DUWAMISH RIVER PEOPLES PARK AND HABITAT AREA
T-117 HABITAT RESTORATION PROJECT – SITES 23 & 25

TEST PILE COMBINED MONITORING REPORT

PREPARED FOR:

PORT OF SEATTLE

PREPARED BY:

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MAY 2021

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1 EXECUTIVE SUMMARY

The Duwamish River People's Park and Habitat Area - Terminal 117 Habitat Restoration Project (also known as T117, or Sites 23 & 25 per the Port's Lower Duwamish River Habitat Restoration Plan) is located south of the South Park Marina on the Duwamish River. It will restore 14 acres of estuarine habitat along the river, including subtidal aquatic area, intertidal sediment slopes, intertidal marsh, native riparian/forested buffer, and shoreline access (Figure 1). Restoration efforts will create upland habitat and restore priority habitat for Chinook salmon and other imperiled species along 2,000 feet of the Duwamish River shoreline. The site has been identified by other local, state, tribal, and federal officials as a high priority habitat restoration area.

As part of this project, the Port is installing a public pedestrian pier and viewpoint in the Duwamish, which requires support pile and consequently pile driving. Consistent with the Port's commitment to be good stewards of the Puget Sound environment, including by reducing underwater noise, a novel pile design was tested as part of this project. The Port installed standard pipe pile and double-walled mandrel pile to assess the efficacy of the latter at reducing noise propagation through both the water and sediment.

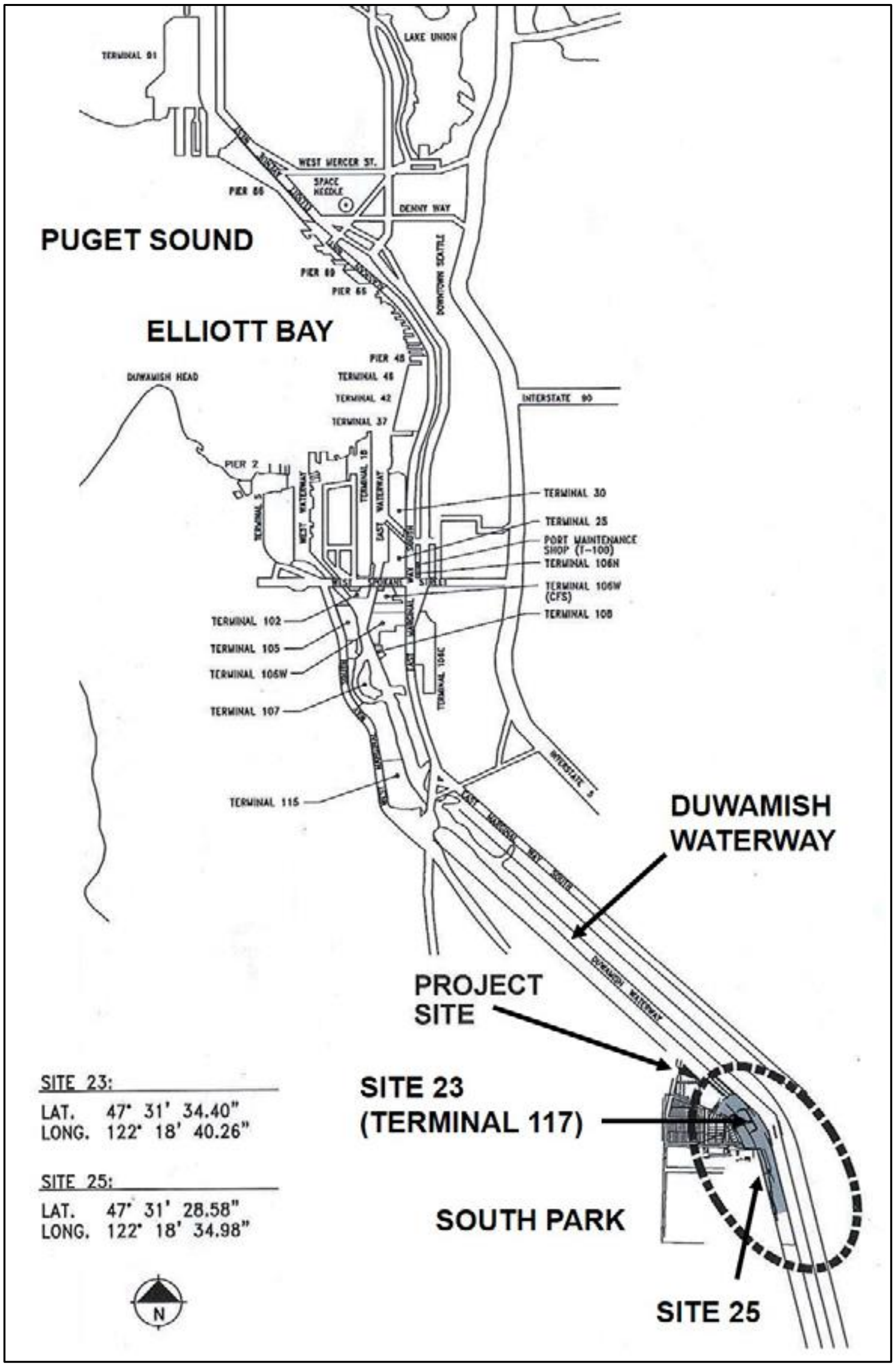
Three types of data were collected to inform the comparison of mandrel pile and single walled pipe pile: underwater noise, atmospheric (in air) noise and ground vibration. This report contains the methods and results for underwater noise monitoring (hydro-acoustics) as well as the results and findings of the in-air and ground vibration monitoring.

2 INTRODUCTION

Impact pile driving is employed to install pile in locations where vibratory driving methods are inadequate. Impact hammers strike the pile, transferring energy to the pile, resulting in a temporary deformation, which in turn creates a compression (sound) wave in surrounding waters and substrate. As the compression wave reaches the sediment layer, there is an impedance differential between the pile and sediment, causing the wave to reflect upward. This upward-reflected wave results in an upward moving cone-shaped acoustic field (Reinhall et al. 2015). Current attenuation methodologies for underwater noise include bubble curtains, pile caps, cofferdams, sleeves, and driving pile in the dry, but these methods are often expensive, time consuming, and inconsistently effective. Reinhall pile were developed as a noise attenuation method that also reduces noise transmission through the sediment. These pile are double-walled, consisting of two concentric tubes connected by a special driving shoe with an air gap between the tubes. They are installed using traditional hammer equipment, but only the inner pipe is struck. Both tubes are driven into the sediment, so the insulating layer (the air gap) penetrates the sediment with the pile being struck. A modification to the Reinhall pile, the mandrel pile, allows for the inner tube to be removed and reused for installation of other pile (Reinhall et al. 2015). The mandrel pile was used for the T-117 Project.

Grette Associates (Grette) was contracted by the Port to record underwater and substrate-borne noise during pile driving of both standard pipe pile (with and without a bubble curtain deployed) and the mandrel pile. The Port conducted in-air monitoring and PanGEO was contracted to record vibration data. This report includes the monitoring results and findings in the following order: 1) hydroacoustic, 2) in-air noise, and 3) vibratory.

Figure 1. T-117 Site Vicinity Map.



3 HYDROACOUSTICS MONITORING REPORT

3.1 Hydroacoustic Monitoring Methods

In-water project elements of the Sites 23 & 25 restoration project include installation of sixteen (16) 24-inch steel support pile to support the approximately 180-foot-long pedestrian pier. Initial design proposed installation of nine (9) double-walled mandrel pile and seven (7) standard pipe pile; eight (8) of the 16 pile were to be included in this hydroacoustic study (four [4] standard and four [4] mandrel) to obtain representative samples of noise levels for each pile type at four tidal elevations (Figure 2.a).

Due to operational issues with the double-walled pile, only three double-walled pile were installed: one upland and two in-water. Hydroacoustic data were collected for the one upland and one of the two in-water pile. The remaining thirteen (13) pile installed were standard pipe pile. Hydroacoustic data were collected for three of these: one upland and two in-water. Pile unique identification numbers are shown in Figure 3.

Figure 2. a) Proposed, and b) Actual hydroacoustic monitoring efforts. Note change of pile type for furthest offshore pile monitored and all pile waterward from Reinhall to standard. North is to the top left.

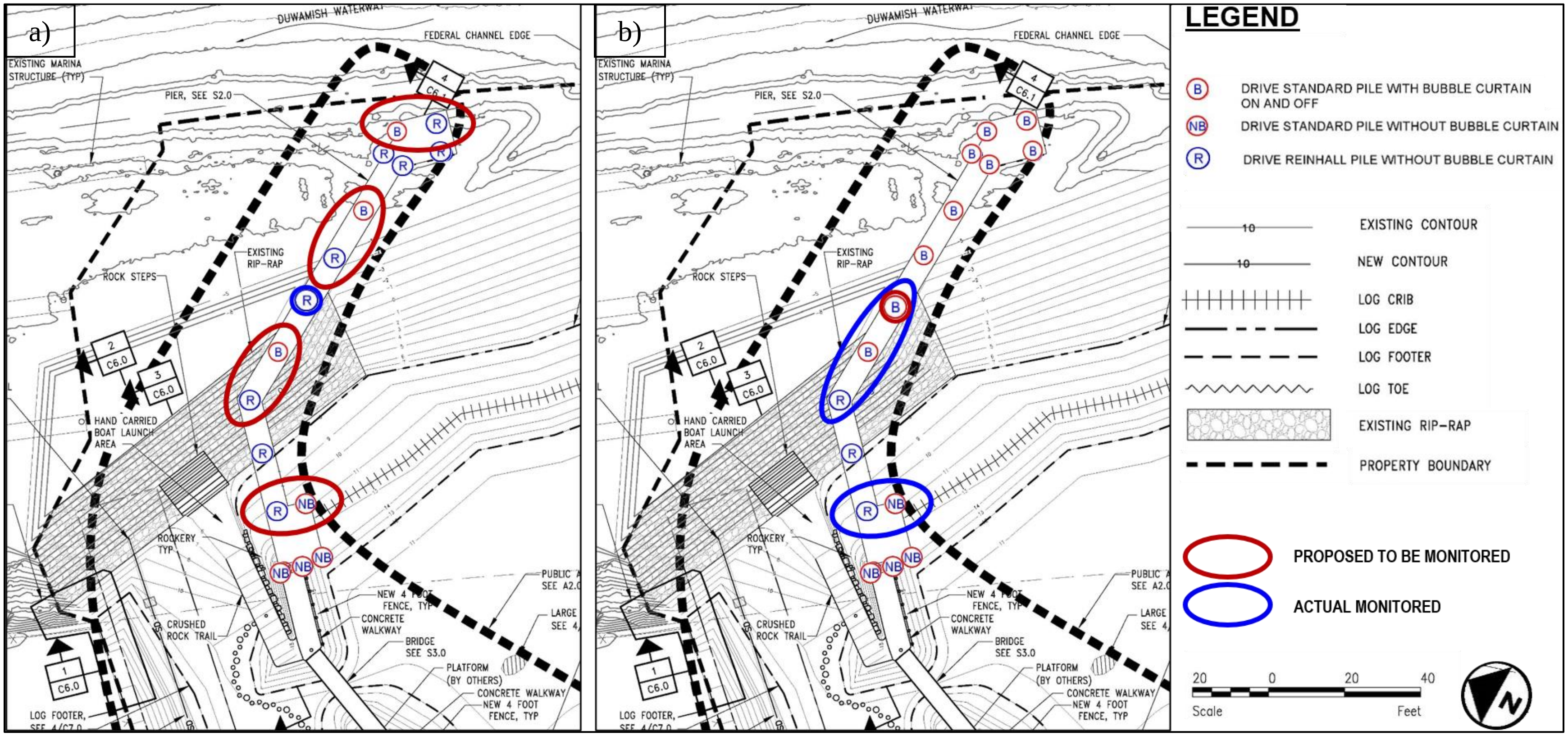
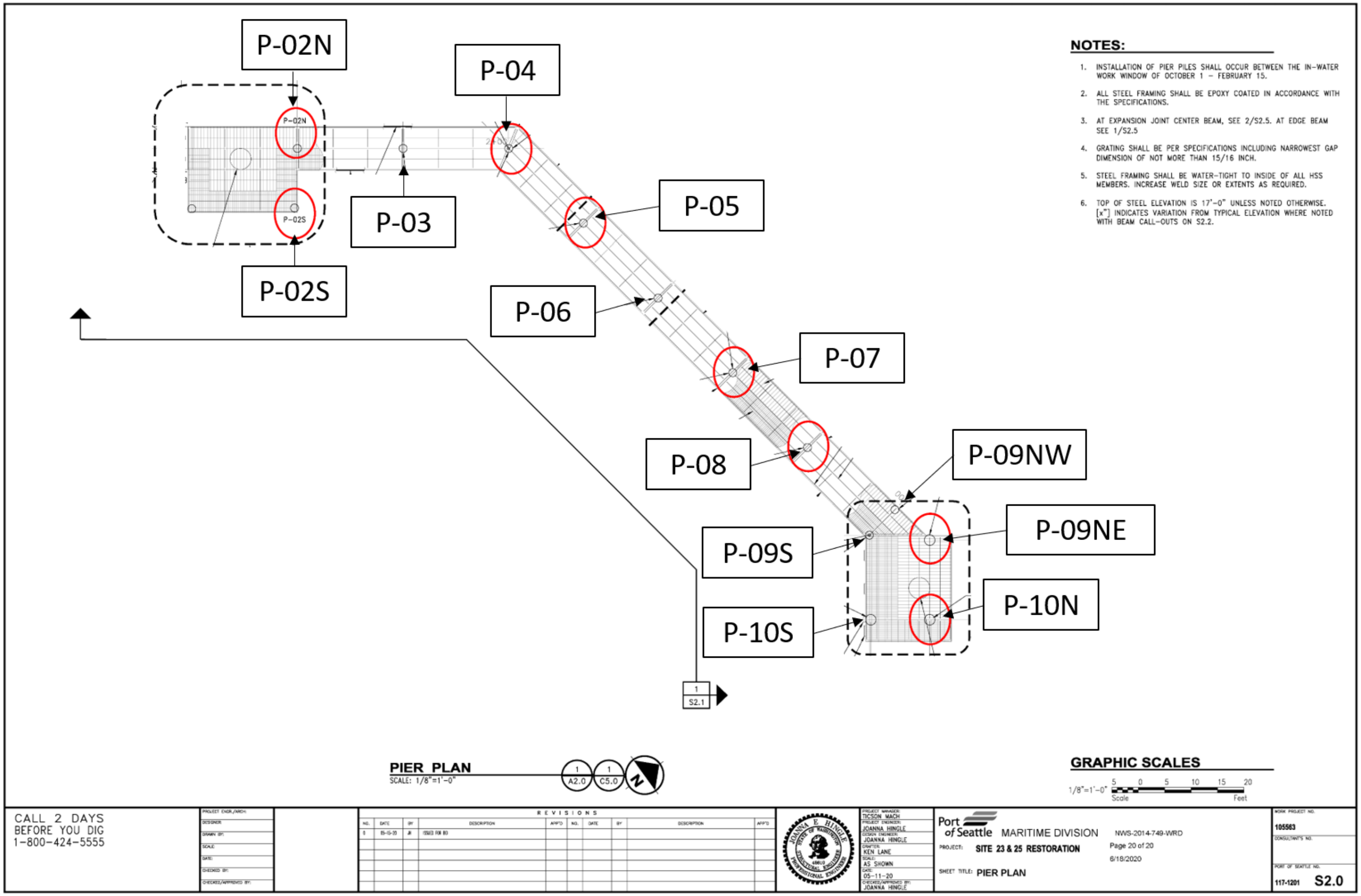


Figure 3. Pile number locations. Note that north is to the top right (rotated 90° clockwise from Figure 2).



NOTES:

1. INSTALLATION OF PIER PILES SHALL OCCUR BETWEEN THE IN-WATER WORK WINDOW OF OCTOBER 1 – FEBRUARY 15.
2. ALL STEEL FRAMING SHALL BE EPOXY COATED IN ACCORDANCE WITH THE SPECIFICATIONS.
3. AT EXPANSION JOINT CENTER BEAM, SEE 2/S2.5. AT EDGE BEAM SEE 1/S2.5
4. GRATING SHALL BE PER SPECIFICATIONS INCLUDING NARROWEST GAP DIMENSION OF NOT MORE THAN 15/16 INCH.
5. STEEL FRAMING SHALL BE WATER-TIGHT TO INSIDE OF ALL HSS MEMBERS. INCREASE WELD SIZE OR EXTENTS AS REQUIRED.
6. TOP OF STEEL ELEVATION IS 17'-0" UNLESS NOTED OTHERWISE. [x"] INDICATES VARIATION FROM TYPICAL ELEVATION WHERE NOTED WITH BEAM CALL-OUTS ON S2.2.

CALL 2 DAYS
BEFORE YOU DIG
1-800-424-5555

PROJECT MANAGER: TICSON MACH
PROJECT ENGINEER: JOANNA HINGLE
DESIGN ENGINEER: JOANNA HINGLE
DRAFTER: KEN LANE
SCALE: AS SHOWN
DATE: 05-11-20
CHECKED/APPROVED BY: JOANNA HINGLE

Port of Seattle MARITIME DIVISION
NWS-2014-749-WRD
PROJECT: SITE 23 & 25 RESTORATION
Page 20 of 20
6/18/2020
SHEET TITLE: PIER PLAN

WORK PROJECT NO. 105563
CONSULTANT'S NO.
PORT OF SEATTLE NO. 117-1201 S2.0

3.1.1 Pile Installation

All pile included in this hydroacoustic monitoring study were impact driven, allowing for cross-comparison of data. Upland standard and Reinhall pile were impact driven with no additional attenuation devices. In-water standard pile were driven with a bubble curtain on except for three approximately thirty-second periods during which the bubble curtain was shut off to record unattenuated noise levels. These periods occurred toward the first third, the middle third, and the final third of the drive. Reinhall pile were driven with no additional attenuation devices beyond the double-walled design.

Pile

All pile included in the study were 24” steel pipe pile. The double-walled mandrel pile included an inner 18” steel pile that was attached at the base by a “shoe.” This inner pile was struck by the impact hammer.

The upland pile (one standard and one double-walled mandrel pile) were installed between +10 and +11 feet MLLW (above the high tide line [HTL]). The in-water pile (one double-walled mandrel and two standard pile) were installed in water between -1 and -5 feet MLLW.

Substrate was common borrow and sand topped with quarry spall and riprap to approximately -10 feet MLLW. Sediment between -10 and -16 feet MLLW was largely well graded sand, changing to silt below that (AECOM 2008).

Hammer Specifications

The impact hammer used was a Delmag D62-22 diesel pile hammer. The impact weight was 6,200 kilograms (6.8 U.S. tons) with an energy per blow of 224-107 kilonewton meter (kNm; 165,214-78,909-foot pounds). The fuel setting ranged from 0 for the dead blows to 3 for the beginning of the drive and 4 for the end of the drive. Two ½-inch micarta and three ½-inch aluminum plates were used as pile caps (2.5 inches total).

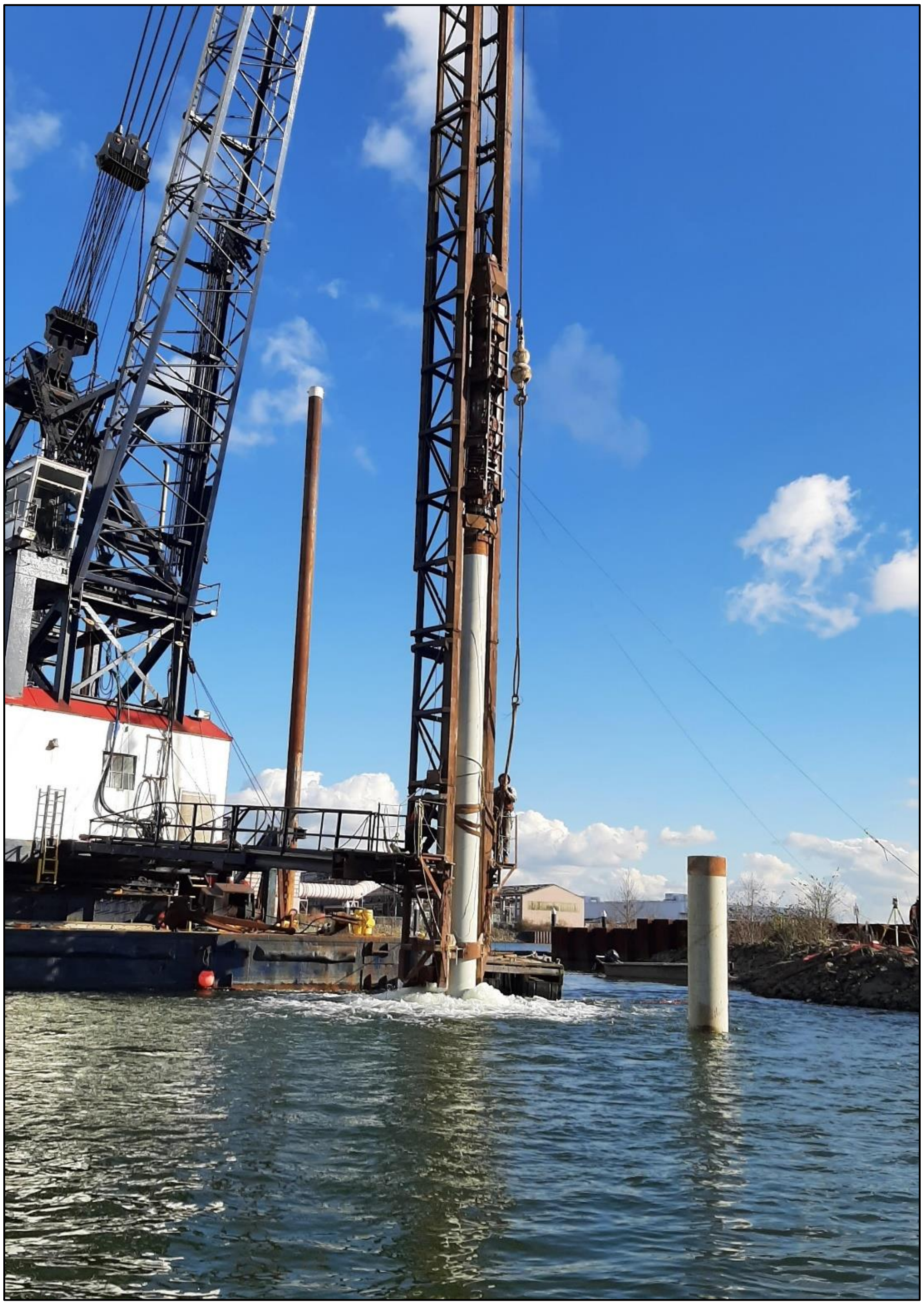
Bubble Curtain Specifications

The bubble curtain was comprised of aerated rings made out of 2.5-inch, schedule 80 marine-grade aluminum pipe (Photograph 2). The rings had 1/16-inch diameter air holes spaced approximately ¾-inch apart, and placed in four (4) adjacent rows along the top-side of the pipe for uniform air bubble flux when in operation. Each ring was comprised of two halves joined at the ends with paired hinge plates secured with removable ¾-inch bolt/hardware. The hinged connection allowed the rings to individually “open up” for easier placement (or removal) around a pile. The system provided bubble flux of approximately 32.91 cubic feet per minute per linear foot of pipe in a single layer (Photograph 3).

Photograph 1. Impact hammer configuration.

Photograph 2. Bubble curtain during deployment for use on pile P-05.

Photograph 3. Bubble curtain running during impact driving of pile P-05.



3.1.2 Underwater Sound Monitoring Methods

Monitoring Equipment Used

The hydrophone utilized for monitoring was a Cetacean Research Technologies CR-1 hydrophone. Sound monitoring and analysis equipment used for the project is summarized in Table 3-1.

Table 3-1. Equipment used for underwater sound monitoring.

Item			
CR-1 Hydrophone with 200 feet of cable	Receiving Sensitivity- 198dB ±3dB re 1V/µPa	1	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment.
SpectraDAQ-200 Data Acquisition Sound Card (2-channel)	Sampling Rate- 24K Hz to 192 kHz	1	Analyzes and transfers digital data to laptop hard drive via USB 3.0.
Laptop computer	Compatible with digital analyzer	1	Record digital data on hard drive and signal analysis.
Real Time and Post-analysis software (SpectraPLUS-SC)	-	1	Monitor real-time signal and post-analysis of sound signals.
Flow shield	Partial custom 3D-printed design by Cetacean Research Technology, light bulb cover, nylon material curtain	1	Data from USGS Station No. 12113390 Duwamish River at golf course at Tukwila

Water velocity data from USGS Station No. 12113390 (approximately five miles upstream from the project site) were assessed for the week prior to the start of the project to determine if a flow shield would be necessary during noise monitoring data collection. The station reported velocities as high as 1.3 meters per second (m/s). Because the threshold for requiring a flow shield is 1.5 m/s and water velocities at the site location were not available, a flow shield was deployed for monitoring.

Pile Driving Monitoring

Monitoring was conducted from the south end of the most inshore float at South Park Marina. This ensured clear acoustic line-of-sight to the pile and minimum horizontal distance of 10 m from the pile (Photograph 4). This location was determined to be the best deployment location for both safety and integrity of data reasons. Distances between hydrophone and pile were measured using a rangefinder.

Water depth was determined using a Laylin Speedtech SM-5 Handheld Depth Meter and verified using a lead line. The hydrophone was deployed at mid-water depth and affixed to the nylon lead line with cable ties. The nylon line was tethered to a cleat; the hydrophone cable was not tethered to minimize unnecessary noise in the recordings. The hydrophone was connected to the SpectraDAQ-200 Data Acquisition Sound Card, which was plugged into the USB port of the laptop.

Two Grette biologists were on station prior to commencement of pile driving operations for the day. Once a pile was lofted and in position, recording was initiated using the pre-programmed configuration settings for impact driving. Monitoring equipment was set to 10 hertz (Hz) to 50 kilohertz (kHz) with a sampling rate of 96 kHz. Monitoring continued until the drive was complete.

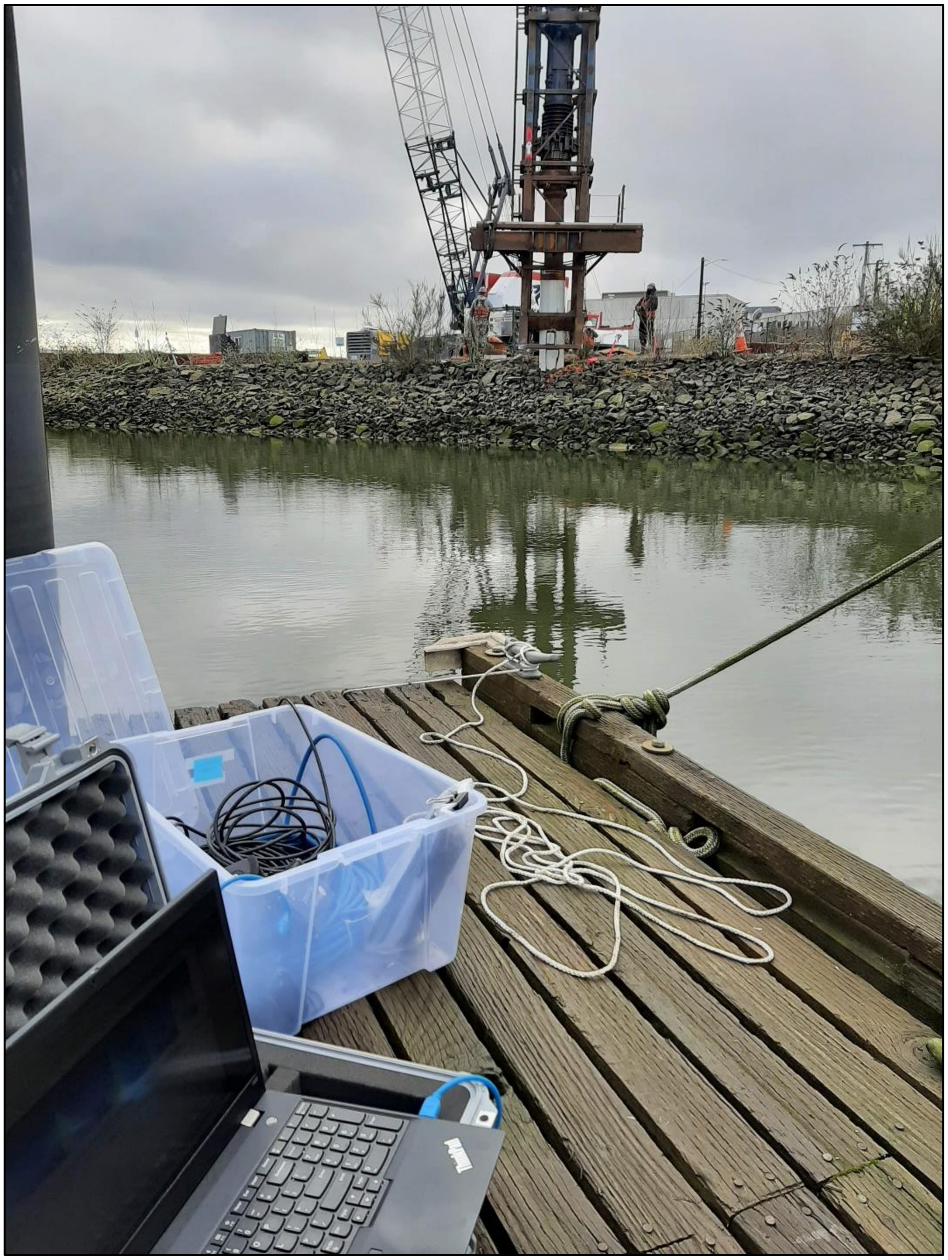
Pile driving noise for the two in-water standard pile was recorded with the bubble curtain on and off (presence and absence). Pile driving for these pile was initiated with the bubble curtain on. After approximately one-quarter of the pile had been driven, the bubble curtain was shut off for 30 seconds, then reactivated. This was repeated approximately halfway and again three-quarters of the way through the drive.

Data were recorded as a wave file (.wav) with a backup text file (.txt). Recorded data were saved in raw form, and were not compressed with algorithms or technologies (e.g. MP3, compressed wave, etc.).

Other data collected included environmental data such as surface water temperature, water depth, water velocity, predicted tide, and weather conditions, and other factors that could influence the underwater sound levels (e.g. aircraft, boats, etc.). Start and stop time of each pile driving event and the time at which the bubble curtain was turned on and off were also recorded.

After work was completed, the resident engineer provided the substrate composition and approximate depth of significant substrate layers and the project superintendent provided hammer model, size, and energy settings, pile cap specifications and final tip elevation of pile.

