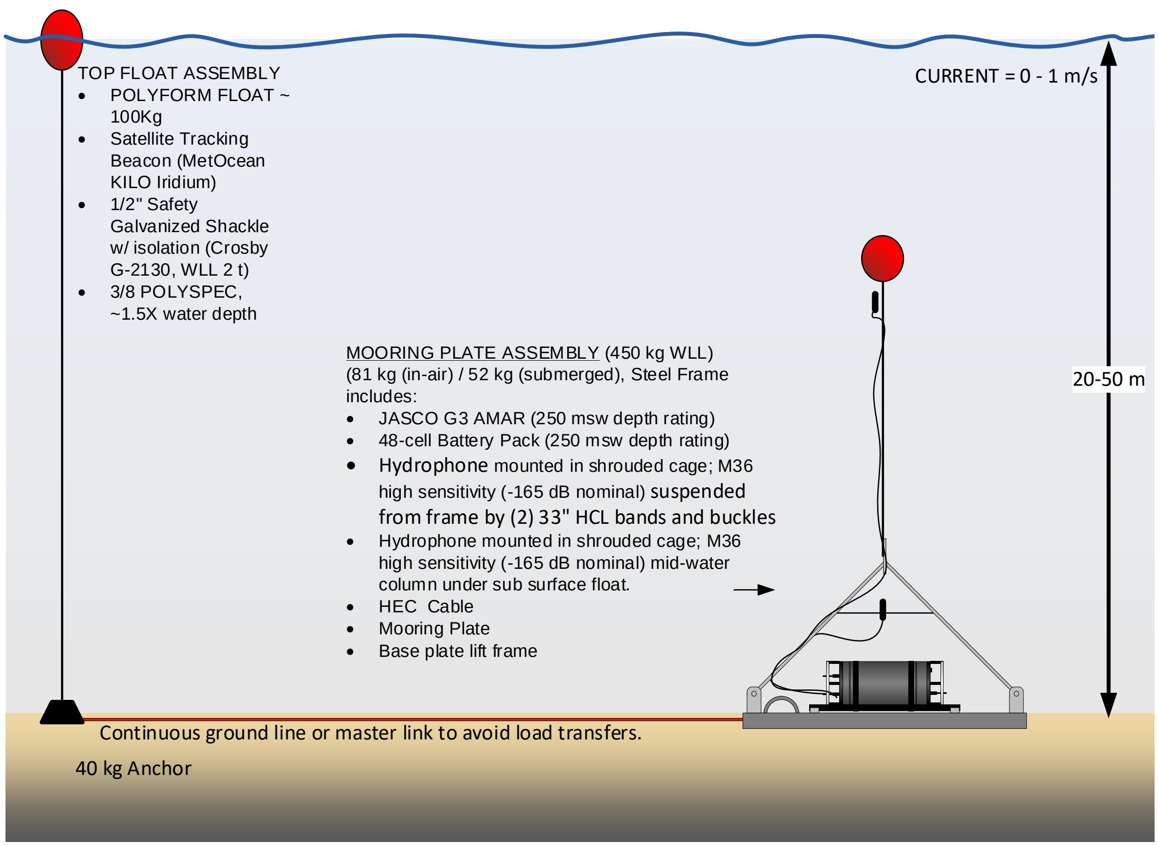
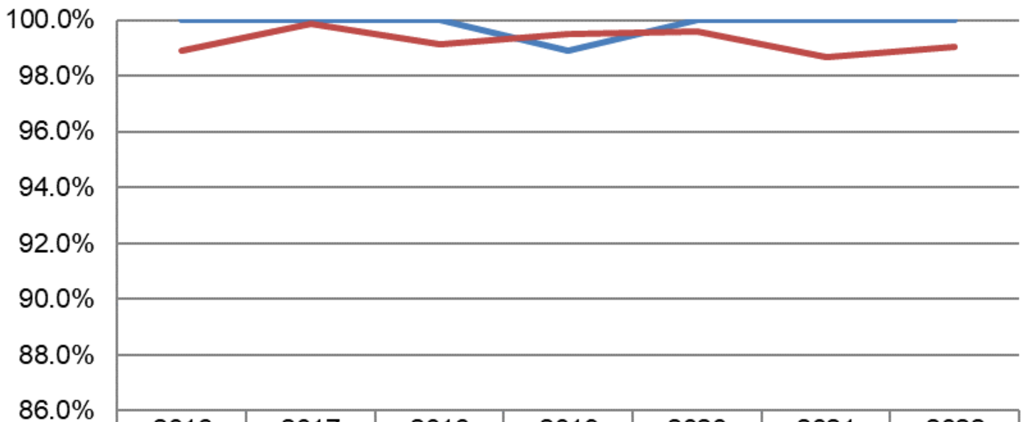


Figure 1. Fixed-location autonomous recording systems for SFV.



	2016	2017	2018	2019	2020	2021	2022
Retrieval rate	100.0%	100.0%	100.0%	98.9%	100.0%	100.0%	100.0%
Data return rate	98.9%	99.9%	99.1%	99.5%	99.6%	98.7%	99.0%

Figure 2. JASCO's retrieval and data recovery rate for more than 500 deployments.

2.3.2. Recording System Calibration

The recorder will be calibrated to verify the sensitivity of each sensor or system as a whole (i.e., the hydrophone, pre-amplifier, and AMAR). Each hydrophone/AMAR will be calibrated prior to deployment and within 24-hours of retrieval (battery life permitting) with a pistonphone type 42AC precision sound source (G.R.A.S. Sound & Vibration A/S; Figure 3). The pistonphone calibrator produces a constant tone at 250 Hz at a fixed distance from the hydrophone sensor in an airtight space with known volume. The recorded level of the reference tone on the hydrophone yields the system gain for the AMAR and hydrophone. To determine absolute sound pressure levels, this gain will be applied during data analysis. Typical calibration variance using this method is less than 0.7 dB absolute pressure.

The calibrations performed prior to the field deployment will be verified for consistency (i.e., <0.7 dB difference) with the measurements acquired within 24 hours of recovery. The post-retrieval calibration allows us to ensure consistent sensitivities were consistent during the deployment (see Attachment E-1).

Figure 3. Split view of a G.R.A.S. 42AC pistonphone calibrator with an M36 hydrophone.

2.4. Data Analysis

2.4.1. Impact pile driving

Autonomous acoustic recordings from the SFV will be processed using PAMlab software (Figure 4) that automatically detects impact pile driving sounds and calculates the relevant metrics. For impact driving, it uses a Teager-Kaiser impulse detector to identify pile-driving strikes. For each pile strike the detector stores:

- Peak pressure level, PK (dB re 1 µPa)
- The duration of the pulse (time span that includes 90% of the pulse energy)
- The sound pressure level, SPL (dB re 1 µPa) (90% energy and IEC fast time-weighted)

From the measured values, the following metrics are calculated:

- The distances where the broadband received SPL (dB re 1 µPa) decays to 160 dB
- The single strike broadband sound exposure level, SEL (dB re 1 µPa²·s)
- The decidecade-band single-strike SEL (dB re 1 µPa²·s)
- The per-day, broadband SEL (dB re 1 µPa²·s)

Note: All measurements will be unweighted, SEL will be weighted in post-processing for hearing groups.

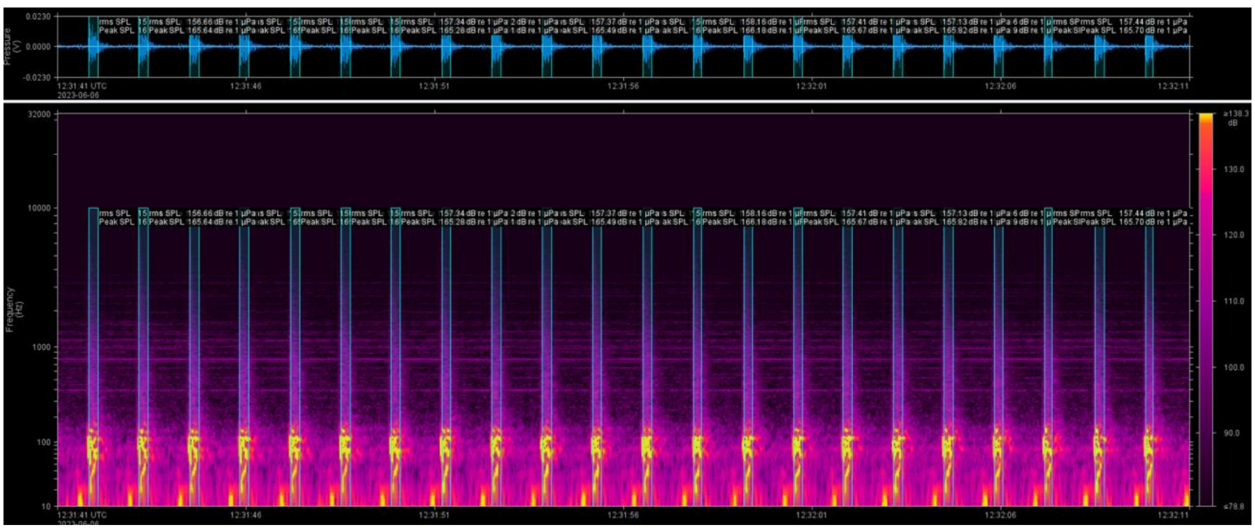


Figure 4. PAMlab software tool for automated detection strikes and associated metrics.

2.4.2. Vibratory pile driving

Autonomous acoustic recordings from the SFV will also be processed using PAMlab software to obtain the SPL and cumulative SEL for vibratory setting of piles. Signals received between the known start and stop times of vibratory piling will be processed to get the SPL, and weighted and unweighted SEL, for each one-second interval of vibratory driving. The cumulative SEL will be calculated by summing the SPL of the one-second intervals.

From the measured values, the following metrics are calculated:

- The distances where the broadband received SPL decays to 120 dB
- The broadband SEL (dB re 1 µPa²·s)
- The decidecade-band SEL (dB re 1 µPa²·s)
- The per-day, broadband SEL (dB re 1 µPa²·s)

Note: All measurements will be unweighted, SEL will be weighted in post-processing for hearing groups.

2.4.3. Pre- and post- piling sound levels

Similar to processing for vibratory pile driving, Autonomous acoustic recordings from the SFV will be processed using PAMlab software on multiple one-second samples taken within 1 hour prior to commencement of pile driving and 30 minutes after cessation of piling. Received levels will be processed to get the SPL, and weighted and unweighted SEL, for each one-second interval.

From the measured values, the following metrics are calculated:

- The broadband received SPL
- The broadband SEL (dB re 1 $\mu Pa^2 \cdot s$)
- The decidecade-band SEL (dB re 1 $\mu Pa^2 \cdot s$)

2.5. Field Measurement

For a thorough SFV, JASCO's field team will consist of two field personnel to deploy and retrieve acoustic equipment (see Attachment E-2) for overview of deployment and retrieval procedures) from a chartered vessel (see Attachment E-3). Two acousticians will be aboard the vessel to process the collected data for rapid analysis and reporting. For an ASFV, one JASCO staff will constitute the field team – responsible for both equipment and data processing. The field personnel will log all activities, interact in real-time with the pile driving contractor and the client, and conduct non-acoustic data collection (e.g., CTD casts).

Field personnel will conduct a Job Safety Analysis (JSA) prior to operations and follow deployment and retrieval procedures. To ensure safety and coordinate activities, communications is required between the installation and monitoring teams. Communication between the measurement team and the construction team is critical for safety and the successful completion of the project. Shoreside communication can be handled using email and phone by JASCO's project manager (PM). In the field, JASCO's point of contact will be the field lead. In the field, the SFV field lead will communicate with the operations lead or construction foreman, and potentially other members of the construction crew, via very-high-frequency (VHF) radio on channel 16, (and/or other designated working channels). A communications matrix indicating methods of communications and details for contacting individuals is shown in Table 5.

Table 5. Communications matrix.

Position	Name	Preferred communication	Secondary communication
DEME Foreman	TBD	VHF ##	TBD
JASCO Field Lead	TBD	VHF ##	TBD
JASCO Field Technician	TBD	VHF ##	TBD
JASCO PM	TBD	VHF ##	TBD
PSO provider's Lead PSO	TBD	VHF ##	TBD
DEME PM/Operations Lead	TBD	VHF ##	TBD

2.5.1. Information to be Communicated

Table 6. Information to be communicated to JASCO.

<table>
<tr><th>Information</th><th>Communicated by</th><th>Method</th><th>Communicated to</th></tr>
<tr><td>Construction vessel to sail to site</td><td rowspan="5">DEME PM</td><td rowspan="5">Email/phone/ WhatsApp</td><td rowspan="5">JASCO PM</td></tr>
<tr><td>construction vessel on site</td></tr>
<tr><td>72-hour NOI to perform driving activities</td></tr>
<tr><td>48-hour update prior to driving activities</td></tr>
<tr><td>24-hour update prior to driving activities</td></tr>
<tr><td>2-hr notice prior to driving activities</td><td rowspan="6">Operations Lead/ DEME WM</td><td rowspan="6">VHF 16 [1]/ WhatsApp</td><td rowspan="6">JASCO Field Lead</td></tr>
<tr><td>Notice of start of driving</td></tr>
<tr><td>Notice of any pause in driving</td></tr>
<tr><td>Notice of resuming driving</td></tr>
<tr><td>Notice of completion of driving</td></tr>
<tr><td>Notice of safe to return to site for retrieval of recorders</td></tr>
</table>

[1] Unless a working channel is specified for the operation.

Table 7. Information that JASCO will communicate.

Information	Communicated by	Method	Communicated to
Notice to sail to site	JASCO PM	Email/phone	DEME PM/ DEME WM
Notice of on-site arrival	JASCO Field Lead	VHF 16[1]	Orion Captain/ DEME WM[2]
Recording systems deployed	JASCO Field Lead	VHF 16[1]	Orion Captain/ DEME WM[2]
Intent to retrieve recording systems	JASCO PM	Email/phone	DEME PM/ DEME WM
Notice of on-site arrival	JASCO Field Lead	VHF 16 [1]	Orion Captain/ DEME WM[2]
Recording systems retrieved	JASCO PM	Email/phone	Orion Captain/ DEME WM[2]
Interim TSFV report	JASCO PM	Email	DEME PM/ DEME WM/ DEME DBBC rep

[1] Unless a working channel is specified for the operation.
[2] Additionally communicated by JASCO PM to DEME's PM by email/phone.

2.6. Thorough Sound Field Verification (TSFV)

2.6.1. Measurement and Processing

Ranges to specified levels are found from transmission loss equations fitted to received levels at different recording distances. Simple transmission loss decays approximately exponentially, and when displayed on a log-log plot, is a straight line. The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds will be extrapolated from a logarithmic regression fitted to the higher received level (among hydrophones at each station) for the L5 (95th percentile) of peak sound pressure level (PK), root-mean-square sound pressure level (SPL), and cumulative sound exposure level (SEL) of the received acoustic energy (from vibratory and impact driving) on each recorder. The logarithmic regression will be performed as a single function in the form of A·Log(r), where A is the attenuation coefficient and r is the distance from the source, and to include absorption of acoustic energy, a logarithmic regression fit of the form A·Log(r) + α·r, where α is an absorption coefficient, will also be done. Two points could be used to establish the fit but it would be subject to noise so at least three measurements locations are desired. JASCO will deploy four receiver stations along the primary measurement radius (~62° as the direction of best propagation, determined from acoustic modeling for the COP and LOA), plus one 90° from the primary radius, allowing for the potential loss of one station during installation measurements while maintaining confidence in calculated ranges.

The LOA requires measurements at 750 m and at the Level B acoustic range, with the remaining systems placed for best understanding of propagation in the area. The longest ranges (two piles per day) to Level B threshold during monopile installation using vibratory driving is 8,866 m and is 6,182 m for impact driving. For jacket foundations the range to Level B during vibratory driving is 3,601 m and 2,172 m for impact driving. It is also noted that the Level A SEL acoustic range for low-frequency cetaceans during impact pile driving of monopile foundations is 5,663 m and 2,680 m for the impact driving of jacket foundations. The modeled distances assuming 10 dB of attenuation for sea turtles are from 0 m to 4,812 m (Table 2) and the distance for potential fish behavioral response is up to 15,010 m (Table 3). Considering these predicted ranges, 750, 3000, 6000, 9000, and 15,000 m, along with a 90° station at 750 m, were chosen to for SFV measurement of monopiles (Table 2); and 750, 2000, 4000, 8000, and 15,000 m, along with a 90° station at 750 m, were chosen to for SFV measurement of jacket foundations (Table 3). The measurement at 750 m 90° from the primary measurement radius provides an indication of sound production and NAS performance in different directions. These measurement distances are also well placed to cover the ranges for potential fish injury (up to 5,880 m; Table 3). Geo-specific locations for the recording systems for the first three monopiles and the three jacket foundations are listed in Table 8.

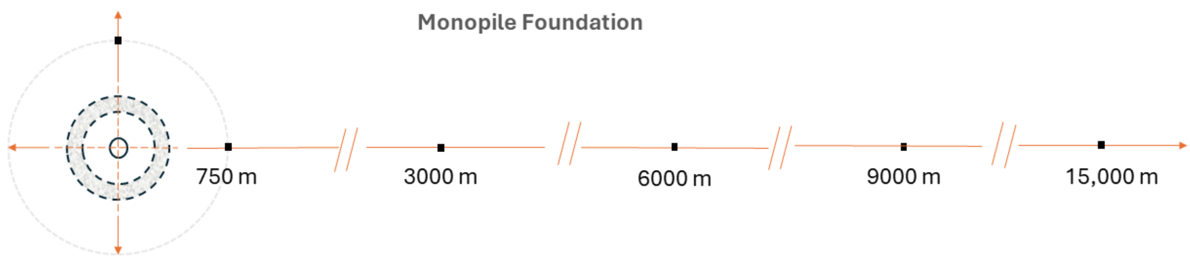


Figure 5. Monopile foundation nominal deployment locations for acoustic measurement systems. The line breaks on the horizontal axis indicate that the axis is not to scale.

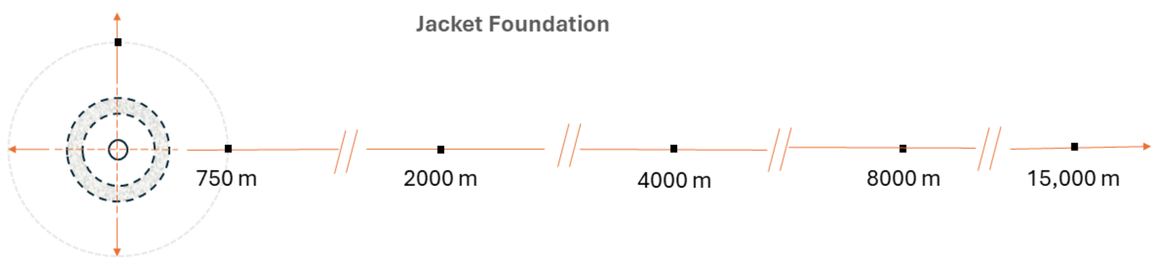


Figure 6. Jacket foundation nominal deployment locations for acoustic measurement systems. The line breaks on the horizontal axis indicate that the axis is not to scale.

2.6.2. TSFV Piles to be monitored and nominal recording locations

The first three monopile foundations of this campaign (G2K04, G2J05, and G2J04) and the three jacket foundations (T1L11, T2G07, and T3G15) will have a thorough SFV performed. All three of the monopile foundations are standard to drive but are expected to use the maximum hammer energy (4000 kJ) and represent both shallow and deep water. The first and third monopile are in shallow water while the second is in deep water (See Figure 8 of the PDMP). If the measured ranges to thresholds are found to be longer than the modeled ranges assuming 10 dB of attenuation, thorough SFV will continue on additional piles while adjustments are made (such as optimizing NAS performance). From these thorough SFV measurements, sound production (received levels at 750 m as a function of hammer energy) and sound propagation in shallow and deep water will be established.

Table 8. Planned foundations to be monitored and nominal recording locations for thorough SFV.