Photograph 4. Hydrophone and equipment setup at T-117 site. Note clear acoustic line-of-sight between corner of dock (hydrophone deployment location) and pile being driven.



3.1.3 Data Processing

Hydroacoustic data were analyzed using SpectraPLUS-SC unless otherwise indicated. Analysis for each pile included calculation of:

1) Total number of pile strikes,
2) For all strikes in a drive (upland and Reinhall pile), or all attenuated and all unattenuated strikes in a drive (in-water standard pile with and without a bubble curtain):
    a. Maximum, mean, and range of the peak sound pressure level (SPL),
    b. Maximum, mean, and range of the root mean square (RMS) sound pressure across 90% of the strike's energy ($RMS_{90\%}$),
    c. Maximum, mean, and range of the sound exposure level (SEL) measured 90% of the accumulated sound energy ($SEL_{90\%}$),
3) Cumulative SEL (cSEL) across all pile strikes,
4) Max peak SPL calculated at 10 m using the Practical Spreading Loss Model,
5) For subsets (five strikes each) in the first, second, third, and fourth quarter of each drive, and for the first, second, and third unattenuated segments for the standard pile without the bubble curtain:
    a. Maximum, mean, and range of the peak SPL,
    b. Maximum, mean, and range of the $RMS_{90\%}$,
    c. Maximum, mean, and range of the $SEL_{90\%}$,
    d. A frequency spectrum, with and without attenuation, between 20 Hz and 20 kHz for up to eight successive strikes with similar sound levels.

For pile that were driven with a bubble curtain, the portion of the time series that was recorded during the transition from the bubble curtain being activated and shut off was not included in the noise analysis. This was done to reduce noise in the data from that period in both the attenuated and unattenuated samples. The three 30-second samples were combined into one file for calculation of means and ranges, as were the attenuated portions of the drive for each pile. For the subsets, five strikes were included in each subset, spaced approximately 15 seconds apart.

3.2 Hydroacoustics Results

Hydroacoustic data were collected on January 19, February 8, and February 9, 2021. The upland standard pile was driven on January 19, the upland double-walled mandrel pile was driven on February 8, and the three in-water pile were driven on February 9. Weather conditions were cold (30s to 40s F) and cloudy and cold and sunny.

Per the T-117 Hydroacoustic Study Plan, the following results are included in this report:

1. The impact hammer model energy rating used to drive the pile;
2. The physical characteristics of the bottom substrate into which the pile were driven;
3. The size and type of pile;
4. The distance between hydrophone and pile;
5. The distance between the hydrophone and the water's edge and water's edge to pile for upland pile;
6. The depth of the hydrophone and depth of water at hydrophone locations;
7. The depth of water in which the pile were driven;
8. The depth into the substrate that the pile were driven;
9. The results of the hydroacoustic monitoring as listed in Section 0.

Items 1 and 2 are reported in Sections 0 and 0. Items 3-8 are presented in Table 3-2. Items 9 and 10 are reported below and summarized in Table 3-3.

Table 3-2. Summary of pile and hydrophone data for the T-117 Hydroacoustic Monitoring Study.

Reporting Requirement	P-02 S (S)	P-02 N (R)	P-04 (R)	P-05 (S)	P-06 (S)
Pile location	Upland	Upland	In-Water	In-Water	In-Water
Size of pile	24"	24"	24"	24"	24"
Type of pile	Standard	Reinhall	Reinhall	Standard	Standard
Distance hydrophone to pile (yds)	28	25	19	24	30
Distance hydrophone to water's edge (yds)	19	20	N/A	N/A	N/A
Distance from pile to water's edge (yds)	9	5	N/A	N/A	N/A
Depth of hydrophone (ft)	6	7	7.5	7.5	7.5
Depth of water at hydrophone (ft)	11.5	14	14.5	15.5	15.25
Depth of water in which pile was driven (ft)	Dry	Dry	9	15	13
Final tip elevation	-44.02	-45.53	-43.56	-44.08	-46.63

3.2.1 Summary of all Pile

Table 3-3. Summary of hydroacoustic results for all pile in the T-117 study. "(S)" indicates standard pipe pile, "(M)" indicates mandrel pile. "A" indicates with attenuation (bubble curtain), "NA" indicates no attenuation.

		Total # of Strikes	**Peak SPL (dB)**			**RMS90% (dB)**		**SEL90% (dB)**		**cSEL**
			Mean	**Range**	**@10 m[1]**	**Mean**	**Range**	**Mean**	**Range**	
Upland	**P-02 S (S)**	662	189	179-194	200	177	168-180	162	153-165	191
	P-02 N (M)	1,118	188	141-195	200	176	129-183	162	127-168	194
In-Water	**P-04 (M)**	1,390	201	181-209	212	189	168-197	176	155-184	206
	P-05 (S) A	523	198	196-201	206	187	183-190	174	171-176	202
	P-05 (S) NA	523	205	202-207	212	193	191-196	179	177-181	202
	P-06 (S) A	562	197	183-201	207	186	172-190	172	158-176	202
	P-06 (S) NA	562	204	201-208	214	193	191-196	180	178-181	202

[1] Peak SPL standardized at 10 m using the Practical Spreading Loss model.

3.2.2 ***P-02 S – Upland Standard Pile***

Field Data

Upland standard pile P-02 S was driven on January 19, beginning at 14:16 and ending at 14:37. Active driving once the pile was aligned began at 14:21. Total drive time was 21 minutes with 16 minutes of active driving.

Surface water temperature was approximately 43° F and water velocity (as recorded at the USGS Station #12113390) was 2.98 feet per second. Weather was partly cloudy to sunny with an air temperature of 44° F and winds 3-6 miles per hour.

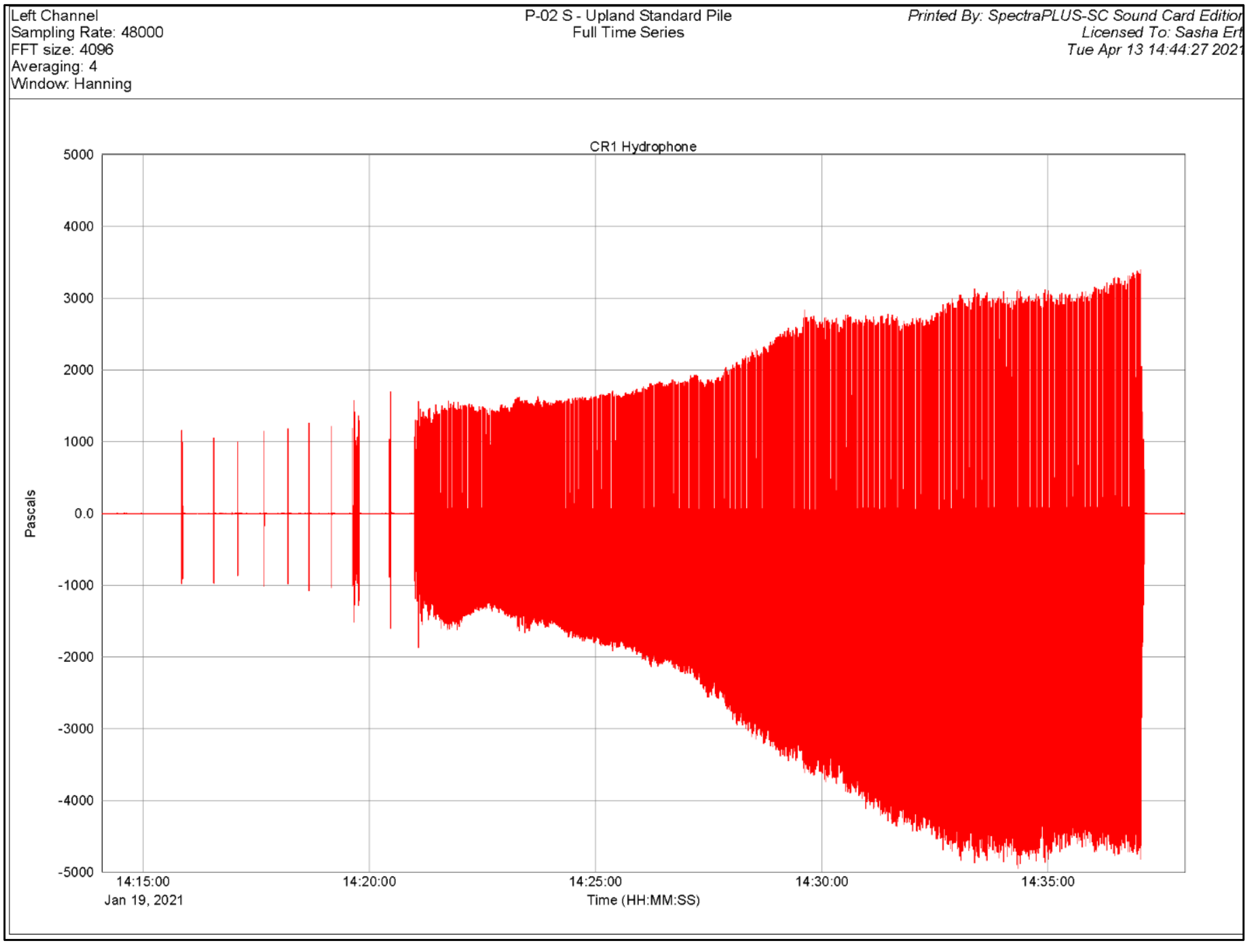
Hydroacoustic Data

Full Drive

Pile P-02 S required 662 strikes to reach final tip elevation. The drive increased in volume as the pile was driven deeper (Figure 3-1). The mean peak SPL for all strikes in the drive was 189 dB with a range of 179-194 dB. The mean $\text{RMS}_{90\%}$ for all strikes was 177 dB and the range was 168-180 dB. Mean $\text{SEL}_{90\%}$ was 162 dB with a range of 153-165 dB. cSEL for all strikes was 191 dB.

Although this was an upland pile and the Practical Spreading Loss Model may not apply, in an effort to standardize results for comparison purposes, the max peak SPL was run through the model. The max peak SPL for this pile at 10 meters was 200 dB_{peak}.

Figure 3-1. Time series for upland standard pile P-02 S.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-02 S - Upland Standard Pile
Full Time Series

Printed By: SpectraPLUS-SC Sound Card Editio
Licensed To: Sasha Ert
Tue Apr 13 14:44:27 2021

Subsets

Hydroacoustic data were analyzed for subsets of five strikes in the first, second, third, and fourth quarters of this drive. Results are presented in Table 3-4. Frequency spectra for subsets of eight strikes in each quarter of the drive are presented in Appendix A in Section 7.1.1.

Table 3-4. Summary of hydroacoustics results for subsets of five strikes in the first, second, third, and fourth quarters of the drive for pile P-02 S.

Segment	Peak SPL (dB)			RMS90% (dB)		SEL90% (dB)	
	Mean	Range	@10 m	Mean	Range	Mean	Range
1st Q	184	183-184	190	174	173-175	159	159-160
2nd Q	186	186-187	193	175	175	161	161
3rd Q	192	192-193	199	178	178-179	163	163-164
4th Q	193	193-194	200	180	180	165	164-165

*3.2.3 **P-02 N – Upland Double-Walled Mandrel Pile***

Field Data

Upland double-walled mandrel pile P-02 N was driven on February 8, with driving efforts beginning at 9:50 and ending at 10:36. Driving was initiated at 9:50, but the pile required realignment several times and steady driving began at 10:03. At 10:06, the drive was stopped again and resumed at 10:10. Driving continued steadily from then until the pile was installed, ending at 10:36. Total time from initiation to completion was 46 minutes with 29 minutes of active driving once the pile was set.

Surface water temperature was approximately 42° F and water velocity (as recorded at the USGS Station #12113390) was 2.5 feet per second. Weather was overcast with an air temperature of 38° F and winds 6-8 miles per hour.

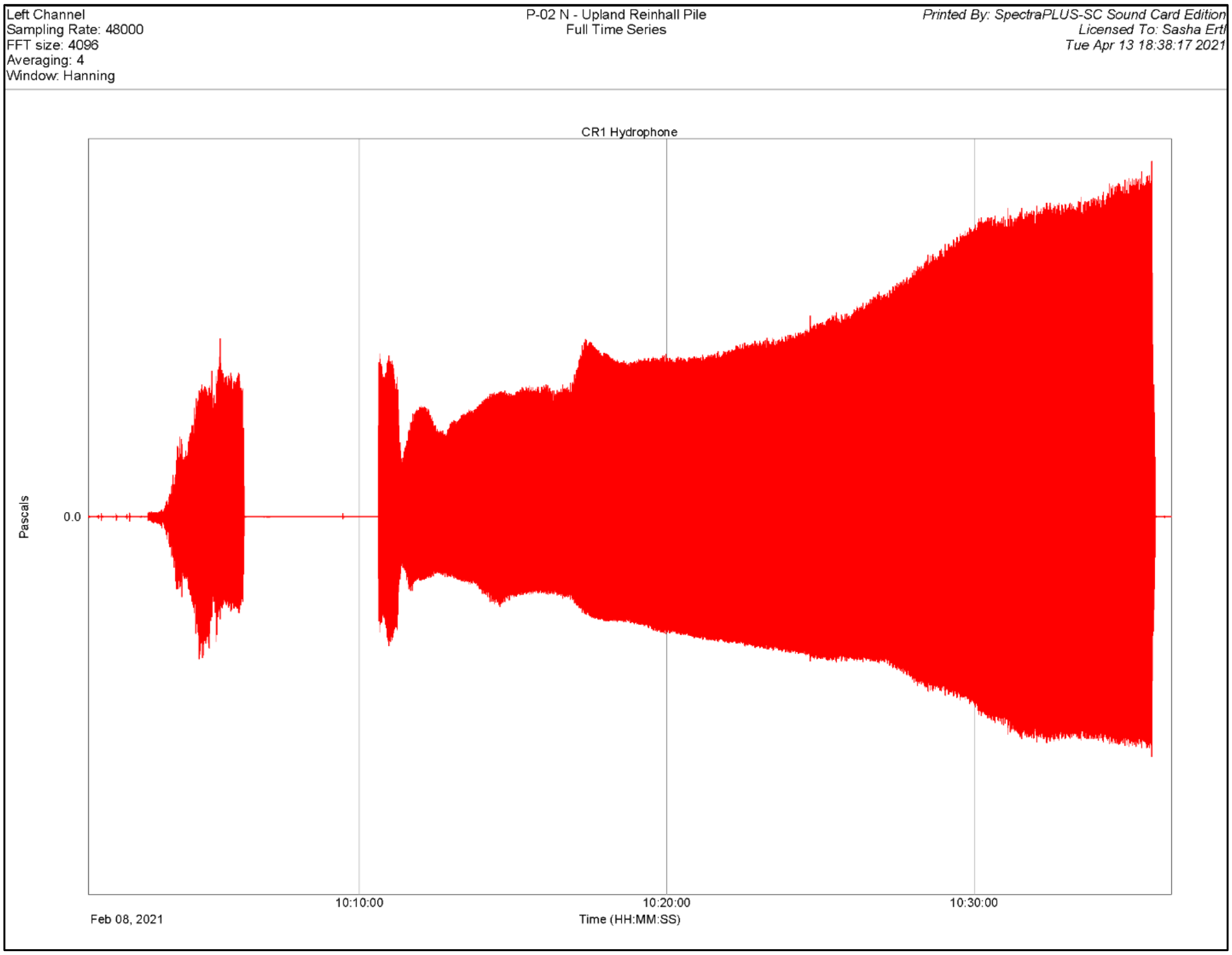
Hydroacoustic Data

Full Drive

Pile P-02 N required 1,118 strikes to reach final tip elevation. The drive increased in volume as the pile was driven deeper (Figure 3-2). The mean peak SPL for all strikes in the drive was 188 dB with a range of 141-195 dB. The mean $RMS_{90\%}$ for all strikes was 176 dB and the range was 129-183 dB. Mean $SEL_{90\%}$ was 162 dB with a range of 127-168 dB. cSEL for all strikes was 194 dB.

As with P-02 S, although this was an upland pile and the Practical Spreading Loss Model may not apply, in an effort to standardize results for comparison purposes, the max peak SPL was run through the model. The max peak SPL for this upland double-walled pile at 10 meters was also 200 dB_{peak}.

Figure 3-2. Time series for upland double-walled mandrel pile P-02 N.



Subsets

Hydroacoustic data were analyzed for subsets of five strikes in the first, second, third, and fourth quarters of this drive. Results are presented in Table 3-5. Frequency spectra for subsets of eight strikes in each quarter of the drive are presented in Appendix A in Section 7.1.2.

Table 3-5. Summary of hydroacoustics results for subsets of five strikes in the first, second, third, and fourth quarters of the drive for pile P-02 N.

Segment	Peak SPL (dB)			RMS90% (dB)		SEL90% (dB)	
	Mean	Range	@10 m	Mean	Range	Mean	Range
1st Q	186	185-186	191	174	173-175	161	160-161
2nd Q	188	188	193	177	177	162	162
3rd Q	191	190-191	196	179	179	165	164-165
4th Q	194	194	199	183	183	168	167-168

*3.2.4 P-04 – **In-Water Double-Walled Mandrel Pile***

Field Data

In-water double-walled mandrel pile P-04 was driven on February 9, with driving efforts beginning at 9:04 and ending at 9:51. Driving was initiated at 9:04 and became steady at 9:16. At 9:24, the computer used for recording was switched out with a new one due to low battery concerns. The time with no recording was less than one minute. The drive was complete at 9:51. Total time from initiation to completion was 47 minutes with 35 minutes of active driving once the pile was set. For the last several minutes of the drive, mud was observed splattering from the top of the inner mandrel and hitting the surface of the water. After the drive was complete, the hydroacoustic monitoring team was informed that pile tip elevation was not reached and efforts were aborted in order to avoid damaging the hammer by striking mud instead of the pile.

Surface water temperature was approximately 41° F and water velocity (as recorded at the USGS Station #12113390) was 2.4 feet per second. Weather was sunny with scattered clouds with an air temperature of 31° F and winds at 8 miles per hour.

Hydroacoustic Data

Full Drive

Pile P-04 required 1,390 strikes to reach final tip elevation. The drive increased in volume in the initial portion of the drive, then decreased and plateaued before increasing again at the end of the drive (Figure 3-3 and Figure 3-4). During this drive, the mandrel (inner pile being struck by the hammer) filled with sediment throughout the drive, resulting in poor contact between the hammer and the pile. Hammer power was reduced to avoid damage to the hammer, and eventually the effort was aborted prior to reaching target tip elevation. The space between the mandrel and the outer pile remained intact.

The mean peak SPL for all strikes in the drive was 201 dB with a range of 181-209 dB. The mean $RMS_{90\%}$ for all strikes was 189 dB and the range was 168-197 dB. Mean $SEL_{90\%}$ was 176 dB with a range of 155-184 dB. cSEL for all strikes was 206 dB.

To standardize results for comparison purposes, the max peak SPL was run through the model. The max peak SPL for this double-walled pile at 10 meters was 212 dB_{peak}.

Figure 3-3. Time series for first half of the drive for the in-water double-walled mandrel pile P-04. This drive was recorded in two files due to change computers after batteries were drained quickly by the equipment and the cold. Note the break in driving as pile was readjusted.

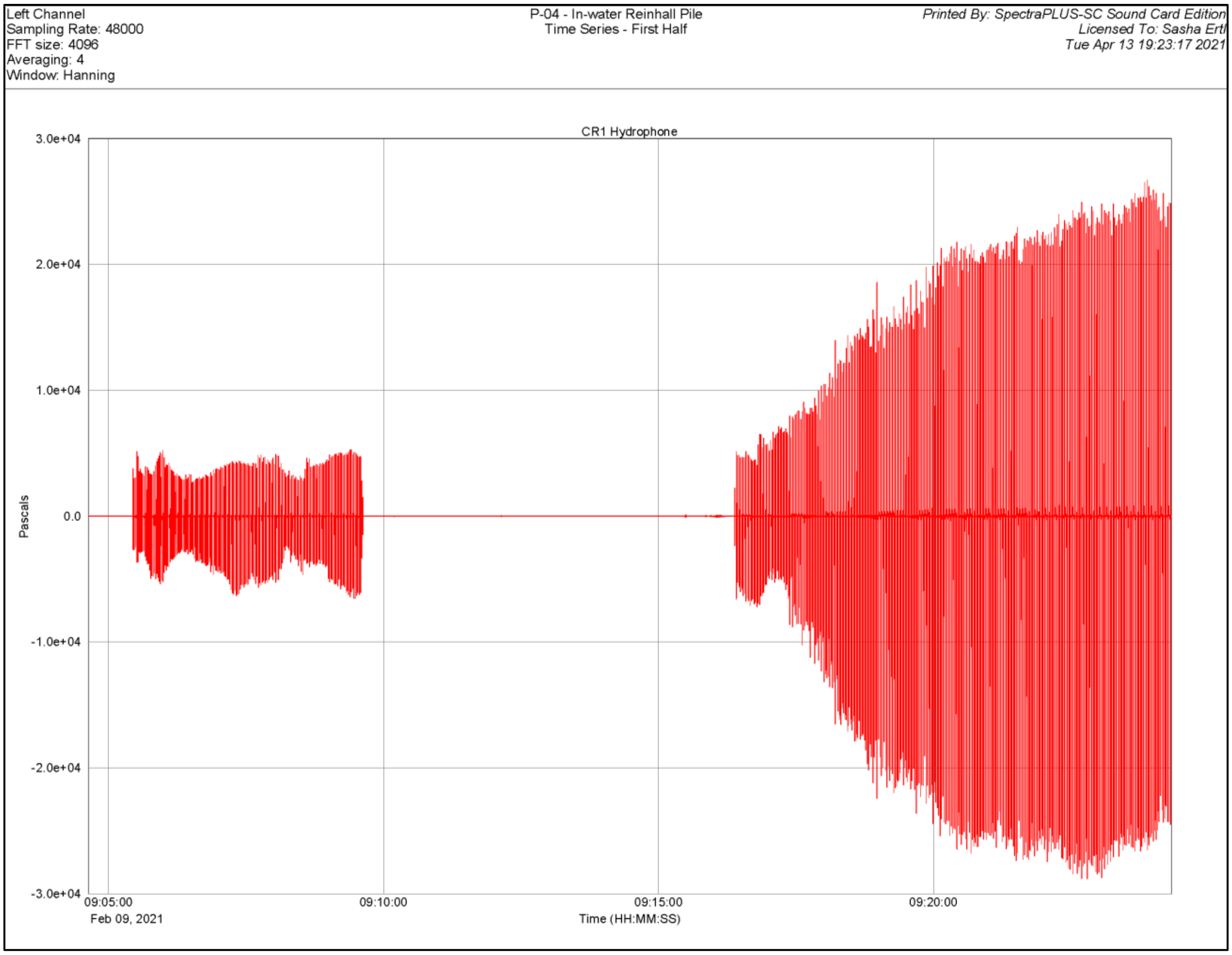
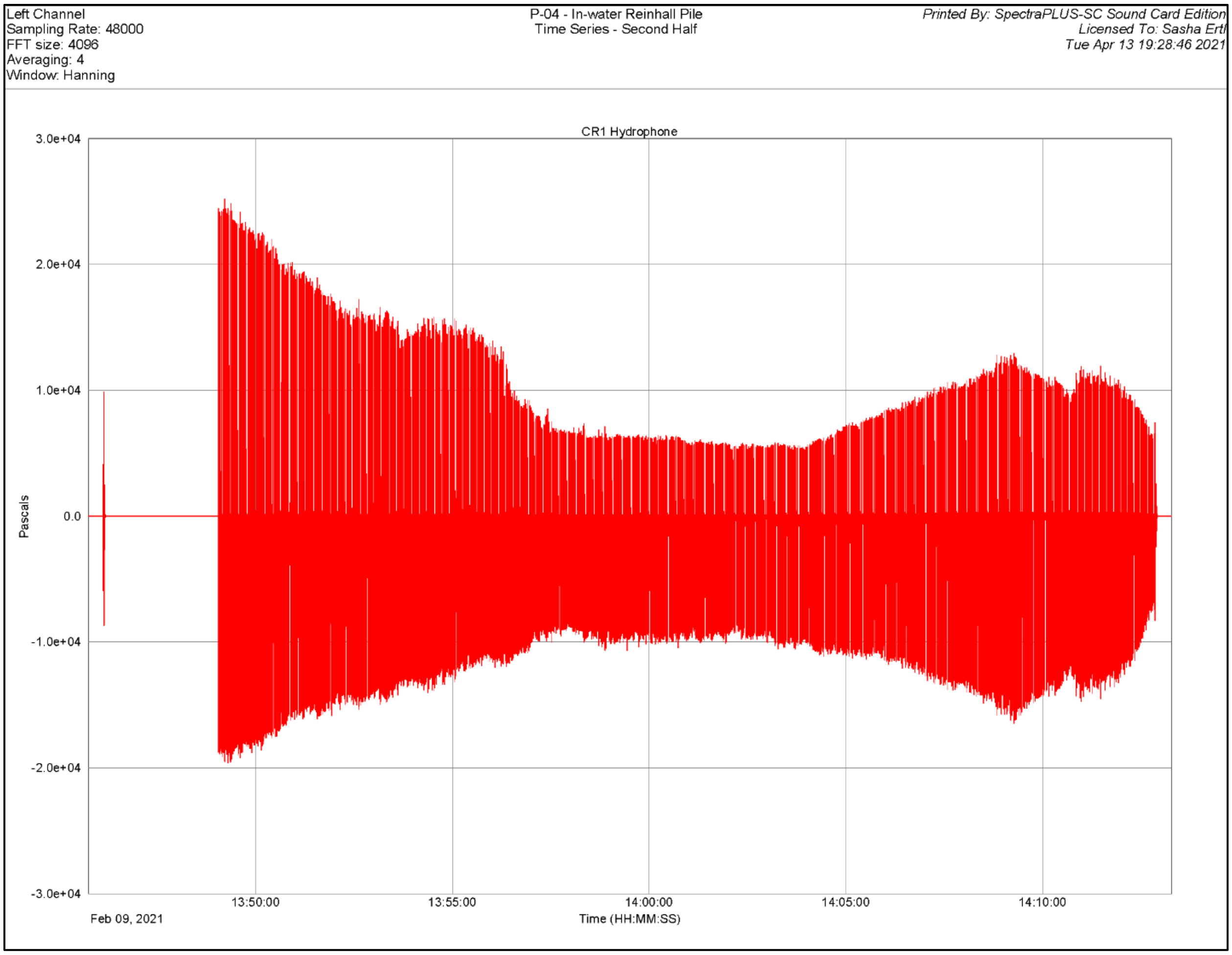


Figure 3-4. Time series for second half of the drive for the in-water double-walled mandrel pile P-04. Note another break in driving as pile was checked for level. The time on the second computer was not calibrated properly so the time reported on the x-axis is not correct.



Subsets

Hydroacoustic data were analyzed for subsets of five strikes in the first, second, third, and fourth quarters of this drive. Results are presented in Table 3-6Table 3-5. Frequency spectra for subsets of eight strikes in each quarter of the drive are presented in Appendix A in Section 7.1.3.

Table 3-6. Summary of hydroacoustics results for subsets of five strikes in the first, second, third, and fourth quarters of the drive for pile P-04.

Segment	Peak SPL (dB)			RMS90% (dB)		SEL90% (dB)	
	Mean	Range	@10 m	Mean	Range	Mean	Range
1st Q	208	208-209	212	195	195-196	183	182-183
2nd Q	204	204-205	208	193	193	179	179-180
3rd Q	199	199-200	203	188	187-188	174	174-175
4th Q	201	201	204	189	189	175	175-176

*3.2.5 **P-05 – In-Water Standard Pile***

Field Data

In-water standard pile P-05 was driven on February 9, with driving efforts beginning at 14:29 and ending at 14:56. Driving was conducted with the use of a bubble curtain for attenuation. For the purposes of assessing the difference in noise levels with and without attenuation, the bubble curtain was shut off for three 30-second periods: at 14:47, 14:49, and 14:52. Total drive time was 27 minutes.

Surface water temperature was approximately 42° F and water velocity (as recorded at the USGS Station #12113390) was 2.3 feet per second. Weather was sunny with scattered clouds with an air temperature of 41° F and winds at 6 miles per hour.

Hydroacoustic Data

Full Drive

Pile P-05 required 523 strikes to reach final tip elevation. The in-water noise volume remained relatively steady as the pile was driven with the exception of the three 30-second segments during which the bubble curtain was deactivated (Figure 3-5).

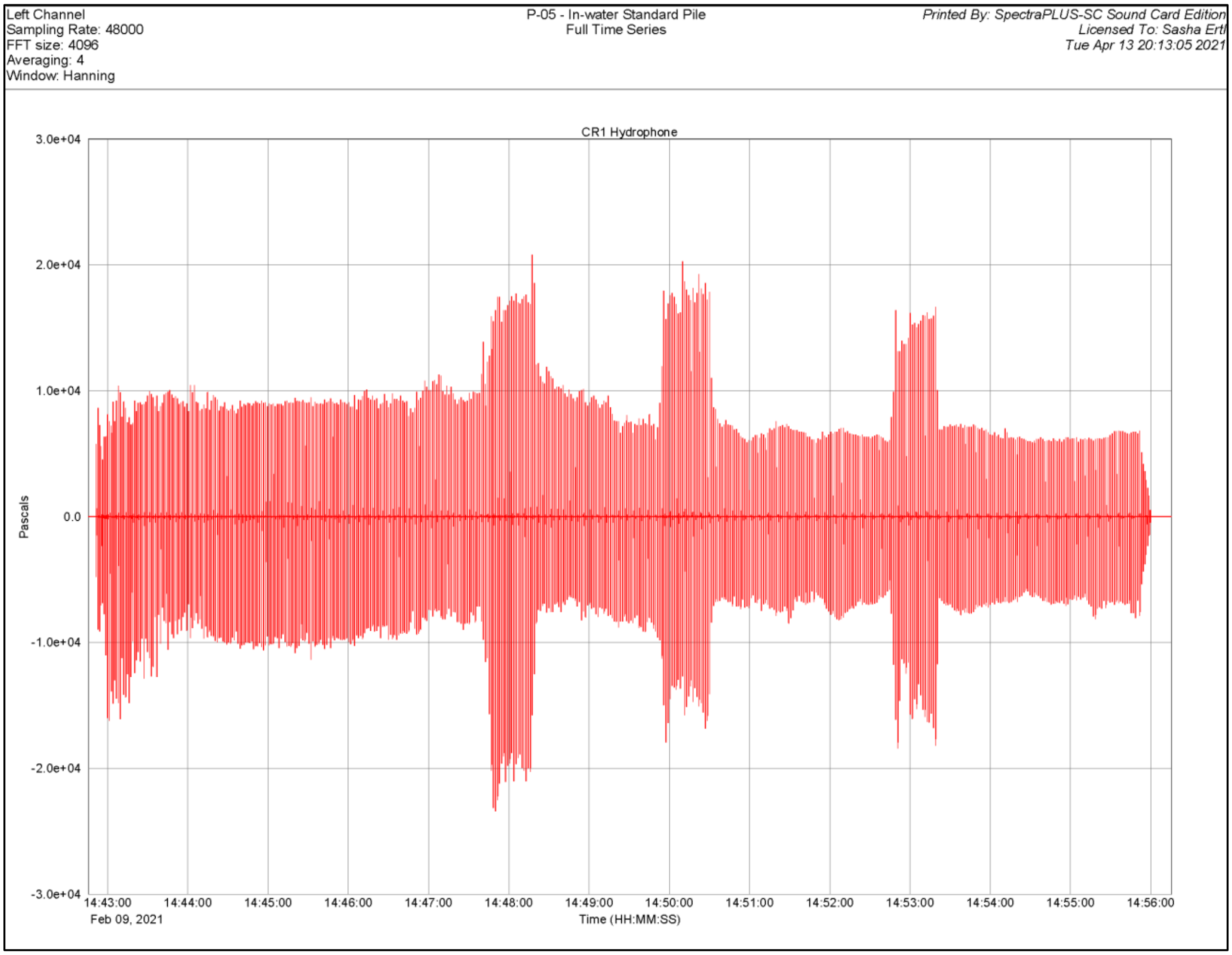
The mean peak SPL for strikes with attenuation (the bubble curtain activated) was 198 dB with a range of 196-202 dB. The mean $RMS_{90\%}$ for these strikes was 187 dB and the range was 183-190 dB. Mean $SEL_{90\%}$ was 174 dB with a range of 171-176 dB.