Foundation Type	Foundation	Driving Type	Depth	Pile Location	750 m	3000 m	6000 m	9000 m	15000 m	750 m (90°)
Monopile Campaign 1 (WTG)	G2K04	Standard	Shallow	36.8691962, -75.45622724	36.8723984, -75.44881617	36.8820025, -75.42657925	36.89480147, -75.3969213	36.907161, -75.366853	36.86972303, -75.28793342	36.87515032, -75.46021345
	G2J05	Standard	Deep	36.8846803, -75.44266223	36.8878818, -75.4352491	36.89748332, -75.41300598	36.91027892, -75.38333977	36.922645, -75.353269	36.98067614, -75.32404126	36.89063495, -75.44664821
	G2J04	Standard	Shallow	36.8846214, -75.45821551	36.8878238, -75.45080304	36.89742823, -75.42856191	36.91022769, -75.39889836	36.922586, -75.368823	36.98063261, -75.33961427	36.89057547, -75.46220269
Foundation Type	**Foundation**	**Drive Type**	**Depth**	**Pile Location**	**750 m**	**2000 m**	**4000 m**	**8000 m**	**15000 m**	**750 m (90°)**
Jacket (OSS)	T1L11	N/A	N/A	36.854144, -75.345434	36.85734134, -75.33798425	36.86266596, -75.32562571	36.87118269, -75.30584846	36.88820629, -75.26628073	36.98936172, -75.34600897	36.8601039, -75.3493754
	T2G07	N/A	N/A	36.915642, -75.415529	36.91884378, -75.40810979	36.92417566, -75.3957463	36.93270402, -75.37596112	36.94975088, -75.33637747	36.91611369, -75.24713056	36.92159951, -75.41951256
	T3G15	N/A	N/A	36.916013, -75.29105	36.91920621, -75.2836262	36.92452518, -75.27125389	36.93303286, -75.25145461	36.95223717, -75.21336946	36.93895869, -75.45693081	36.92197391, -75.29502464

2.6.3. TSFV Reporting

A complete record of installation is planned for each pile monitored so that accurate total sound energy (SEL) is measured and reported. Pile driving logs of the applied hammer energy per strike and pile insertion depth (e.g., in 25 cm increments) are required for data interpretation, such that a relationship between sound output and applied hammer energy or insertion depth can be derived. This information is necessary for ASFV planning and performance (see Section 2.7). Data will be stored on the AMAR recorders deployed on the seabed and downloaded once the recording is complete and the recorder retrieved. For interim reporting, the first four stations along the radial measurement (e.g., 750, 3000, 6000, and 9000 m for MP) will be prioritized. The stations at 15,000 m and 750 m (90°) will be processed and included in the interim report if time allows. Similarly, if constrained by time, data from different recording stations along the measurement radius will be prioritized over reporting data from multiple channels at fewer locations.

An interim summary report for each measured pile that includes the processed data (Sections 2.4 and 2.6.1) along with number of strikes detected and a log of hammering activity will be submitted by Dominion Energy within 48 hours to the following emails: BSEE and NMFS at protectedspecies@bsee.gov, pr.itp.monitoringreports@noaa.gov, and jaclyn.daly@noaa.gov, GARFO at nmfs.gar.incidental-take@noaa.gov, and BOEM at renewable_reporting@boem.gov.

A full report (including, e.g., peak pressure, sound pressure level, sound exposure level, and ranges for Level A and B for marine mammals and injury and behavioral disruption threshold for sea turtles and Atlantic Sturgeon) will be completed within 90 days of completion of pile driving (see Section 2.8).

2.6.4. TSFV Mitigation procedures

If the ranges are found to exceed the modeled distances with 10 dB of attenuation Dominion Energy Dominion Energy will communicate this information and discuss with all relevant regulatory authorities (i.e., BOEM, NMFS, BSEE) to determine the next steps. Additional measures may include improving the efficacy of the implemented noise attenuation technology and/or modifying the piling schedule to reduce the sound source. Each sequential modification will be evaluated empirically by TSFV.

- **Attenuate confounding factors** to the sound field measurements, e.g., root cause analysis of differences between mid-water vs bottom hydrophone, reposition vessels in field to aim for the highest possible distance between dynamic positioning thrusters to SFV hydrophones, under the conditions it is safe and does not jeopardize pile driving operations.
- **Evaluate the performance of the installed NAS** and, if needed and possible, increase its efficiency, e.g., execute additional maintenance, increase DBBC bubble flow rate, add compressors, redrill holes, etc.
- **Reduce hammer energy**, under the condition it is safe, it does not increase pile refusal risk and it is within the hammer supplier tolerances.

In the event that SFV measurements continue to indicate distances to isopleths corresponding to Level A harassment and Level B harassment thresholds are consistently greater than the distances predicted by modeling, NMFS may expand the relevant clearance and shutdown zones

- **Extend clearance and shutdown zones**, i.e., increase the visual and acoustic clearance zones, and shutdown zones to meet the actual isopleth (Level A and level B) and if needed, increase the PSO and PAM detection range with as goal of ensuring the ability to maintain all clearance and shutdown zones for all ESA-listed species.

2.7. Abbreviated SFV (ASFV)

2.7.1. Measurement and Processing

The goal of the ASFVs is to create a record of performance during pile driving, monitor for potential performance issues, and determine when ranges to thresholds may have exceeded the modeled distances. Hence, the ASFV is not a compliance tool, but purely a performance monitoring tool.

Determining if there are performance changes or if modeled ranges to threshold were exceeded based on a single measurement location at 750 m is challenging. At least three thorough SFVs, with two recording systems at 750 m and four (or more) along the primary measurement radius, will have been completed prior to conducting an ASFV. Data from the thorough SFVs will be used to establish expected received levels (baseline) at 750 m and define propagation in the region. The top 10% of the one-second interval received levels during vibratory driving and top 10% of received impulses (representing ~300-400 strikes) during impact driving from each recording station will be extracted to get a distribution of received levels. The distributions will be compared, and if similar, will be pooled to form a distribution with a larger sample size. If the distributions differ, the one(s) with the larger mean value will be chosen as the baseline. With a well-defined distribution of received levels at 750 m from the thorough SFVs, a similar distribution of the top 10% of received levels from the single 750 m recording station from an ASFV can be compared. This is a robust comparison, so a difference in these distributions indicates something has changed in the sound production or sound attenuation (and, possibly, propagation within 750 m but will be considered as part of the sound production). It is possible that the initial piles do not require operating the hammer to the maximum available energy. In this case, a prediction for received levels at higher hammer energies could conservatively be obtained assuming 3 dB per doubling of hammer energy (Bellmann 2020 found the scaling factor to be ~2.5 dB per doubling of hammer energy). The progression with hammer energy, however, can also be determined from the collected data, even if it is from an ASFV instead of a thorough SFV.

During the thorough SFV, received levels at multiple distances are collected and fitted, defining propagation in the region. Using the thorough SFV propagation information, the maximum allowable received level (PK, cumulative weighted SEL, and SPL) that can be received at 750 m will be determined for SPL and each hearing group for SEL. All three (cSEL, PK, and SPL) values will be compared to their respective maximum allowable RL at 750 to gauge the possibility of exceeding the modeled ranges. Determining the maximum allowable level at 750 is, essentially, the same for all three as well. The maximum allowable level will come from backpropagating from the modeled range to 750 m using the measured transmission loss. The mean value from the distribution of the top 10% of received levels for SPL and PK, and the cumulative weighted SEL(s) from the ASFV will be compared to the maximum allowable received level. (Note that the mean of the top 10% is ~95%, or L5, of the overall received levels.) If the mean of the top 10% of received levels remains below the maximum allowable received level then the distances to threshold remain below the modeled ranges as long as the propagation remains the same. The primary factors affecting propagation are water depth, sound velocity profile (SVP), and bottom composition (geo-acoustics). Water depth is known in advance for all piles, the historic SVP data was included in the modeling (summer/winter) and SVP can be measured (by CTD) during the thorough SFVs and ASFVs. Variation of bottom composition is most difficult to assess but the composition in the area is relatively uniform and the propagation determined in the thorough SFVs includes the contribution of the bottom. Similarly, the SVP can change rapidly and primarily is either slightly downwardly refracting in summer or well-mixed in winter. The maximum allowable received level at 750 m can be scaled using depth and SVP data to refine the range to threshold estimates. For example, deeper water and a more vertical SVP would bring the maximum allowable received level down because propagation would be longer, and conversely shallower locations with more downwardly refracting SVP would increase the maximum allowable received level threshold because propagation would be shorter. Depth scaling would be done by interpolating between the results of the shallow and deep water through SFV results and SVP scaling by whether the measured SVP is downwardly refracting (summer profile) or not (winter profile).

The (weighted) cumulative SEL, like the L5 of PK and SPL, is a single value (for each hearing group) and the data that will be compared to the maximum allowable received level at 750 m. The cumulative SEL for each hearing group is used to evaluate potential range exceedance and the per strike distribution comparisons indicate whether sound production changed. If the cumulative SEL indicates a range exceedance occurred, the distribution comparison tells us if it was simply because there were more strikes (distributions were the same) or something in sound production changed (distributions differ), or both.

Using this approach, changes in sound production can be detected and ranges to thresholds better estimated from single measurement points. This leads to a better understanding of whether ranges were exceeded, allows for a running record of the ensonified area, and more accurate pile forecasts. The method can be refined as more data are collected. For example, thorough SFVs conducted in different water depth can be used to refine the scaling of the maximum allowable threshold for depth.

Using the per-strike received levels relies on well-behaved distributions collected during the thorough SFVs. If the process is found to be unworkable then a fallback option is to use the maximum of the L5 PK and SPL, and cumulative SEL received levels at 750 m measured during the thorough SFVs as the maximum allowable level at 750 m for the ASFVs. This option results in less understanding of sound production and changes in sound production, and it limits range forecasting, but it does provide a threshold to indicate possible exceedance of modeled ranges.

2.7.2. ASFV piles to be monitored

For all monopile foundations for which a TSFV was not performed, an ASFV, consisting of a single recorder placed at 750 m will be conducted.

2.7.3. ASFV Reporting

The same equipment used for the TSFV will be used for the ASFV (see Section 2.3 for details), and as with the thorough SFV, the recording system will be placed at least 60 minutes before the start of pile driving and retrieved 30 min after the completion of driving. To minimize vessel presence around the installation vessel and to ensure timely deployment, several recording systems will likely be pre-laid for upcoming monopiles, and due to operational and logistical constraints it is not possible to guarantee retrieval after each monopile. ASFV data processing will also take longer than the time between subsequent monopiles so it is proposed that available ASFV results be included with the weekly report. The expectation is that ~3 piles per week will be driven and reported but the number will vary and depends on piling performance and potential (e.g., weather) delays. If monopile installation were to proceed rapidly, there will be a break in installation as the installation vessel returns to port to load six monopiles; allowing time for the dedicated ASFV support vessel to finish retrieving all recorders and for the acousticians to process the data from the (up to) six past monopiles.