The mean peak SPL for strikes without attenuation (the bubble curtain shut off) was 205 dB with a range of 202-207 dB. The mean $RMS_{90\%}$ for these strikes was 193 dB and the range was 191-196 dB. Mean $SEL_{90\%}$ was 179 dB with a range of 177-181 dB.

cSEL for all strikes was 202 dB.

To standardize results for comparison purposes, the max peak SPL was run through the model for both the attenuated and unattenuated portions of the drive. The max peak SPL with the bubble curtain at 10 meters was 206 dB_{peak} and without the bubble curtain was 212 dB_{peak}.

Figure 3-5. Time series for in-water standard pile P-05.



Subsets

Hydroacoustic data were analyzed for subsets of five strikes in the first, second, third, and fourth quarters of this drive and from each of the three segments during which the bubble curtain was inactive. Results are presented in Table 3-7Table 3-5. Frequency spectra for subsets of eight strikes during the same seven segments are presented in Appendix A in Section 7.1.4.

Table 3-7. Summary of hydroacoustics results for subsets of five strikes in the first, second, third, and fourth quarters of the drive for pile P-05 and during each of the three segments with the bubble curtain inactive (NA = no attenuation).

Segment	Peak SPL (dB)			RMS90% (dB)		SEL90% (dB)	
	Mean	Range	@10 m	Mean	Range	Mean	Range
1st Q	200	199-200	205	188	188-189	175	174-175
1st NA	206	206-207	212	195	195-196	181	180-181
2nd Q	199	198-200	205	188	188-189	174	174
2nd NA	205	204-205	210	193	192-194	179	178-180
3rd Q	197	197-198	203	186	186-187	173	172-173
3rd NA	204	203-205	210	192	190-194	178	177-179
4th Q	196	196-197	202	186	185-186	172	171-173

3.2.6 *P-06 – In-Water Standard Pile*

Field Data

In-water standard pile P-06 was driven on February 9, with driving efforts beginning at 16:17 and ending at 16:31. Driving was conducted with the use of a bubble curtain for attenuation. For the purposes of assessing the difference in noise levels with and without attenuation, the bubble curtain was shut off for three 30-second periods: at 16:19, 16:21, and 16:24. Total drive time was 15 minutes.

Surface water temperature was approximately 42° F and water velocity (as recorded at the USGS Station #12113390) was 2.3 feet per second. Weather was sunny with scattered clouds with an air temperature of 41° F and winds at 6 miles per hour.

Hydroacoustic Data

Full Drive

Pile P-06 required 562 strikes to reach final tip elevation. The in-water noise volume remained relatively steady as the pile was driven with the exception of the three 30-second segments during which the bubble curtain was deactivated (Figure 3-6).

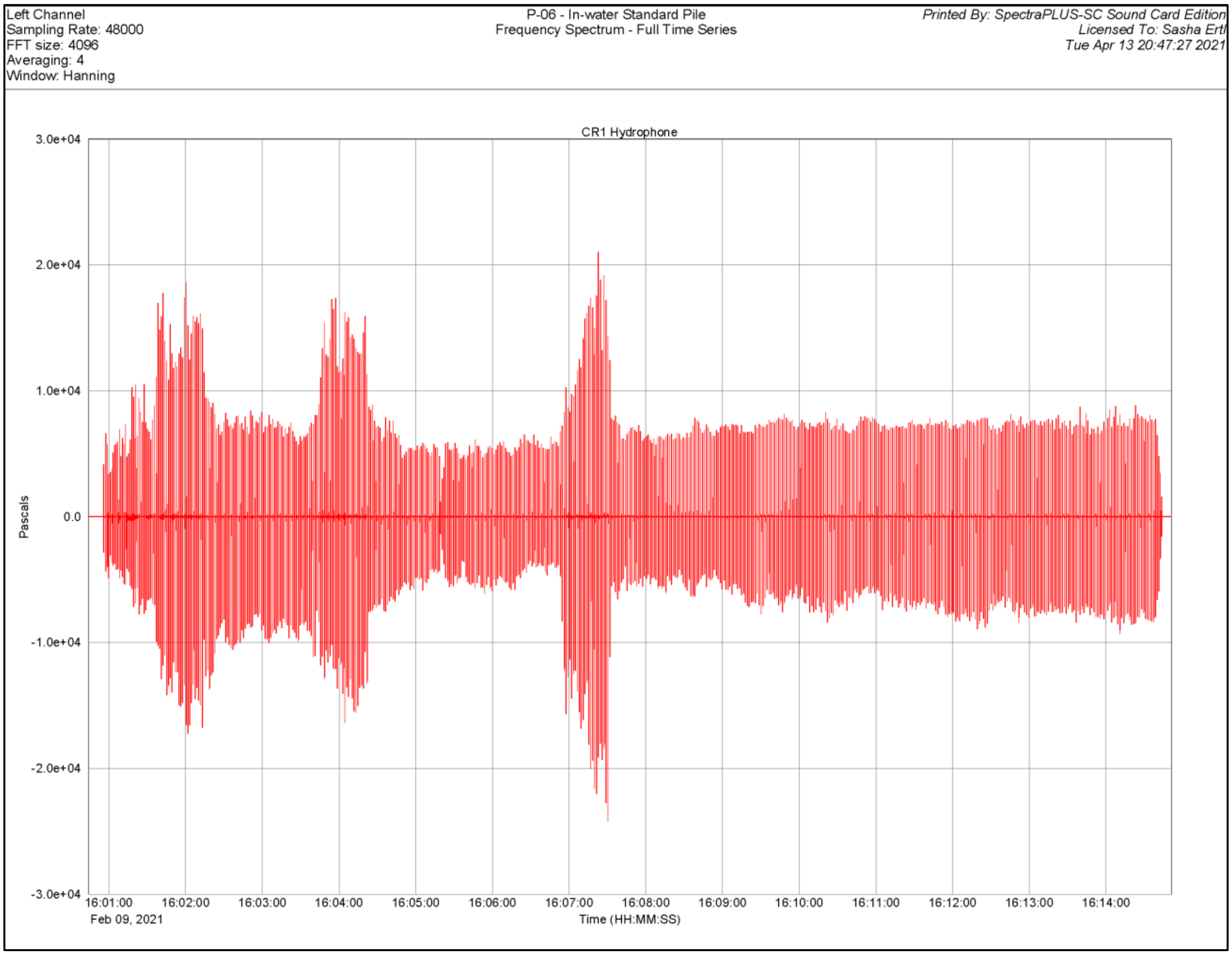
The mean peak SPL for strikes with attenuation (the bubble curtain activated) was 197 dB with a range of 183-201 dB. The mean $\text{RMS}_{90\%}$ for these strikes was 186 dB and the range was 172-190 dB. Mean $\text{SEL}_{90\%}$ was 172 dB with a range of 158-176 dB.

The mean peak SPL for strikes without attenuation (the bubble curtain shut off) was 204 dB with a range of 201-208 dB. The mean RMS90% for these strikes was 193 dB and the range was 191-196 dB. Mean SEL90% was 180 dB with a range of 178-181 dB.

cSEL for all strikes was 202 dB.

To standardize results for comparison purposes, the max peak SPL was run through the model for both the attenuated and unattenuated portions of the drive. The max peak SPL with the bubble curtain at 10 meters was 207 dBpeak and without the bubble curtain was 214 dBpeak.

Figure 3-6. Time series for in-water standard pile P-06.



Subsets

Hydroacoustic data were analyzed for subsets of five strikes in the first, second, third, and fourth quarters of this drive and from each of the three segments during which the bubble curtain was inactive. Results are presented in Table 3-8Table 3-5. Frequency spectra for subsets of eight strikes during the same seven segments are presented in Appendix A in Section 7.1.5.

Table 3-8. Summary of hydroacoustics results for subsets of five strikes in the first, second, third, and fourth quarters of the drive for pile P-06 and during each of the three segments with the bubble curtain inactive (NA = no attenuation).

Segment	Peak SPL (dB)			RMS90% (dB)		SEL90% (dB)	
	Mean	Range	@10 m	Mean	Range	Mean	Range
1st Q	197	194-200	206	186	183-188	173	171-175
1st NA	204	201-205	211	193	192-194	180	179-180
2nd Q	199	199-200	206	188	187-189	175	174-175
2nd NA	203	201-204	210	193	191-194	179	178-180
3rd Q	195	194-195	201	183	183-184	170	170-171
3rd NA	206	205-207	213	194	193-195	181	180-181
4th Q	197	197-198	204	188	187-188	173	173-174

Hydroacoustics Observations

Grette biologists noted any possible contributors of noise to the study while in the field. Due to proximity to SeaTac Airport, airplanes commonly passed overhead, but no noise was detected on the hydrophone from the planes. No vessels passed the project site in the Duwamish River during hydroacoustic recording. No other sources of additional noise were observed.

3.3 Hydroacoustics Discussion

Due to operational issues with the double-walled mandrel pile, only three of these pile were installed: one upland and two in-water. As the pile were driven, mud filled the inner pipe (mandrel) until the hammer no longer made contact with the steel driving surface of the pile. Because of this, use of the test pile was abandoned for the remainder of the project.

The initial study plan included hydroacoustic monitoring of only one of the two in-water pile, so data were only collected for that and the upland pile. The space between the inner and outer pile was not compromised, so the attenuation component remained intact, allowing for comparison between these pile and the standard pipe pile. This discussion compares the results between the standard and mandrel upland pile (one each) and between two in-water standard and one in-water mandrel pile.

Installation of the both double-walled mandrel pile required approximately double the number of strikes as the equivalent standard pile. This may have been due to the hammer striking mud instead of the driving surface of the pile and thus requiring a decrease in hammer power and an increase in number of strikes. The second in-water pile (the first in-water standard pile) was driven with the mandrel shoe attached but without the inner mandrel, so the shoe was not likely the cause of the higher strike count.

The shape of both upland pile time series profiles showed that volume increased as the pile were driven deeper into the sediment. The in-water mandrel pile's profile shape was less consistent and clear, possibly due to the adjustments in hammer power to accommodate the clogged mandrel. The in-water standard piles' profiles showed very consistent volume throughout the drive. One of the intended benefits of the double-walled pile design is to ensure sound attenuation through the sediment, in contrast to the water column-only attenuation provided by a bubble curtain. The shape of the sound profiles suggests that the mandrel pile did not attenuate sound considerably differently than the standard pile. The peak SPLs @10 m in each quarter of the drives were also not considerably different (standard = 190 dB, 193 dB, 199 dB, and 200 dB; mandrel = 191 dB, 193 dB, 196 dB, and 199 dB). The mean peak SPL for the in-water mandrel pile was between the means for the attenuated and unattenuated levels for the standard in-water pile. When standardized @10 m, the mean peak SPL for the in-water mandrel pile was the same as the unattenuated standard pile (mandrel = 212 dB_{peak}; standard attenuated = 206 and 207 dB_{peak}, standard unattenuated = 212 and 214 dB_{peak}). Again, the efficacy of the attenuation may have been compromised with the inner pipe filled with material.

Cumulative SEL for the upland mandrel pile was higher than that of the upland standard pile (194 dB vs 191 dB), and cSEL for the in-water mandrel was the highest recorded of all five pile (206 dB vs. 202 for both standard pile). However, the number of strikes was considerably higher for the mandrel pile which would lead to higher cSEL.

The efficacy of Reinhall pile has been tested in two field test projects in Puget Sound. In December 2015, hydroacoustic data were collected during installations of test 30-inch double-walled Reinhall pile, double-walled mandrel pile, and single-walled control pile. These tests were conducted in Commencement Bay and at the north end of Vashon Island, Washington. In the Commencement Bay study, a bubble curtain was used on the control pile, but in the Vashon Island study, orientation of pile did not allow for use of a bubble curtain. The Commencement Bay site was chosen to represent soft substrate conditions, whereas the Vashon Island test was conducted in significantly denser glacial tills (Reinhall et al. 2015).

Results of the Commencement Bay study showed that peak sound pressure (measured at 8 m) was reduced by 21 dB by using the double-walled pile and 23 dB by using a mandrel pile compared with only 6 dB using a single-walled pile with a bubble curtain (Reinhall et al. 2015). Results of the Vashon Island study showed that both double-walled pile reduced peak sound volumes by 12 dB_{PEAK} compared to the single-wall control pile without a bubble curtain (measured at 20 m from the pile; Soderberg and Laughlin 2016). RMS values were 5 and 7 dB_{RMS} lower with the double-walled pile than the single-walled without a bubble curtain. During installation, pile were chained to a temporary steel driving template by the contractor, which reduced overall attenuation as a result of metal to metal contact and precluded use of a bubble curtain.

As discussed above, the results of the T-117 study were not consistent with those of the prior two studies. Peak sound pressure of the upland pile @10 m was the same for both the double-walled and the standard pile (200 dB_{peak}), and for the in-water pile were approximately the same as the standard pile without the bubble curtain (a 6 dB_{peak} increase). Mean RMS values for the double-walled pile were between those for the standard pile (mandrel = 189 dB_{RMS}; standard attenuated = 187 and 186 dB_{RMS}, standard unattenuated = 193 dB_{RMS} for both).

4 IN-AIR MONITORING

4.1 In-Air Monitoring Methods

Port of Seattle staff was onsite to monitor ambient in-air noise and in-air noise during installation of pile on January 12, 14, 15, 19, and 20, and February 8-11, 2021. In-air noise was recorded at the intersection of Dallas Avenue South and 17th Avenue South. This was the site property line, approximately 140-180 feet from the pile installation locations and 1-11 feet above the finish pile grade. Pile monitored included one net attachment steel pipe pile, one debris deflector steel pipe pile, and support pile numbers P-02S, P-02N, P-03, P-04, P-05, P-06, P-07, P-09NW, and P09-NE.

Data were collected using a Gen Rad Sound Level Meter (GenRad Precision Integrating Sound-Level Meter and Analyzer, GR1988-9700/9710). Results are reported as equivalent time averaged sound pressure levels, during a 10 second period (10 second/leq). This is the sound pressure level of noise fluctuating over 10 seconds when using a 3-decibel exchange rate, expressed as the amount of energy. Results include the mean, low, and high average sound pressure levels recorded and the low and high peak sound pressure levels for background, ambient noise (with no equipment operating or simply idling construction equipment) and piling installation noise, including vibratory and impact pile driving noise.

4.2 In-Air Monitoring Results

A summary of pile driving noise levels is presented in 2-1. Data are raw, not weighted or corrected for distance.

4.2.1 Pile Driving Results Table

Table 4-1. Summary of all pile driving in-air noise monitoring results.

Upland	**Net Attachment**	Standard	66.0	64.0	68.4	--	--	N/A	N/A	N/A	N/A	N/A
	P-02S	Standard	78.2	74.8	79.4	80.1	80.5	85.1	84.2	86.2	90.7	96.7
	- -										--	--
	- -											
	- -										--	--
In-Water	**P-03 - Start**	Mandrel	N/A	N/A	N/A	N/A	N/A	83.8	83.1	84.9	--	--
	P-03 - Middle		N/A	N/A	N/A	N/A	N/A	84.9	84.7	85.1	93.3	93.5
	P-03 - End		N/A	N/A	N/A	N/A	N/A	84.7	83.8	84.8	--	--
	- -								--	--		
	- -											
	- -											
	P-05 - Start	Standard	N/A	N/A	N/A	N/A	N/A	86.7	--	--	93.3	93.6
	P-05 - Middle		N/A	N/A	N/A	N/A	N/A	84.7	84.0	85.5	--	--
	P-05 - End		N/A	N/A	N/A	N/A	N/A	81.9	81.4	82.3	--	--
	P-05 – End @ 50’ Distance		N/A	N/A	N/A	N/A	N/A	91.9	91.8	92.0	100.3	100.5
	- -										--	--
	- -										--	--

		Pile Type	**Vibratory Driving**					**Impact Driving**				
			Average Sound Level (dB) (10 sec/Leq)			**Peak Sound Level (dB) (10 sec/Leq)**		**Average Sound Level (dB) (10 sec/Leq)**			**Peak Sound Level (dB) (10 sec/Leq)**	
			Mean	**Low**	**High**	**Low**	**High**	**Mean**	**Low**	**High**	**Low**	**High**
	P-06 - End	Mandrel Shoe	N/A	N/A	N/A	N/A	N/A	85.0	84.4	86.1	93.0	94.0
	P-07 - Start	Standard	N/A	N/A	N/A	N/A	N/A	84.0	83.7	84.3	--	--
	P-07 - Middle		N/A	N/A	N/A	N/A	N/A	83.1	81.7	84.3	--	--
	P-07 - End		N/A	N/A	N/A	N/A	N/A	83.0	82.2	84.0	91.6	93.0
	P-09NW - Middle	Standard with Mandrel Shoe	N/A	N/A	N/A	N/A	N/A	75.4	73.2	77.6	--	--
	P-09S - Middle	Standard with Mandrel Shoe	N/A	N/A	N/A	N/A	N/A	82.2	81.0	83.4	--	--
	P-09S - End		N/A	N/A	N/A	N/A	N/A	81.4	80.3	82.5	89.5	90.6

4.3 In-Air Monitoring Discussion

The data did not reveal any compelling differences in in-air noise between standard and double-walled mandrel pile during impact pile driving. When comparing upland standard and double-walled mandrel pile, the difference in average Leq at the end of the drive was 2.5 dB, with the mandrel pile being the louder of the two (P-02S was driven with a vibratory hammer to refusal and was only impact-driven at the end of the drive). For in-water pile, the average Leq for the two mandrel pile were within 2 dB of each other at all three stages of the drive; the two most inshore standard pile were also within 2 dB of each other at the beginning and middle of the drive, and 3 dB at the end of the drive. The average Leq for the beginning, middle, and end of the drive for the two in-water mandrel pile were 83.05 dB, 84 dB, and 83.85 dB, respectively. The average Leq for the same segments for the two standard pile closest to the mandrel pile were 85.45 dB, 85.2 dB, and 83.45 dB, respectively.

5 VIBRATION MONITORING

5.1 Vibration Monitoring Methods

PanGEO performed vibration monitoring during installation of the structural piles (both Reinhall and non-Reinhall piles) for the proposed pedestrian pier, for both vibratory and impact hammers. The purpose of the monitoring was to determine how the magnitude of vibration, measured as peak particle velocity, attenuates with distance from the source of vibration.

The levels of vibrations as determined by peak particle velocities (PPV) were measured using *MiniMate Plus* monitoring units manufactured by Instantel®. The three components (transverse, longitudinal and vertical) of the peak particle velocities were recorded simultaneously using a tri-axial transducer placed at distances of 10 to 100 feet from the source of vibration. The peak particle velocities summarized in Section 5.2.5 are calculated as a vector sum of the three components.

5.2 Vibration Monitoring Results

As requested, a PanGEO representative was on-site on February 1, 8, 9, 10, and 11, 2021 to provide continuous monitoring of the installation of pipe piles at Sites 23 and 25 for the Terminal 117 Habitat Restoration project. A total of 14 piles were installed, which include 12 structural piles for supporting the pedestrian pier, and 2 treaty piles (non-structural). The locations of the observed piles are shown on Appendix B - Attachment 1- Modified Habitat Plan, Sheets C5.0 through C5.3. While on-site on February 8, 9, and 10, we also provided vibration monitoring during the installation of the structural piles. The following summarizes our field observations:

5.2.1 Brief Daily Summary

- **2/1** – Install 2 treaty piles P-12-22 and P-12-26 with vibratory hammer.
- **2/8** – Install 2 structural piles P-02N and P-03 (both Reinhall) with diesel impact hammer.
- **2/9** – Install 3 structural piles P-04 (Reinhall) and P-05 and P-06 (non-Reinhall with bubble curtain) with diesel impact hammer.
- **2/10** – Install 3 structural piles P-07, P-06, and P-09NW (non-Reinhall with bubble curtain) with diesel impact hammer.
- **2/11** – Install 4 structural piles P-09NE, P-09S, P-10N, and P-10S (non-Reinhall with bubble curtain) with diesel impact hammer.

5.2.2 Pile Installation

<u>Treaty Piles</u>

On February 1, PanGEO observed American Construction install two (2) non-structural treaty piles using an ICE 44B Vibratory hammer at the locations shown in Appendix B - Attachment 1. The treaty piles consisted of 40-foot lengths of 12¾-inch diameter ASTM A252 Grade 3 steel pipes with a 0.50-inch wall thickness, which was revised from the 24-inch diameter 5/8-inch thick piles specified in the permitted plan set dated June 11, 2020. We understand that the revision was part of an approved submittal from October 2020.

Our observations for treaty pile installation are summarized below:

- *P-12-22* – American Construction previously attempted to install P-12-22 on January 21, 2021 but encountered an obstruction about 15 feet below grade at the design location (see PanGEO Field Report #2). During our site visit on February 1, 2021 PanGEO observed American Construction install pile P-12-22 approximately 40 feet upstream (south) of the design location, per recommendation from the structural engineer. The pile was vibrated to a tip elevation of approximately –13½ feet below existing grade before encountering an obstruction, which is about 6½ feet higher than the design tip elevation of – 20 feet. Based on conversations with American Construction, the as-built pile tip elevation (-13 1/2 feet) of pile P-12-22 was approved by the structural engineer the same day.
- *P-12-26* – Pile P-12-26 was vibrated into the ground at the design location until reaching the design tip elevation of –20 feet.

At this time, the installation of all 8 treaty piles have been completed per the design plans.

Pedestrian Pier Piles

On February 8, 9, 10, 11, 2021, we observed the pile contractor, American Construction, install a total of twelve (12) structural piles (including 3 Reinhall piles) for the proposed pier located in the north portion of Site 23. All piles were installed using a Delmag D62-22 diesel impact hammer. Horizontal and vertical control for the project was provided by a nearby benchmark and verified by American Construction with a total station theodolite during driving of the piles.

The installed Reinhall structural piles consisted of 24-inch diameter ASTM A252 Grade 3, open-end steel pipe pile (0.75-inch wall thickness) structurally attached to a proprietary tip assembly with inner rings, delivered to the site in 64-foot length (see Plate 1, Page 6). The Reinhall pile also consists of a smaller pile (mandrel) located inside the structural pile and the mandrel is 66-foot long, 18-inch diameter open-ended steel pile with 0.8-inch wall thickness used only for pile driving purpose. The mandrel, directly impacted by the diesel hammer (see Plate 2, Page 6) hit the inner rings of the (outside) structural pile to drive the pile into the ground. After installation, the mandrel was extracted.

The reminder of the structural piles (non-Reinhall piles) consisted of 24-inch diameter ASTM A252 Grade 3, open-end steel pipe pile with 0.75-inch wall thickness delivered to the site in 61-foot length. Six (6) originally planned Reinhall piles (P-06, P-07, P-09S, P-09NW, P-10N, P-10S) were replaced with non-Reinhall piles, as detailed in the section below.

5.2.3 Pile Driving (Reinhall Piles)

We observed American install Reinhall Piles P-02N and P-03 to the design tip elevation of -44 feet on February 8. Each pile was driven with a separate mandrel (no reuse of mandrel).

Blow counts for the final foot of pile driving was about 54 to 63 blows per foot. Based on the number of blow counts per minute we observed, the corresponding hammer stroke was about 10 feet at the end of the pile driving. In our opinion, based on our observations of the pile installation and the number of blow counts we observed at the end of the impact pile driving, it is our opinion that the installed piles are adequate to support the design ultimate load of 90 kips per pile.

On February 9, PanGEO observed American attempt to drive Reinhall pile P-04 using the mandrel that was previously used to drive P-02N. During driving, the inside of the mandrel became plugged with soils, which significantly increased the driving resistance. As a result, American was unable to drive the pile to the design tip elevation of -44 feet, meeting refusal at tip elevation of about -43 feet (with about 80+ blows/ft at the end of the pile driving). American contacted the owner and structural engineer on the same day to discuss the issue. Based on conversations with American, we understand that the structural engineer has approved the at- built pile tip elevation -43 feet for pile P-04. From a geotechnical standpoint, based on the observed number of blow counts per minute and the corresponding hammer stroke (~10 feet) and the number of blow counts (80+ blows/ft) we observed at the end of the impact pile driving, it is our opinion that the installed pile P-04 with the at-built pile tip elevation -43 feet is adequate to support the design ultimate load of 90 kips per pile.

Because the mandrel that was plugged with soils and cannot be re-used for pile driving, the reminder of the originally proposed Reinhall piles (P-06, P-07, P-09S, P-09NW, P-10N, P-10S) are to be installed with non-Reinhall piles using a bubble curtain per the Port of Seattle.

5.2.4 Pile Driving (Non-Reinhall Piles)

On the afternoon of February 9 and on February 10 and 11, PanGEO observed American install the remaining 9 structural piles (non-Reinhall piles) using a Delmag D62-22 diesel impact hammer (see Plate 3, Page 7). All piles were installed using a bubble curtain (steel ring with holes that releases bubbles of compressed air) to reduce the propagation of acoustic waves from the pile driving (see Plate 4, Page 7). All installed structural piles were driven to approximately design pile tip Elevation -44 feet or deeper (about 26 to 40 feet below the existing site grades) with a blow count of about 22 to 38 blows per foot for the final foot of the pile driving. Based on the number of blow counts per minute we observed, the corresponding hammer stroke was about 9 feet at the end of the pile driving. In our opinion, based on our observations of the pile installation and the number of blow counts we observed at the end of the impact pile driving, it is our opinion that the installed piles are adequate to support the design ultimate load of 90 kips per pile.

Detailed installation records for the twelve structural piles which include the recorded blows per foot and blows per minute during impact, estimated tip elevation and date/time of installation are included as Appendix B - Attachment 2.

At this time, the installation of all 16 structural piles (for pedestrian pier) and 10 non-structural piles (8 treaty piles and 2 debris deflector piles) have been completed per the design plans.

5.2.5 Vibration Monitoring

Results of our vibration measurements are summarized and plotted on Figure 1 – Summary of Vibration Measurements, found on Page 8 of this report. Also shown on Figure 1 are approximate upper and lower boundaries of PPVs that can be anticipated during pile driving at the site based on the measurements and our observations. The histograms (measured PPVs vs. time) recorded at distances of 15, 25, and 35 feet for Reinhall piles (P-02N and P-03) and conventional piles (P-01S, P-02S, P-01NA) and their pile driving records are included as Appendix B - Attachment 3.

In summary, the highest recorded PPVs were about 1.97 inch/sec (impact hammer, Reinhall pile, 15 feet from the source) and about 1.8 inch/sec (vibratory hammer, non-Reinhall pile, 10 feet from the source). The trend of the data indicates the measured PPVs generally attenuated with distance from the source of vibration.

5.3 Vibration Monitoring Discussion

Based on the measurements and observations made during pile driving, we also observed the following:

- The highest PPVs measured during vibratory hammer driving were frequently recorded during hammer startup and shutdown, particularly when the pile was vibrated in the upper loose fill/alluvium.
- For non-Reinhall piles (i.e., conventional piles), the data indicate the vibration attenuation with distance from the source was more significant when pile was driven with the vibratory hammer than with the impact hammer in dense soils. The data also indicate PPVs measured from vibratory hammer driving in dense soils are on average about half to two-thirds of the values measured from impact hammer driving in dense soils.
- For both Reinhall and non-Reinhall piles, the highest recorded PPVs were measured during pile driving in medium dense soils with a driving resistance of about 20 to 30 blows per foot (see Appendix B - Attachment 3). In comparison, the highest recorded PPVs from driving Reinhall piles are greater than the highest recorded PVs from driving non-Reinhall piles, as summarized in Table 5-1 below.

Table 5-1. Measured Peak PPVs from pile driving in medium dense soils at distances of 15, 25, and 35 feet.

Distance from source (feet)	Reinhall Pile #	Measured Peak PPVs (in/sec)	Non-Reinhall Pile #	Measured Peak PPVs (in/sec)	% Increase PPVs (Reinhall piles) to PPVs (Non-Reinhall piles)	Soil Condition and Driving Resistance
15	**P-02N**	**1.97**	**P-01S**	**0.99**	**99**	**Medium dense soils with average 20-30 blows/ft**
25	**P-03**	**1.12**	**P-02S**	**0.85**	**31**	
35	**P-02N**	**0.86**	**P-01NA**	**0.74**	**16**	

- For pile driving in dense to very dense soils with a driving resistance of about 40 to 55 blows per foot, the average measured PPVs from driving Reinhall piles are greater than the average measured PPVs from driving non-Reinhall piles, as summarized in Table 5-2 below.

Table 5-2. Measured Average PPVs from pile driving in dense/very dense soils at distances of 15, 25, and 35 feet.