Dominion Energy understands six consecutive monopile installations may to be too infrequent to be notified of potential need for corrective measures. Given safety, logistical, and environmental (weather) constraints, Dominion Energy will try to uphold reporting frequency of ~3 consecutive MPs by scheduling ASFV equipment retrieval but can only guarantee ASFV data processing during Orion load-in breaks (foreseen maximum every 6 monopiles or on weekly basis). The ASFV results from the respective weekly reporting period will be included in the respective weekly report. This may range from 0-6 piles.

ASFV information for the weekly report will, at minimum, include the L5 (and/or mean of top 10%) of received levels comparison to maximum allowable received levels at 750 m. Additional information may include a statistical comparison of the received level distribution to the baseline distribution established during the thorough SFV, range estimates for the ASFV based on propagation determined during the thorough SFV, running total of ensonified area compared to predicted totals for the project.

2.7.4. ASFV corrective measures

Because the distribution of received levels with hammer energy establishes sound production characteristics and thorough SFV measurements in shallow and deep water establish propagation in the area, all relevant information is available to gauge potential modeled range exceedance from an ASFV measured at 750 m. The procedure for assessing ASFVs and proceeding with any actions (corrective or otherwise) outlined below are only valid and to be followed to the extent that the procedure does not conflict with the related requirements as stated in the LOA, COP T&C, and the NMFS BiOp.

The actions taken in response to ASFV results are:

- If the PK, and SPL L5 (or mean of top 10%) and cumulative SEL are less than the adjusted (by depth and SVP) maximum allowable received levels and the comparison of the distribution of top 10% of received levels from the ASFV to the baseline established during the thorough SFV indicates that they do not differ, then no immediate action is taken, and the results are reported with the next weekly report,
- If the PK and SPL L5 (or mean of top 10%) and cumulative SEL are less than the adjusted (by depth and SVP) maximum allowable received levels but the distributions are found to differ such that the ASFV distribution is significantly larger than the baseline distribution, then production systems (NAS, hammer energy used, number of strikes required, ...) will be reviewed and action taken if appropriate. Results will be reported with the next weekly report,
- If any of the PK and SPL L5 (or mean of top 10%) and cumulative SEL are greater than the adjusted (by depth and SVP) maximum allowable received levels and the distributions are found to differ such that the ASFV distribution is significantly larger than the baseline distribution, then production systems (NAS, hammer energy used, number of strikes required, ...) will be reviewed:
    - If the cause is evident and correctable, then corrective action will be taken, piling will continue, and notice, with corrective action, will be given to the agencies as soon as possible. The ASFV results and incident will also be included in the next weekly report (along with any available follow up information),
    - If a cause cannot be identified or can be identified but not corrected, then, if the predicted range exceedance is <1500 m, piling will continue, the incident and actions reported to the agencies as soon as possible, and included in the next weekly report (along with any available follow up information). A meeting will be scheduled with regulating agency representatives to determine if any additional action is necessary.

        - If additional, permanent, action is taken that could reduce the ranges, then an additional thorough SFV to verify the ranges will be done for the next similar pile type (e.g., if the issue was identified for hard to drive piles while the ranges for standard to drive piles were acceptable, and the next pile(s) are standard to drive, then a thorough SFV would be done on the next hard to drive pile. Similarly, if the issue was identified for jacket foundations, it would not apply to monopiles).

    - If a cause cannot be identified or can be identified but not corrected, then, if the predicted range exceedance is >1500 m, monitoring zones will be increased, piling will continue, the incident and actions (e.g., increased monitoring zones) will be reported to the agencies as soon as possible and included in the next weekly report (along with any available follow up information). A meeting will be scheduled with regulating agency representatives to determine if any additional action is necessary.

        - If additional, permanent, action is taken that could reduce the ranges, then an additional thorough SFV to verify the ranges will be done for the next similar pile type (e.g., if the issue was identified for hard to drive piles while the ranges for standard to drive piles were acceptable, and the next pile(s) are standard to drive, then a thorough SFV would be done on the next hard to drive pile. Similarly, if the issue was identified for jacket foundations, it would not apply to monopiles).

2.8. Project Reporting

The LOA and COP T&Cs, and BiOp have been issued and provide reporting requirements for sound field monitoring. Initial results of the field measurements during a thorough SFV will be required by NMFS, USACE, and BOEM/BSEE in interim reports as soon as they are available, but no later than 48 hours following the completion of each TSFV-monitored foundation. All reporting requirements to BSEE will follow JOINT NTL 2023-N01 Appendix B. Also, where the LOA requires notifications or submittals to NMFS, a report will be made to NMFS Office of Protected Resources (OPR), and where the BiOp requires notification or submittals to NMFS, a report will be made to GARFO. Where the LOA and BiOp both require a notification or submittal, both NMFS OPR and GARFO will be included in the reporting, respectively. Where specificity is lacking in any other Project permit (i.e., COP T&C), the report will be made to both NMFS OPR and GARFO.

Project internal reports from JASCO:

- Initial results of a thorough SFV will be processed, compiled, and reported to the contractor (Dominion Energy/DEME) as soon as possible but no longer than 36 hours of sound field measurements as interim report. DEME will share the interim report results with the bubble curtain contractor.
- Initial results of an ASFV will be compiled per minimum 3 and maximum 6 MP and delivered in the following weekly draft report to the contractor (Dominion Energy/DEME).
- A thorough SFV and NAS assessment report (including raw data and metadata) describing the results of the field data collection efforts and comparing the field measurements relative to the model within 60 days of data collection to the contractor (Dominion Energy/DEME).

Dominion Energy will report to Regulators:

- Initial results of a TSFV no longer than 48 hours of sound field measurements as interim report.
- Initial results of an ASFV will be compiled per 3 to 6 MP and delivered in the following final weekly report.
- An annual final report of all TSFV and ASFV will be provided within 90 days of seasonal completion of pile driving activity. The reports will include (as applicable):
    - Peak sound pressure level (SPLpk), root-mean-square sound pressure level that contains 90% of the acoustic energy (SPLrms), single strike sound exposure level (SELss), integration time for SPLrms, distances where the received SPLrms decay to 160 dB, as well as integration time for such SPLrms, SELss spectrum, and 24-hour cumulative SEL extrapolated from measurements. All these levels will be reported in the form of (1) median, (2) mean, (3) maximum, and (4) minimum.
    - Root-mean-square sound pressure level (SPLrms) and cumulative sound exposure level (SEL) during vibratory driving, distances where the received SPLrms decay to 120 dB, as well as SEL spectrum, and 24-hour cumulative SEL extrapolated from measurements. All these levels will be reported in the form of (1) median, (2) mean, (3) maximum, and (4) minimum.
    - Root-mean-square sound pressure level (SPLrms) and sound exposure level (SEL) spectral ambient levels prior to and following pile driving activity.
    - The sound levels reported must be in median and linear average (i.e., taking averages of sound intensity before converting to dB).
    - A description of depth and sediment type at the recording location.
    - Number of strikes per pile measured (hammer logs and penetration depth), one-third octave band (or decidecade) spectrum and/or power spectral density.
- All raw data must be sent to the NCEI Passive Acoustic Data archive within 90 days following the completion of each pile-driving season and the Lessee must follow NCEI guidance for packaging the data.

All interim and final monitoring reports will be submitted to protectedspecies@BSEE.com, PR.ITP.MonitoringReports@noaa.gov, itp.daly@noaa.gov, and GARFO at nmfs.gar.incidental-take@noaa.gov.

3. Attachments

Attachment E-1: Hydrophone Sensitivity

Three different sensitivity GTI hydrophones (-210, -200, and -165 dB re 1V/µPa) will be used on the moorings for the SFV. The closest two stations will have the least sensitive hydrophones, -210 dB re 1V/µPa, to avoid saturation during pile driving events. The middle stations will use -200 dB re 1V/µPa hydrophones, and the farthest station will have one -200 dB re 1V/µPa along with one higher sensitivity hydrophone, -165 dB re 1V/µPa, so that ambient levels will be captured along with the pile driving sounds. Hydrophone sensitivity as a function of frequency is shown in Figures 7 - 9.

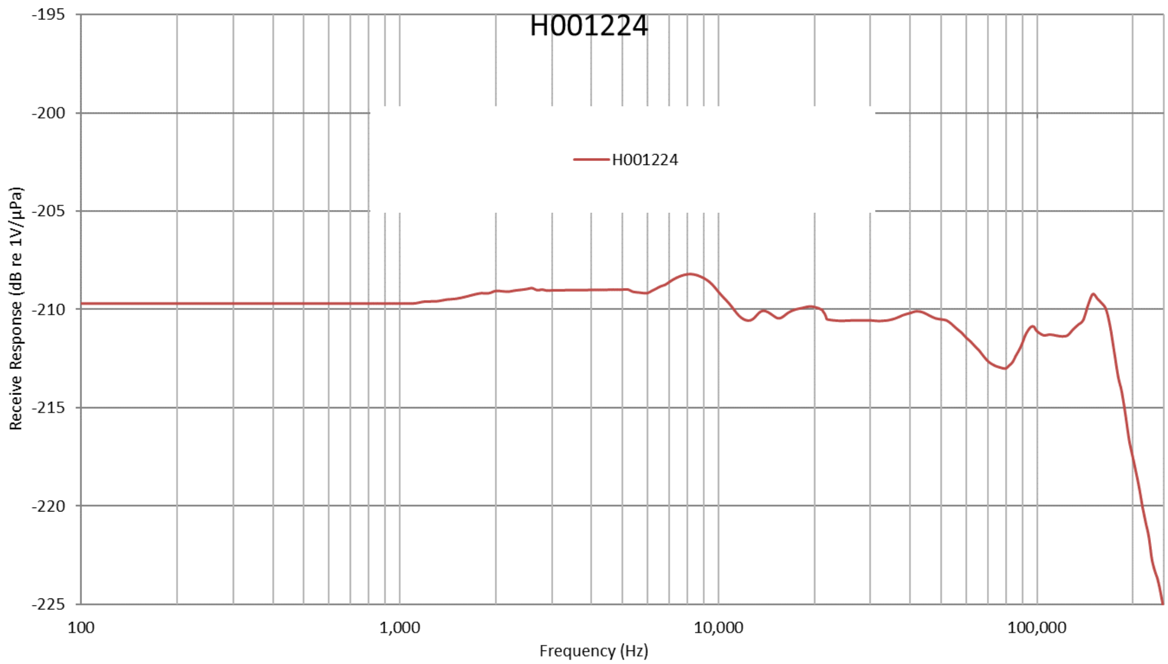


Figure 7. Spectral response of -210 dB re 1V/µPa GTI M36-V00-902 hydrophones

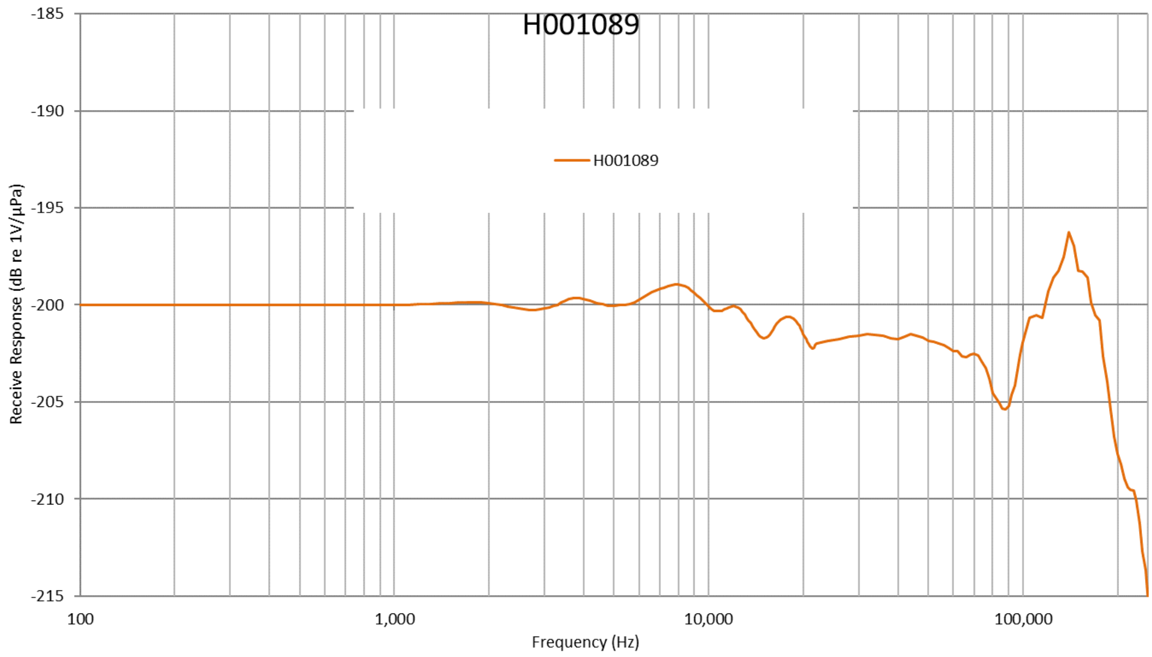


Figure 8. Spectral response of -200 dB re 1V/µPa GTI M36-900 hydrophones

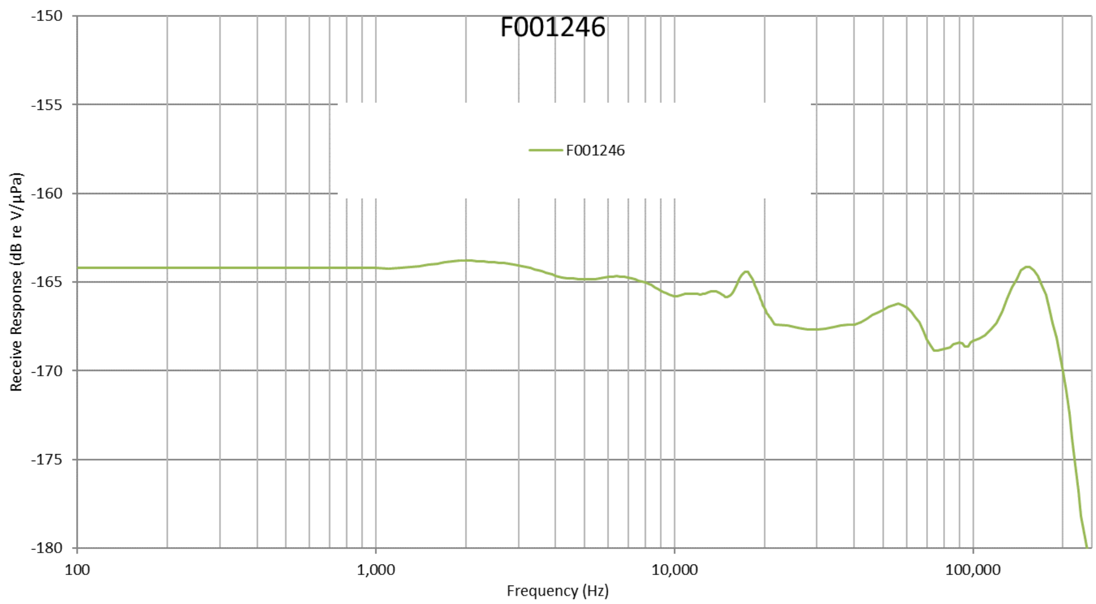


Figure 9. Spectral response of -165 dB re 1V/µPa GTI M36-V35-900 hydrophone

Attachment E-2: Deployment and Retrieval of Recording Equipment

Baseplate deployment consists of preparing the equipment, lowering the baseplate to the seabed then deploying the ground line and anchor weight. Retrieval reverses these steps. The anchor weight is first retrieved by lifting the surface float then the ground line is used to pull up the baseplate recorder. Deployment and retrieval positions of AMARs will be recorded using GPS equipment or alternatively precise methodology. Detailed steps for deploying the baseplate recorders are listed below:

Task: Prepare equipment for deployment

1. Tie the stinger with anchor over the side at a location near the A-frame but as far away as practical from the deployment area. Secure the anchor to a deck cleat and positioned near the water surface with passthrough tagline.
2. Attach and wind the upper 10 m wire cable onto the winch. The free end of the wire cable should be the one with the shackle (not the one with the universal joint).
3. With safety shackle, connect free end of wire cable through the A-fame to the lifting point of the baseplate (top of the triangular structure).
4. Attach lowering line which acts as tag line to baseplate to control movement during deployment.

Task: Deploy baseplate

1. Lift AMAR baseplate over the vessel stern with the A-frame and slowly lower it to the seafloor while using the ground line as a tag line.
2. Release the deployment rig by pulling in the pass-through lowering line when the mooring is on bottom.

Task: Deploy ground line

1. Once the AMAR is on the seafloor, the vessel starts moving away from the deployment location, in a direction such that the AMAR ground line is guided away from the vessel, against the current if possible. Vessel speed should be 1–2 kts during this step. JASCO field team will discuss a direction with the vessel crew prior to deployment to best accommodate weather, current speed and direction, as well as any other considerations identified.
2. As the vessel moves away from the deployment location, pay out the ground line as needed, being careful not to pay out excess line while maintaining minimum tension.

Task: Deploy anchor weight

1. Prepare to untie the anchor assembly before the line is taut. Be careful not to drag the AMAR from its deployment position.
2. Release the anchor assembly into the water using a pull through tag line to prevent shock loading.
3. Lower anchor as far as possible into water with pull through tag line and release once ground line has been paid out.
4. Retrieve tag line.

Task: Debriefing meeting

Hold debrief meeting to capture lessons learned

Attachment E-3: Interim TSFV template

Underwater Sound Field Verification

CVOW-C Interim Report: Monopile GRXX

17 May 2024

Submitted to:

DEME Offshore US

Authors:

Author 1
Author 2
Author 3

P00XXXX-001
Document 0XXXXX
Version 1.0

JASCO APPLIED SCIENCES

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Contents

Figures

Tables

1. Summary

1.1. Pile Location and Monitoring Summary

Pile GRXX is a XX m diameter pile driven at the CVOW-C lease area (OCS-A-0483) on May X 2024 (Table 1). Five autonomous acoustic monitoring systems were deployed by JASCO (Section 2.1) on behalf of Dominion Energy to measure sound levels at ranges of 750 to 9,000 m from the pile (Table 2). Pile driving occurred between *XX:XX:XX* and *XX:XX:XX May X*th Coordinated Universal Time (UTC). Start and end times reported here were retrieved from the pile driving log for GRXX provided by DEME.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of decidecade-band single-strike sound exposure levels (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 1. Summary of Pile GRXX activities, X May 2024.

Date	2024-05-0X
Pile-Driving Activity	
Pile identifier	GRXX
Pile diameter	
Water depth	
Sediment Type	
Vibratory hammer model	
Vibratory piling duration	
Vibratory piling pentration	
Impact hammer model	
Total hammer strikes	
Total penetration:	
Pile Driving Start Time (hh:mm:ss)	
Pile Driving End Time (hh:mm:ss)	
Net duration of pile driving (hh:mm:ss)	
Maximum single strike energy	
Total energy transferred	
Noise Attenuation Systems (NAS)	
BBC (XXX m length)	
BBC (XXX m length)	

Table 2. Summary of Autonomous Multichannel Acoustic Recorders (AMAR) locations and measured sound levels. Computed levels are shown for the L_{max}. Detailed sound level plots are contained in Appendix A.

Location (nominal)	Recorder ID	Distance (m)	Water depth (m)	Impulses detected (clipped)	Max PK (dB re 1 µPa)	cSEL (dB re 1 µPa^2·s)
750	AMAR-XXX					
3000	AMAR-XXX					
6000	AMAR-XXX					
9000	AMAR-XXX					
750 @ 90	AMAR-XXX					

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated from a logarithmic regression fitted to the higher received level (among hydrophones at each station) for the L5 (95th percentile) of peak sound pressure level (PK), root-mean-square sound pressure level (SPL), and cumulative sound exposure level (SEL) of the received impulses on each recorder (Impact Pile Driving

Table 3 and Figure 1). The logarithmic regression was performed as a single function in the form of A·Log(r), where A is the attenuation coefficient and r is the distance from the source (Figure 1). To include absorption of acoustic energy, a logarithmic regression fit of the form A·Log(r) + α·r, where α is the absorption coefficient, was also done (Figure 2).

1.2.1. Impact and Vibratory Pile Driving

Table 3. Estimated distances to the NMFS physiological thresholds vibratory driving of GRXX. Expected ranges are the permitted 10-dB attenuation ranges for a WTG-Monopile 1 – Standard to Drive pile listed in Table 2 and 3 in the IHA, and Table 34, 37, and 40 of BiOp.