Distance from source (feet)	Reinhall Pile #	Measured Average PPVs (in/sec)	Non-Reinhall Pile #	Measured Peak PPVs (in/sec)	% Increase PPVs (Reinhall piles) to PPVs (Non-Reinhall piles)	Soil Condition and Driving Resistance
15	**P-02N**	**0.64**	**P-01S**	**0.52**	**24**	**Dense to very dense soils with average 40-55 blows/ft**
25	**P-03**	**1.13**	**P-02S**	**0.56**	**102**	
35	**P-02N**	**0.69**	**P-01NA**	**0.56**	**23**	

The histograms (measured PPVs vs. time) recorded at distances of 15, 25, and 35 feet for Reinhall piles (P- 02N and P-03) and non-Reinhall piles (P-01S, P-02S, P-01NA) and their pile driving records are included as Appendix B - Attachment 3 at the end of this report.

6 DISCUSSION

Based on the collective results of the data recording (hydroacoustic, in-air, vibration) for the T-117 installation, the mandrel pile did not perform significantly different in comparison to single wall pile. The hydroacoustic results for upland installation demonstrated similar performance, which could be expected: the mandrel pile is designed for sound attenuation in water.

Regarding in-water sound attenuation, the observation that single wall pile with an operating bubble curtain had (slightly) higher attenuation than the mandrel pile was inconsistent with previous tests in Commencement Bay and Vashon Island (Reinhall et al. 2015). The data collection was limited to one in-water mandrel pile, so the performance could vary with more information at this site.

Both the Commencement Bay and Vashon studies were conducted in marine waters with soft substrates. It is interesting to note that the vibration monitoring identified some the higher PPV when operating in dense to very dense soils, regardless of whether the pile was driven in water or upland. Substrate conditions appear to include hard ledges and subgrade boulders (based on the pile driving notes). Since T-117 is located withing the Duwamish channel, it makes sense that the pile have a higher likelihood of encountering bed load materials: in Commencement Bay and at Vashon Island pile testing occurred beyond the extent of any outwash. Soil profiles at all three sites could provide clear evidence of differences at pile tip depth.

In-air noise monitoring also found little difference between the pile types. Sound generation and transmission in air isn’t comparable to hydroacoustics. Future pile testing that includes in-air monitoring could inform site to site comparisons that may illuminate differences based on substrate conditions, but it is unclear if pile design would have noticeable effect.

The observation of mud coming out of the mandrel during driving of P-04 with subsequent operational issues may point to a construction consideration. If the mandrel was clogged (partially) after driving mandrel P-02, then using the same mandrel would serve to advance the sediment upward through the remainder of the mandrel, until it overflowed. Either the mandrel would need to be ‘cleared’ between uses or a different mandrel used. The PanGEO report observes that the sediment within the mandrel was very tightly packed: a solid plug could affect the attenuating effect of the double wall: that would have to be tested in future studies.

The Port of Seattle is committed to operations that support and facilitate Puget Sound recovery while providing sustainable economic benefit to the state of Washington and beyond. The mandrel pile test was conducted in concert with other on-going stewardship initiatives the Port of Seattle is conducting to further the science and practice of in-water construction that reduces impact to listed species. The T-117 study adds to the body of data and provides valuable insights into specific opportunities for noise attenuation, and constraints of site conditions.

7 APPENDICES

7.1 Appendix A – Hydroacoustics Frequency Spectra

7.1.1 P-02 S – Upland Standard Pile

Figure 7-1. Frequency spectrum for subsample from first quarter of P-02 S drive.

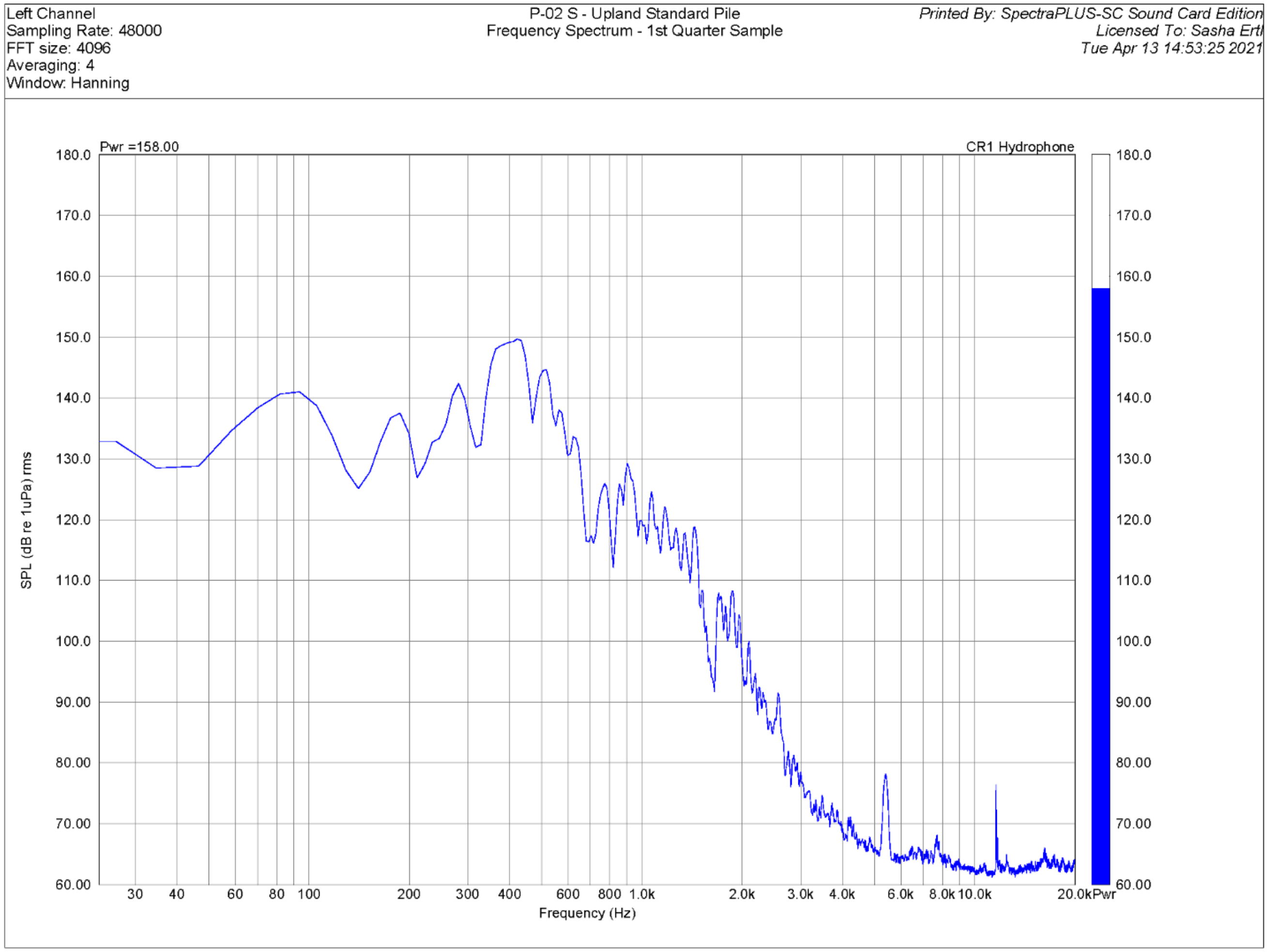
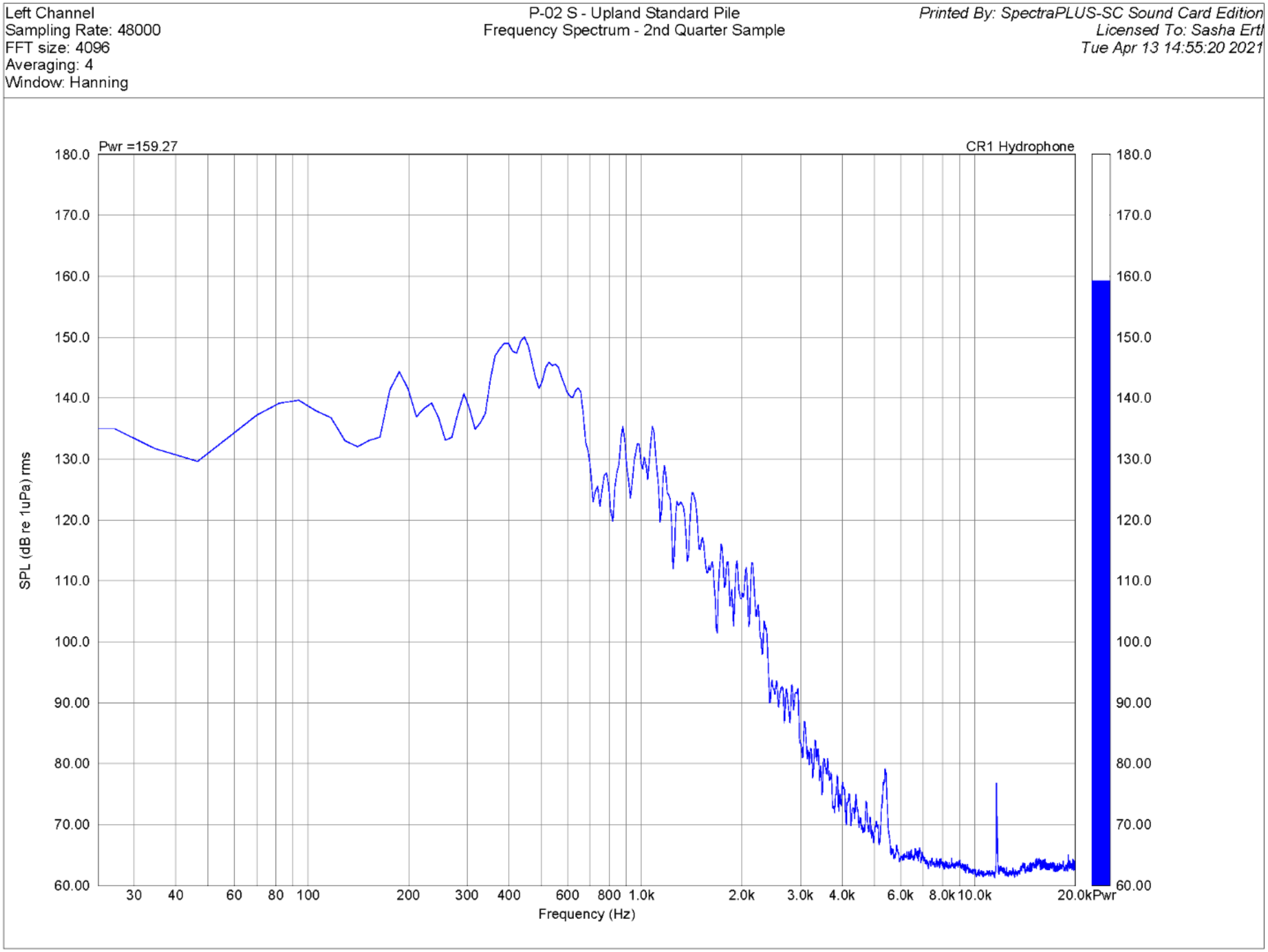


Figure 7-2. Frequency spectrum for subsample from second quarter of P-02 S drive.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-02 S - Upland Standard Pile
Frequency Spectrum - 2nd Quarter Sample

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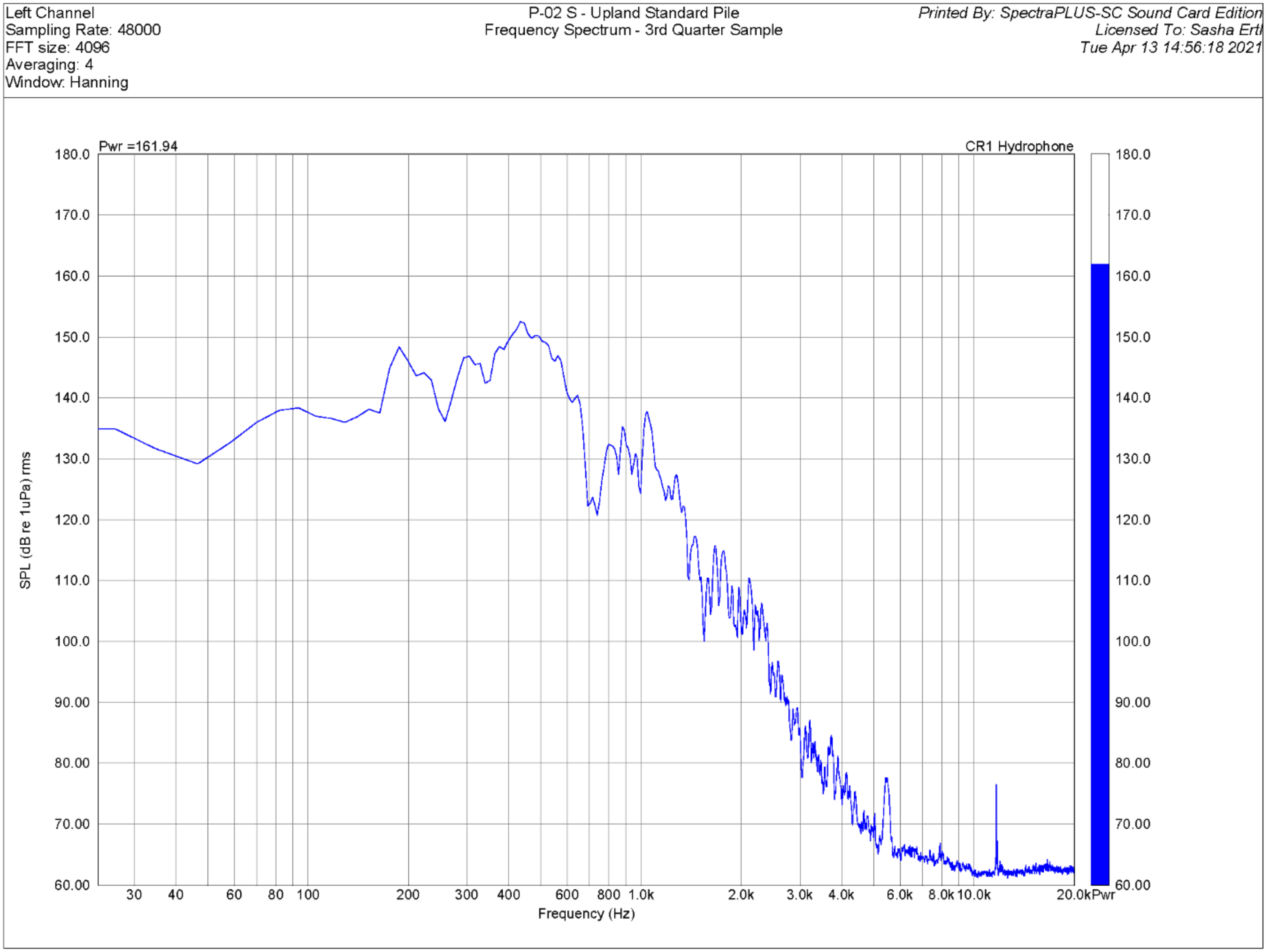
Figure 7-3. Frequency spectrum for subsample from third quarter of P-02 S drive.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-02 S - Upland Standard Pile
Frequency Spectrum - 3rd Quarter Sample

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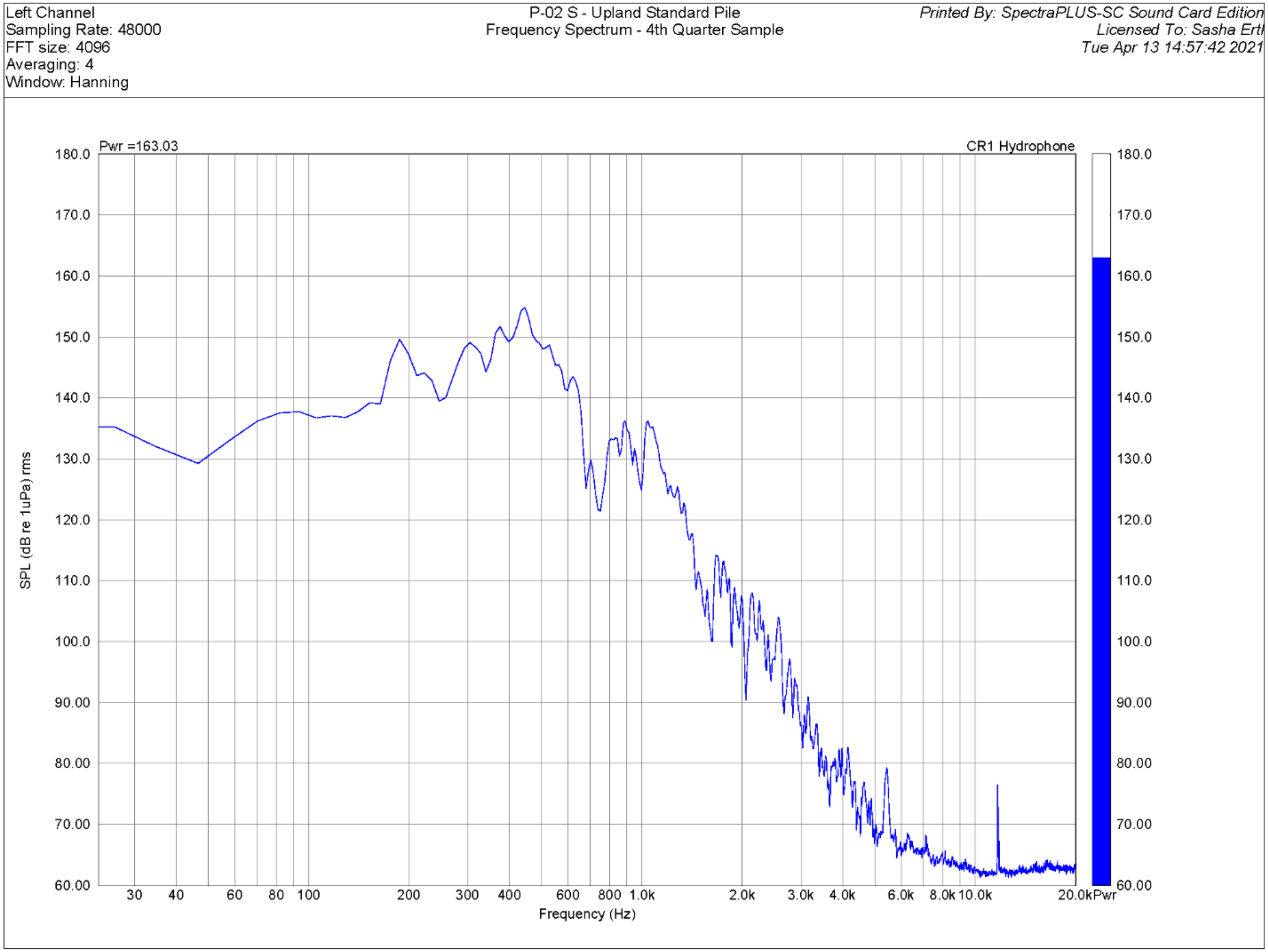
Figure 7-4. Frequency spectrum for subsample from fourth quarter of P-02 S drive.



7.1.2 *P-02 N – Upland Double-Walled Mandrel Pile*

Figure 7-5. Frequency spectrum for subsample from first quarter of P-02 N drive.

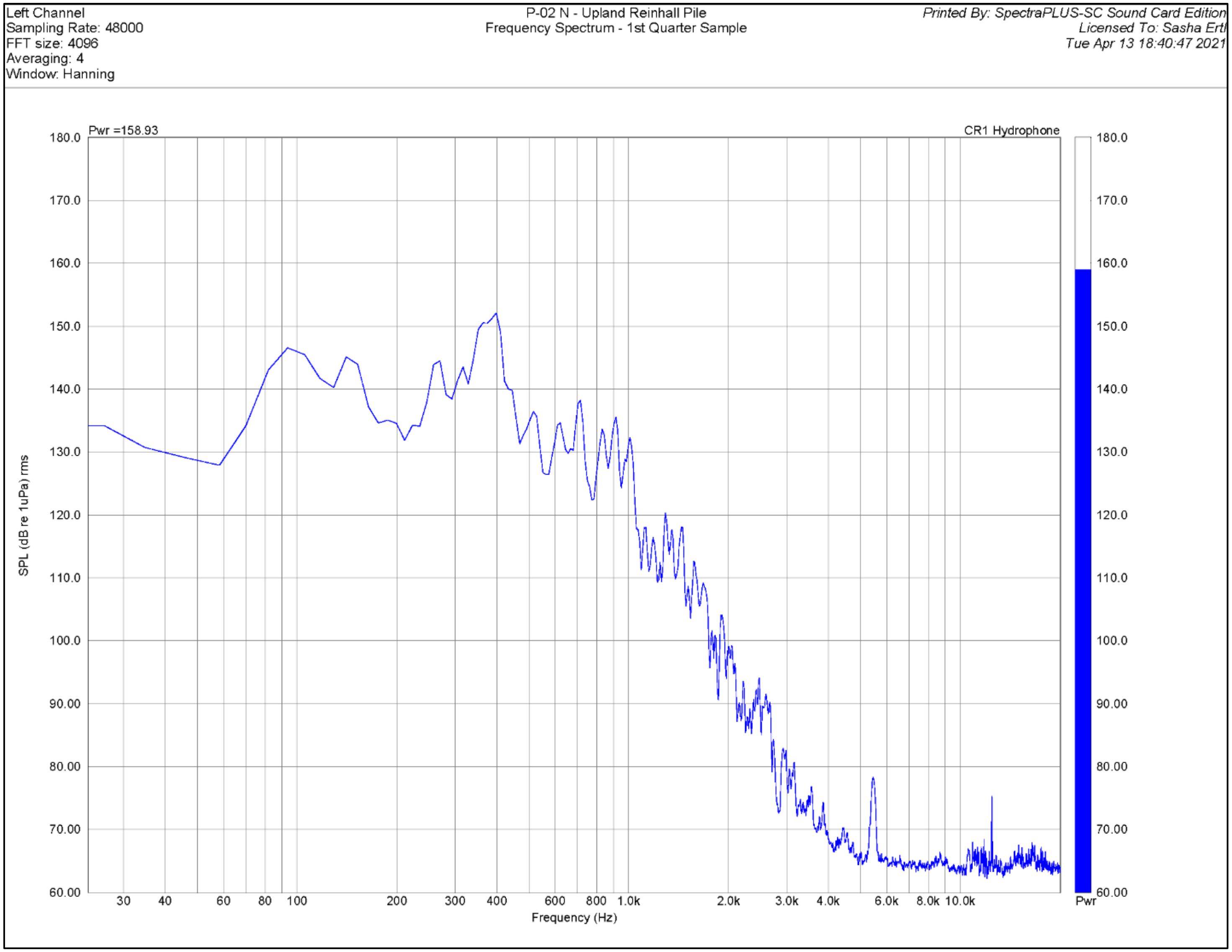


Figure 7-6. Frequency spectrum for subsample from second quarter of P-02 N drive.

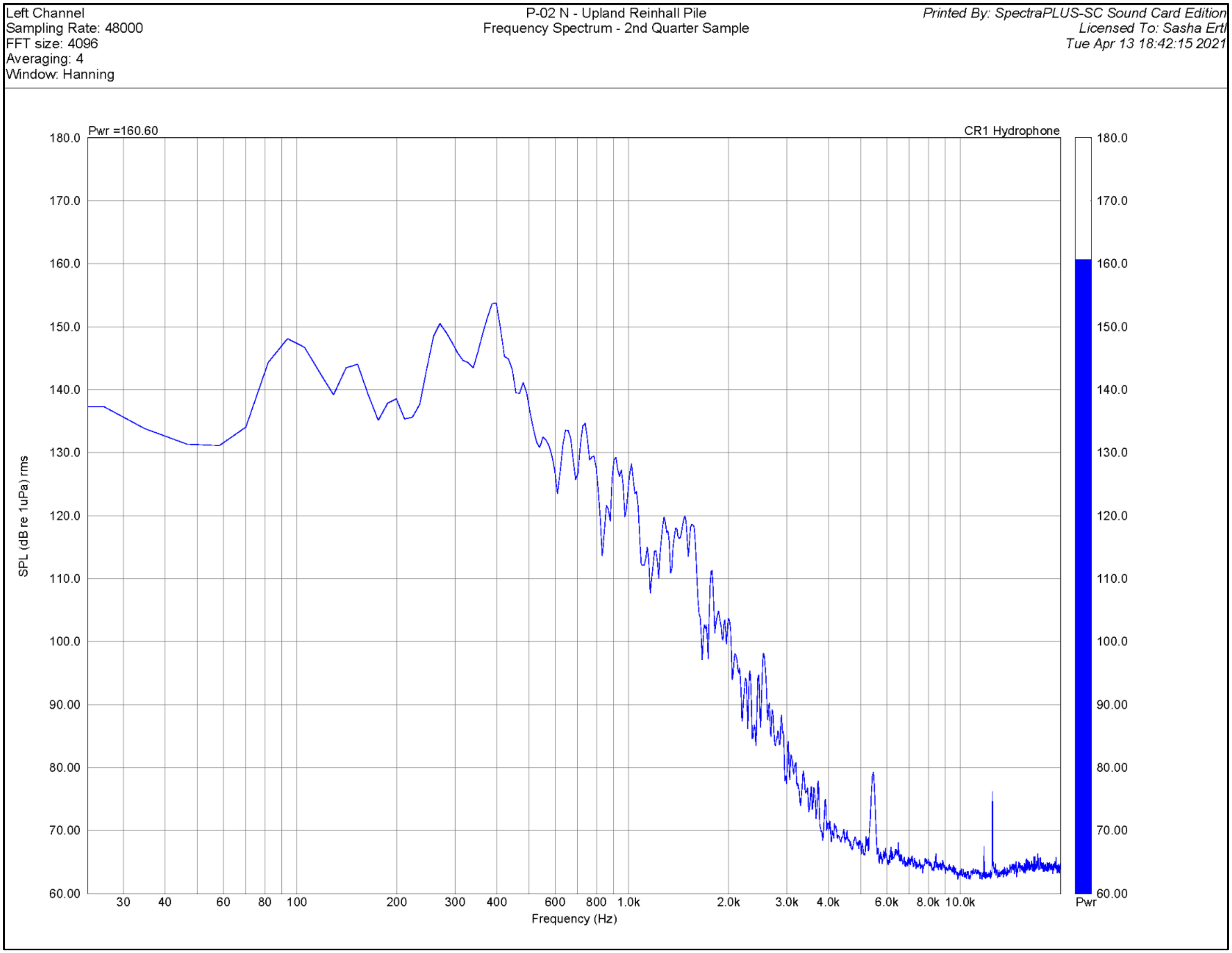


Figure 7-7. Frequency spectrum for subsample from third quarter of P-02 N drive.

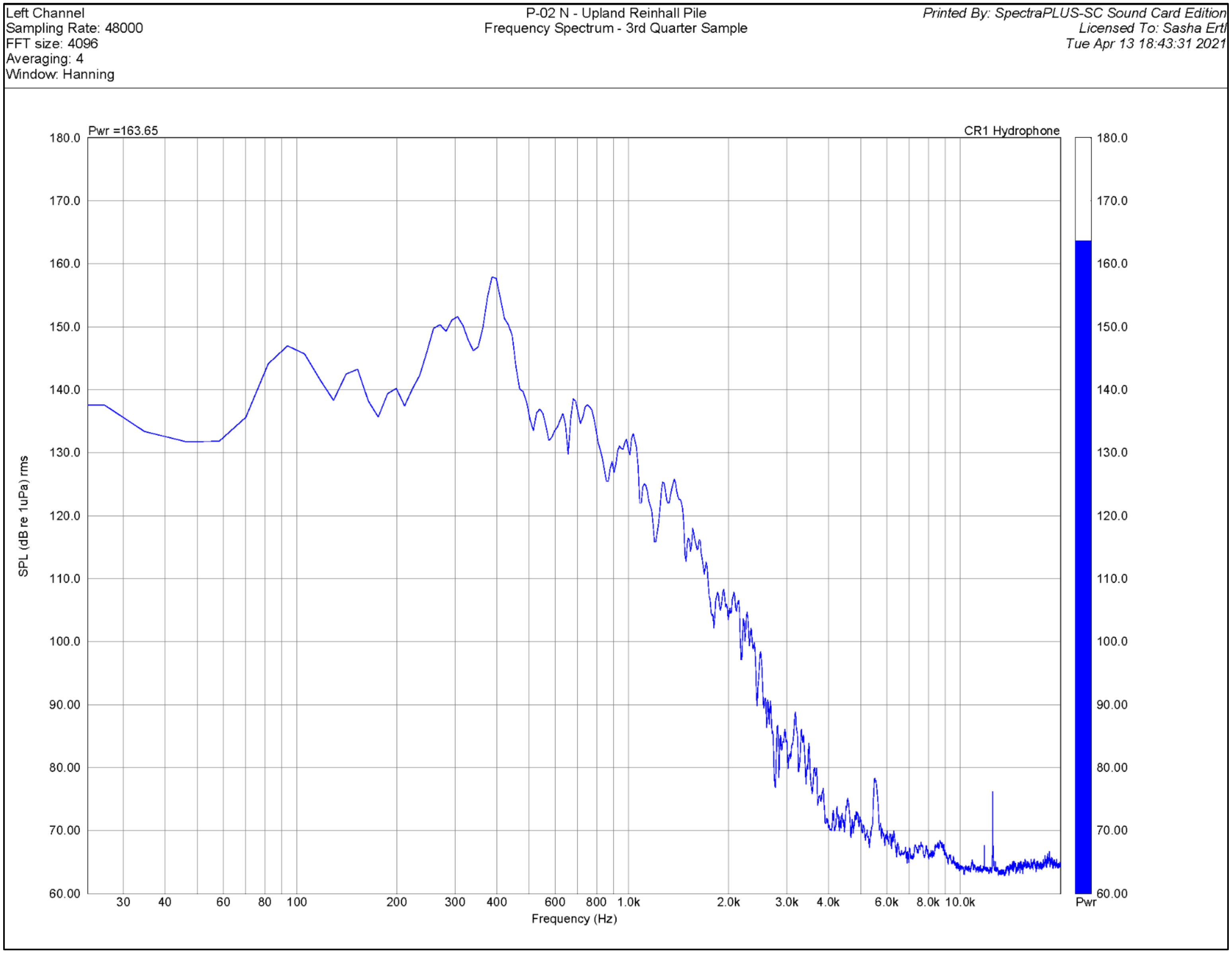
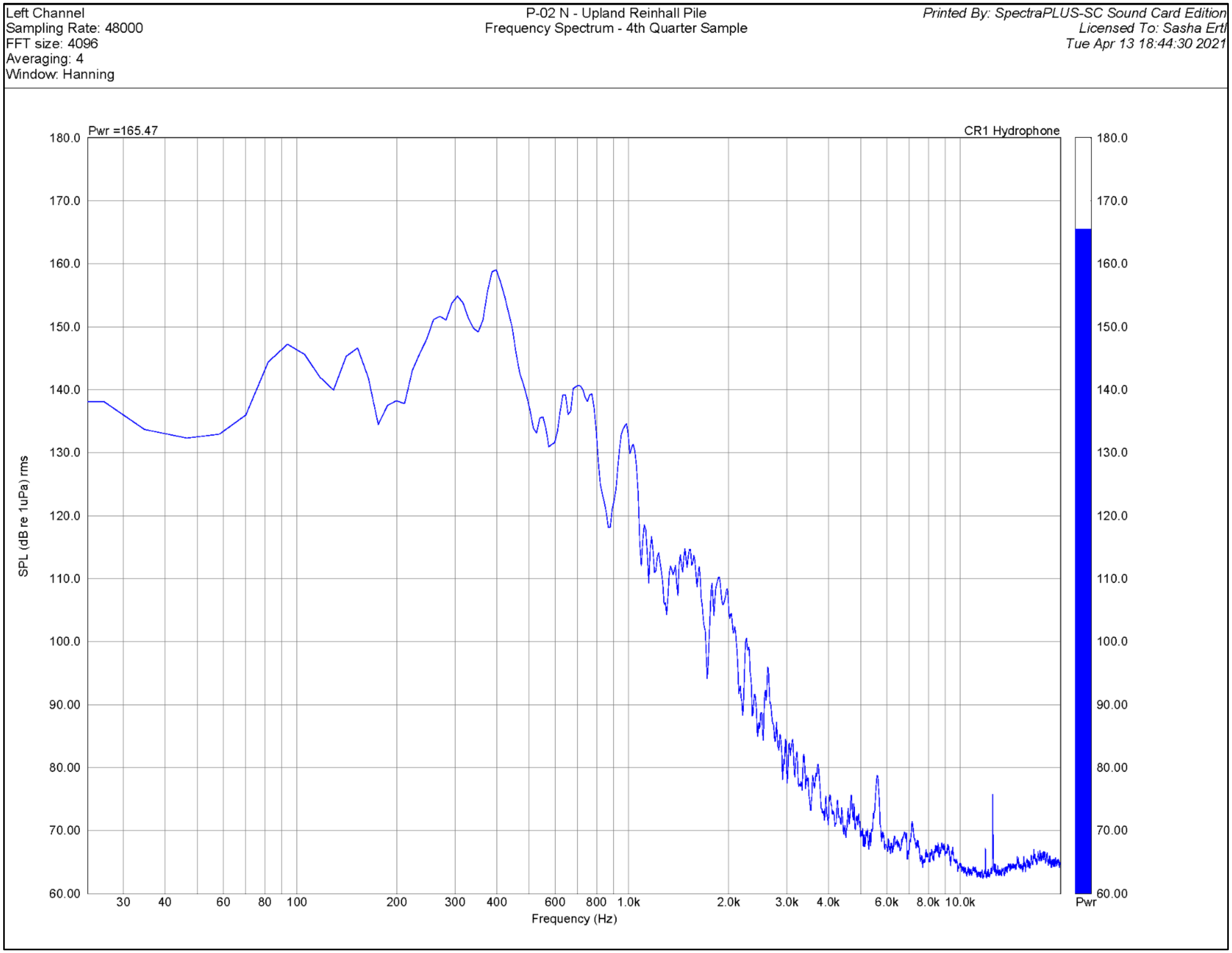


Figure 7-8. Frequency spectrum for subsample from fourth quarter of P-02 N drive.