Group	Level A: cSEL*			
	Level (dB re 1 µPa2·s)	Expected (m)	Measured (m)	Measured w/ absop. (m)
LFC	199			
MFC	198			
HFC	173			
PPW	201			
ST	220			

* At the end of pile driving

Table 4. Estimated distances to the NMFS behavioral thresholds for vibratory driving of GRXX as a WTG-Monopile 1 – Standard to Drive pile listed in Table 2 and 3 in the IHA, and Table 34, 37, and 40 of BiOp

	Level B: SPL			
Group	Threshold Level (dB re 1µPa)	Expected (m)	Measured (m)	Measured w/ absorp. (m)
MM	120			
ST	175			
AS	150			

Table 5. Estimated distances to the NMFS physiological thresholds impact driving of GRXX. Expected ranges are the permitted 10-dB attenuation ranges for a WTG-Monopile 1 – Standard to Drive pile listed in Table 2 and 3 in the IHA, and Table 34, 37, and 40 of BiOp.

Group	Level A: PK				Level A: cSEL*			
	Level (dB re 1µPa)	Expected (m)	Measured (m)	Measured w/ absorp. (m)	Level (dB re 1 µPa2·s)	Expected (m)	Measured (m)	Measured w/ absop. (m)
LFC	219				183			
MFC	230				185			
HFC	202				155			
PPW	218				185			
ST	232				204			
AS	206				187			

* At the end of pile driving

Table 6. Estimated distances to the NMFS behavioral thresholds for impact driving of GRXX as a WTG-Monopile 1 – Standard to Drive pile listed in Table 2 and 3 in the IHA, and Table 34, 37, and 40 of BiOp

	Level B: SPL			
Group	Threshold Level (dB re 1µPa)	Expected (m)	Measured (m)	Measured w/ absorp. (m)
MM	160			
ST	175			
AS	150			

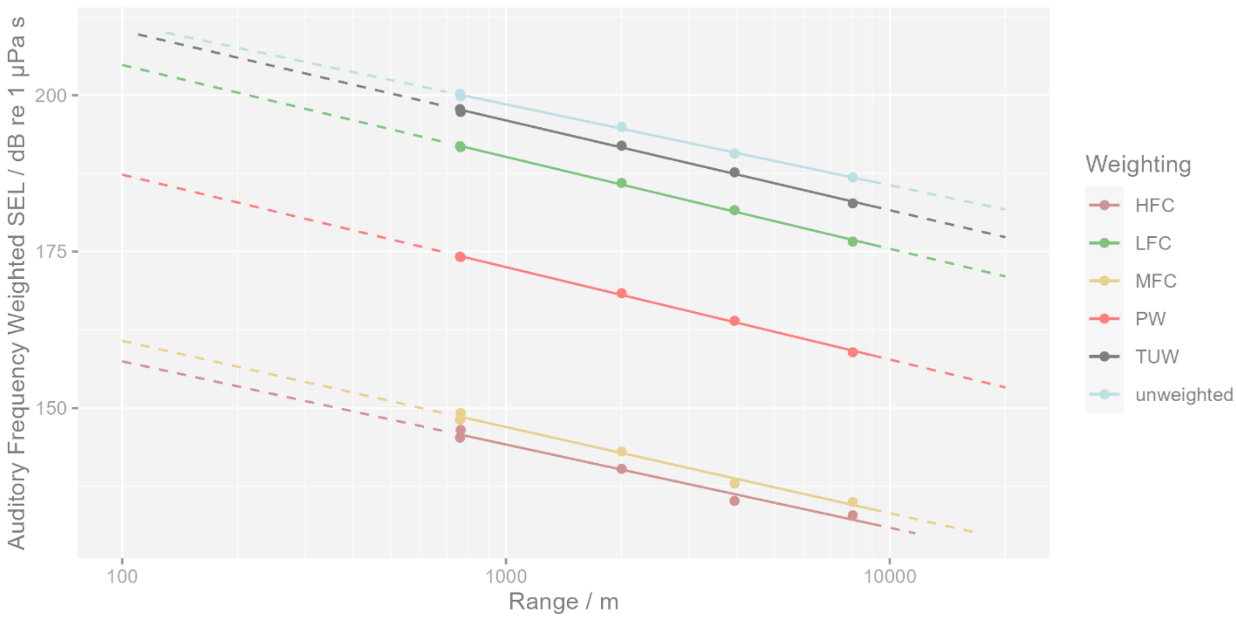

Figure 1. Regression without absorption based on the maximum cumulative SEL from each recorder from pile driving of GRXX on X May 2024. The cSEL represents total sound energy measured during the pile driving. The regression fit was an equation of the form A Log(r), where A is the attenuation coefficient and r is the range.

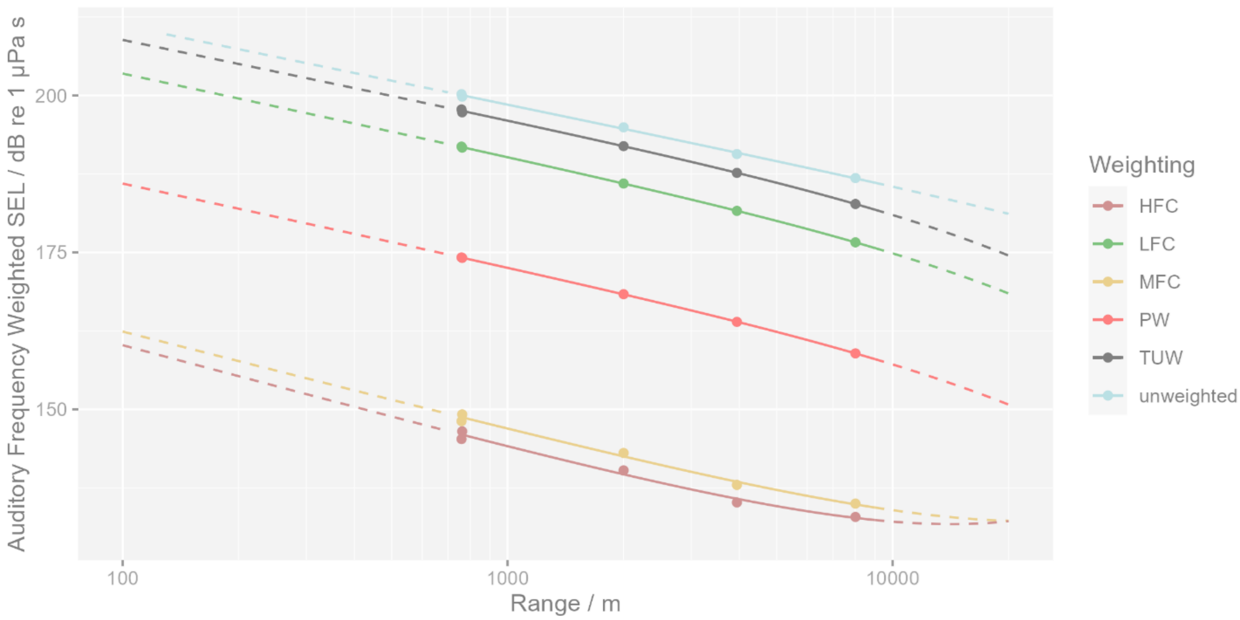

Figure 2. Regression with absorption based on the maximum cSEL from each recorder from pile driving of GRXX on X May 2024. The cSEL represents total sound energy measured during the pile driving. The regression fit was an equation of the form A Log(r) - αr, where A is the attenuation coefficient and r is the range, and α is the acoustic coefficient of absorption.

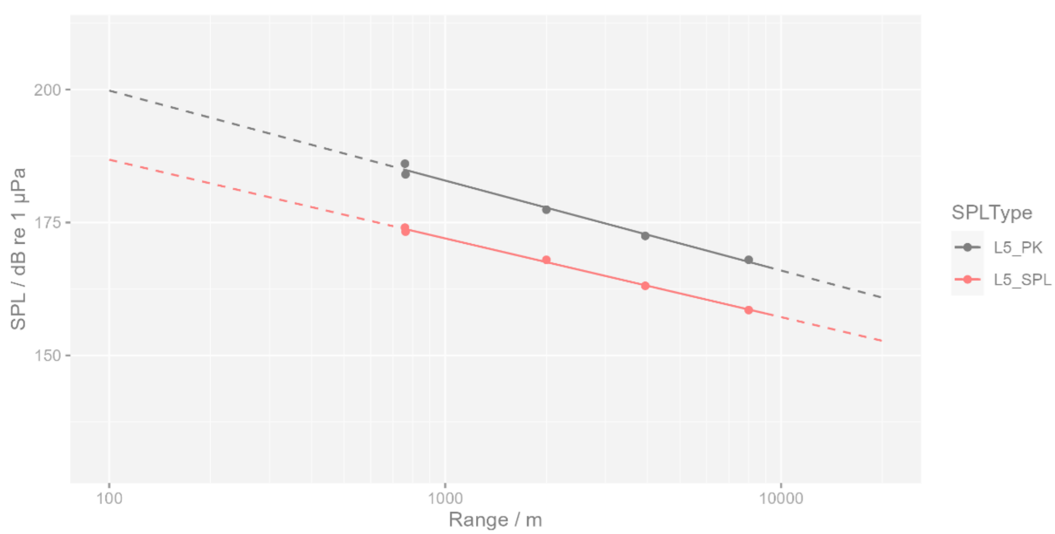

Figure 3. Regression without absorption based on measured L95 PK and SPL maxima for vibratory and impact driving between hydrophones at each recording station from pile driving of GRXX on X May 2024. The regression fit was an equation of the form A Log(r), where A is the attenuation coefficient and r is the range.

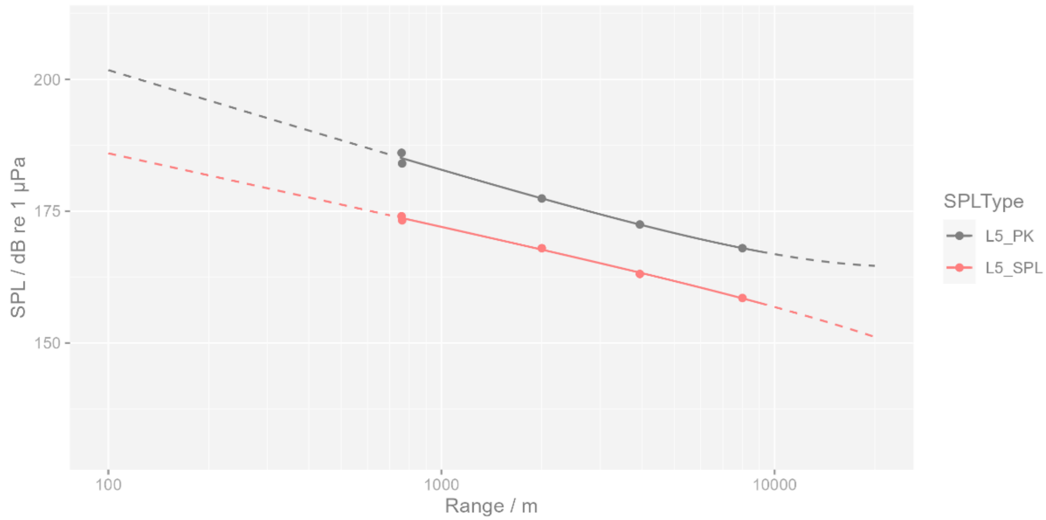

Figure 4. Regression with absorption based on the measured L95 PK and SPL maxima for vibratory and impact driving between hydrophones at each recording station from pile driving of GRXX on X May 2024. The regression fit was an equation of the form A Log(r) - αr, where A is the attenuation coefficient and r is the range, and α is the acoustic coefficient of absorption.

1.3. Signal kurtosis and rise times

The kurtosis of the received signals was calculated at each of the recording locations (Figure 5). The pulse duration time of the received signals was calculated at each of the recording locations (Figure 6).

Figure 5. Signal kurtosis for each strike at each recording location.

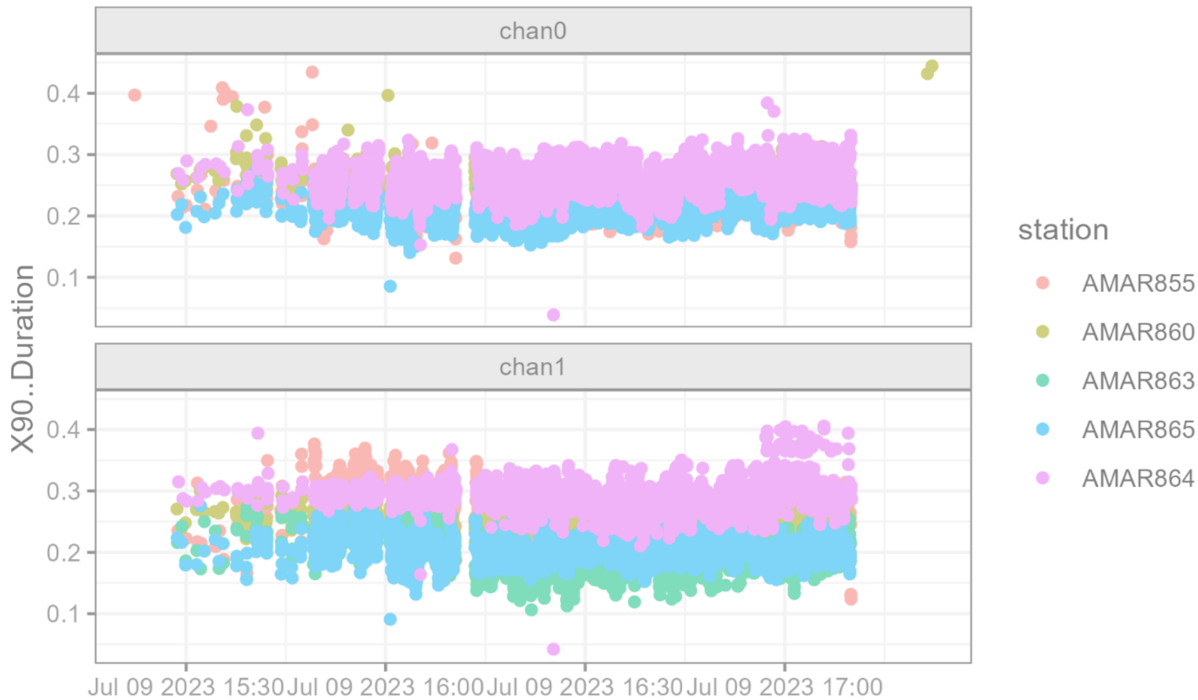

Figure 6. Pulse duration for each strike at each recording location.

1.4. Observations

To be filled out when observations are completed:

The impact hammer performed XXXX strikes and operated at a hammer energy up to XXXX kJ and total energy of XXXXXX [kJ] (Section 1.5.1). Data were collected at the nominal recording locations (750, 3000, 6000, and 9000 m), and ranges to the regulatory (Level A and Level B) thresholds were determined for the different hearing groups by fitting the data with a spreading loss function and a spreading loss function with absorption.

For Level B, the range for marine mammals was found to be XXXX and XXXX m with and without absorption.

1.5. Pile Driving Logs

1.5.1. Vibratory Hammering Log

1.5.2. Impact Hammering Log

Figure 7. Hammering log for the impact pile driving of X May 2024.

Figure 8. Hammer energy over time for impact pile driving of GRXX on X May 2024.

2. Sound Velocity Profile

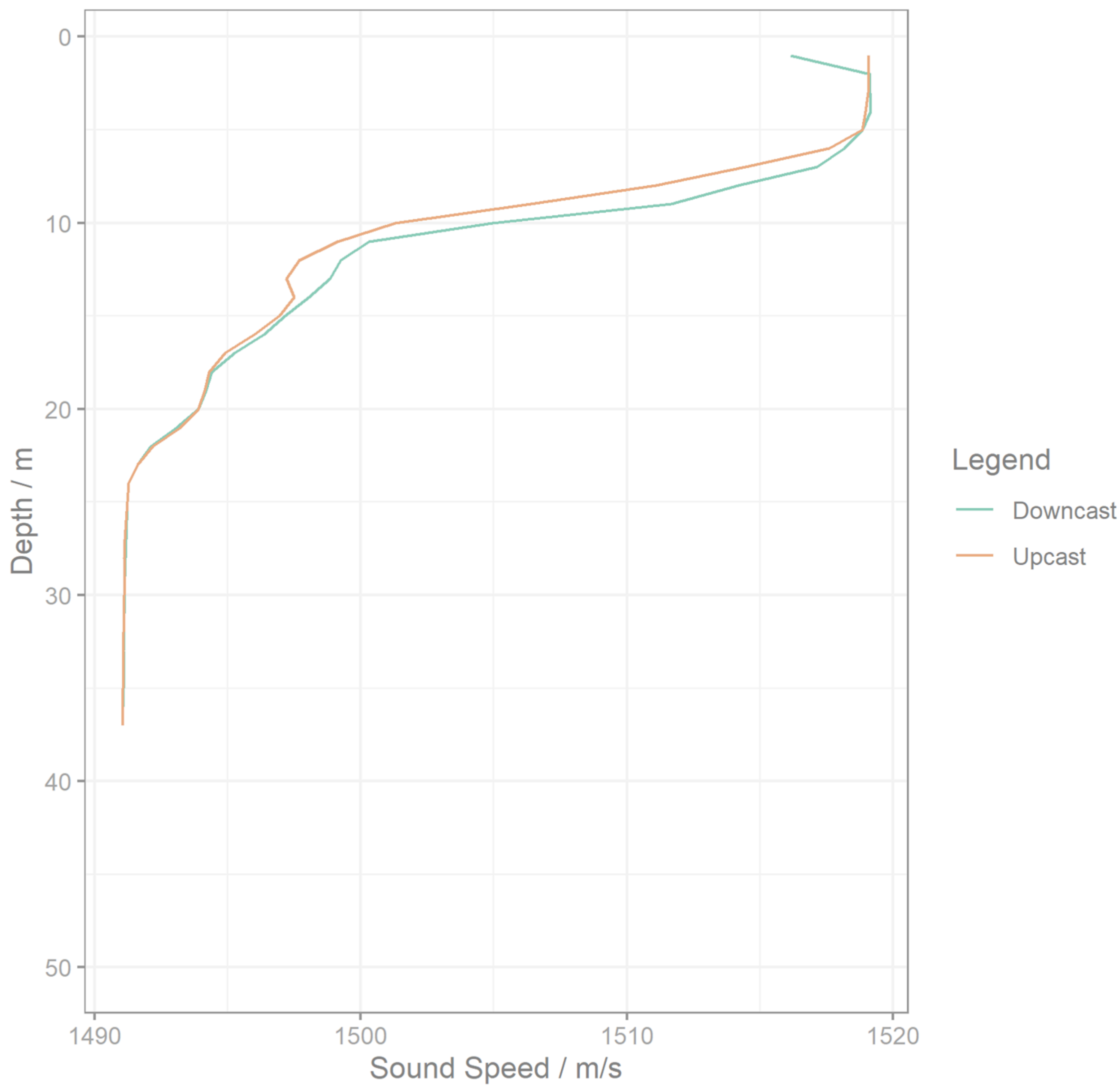

Figure 9. CTD casts performed at each monitoring location, consequent with the deployment of each monitoring system on X May 2024. Profiles display in-situ sound speed down to XX m. To create smooth profiles that can be used in tandem with bathymetry data for modeling, the in-situ data were extended to XX m using the Empirical Orthogonal Functions (EOFs) of the in-situ casts in combination with historic averaged sound speed profiles from the month of XXXX.

2.1. Autonomous Monitoring Equipment

Table 7 provides information about the autonomous monitoring equipment used on X May 2024. Table 8 provides the locations of the autonomous recorders.

Table 7. Autonomous monitoring equipment for GRXX, X May 2024.