7.1.3 P-04 – In-Water Double-Walled Mandrel Pile

Figure 7-9. Frequency spectrum for subsample from first quarter of P-04 drive.

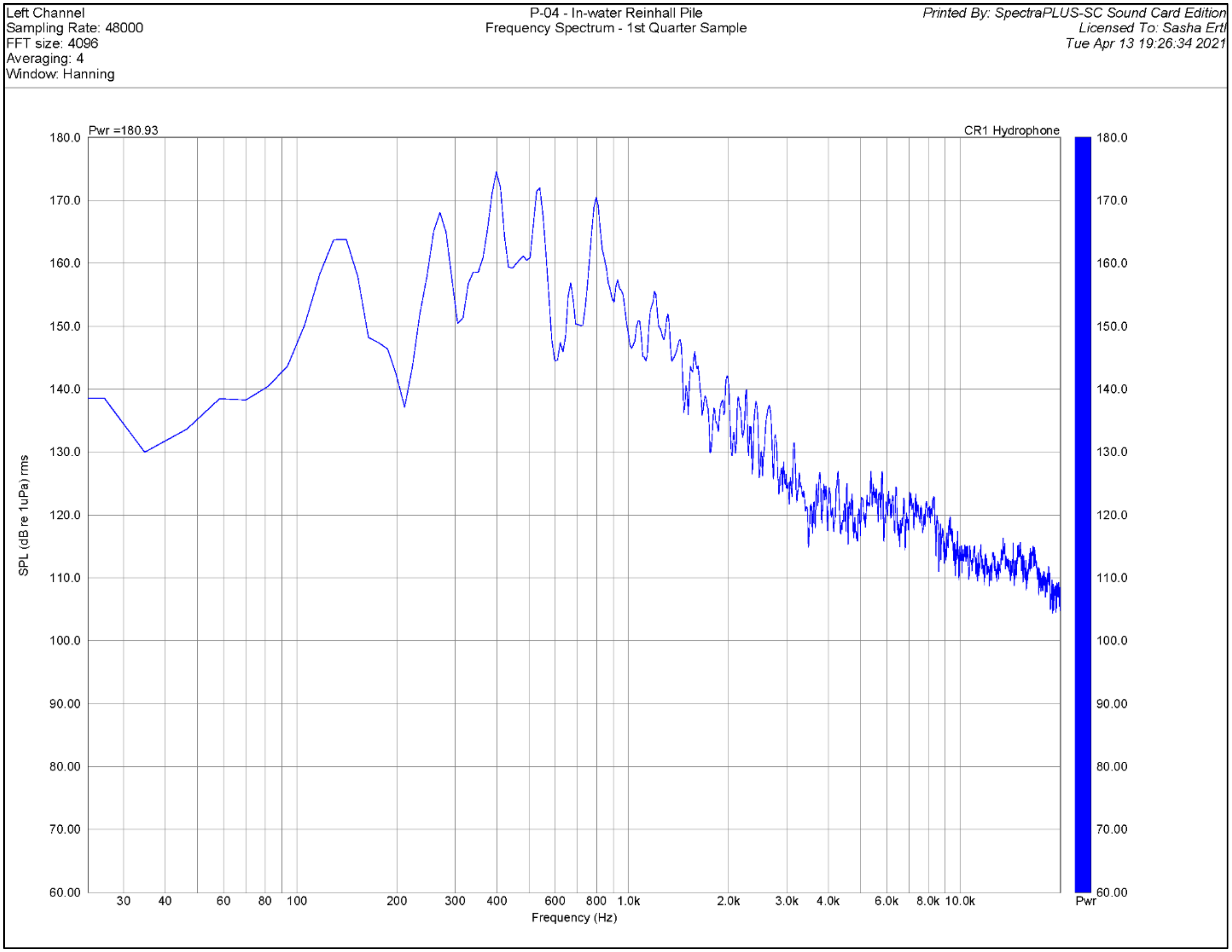
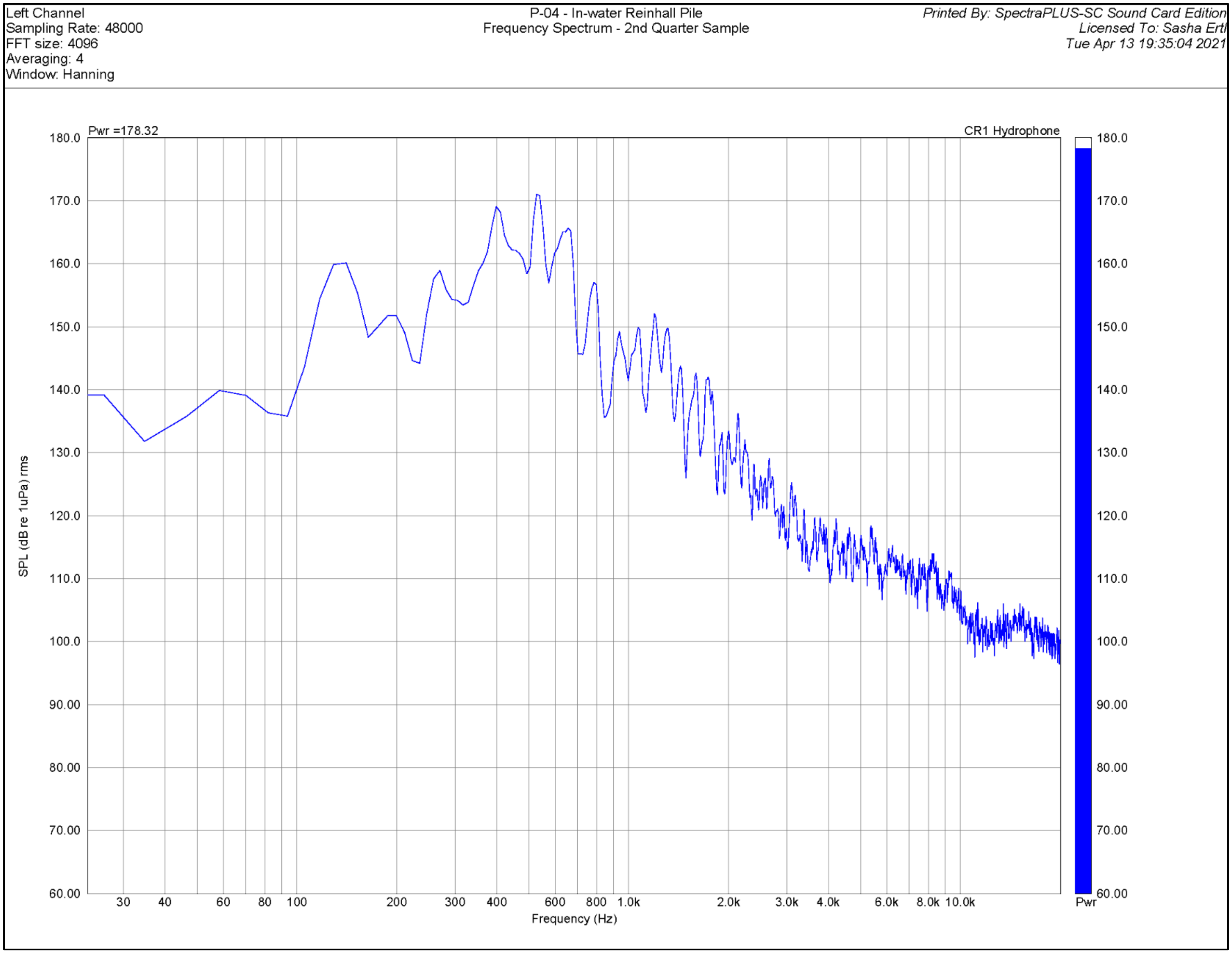


Figure 7-10. Frequency spectrum for subsample from second quarter of P-04 drive.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-04 - In-water Reinhall Pile
Frequency Spectrum - 2nd Quarter Sample

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Figure 7-11. Frequency spectrum for subsample from third quarter of P-04 drive.

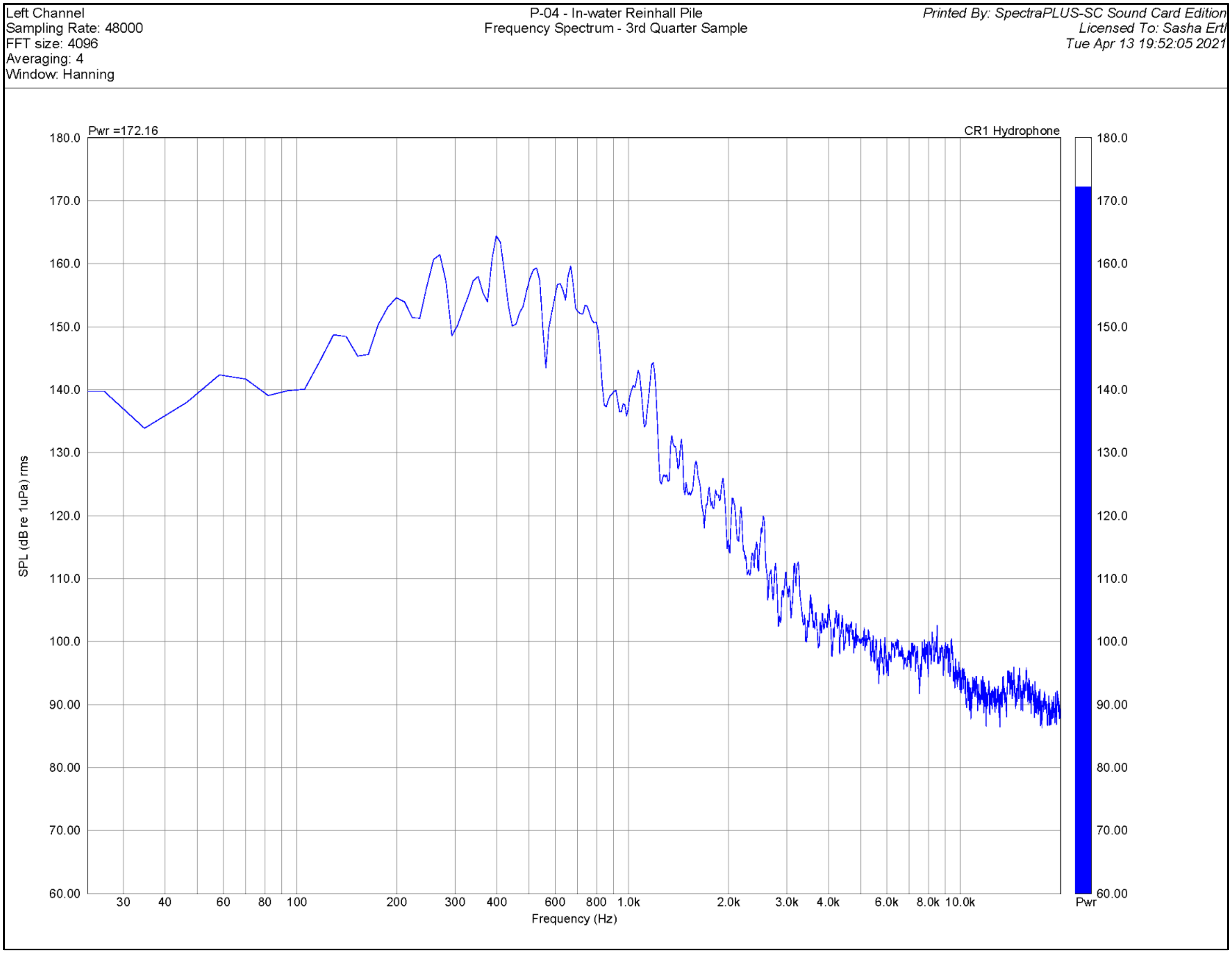
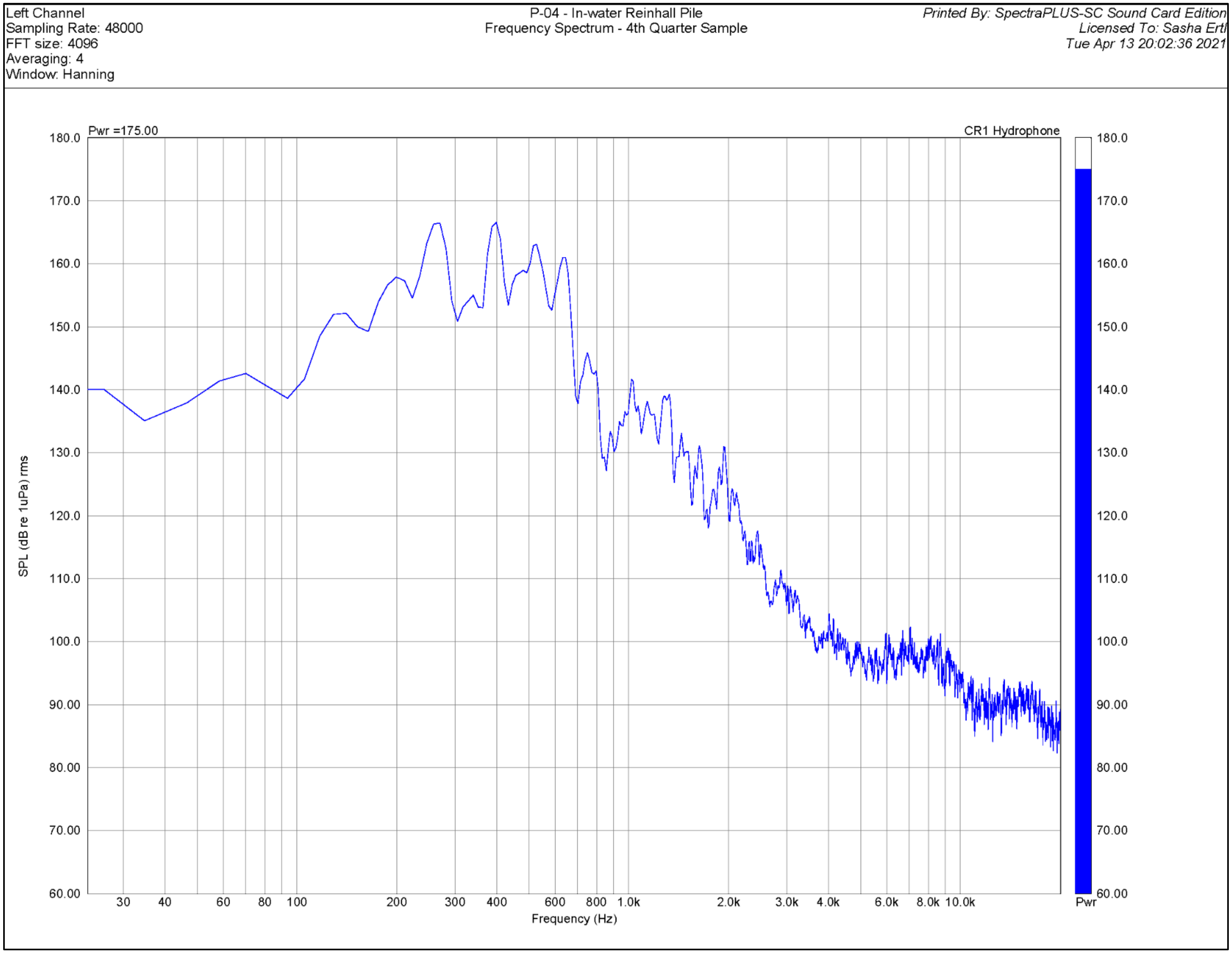


Figure 7-12. Frequency spectrum for subsample from fourth quarter of P-04 drive.



7.1.4 P-05 – In-Water Standard Pile

Figure 7-13. Frequency spectrum for subsample from first quarter of P-05 drive with the bubble curtain on.

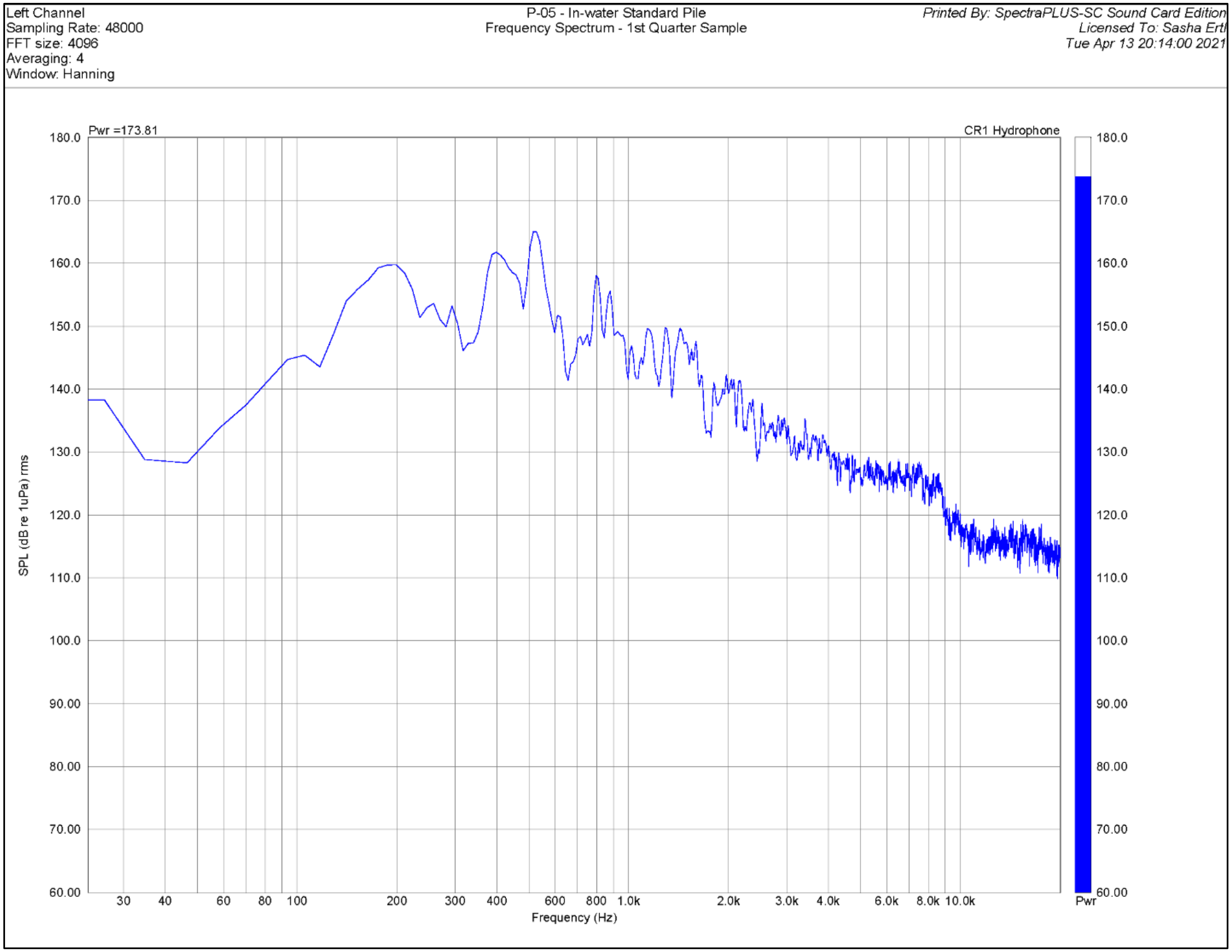


Figure 7-14. Frequency spectrum for subsample from first 30-second segment of P-05 drive with the bubble curtain off.

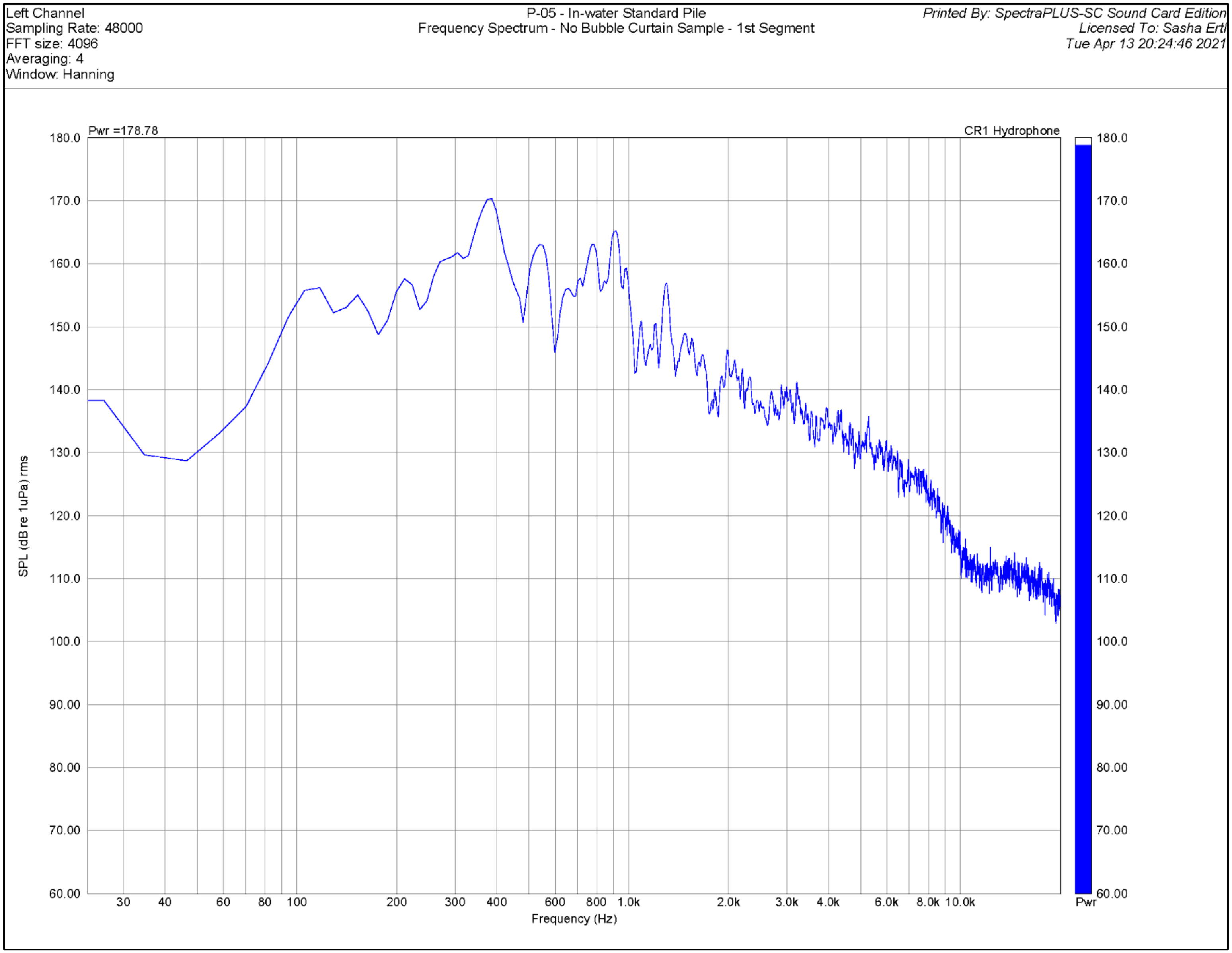


Figure 7-15. Frequency spectrum for subsample from second quarter of P-05 drive with the bubble curtain on.

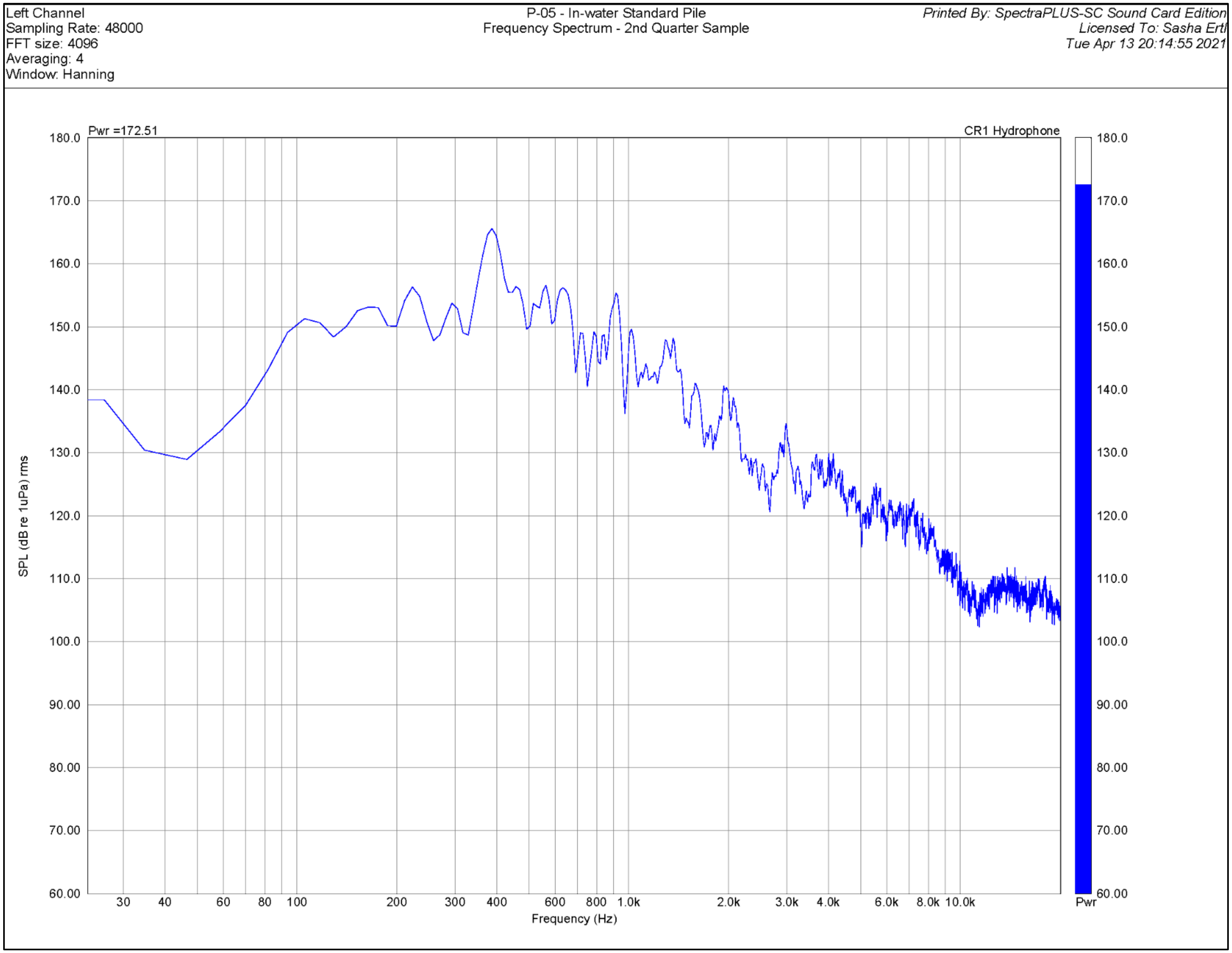


Figure 7-16. Frequency spectrum for subsample from second 30-second segment of P-05 drive with the bubble curtain off.

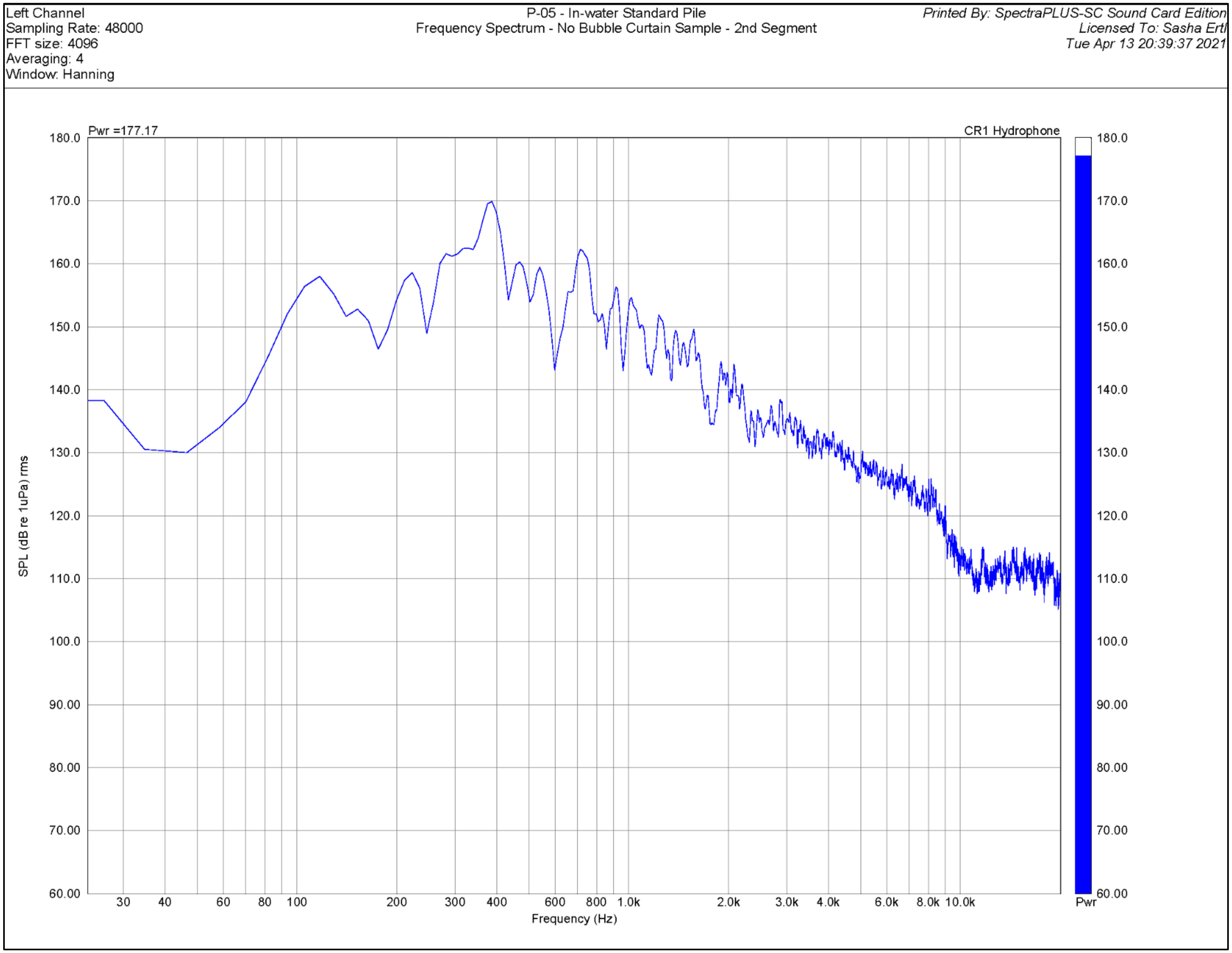


Figure 7-17. Frequency spectrum for subsample from third quarter of P-05 drive with the bubble curtain on.

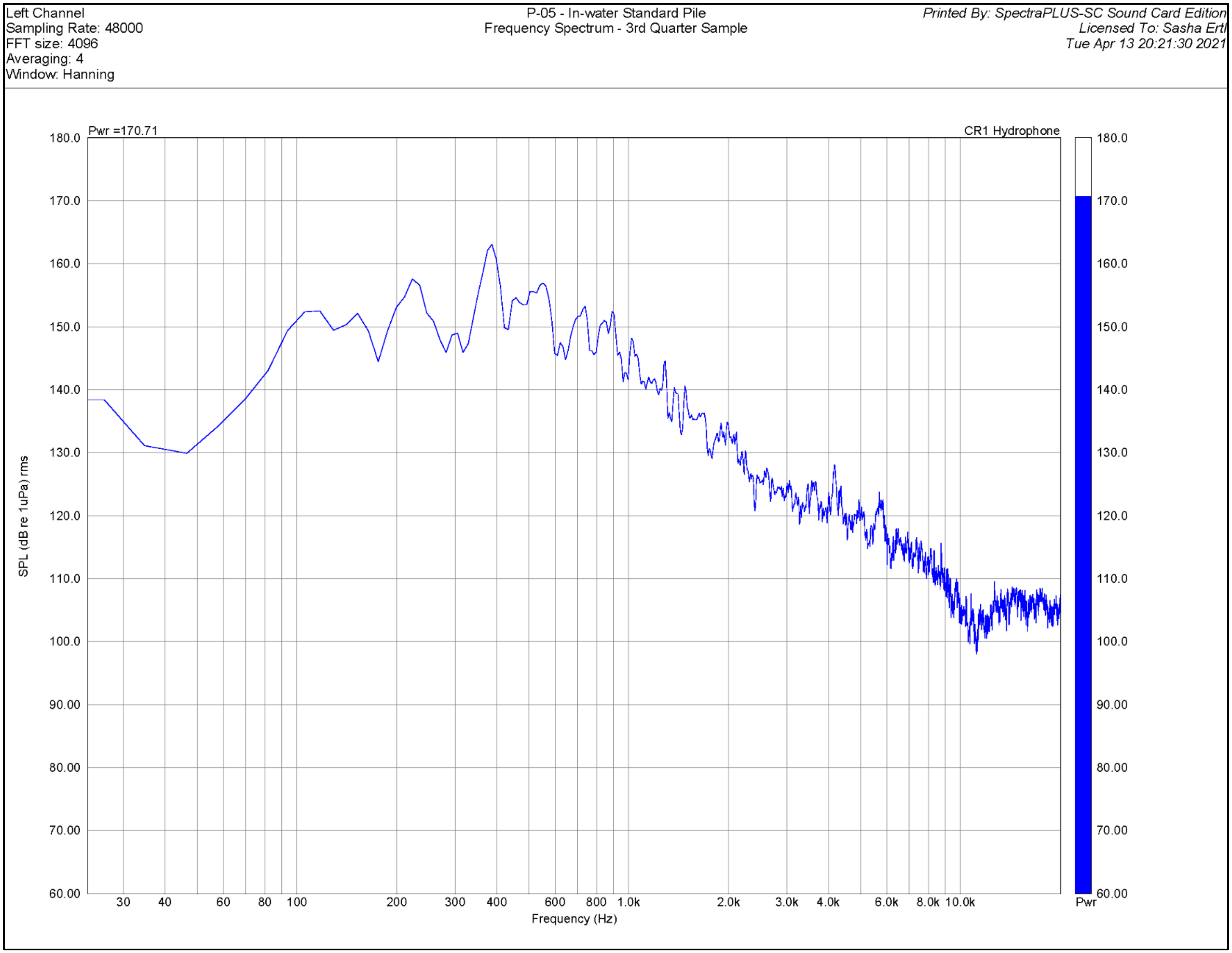


Figure 7-18. Frequency spectrum for subsample from third 30-second segment of P-05 drive with the bubble curtain off.

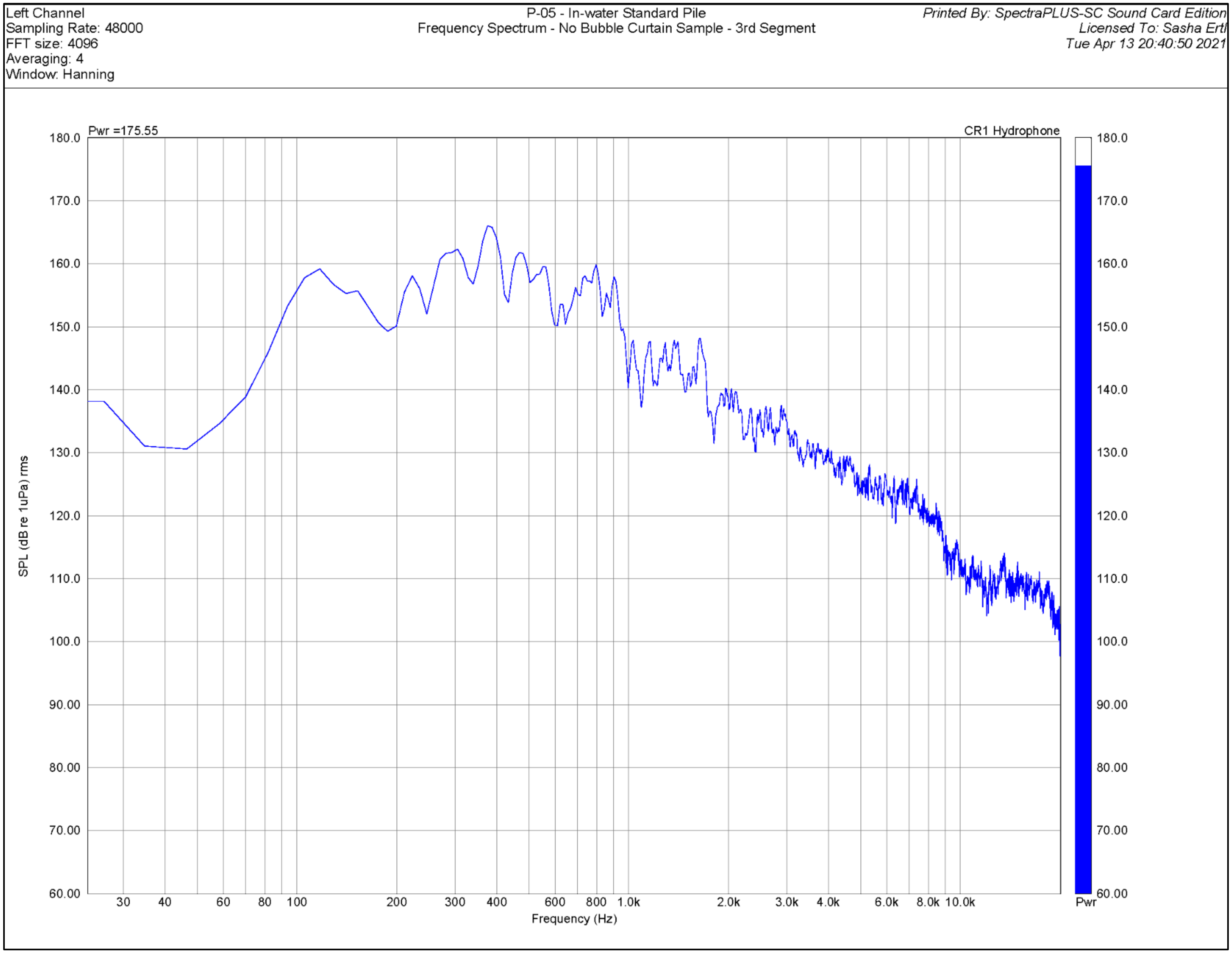
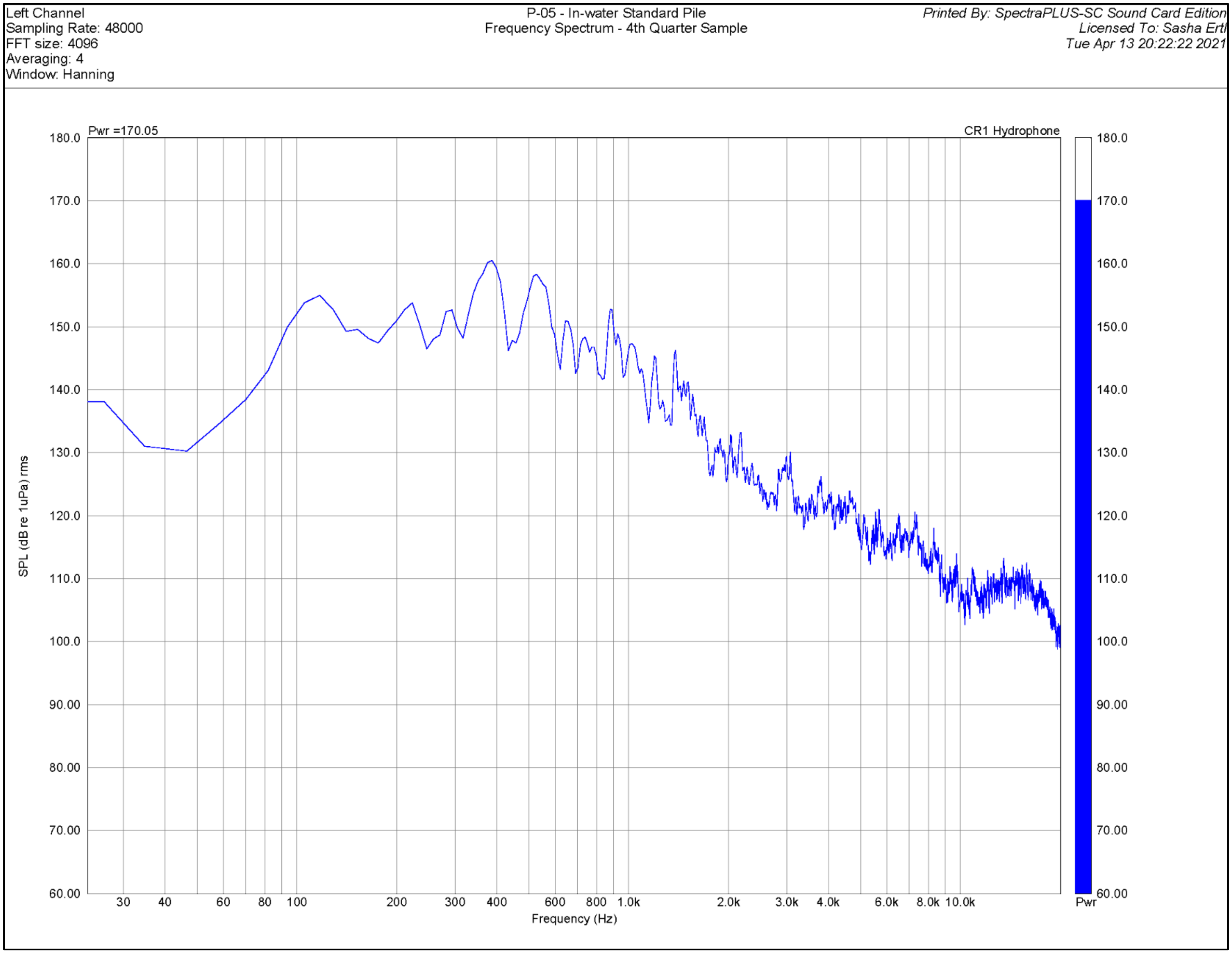


Figure 7-19. Frequency spectrum for subsample from fourth quarter of P-05 drive with the bubble curtain on.



7.1.5 P-06 – In-Water Standard Pile

Figure 7-20. Frequency spectrum for subsample from first quarter of P-06 drive with the bubble curtain on.

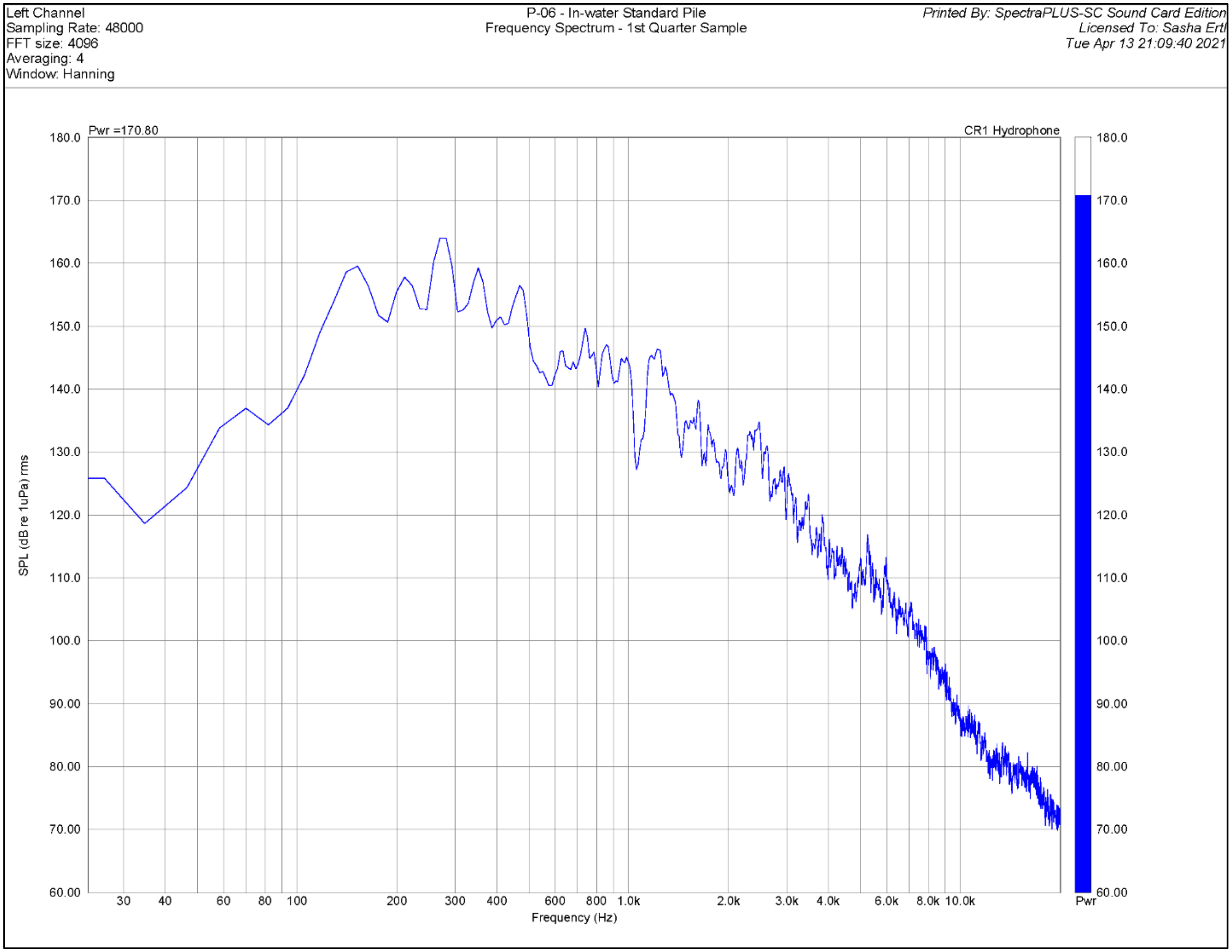
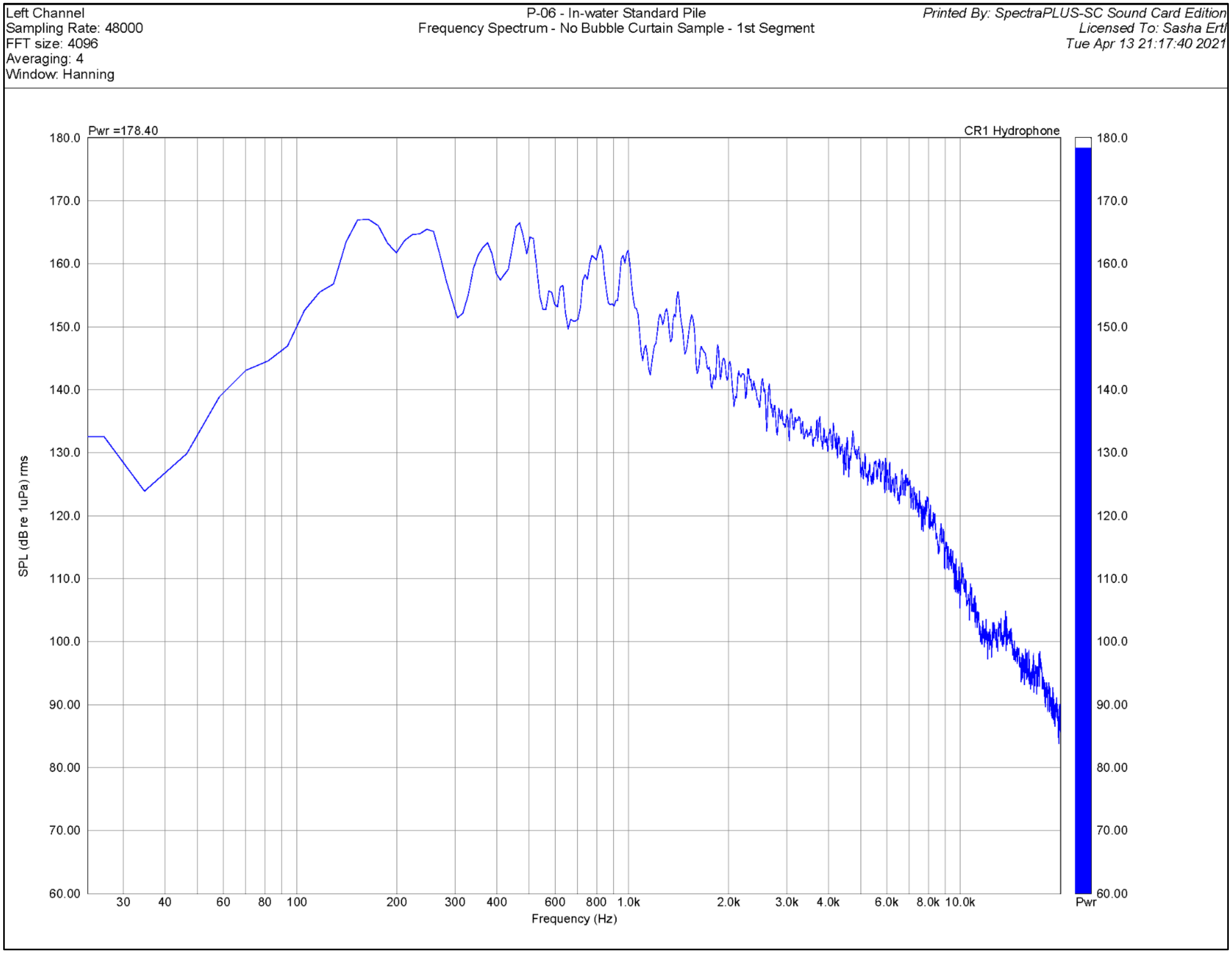


Figure 7-21. Frequency spectrum for subsample from first 30-second segment of P-06 drive with the bubble curtain off.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-06 - In-water Standard Pile
Frequency Spectrum - No Bubble Curtain Sample - 1st Segment

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Figure 7-22. Frequency spectrum for subsample from second quarter of P-06 drive with the bubble curtain on.

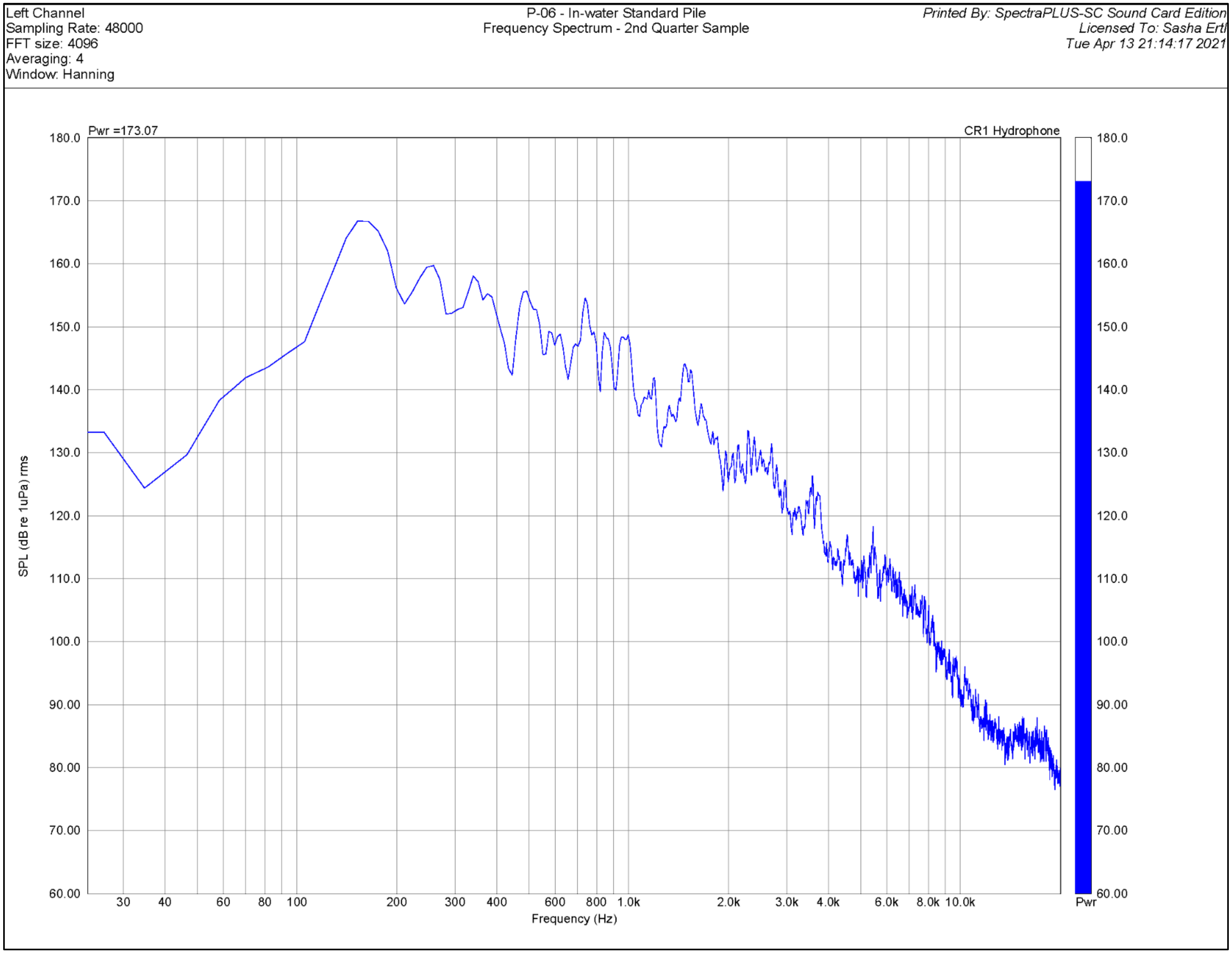
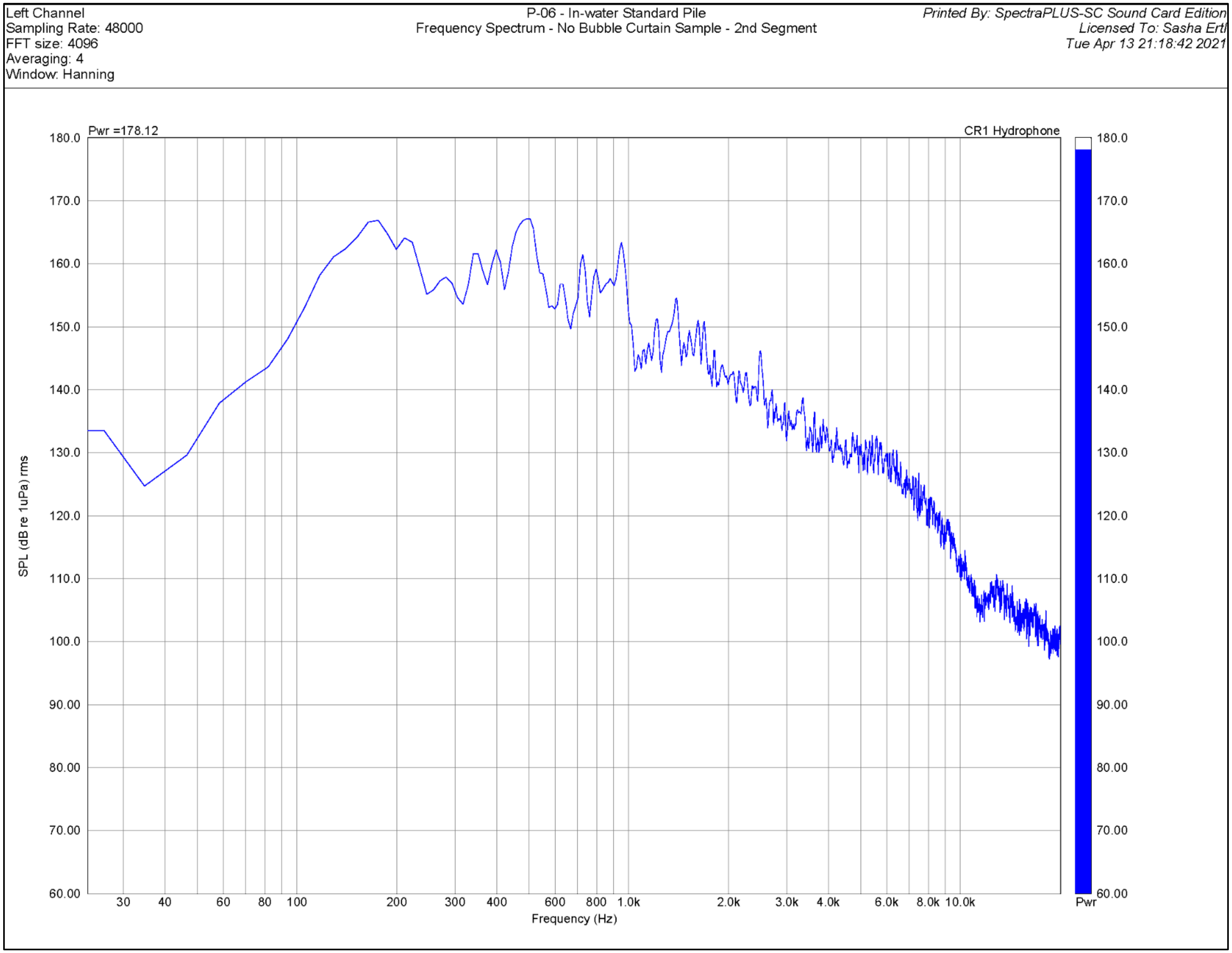


Figure 7-23. Frequency spectrum for subsample from second 30-second segment of P-06 drive with the bubble curtain off.



Left Channel
Sampling Rate: 48000
FFT size: 4096
Averaging: 4
Window: Hanning

P-06 - In-water Standard Pile
Frequency Spectrum - No Bubble Curtain Sample - 2nd Segment

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Figure 7-24. Frequency spectrum for subsample from third quarter of P-06 drive with the bubble curtain on.