Equipment used					Units deployed
Acoustic data logger					
Model:	AMAR G4 Acetal (JASCO Applied Sciences)				5
PAMLab	9.7.3				1
Hydrophone					
Station	AMAR	Channel	Height from Bottom (m)	Model	Sensitivity dB re 1 V/µPa

Table 8. Locations (WGS84) and deployment times (EDT) of the Autonomous AMAR monitoring stations on X May 2024.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Water depth (m)	Distance to pile (m)

Appendix A. Pile Driving Plots

A.1. 750 m

A.1.1. Vibratory Pile-Driving Sound Levels at 750 m

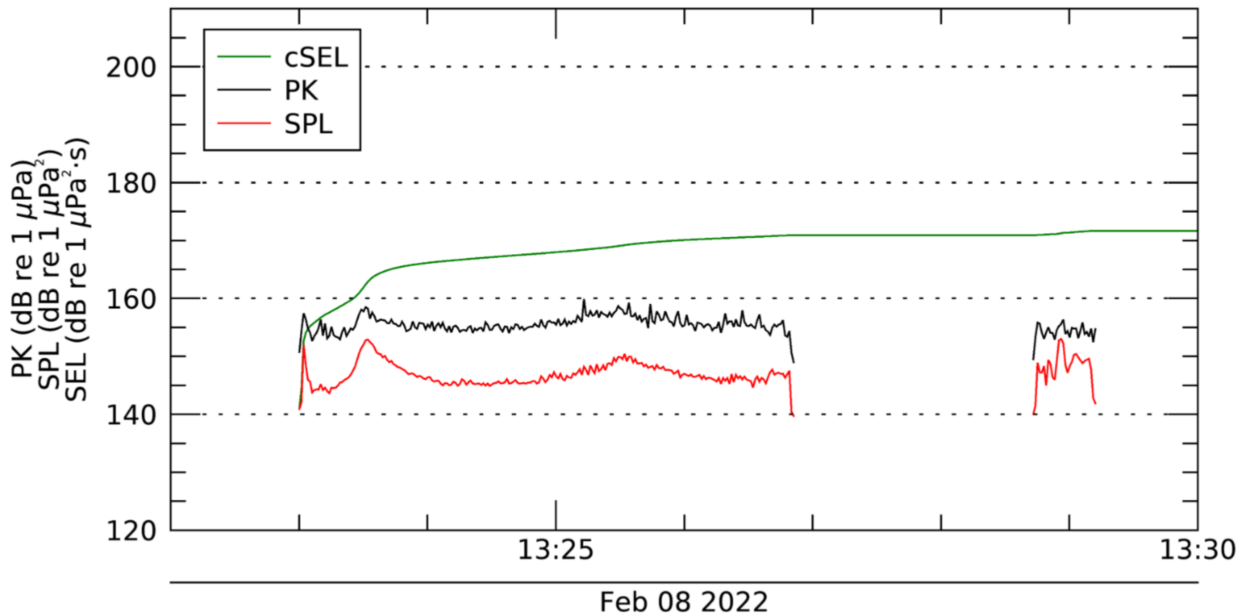

Figure A-1. Vibratory Pile Driving 1 s rms SPL and cumulative SEL versus time (UTC) for Pile GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

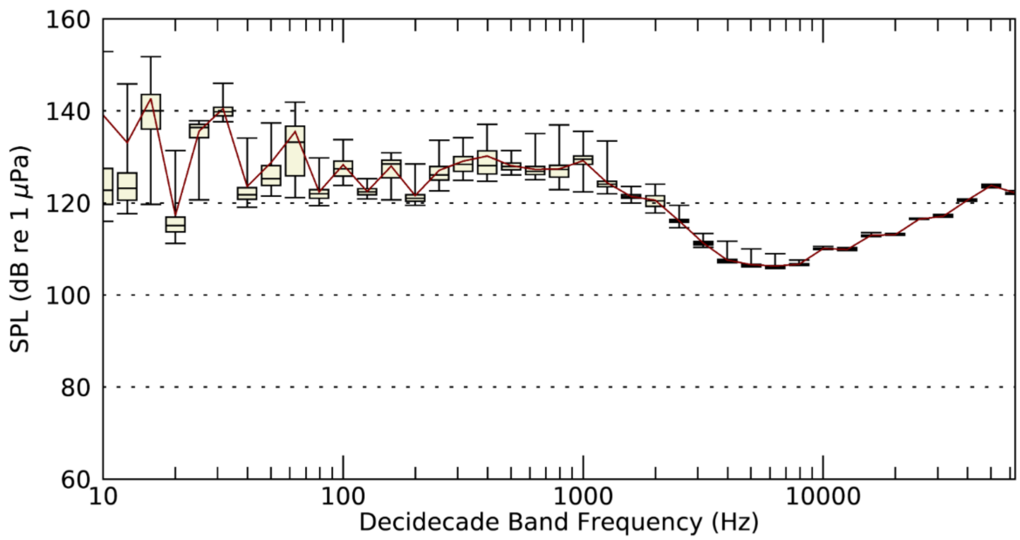

Figure A-2. Distribution of decidecade band 1 s SPL for the pile driving of GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table A-1. Sound levels for the pile driving of GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1.

Sound level statistic*	rms SPL (dB re 1 µPa)
L_{max}	
L_5	
L_{25}	
L_{50}	
L_{75}	
L_{95}	
L_{mean}	

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.1.2. Impact Pile-Driving Sound Levels at 750 m

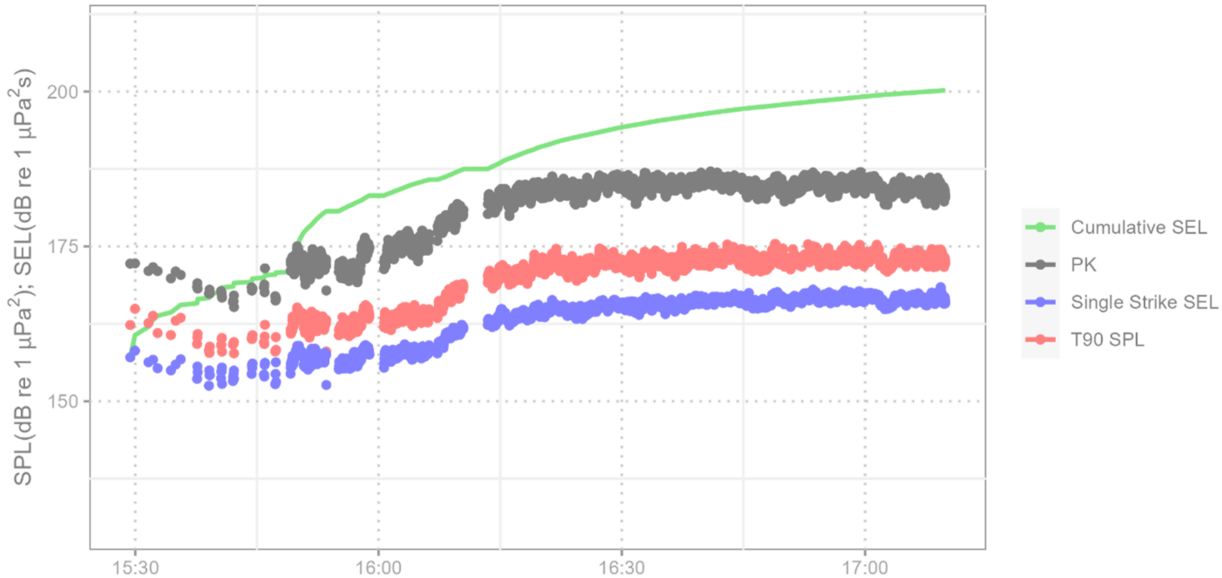

Figure A-3. Impact Pile Driving: Peak SPL, rms SPL, SELss and cSEL versus time (UTC) for the pile driving of Pile GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

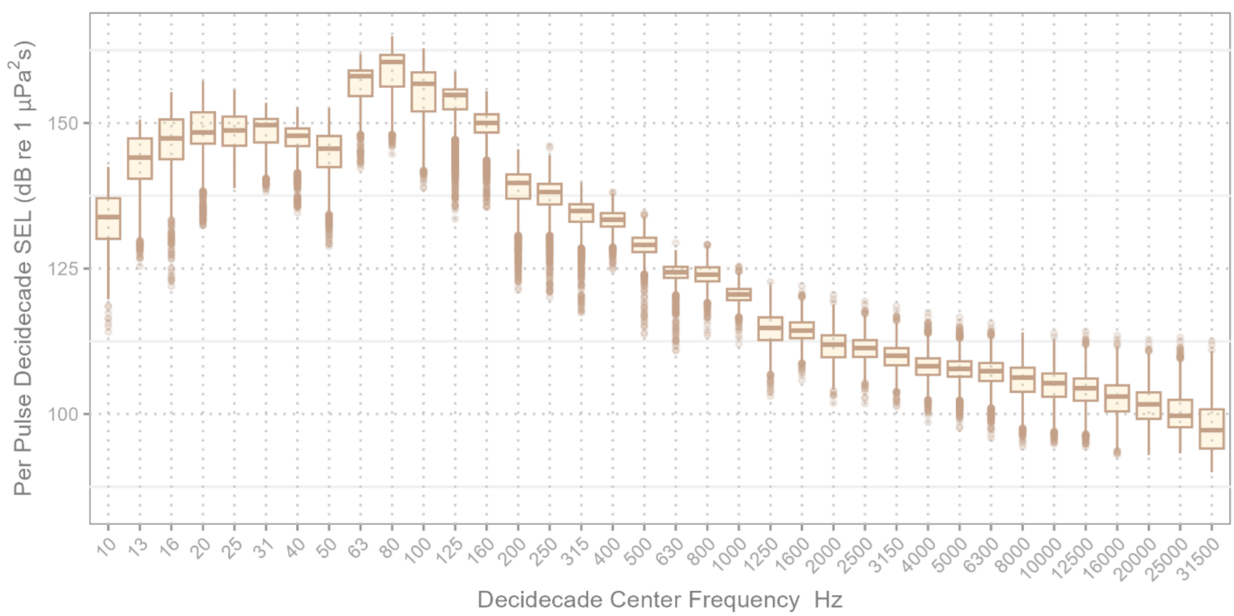

Figure A-4. Distribution of decidecade band SELss for the pile driving of GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table A-2. Sound levels for the pile driving of GRXX measured XXX m from the pile at monitoring station XXXXX for Channel 1.

Sound level statistic*	PK (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa²·s)
L_{max}			
L_5			
L_{25}			
L_{50}			
L_{75}			
L_{95}			
L_{mean}			

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.2. 750 m 90 degrees

A.2.1. Vibratory Pile-Driving Sound Levels at 750 m 90 degrees

A.2.2. Impact Pile-Driving Sound Levels at 750 m 90 degrees

A.3. 3000 m

A.3.1. Vibratory Pile-Driving Sound Levels at 3000 m

A.3.2. Impact Pile-Driving Sound Levels at 3000 m

A.4. 6000 m

A.4.1. Vibratory Pile-Driving Sound Levels at 6000 m

A.4.2. Impact Pile-Driving Sound Levels at 6000 m

A.5. 9000 m

A.5.1. Vibratory Pile-Driving Sound Levels at 9000 m

A.5.2. Impact Pile-Driving Sound Levels at 9000 m