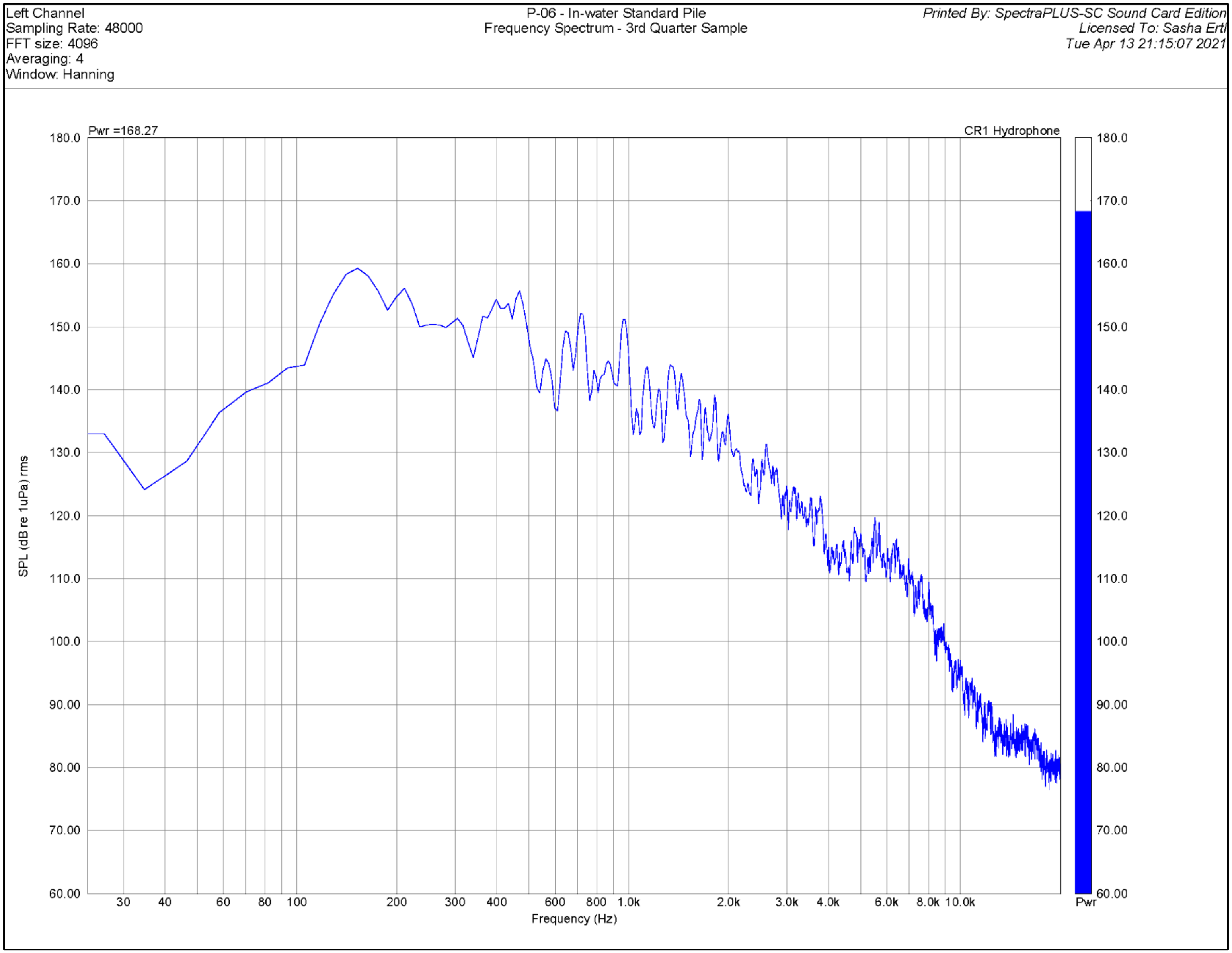


Figure 7-25. Frequency spectrum for subsample from third 30-second segment of P-06 drive with the bubble curtain off.

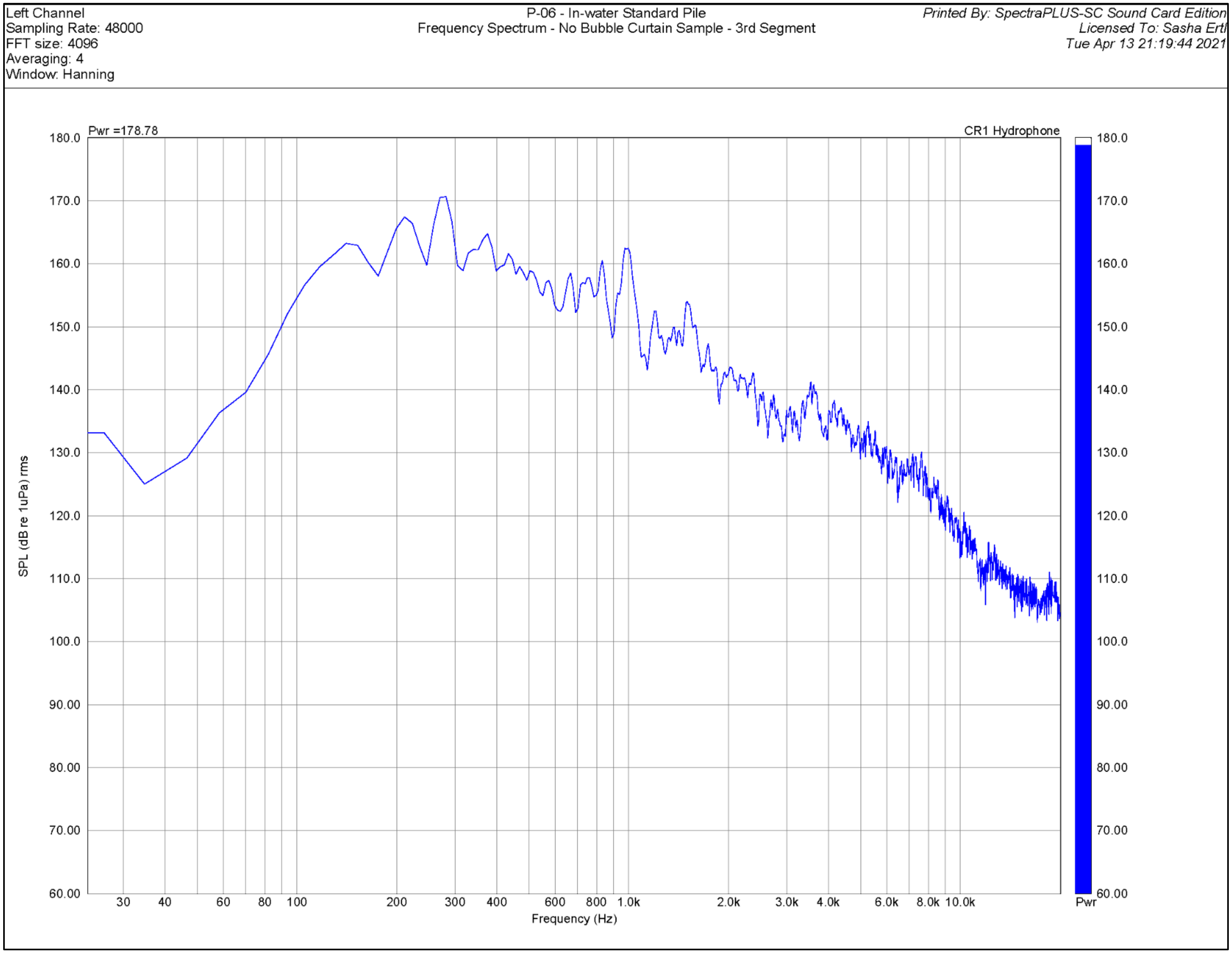
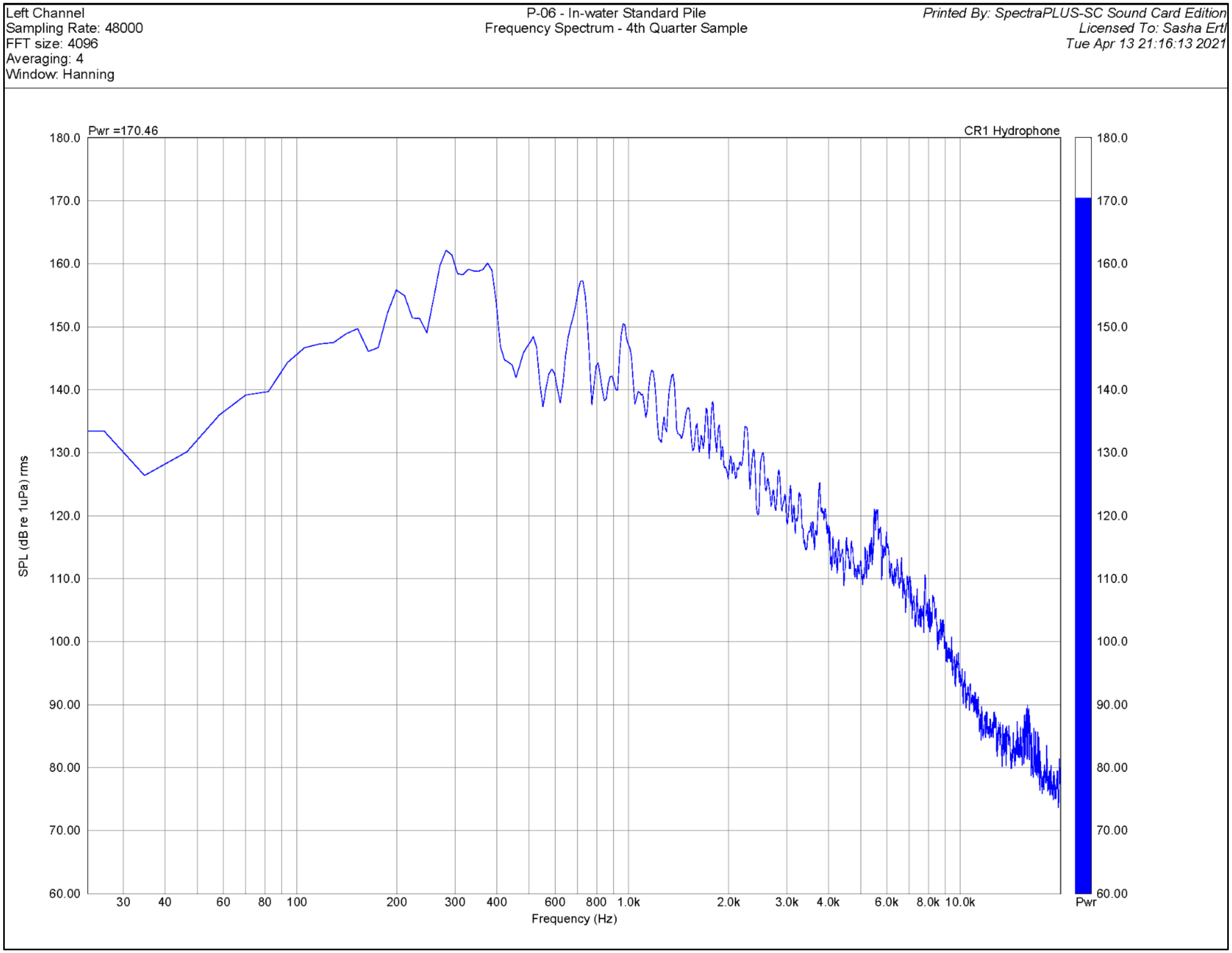


Figure 7-26. Frequency spectrum for subsample from fourth quarter of P-06 drive with the bubble curtain on.



7.2 Appendix B – Vibration Monitoring Field Report

PanGEO INCORPORATED Geotechnical and Earthquake Engineering Consultants		
3213 Eastlake Ave E, Ste B Seattle, WA 98102	**Project No.** 20-478	**Page No.** 1 of 8
Tel: (206) 262-0370 Fax: (206) 262-0374	**Report No.** 3	**Dates** February 1, 2021 / Mon February 8 – 11, 2021 / Mon – Thurs
Project Name Terminal 117 Habitat Restoration – Site 23 & 25	**Location or Address**: 8700 Dallas Avenue S, Seattle, Washington 98108	
Owner Port of Seattle Ticson Mach (Capital Project Manager)	**General Contractor** Scarsella Brothers, Inc. Jim Lasher (Project Superintendent)	**Weather** 2/1 - 40s / Partly Cloudy 2/8 – 2/10 – 40s / Partly Sunny 2/11 – 30s / Overcast to Snow
	Pile Contractor American Construction Company, Inc.	**PanGEO Field Rep.** Shawn Harrington

As requested, a PanGEO representative was on-site on February 1, 8, 9, 10, and 11, 2021 to provide continuous monitoring of the installation of pipe piles at Sites 23 and 25 for the Terminal 117 Habitat Restoration project. A total of 14 piles were installed, which include 12 structural piles for supporting the pedestrian pier, and 2 treaty piles (non-structural). The locations of the observed piles are shown on Attachment 1- Modified Habitat Plan, Sheets C5.0 through C5.3. While on-site on February 8, 9, and 10, we also provided vibration monitoring during the installation of the structural piles. The following summarizes our field observations:

Brief Daily Summary:

- **2/1 –** Install 2 treaty piles P-12-22 and P-12-26 with vibratory hammer.
- **2/8 –** Install 2 structural piles P-02N and P-03 (both Reinhall) with diesel impact hammer.
- **2/9 –** Install 3 structural piles P-04 (Reinhall) and P-05 and P-06 (non-Reinhall with bubble curtain) with diesel impact hammer.
- **2/10 –** Install 3 structural piles P-07, P-06, and P-09NW (non-Reinhall with bubble curtain) with diesel impact hammer.
- **2/11 –** Install 4 structural piles P-09NE, P-09S, P-10N, and P-10S (non-Reinhall with bubble curtain) with diesel impact hammer.

Pile Installation:

***Treaty Piles* –** On February 1, PanGEO observed American Construction install two (2) non-structural treaty piles using an ICE 44B Vibratory hammer at the locations shown in Attachment 1. The treaty piles consisted of 40-foot lengths of 12¾-inch diameter ASTM A252 Grade 3 steel pipes with a 0.50-inch wall thickness, which was revised from the 24-inch diameter 5/8-inch thick piles specified in the permitted plan set dated June 11, 2020. We understand that the revision was part of an approved submittal from October 2020.

Our observations for treaty pile installation are summarized below:

- *P-12-22* – American Construction previously attempted to install P-12-22 on January 21, 2021 but encountered an obstruction about 15 feet below grade at the design location (see PanGEO Field Report #2). During our site visit on February 1, 2021 PanGEO observed American Construction install pile P-12-22 approximately 40 feet upstream (south) of the design location, per recommendation from the structural engineer. The pile was vibrated to a tip elevation of approximately –13½ feet below existing grade before encountering an obstruction, which is about 6½ feet higher than the design tip elevation of – 20 feet. Based on conversations with American Construction, the as-built pile tip elevation (-13 1/2 feet) of pile P-12-22 was approved by the structural engineer the same day.

- *P-12-26* – Pile P-12-26 was vibrated into the ground at the design location until reaching the design tip elevation of –20 feet.

At this time, the installation of all 8 treaty piles have been completed per the design plans.

Pedestrian Pier Piles – On February 8, 9, 10, 11, 2021, we observed the pile contractor, American Construction, install a total of twelve (12) structural piles (including 3 Reinhall piles) for the proposed pier located in the north portion of Site 23. All piles were installed using a Delmag D62-22 diesel impact hammer. Horizontal and vertical control for the project was provided by a nearby benchmark and verified by American Construction with a total station theodolite during driving of the piles.

The installed Reinhall structural piles consisted of 24-inch diameter ASTM A252 Grade 3, open-end steel pipe pile (0.75-inch wall thickness) structurally attached to a proprietary tip assembly with inner rings, delivered to the site in 64-foot length (see Plate 1, Page 6). The Reinhall pile also consists of a smaller pile (mandrel) located inside the structural pile and the mandrel is 66-foot long, 18-inch diameter open-ended steel pile with 0.8-inch wall thickness used only for pile driving purpose. The mandrel, directly impacted by the diesel hammer (see Plate 2, Page 6) hit the inner rings of the (outside) structural pile to drive the pile into the ground. After installation, the mandrel was extracted.

The reminder of the structural piles (non-Reinhall piles) consisted of 24-inch diameter ASTM A252 Grade 3, open-end steel pipe pile with 0.75-inch wall thickness delivered to the site in 61-foot length. Six (6) originally planned Reinhall piles (P-06, P-07, P-09S, P-09NW, P-10N, P-10S) were replaced with non-Reinhall piles, as detailed in the section below.

Pile Driving (Reinhall Piles) – We observed American install Reinhall Piles P-02N and P-03 to the design tip elevation of -44 feet on February 8. Each pile was driven with a separate mandrel (no reuse of mandrel).

Blow counts for the final foot of pile driving was about 54 to 63 blows per foot. Based on the number of blow counts per minute we observed, the corresponding hammer stroke was about 10 feet at the end of the pile driving. In our opinion, based on our observations of the pile installation and the number of blow counts we observed at the end of the impact pile driving, it is our opinion that the installed piles are adequate to support the design ultimate load of 90 kips per pile.

On February 9, PanGEO observed American attempt to drive Reinhall pile P-04 using the mandrel that was previously used to drive P-02N. During driving, the inside of the mandrel became plugged with soils, which significantly increased the driving resistance. As a result, American was unable to drive the pile to the design tip elevation of -44 feet, meeting refusal at tip elevation of about -43 feet (with about 80+ blows/ft at the end of the pile driving). American contacted the owner and structural engineer on the same day to discuss the issue. Based on conversations with American, we understand that the structural engineer has approved the at-built pile tip elevation -43 feet for pile P-04. From a geotechnical standpoint, based on the observed number of blow counts per minute and the corresponding hammer stroke (~10 feet) and the number of blow counts (80+ blows/ft) we observed at the end of the impact pile driving, it is our opinion that the installed pile P-04 with the at-built pile tip elevation -43 feet is adequate to support the design ultimate load of 90 kips per pile.

Because the mandrel that was plugged with soils and cannot be re-used for pile driving, the reminder of the originally proposed Reinhall piles (P-06, P-07, P-09S, P-09NW, P-10N, P-10S) are to be installed with non-Reinhall piles using a bubble curtain per the Port of Seattle.

Pile Driving (Non-Reinhall Piles) – On the afternoon of February 9 and on February 10 and 11, PanGEO observed American install the remaining 9 structural piles (non-Reinhall piles) using a Delmag D62-22 diesel impact hammer (see Plate 3, Page 7). All piles were installed using a bubble curtain (steel ring with holes that releases bubbles of compressed air) to reduce the propagation of acoustic waves from the pile driving (see Plate 4, Page 7). All installed structural piles were driven to approximately design pile tip Elevation -44 feet or deeper (about 26 to 40 feet below the existing site grades) with a blow count of about 22 to 38 blows per foot for the final foot of the pile driving. Based on the number of blow counts per minute we observed, the corresponding hammer stroke was about 9 feet at the end of the pile driving. In our opinion, based on our observations of the pile installation and the number of blow counts we observed at the end of the impact pile driving, it is our opinion that the installed piles are adequate to support the design ultimate load of 90 kips per pile.

Detailed installation records for the twelve structural piles which include the recorded blows per foot and blows per minute during impact, estimated tip elevation and date/time of installation are included as attachment 2 at the end of this report.

At this time, the installation of all 16 structural piles (for pedestrian pier) and 10 non-structural piles (8 treaty piles and 2 debris deflector piles) have been completed per the design plans.

Vibration Monitoring:

PanGEO performed vibration monitoring during installation of the structural piles (both Reinhall and non-Reinhall piles) for the proposed pedestrian pier, for both vibratory and impact hammers. The purpose of the monitoring was to determine how the magnitude of vibration, measured as peak particle velocity, attenuates with distance from the source of vibration.

The levels of vibrations as determined by peak particle velocities (PPV) were measured using *MiniMate Plus* monitoring units manufactured by Instantel®. The three components (transverse, longitudinal and vertical) of the peak particle velocities were recorded simultaneously using a tri-axial transducer placed at distances of 10 to 100 feet from the source of vibration. The peak particle velocities summarized below are calculated as a vector sum of the three components.

Results of our vibration measurements are summarized and plotted on Figure 1 – Summary of Vibration Measurements, found on Page 8 of this report. Also shown on Figure 1 are approximate upper and lower boundaries of PPVs that can be anticipated during pile driving at the site based on the measurements and our observations. The histograms (measured PPVs vs. time) recorded at distances of 15, 25, and 35 feet for Reinhall piles (P-02N and P-03) and conventional piles (P-01S, P-02S, P-01NA) and their pile driving records are included as Attachment 3 at the end of this report.

In summary, the highest recorded PPVs were about 1.97 inch/sec (impact hammer, Reinhall pile, 15 feet from the source) and about 1.8 inch/sec (vibratory hammer, non-Reinhall pile, 10 feet from the source). The trend of the data indicates the measured PPVs generally attenuated with distance from the source of vibration.

Based on the measurements and observations made during pile driving, we also observed the followings:

- The highest PPVs measured during vibratory hammer driving were frequently recorded during hammer startup and shutdown, particularly when the pile was vibrated in the upper loose fill/alluvium.

- For non-Reinhall piles (i.e., conventional piles), the data indicates the vibration attenuation with distance from the source was more significant when pile was driven with the vibratory hammer than with the impact hammer in dense soils. The data also indicates PPVs measured from vibratory hammer driving in dense soils are on average about half to two-third of the values measured from impact hammer driving in dense soils.
- For both Reinhall and non-Reinhall piles, the highest recorded PPVs was measured during pile driving in medium dense soils with a driving resistance of about 20 to 30 blows per foot (see Attachment 3). In comparison, the highest recorded PPVs from driving Reinhall piles are greater than the highest recorded PVs from driving non-Reinhall piles, as summarized in Table 1 below.

Table 1 – Measured Peak PPVs from pile driving in medium dense soils at distances of 15, 25, and 35 feet

Distance from source (feet)	Reinhall Pile #	Measured Peak PPVs (in/sec)	Non-Reinhall Pile #	Measured Peak PPVs (in/sec)	Percent Increase PPVs (Reinhall piles) to PPVs (Non-Reinhall piles)	Soil Condition and Driving Resistance
15	P-02N	1.97	P-01S	0.99	99	Medium dense soils with average 20-30 blows/ft
25	P-03	1.12	P-02S	0.85	31	
35	P-02N	0.86	P-01NA	0.74	16	

- For pile driving in dense to very dense soils with a driving resistance of about 40 to 55 blows per foot, the average measured PPVs from driving Reinhall piles are greater than the average measured PPVs from driving non-Reinhall piles, as summarized in Table 2 below.

Table 2 – Measured Average PPVs from pile driving in dense/very dense soils at distances of 15, 25, and 35 feet

Distance from source (feet)	Reinhall Pile #	Measured Avg. PPVs (in/sec)	Non-Reinhall Pile #	Measured Avg. PPVs (in/sec)	Percent Increase PPVs (Reinhall piles) to PPVs (Non-Reinhall piles)	Soil Condition and Driving Resistance
15	P-02N	0.64	P-01S	0.52	24	Dense to very dense soils with average 40-55 blows/ft
25	P-03	1.13	P-02S	0.56	102	
35	P-02N	0.69	P-01NA	0.56	23	

The histograms (measured PPVs vs. time) recorded at distances of 15, 25, and 35 feet for Reinhall piles (P-02N and P-03) and non-Reinhall piles (P-01S, P-02S, P-01NA) and their pile driving records are included as Attachment 3 at the end of this report.

FIELD REPORT

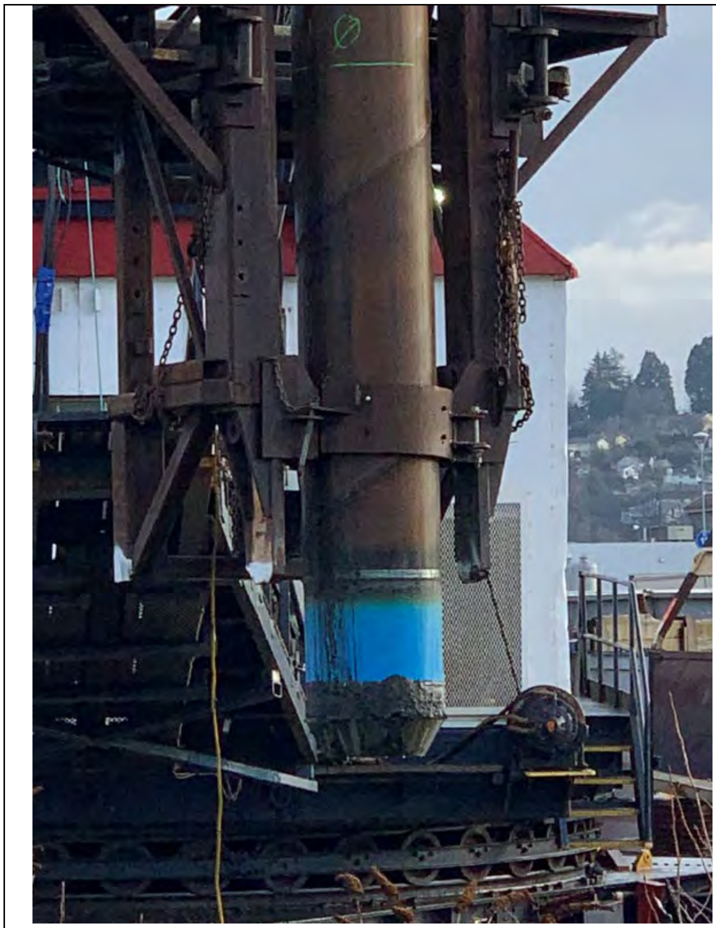


Plate 1 – Impacting Reinhall pile P-02N using Delmag D62-22 impact hammer on 2/8/2021. Note about the bottom of the structural pile attached to a 3-foot-long tip assembly with inner rings. The inner rings of the structural pile were impacted by the (inside) mandrel during pile driving.

Plate 2 – Impacting Reinhall pile P-02N using Delmag D62-22 impact hammer on 2/8/2021. Note 18” O.D. mandrel inside the structural pile was directly impacted by the diesel hammer.

FIELD REPORT

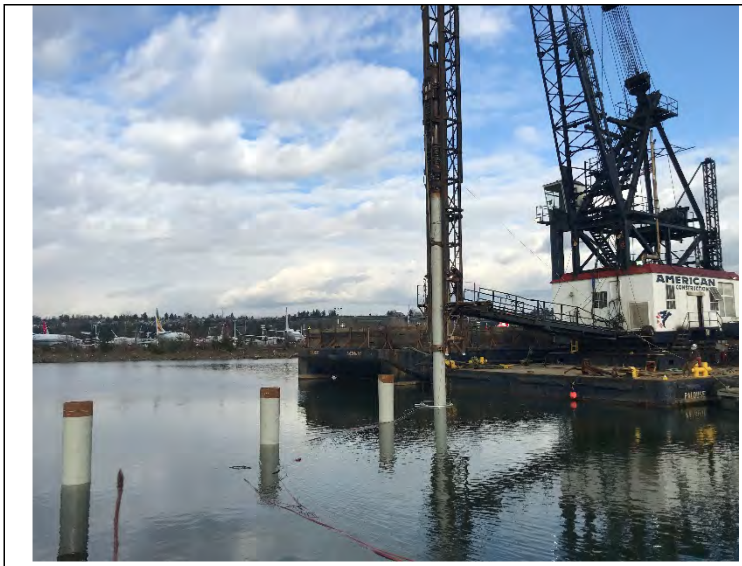


Plate 3 – Setting up D62-22 impact hammer to drive pile P-07 on 2/10/21. Looking east.

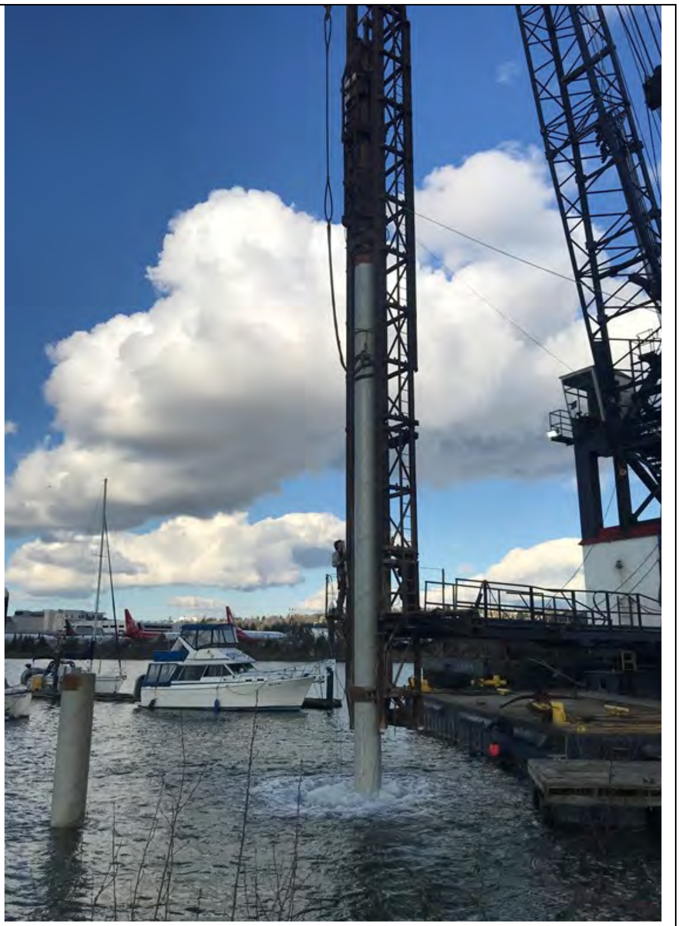


Plate 4 **– Impacting pile P-05 on 2/9/21 using bubble curtain method. Looking northeast.**

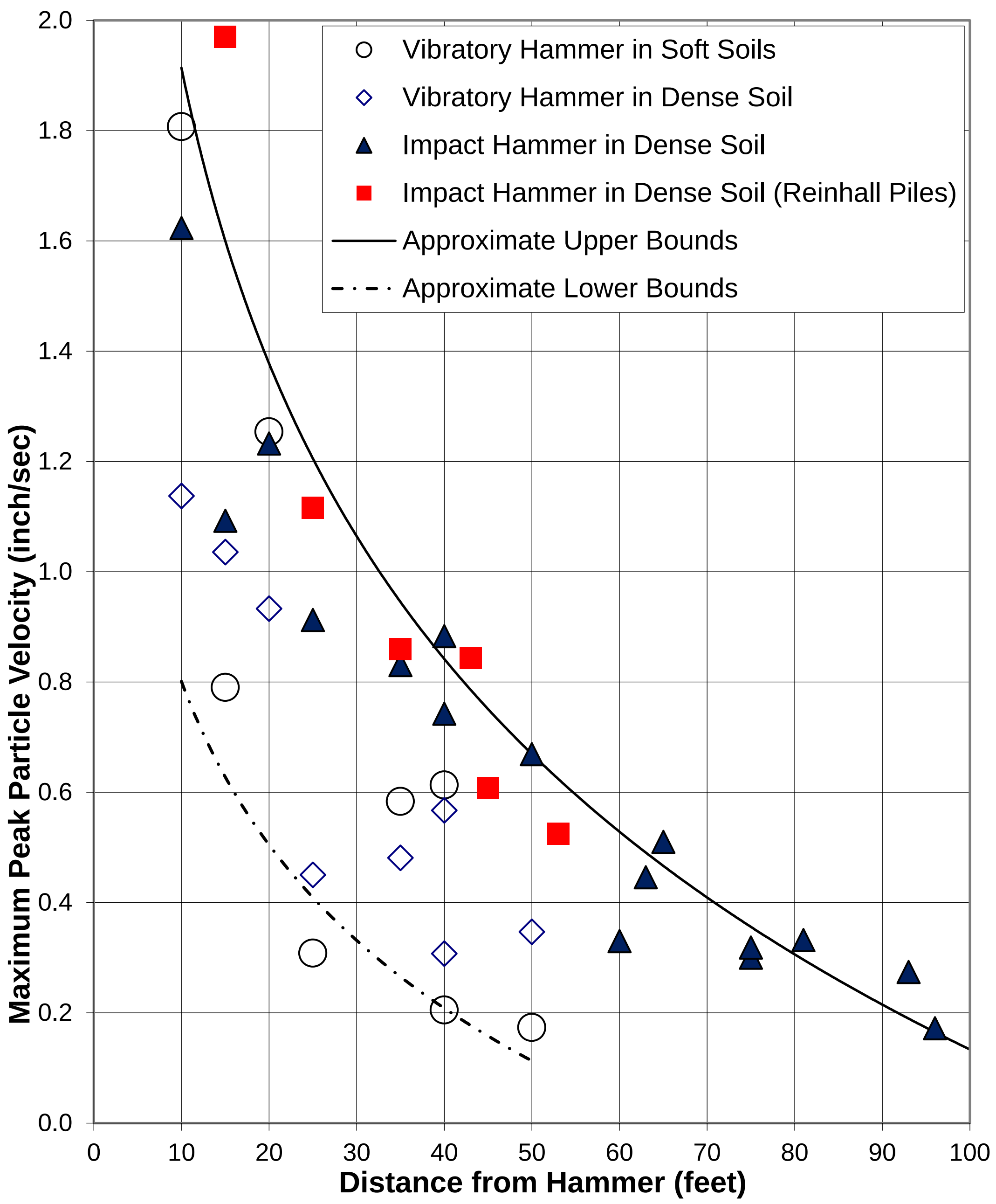


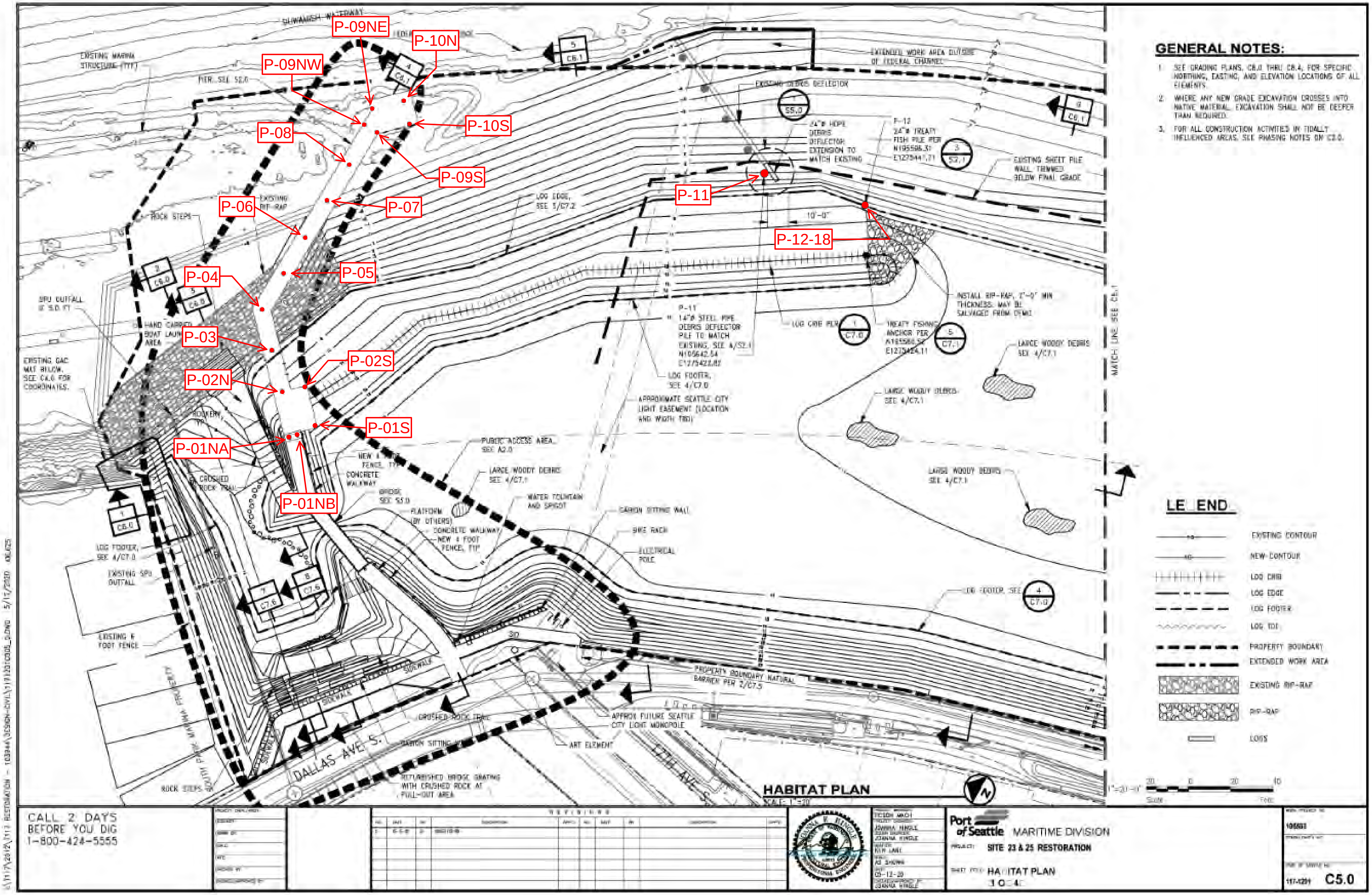
Figure 1 – Summary of Vibration Measurements

Signed:____________________________ Reviewed:____________________________

Attachments:

- Attachment 1 – Modified Habitat Plan, Sheets C5.0 through C5.3 (4 sheets)
- Attachment 2 – Pile Installation Records (12 sheets)
- Attachment 3 – Histograms (measured PPVs vs. time) and pile driving records for Reinhall piles (P-02N and P-03) and non-Reinhall piles (P-01S, P-02S, P-01NA)

Attachment 1 - Modified Habitat Plan, Sheet C5.0



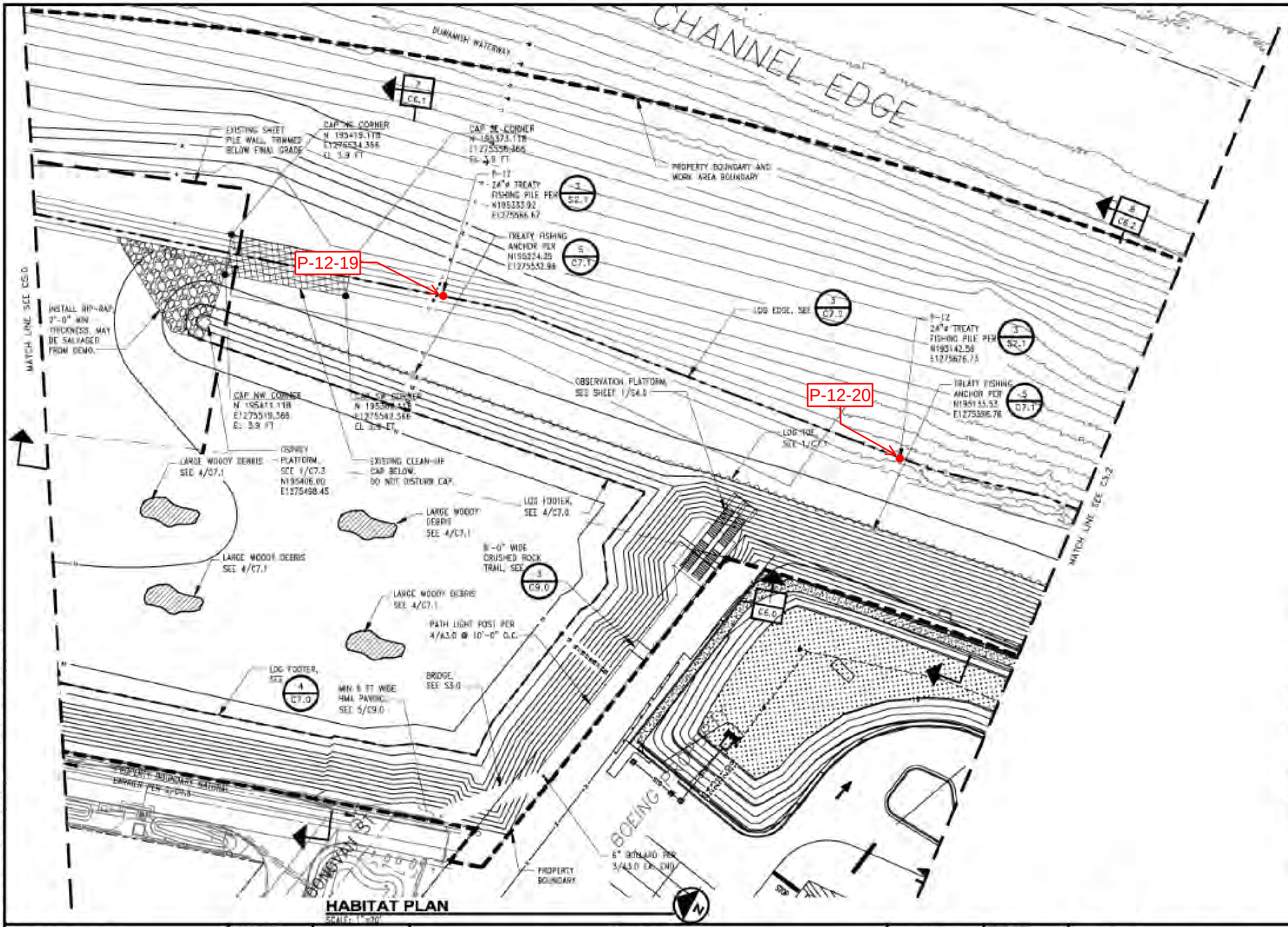
GENERAL NOTES:

1. SEE GRADING PLANS, C8.0 THRU C8.4, FOR SPECIFIC NORTHING, EASTING, AND ELEVATION LOCATIONS OF ALL ELEMENTS.
2. WHERE ANY NEW GRADE EXCAVATION CROSSES INTO NATIVE MATERIAL, EXCAVATION SHALL NOT BE DEEPER THAN REQUIRED.
3. FOR ALL CONSTRUCTION ACTIVITIES IN TIDALLY INFLUENCED AREAS, SEE PHASING NOTES ON C3.0.

HABITAT PLAN
SCALE: 1"=20'

CALL 2 DAYS
BEFORE YOU DIG
1-800-424-5555

Attachment 1 - Modified Habitat Plan, Sheet C5.1



HABITAT PLAN

SCALE: 1"=20'

NOTES:

1. SEE SHEET C5.0 FOR NOTES.

LEGEND:

─┼─	EXISTING CONTOUR
─┼─	NEW CONTOUR
┼┼┼┼┼	LOG CRIB
— - —	LOG EDGE
— — —	LOG FOOTER
∿∿∿	LOG TOE
▬ ▬ ▬	PROPERTY BOUNDARY
▬ - ▬	EXTENDED WORK AREA
▨	RIP-RAP

GRAPHOC SCALE:

1"=20'-0" 20 0 20 40
Scale Feet

CALL 2 DAYS
BEFORE YOU DIG
1-800-424-5555

REVISIONS

TCSON MACH
JOANNA HINGLE
JOANNA HINGLE
JORGE GAMBOA
AS SHOWN
05-12-20
JOANNA HINGLE

Port of Seattle MARITIME DIVISION

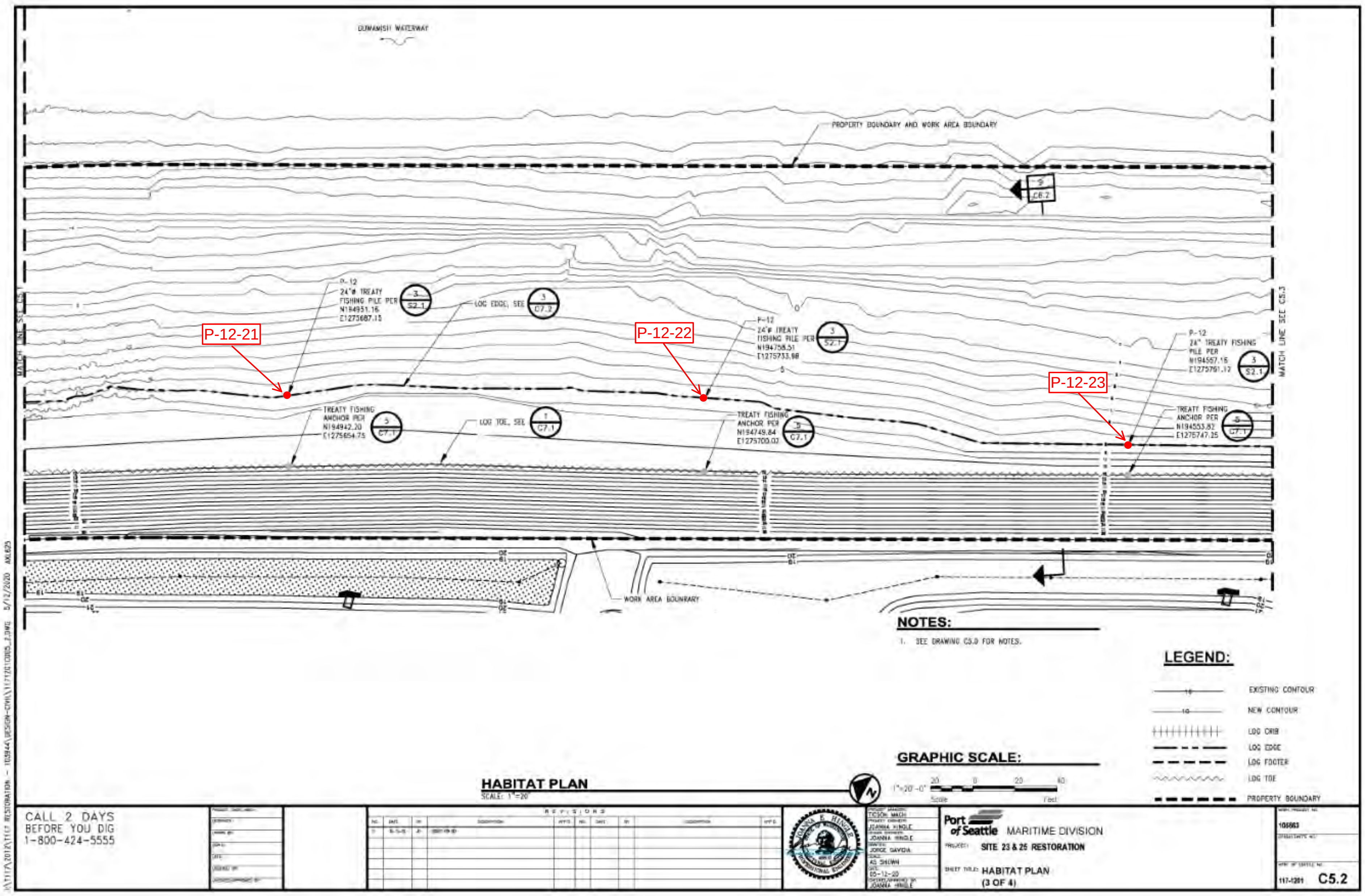
PROJECT: **SITE 23 & 25 RESTORATION**

SHEET TITLE: **HABITAT PLAN**
(2 OF 4)

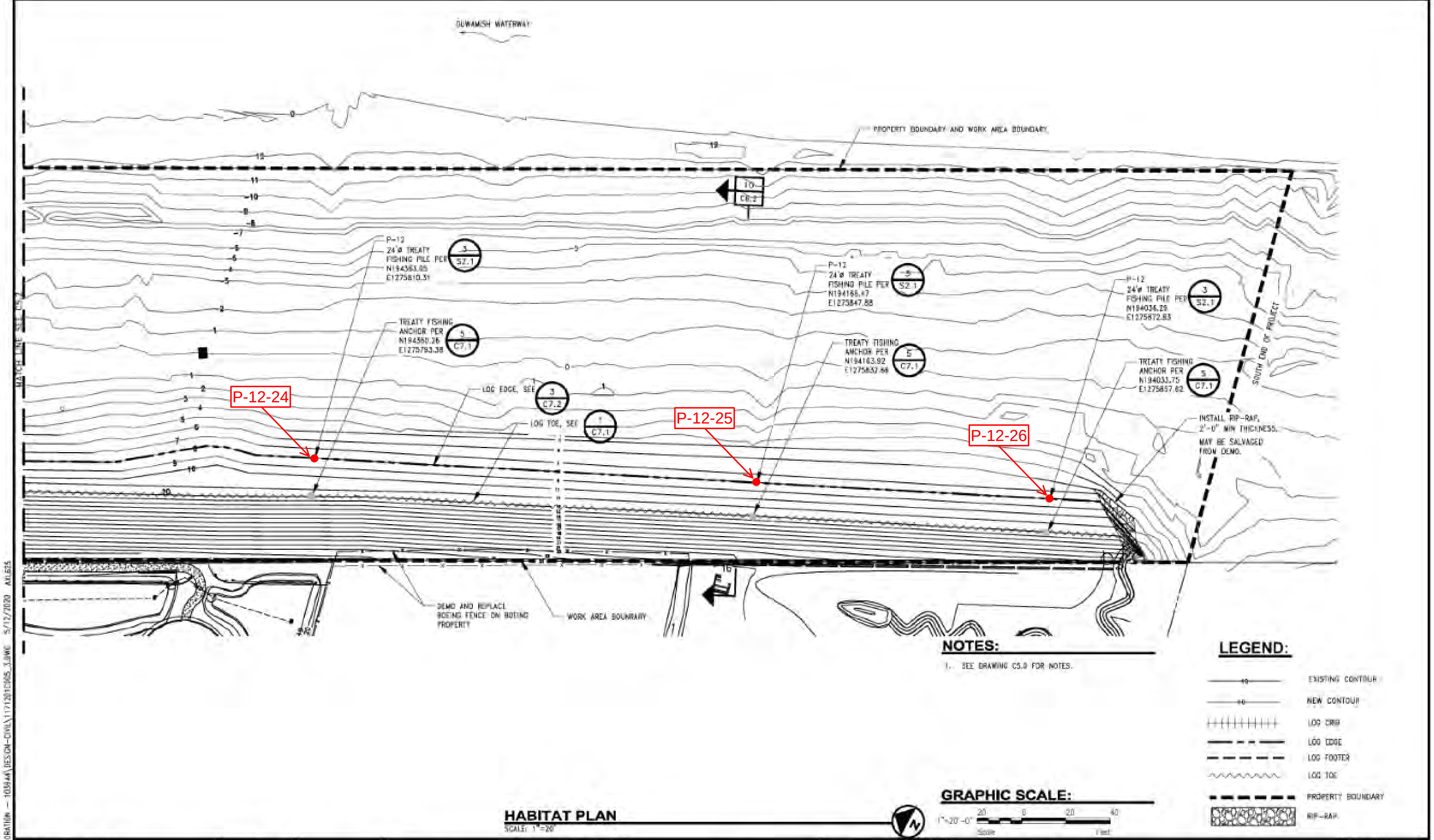
105583

17-1201 **C5.1**

Attachment 1 - Modified Habitat Plan, Sheet C5.2



Attachment 1 - Modified Habitat Plan, Sheet C5.3



NOTES:

1. SEE DRAWING C5.0 FOR NOTES.

LEGEND:

—10—	EXISTING CONTOUR
—10—	NEW CONTOUR
┼┼┼┼┼┼┼┼┼	LOG CRIB
━ ‒ ‒ ━	LOG EDGE
‒ ‒ ‒ ‒ ‒	LOG FOOTER
∿∿∿∿∿	LOG TOE
▬ ▬ ▬ ▬	PROPERTY BOUNDARY
▨	RIP-RAP

GRAPHIC SCALE:

CALL 2 DAYS
BEFORE YOU DIG
1-800-424-5555

REVISIONS

JOANNA E. BINGLE

TICSON MACH
JOANNA BINGLE
JOANNA BINGLE
JORGE GAVIDIA
AS SHOWN
05-12-20
JOANNA BINGLE

Port of Seattle MARITIME DIVISION
PROJECT: SITE 23 & 25 RESTORATION
SHEET TITLE: HABITAT PLAN
(4 OF 4)

105563
117-1201 C5.3

L:\T-17\2012\T117 RESTORATION - 103944\DESIGN-CIVIL\T17120105_3.DWG 5/12/2020 AXLEE5

Attachment 2 (12 Sheets)

Rental 11

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration
Project No: 20-478
Date: 2/8/21
Weather: ~40°F
Start Time: 9:58 am
Stop Time: 10:35 am
Pile No.: P-02N
Pile Type: Open-ended
Tip Ø: 24 in.
Butt Ø: 18 in.
Batter: N/A
Pile Length: 63 ft.
Length Driven: ~60 ft.
Ref. Elev. — ft.
Tip Elev. -45.03' ft.
Cutoff Elev. 15'11" ~~ft.~~
Steel Pile Grade/Heat: A252 Grad. 3
Wall Thickness: 0.75 in.
Shoe: N/A (Open-ended)
Hammer M&M: ICE 44B Vibratory
Hammer Wt.: 5,500 lbs
Driving Force: 207 tons
Frequency: 900-1800 vpm
Hammer M&M: APE D62-22
Ram Wt.: 13,671 lbs.
Rated Energy: 164,052 ft.-lbs.
~~Pile Cushion~~ thickness/material:
PanGEO Repr.: S. Harrington

Rental coupler (feet 1–3)
15 (feet 7–10)
24 (feet 11–15)
25 (feet 16–20)

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
1			Stabbed in ~ 1½'	31	8		
2			w/ just weight of hammer	32	11		
3	2		↑	33	12	42	
4	2		Aligning after every	34	16	42	
5	3		blow	35	17		
6	4		↓	36	18		
7				37	19		
8				38	21	44	
9				39	24		
10				40	24	40	
11				41	23		
12				42	25	40	
13				43	22		
14				44	25	46	
15				45	31		
16				46	35	40	~9' stroke
17				47	38	38	~10' stroke
18				48	39		
19				49	37		
20				50	38		
21	5			51	37		
22	7			52	39	38	~10' stroke
23	7			53	42		
24	8			54	43		
25	7			55	44	38	~10' stroke
26	7			56	46		
27	8			57	56		
28	8			58	56	38	~10' stroke
29	8			59	54		
30	9			60	~19 blows		

+17.97' butt elevation

Reinhall

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/8/21 **Weather:** ~41° Partly Cloudy **Start Time:** 1:15 pm **Stop Time:** 2:29 pm

Pile No.: P-03 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 18 in. **Batter:** N/A

Pile Length: 63 ft. **Length Driven:** ~55 ft. **Ref. Elev.** ______ ft. **Tip Elev.** -45.47 ft. **Cutoff Elev.** 15'11" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

~~Pile Cushion~~ thickness/material: ______ **PanGEO Repr.:** S. Harrington

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
1	↓		2' water at driving	31	13	44	7.5' stroke height
2			location	32	13		
3	1		stabbed in 2' below grade w/ weight of hammer	33	14		
4	1			34	16		
5	1			35	21	40	9' stroke height
6	1½'		– Aligning –	36	23		– stop to move straps
7	1		1:55 pm	37	31		2:04 pm
8	2			38	34		
9	2			39	37	40	
10	2			40	40		
11	2		– aligning – 1:57 pm	41	41	38	10' stroke height
12	2			42	46		
13	2			43	53		
14	2			44	50	39	~9.8' stroke height
15	2			45	56		
16	3			46	57		
17	4			47	58	38	~10' stroke height
18	6			48	62		
19	7		Steady driving	49	63		
20	6			50	59	38	~10' stroke height
21	5			51	58		
22	5			52	59		
23	6			53	59	39	~9.5' stroke height
24	7			54	70		
25	8			55	63		~stopped ~3" shy of 55' mark
26	9			56			
27	10			57			
28	10			58			
29	12			59			
30	13			60			

30'

+ 17.53' tip

Remhall

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/9/21 **Weather:** 36° Sunny **Start Time:** 9:00 am **Stop Time:** 9:48 am

Pile No.: P-04 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 18 in. → mandrel **Batter:** N/A

Pile Length: 63' ft. **Length Driven:** ~40' ft. **Ref. Elev.** ft. **Tip Elev.** -43.06 ft. **Cutoff Elev.** +15-10½" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62- **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: **PanGEO Repr.:** S. Harrington

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
1	1		12' water above grade	31	59		
2	2		at time of driving	32	51		
3				33	56		
4				34	58		
5				35	59	40	
6				36	61		
7				37	58		
8	6			38	57		
9	6			39	62	38	
10	5			40	80+		called it b/c
11	7			41			hammer is
12	7			42			bouncing on
13	10			43			plug
14	10			44			
15	12	44	~7.5' stroke height	45			
16	14			46			
17	24			47			
18	31			48			
19	40	40	Paused to remove	49			
20	46		strap 9:10 am	50			
21	56			51			
22	57			52			
23	48	39		53			
24	58			54			
25	59			55			
26	52			56			
27	54	38	~10' stroke height	57			
28	57			58			
29	58			59			
30	50	38	~10' stroke height	60			

~19 total

Butt elev +19.94'

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/9/21 **Weather:** ~40° Sunny **Start Time:** 2:31 **Stop Time:** 2:56 pm

Pile No.: P-05 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** N/A

Pile Length: 61 ft. **Length Driven:** ~40' ft. **Ref. Elev.** ______ ft. **Tip Elev.** -44.08' ft. **Cutoff Elev.** +15.11' ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: ______ **PanGEO Repr.:** S. Harrington

	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~16' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	0		Pushed w/ hammer	31	23	40	
	2	1			32	25		
	3	1		2:24 pm	33	25	40	
20.	4	1		↓	34 50	30		
	5	1		aligning	35	33		
'	6	2		2:31 driving	36	37	38	~10' Stroke height
	7				37	39		
	8				38	41	38	
25.	9	2			39 55	46		
	10	blows			40	38	38	-Stopped ~ 2" short of 40'
	11				41			
	12				'42			
	13				43			
30	14	↓		Stopping to align	44 60			
	15	2		2:42	45			
	16	2			46			
	17	3			47			
	18	4			48			
35	19	6			49			
	20	7			50			
	21	9			51			
	22	10			52			
	23	7			53			
40.	24	13			54			
	25	15			55			
	26	17			56			
	27	16	40		57			
	28	18			58			
45.	29	20			59			
	30	22			60			

* Installed using bubble curtain (curtain on 2:21 pm)
Pile top +16.92'

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/9/21 **Weather:** 40° sunny **Start Time:** 4:07 pm **Stop Time:** 4:31 pm

Pile No.: P-06 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** N/A

Pile Length: 63 ft. **Length Driven:** ~38 ft. **Ref. Elev.** ______ ft. **Tip Elev.** -46.13 ft. **Cutoff Elev.** 15'-11" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ~~ICE 44B Vibratory~~ **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62- 22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: ______ **PanGEO Repr.:** S. Harrington

	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~18' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	1			31	25		
20.	2	3		4:04 pm	32 50	27	42	
	3	4			33	27		
	4	3			34	32	40	
	5	3			35	31		
	6	3		aligning at 4:08pm	36	40		
25	7	2		-4:15pm	37 55	47	39	
	8	2			38	44	38	—
	9	2		aligning 4:15-4:17	39			
	10	2			40			
	11	4			41			
30	12	3			42 60			
	13	4			43			
	14	5			44			
	15	7			45			
	16	14			46			
35	17	14			47			
	18	11			48			
	19	12			49			
	20	12	48		50			
	21	16			51			
40	22	19			52			
	23	18			53			
	24	24	44		54			
	25	21			55			
	26	23			56			
45	27	19			57			
	28	22			58			
	29	26	42		59			
	30	26			60			

★ Bubble curtain on @ 3:59 pm

+16.87'

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/10/21 **Weather:** ~34°/Partly Cloudy **Start Time:** 8:53am **Stop Time:** 9:13

Pile No.: P-07 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** N/A

Pile Length: 61 ft. **Length Driven:** ~30' ft. **Ref. Elev.** ______ ft. **Tip Elev.** 44.45' ft. **Cutoff Elev.** +15'10½" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: ______ **PanGEO Repr.:** S. Harrington

	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~23' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	2		aligning	31			
25	2	2		↓	32 52			
	3	2		↓	33			
	4	2		9:00 am	34			
	5	3		↓	35			
	6	2		↓	36			
30	7	2		aligning 9:02 am	37 60			
	8	4		↓	38			
	9	3		↓	39			
	10	3		Removing rigging &	40			
	11	3		aligning 9:04	41			
35	12	4			42			
	13	5			43			
	14	5			44			
	15	5			45			
	16	7			46			
40	17	11			47			
	18	12			48			
	19	12	42		49			
	20	14			50			
	21	15			51			
45	22	16	42		52			
	23	22			53			
	24	22			54			
	25	23	42		55			
	26	25			56			
50	27	26			57			
	28	30	40	~9' stroke height	58			
	29	31			59			
	30	☆28	40	~9' stroke height	60			

+16.55' butt elevation

☆ Stopped few inches shy of 52' mark on pile

☆ Installed w/ bubble curtain

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/10/21 **Weather:** 34°/ Partly Sunny **Start Time:** 11:04 am **Stop Time:** 11:15 am

Pile No.: P-08 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** N/A

Pile Length: 61 ft. **Length Driven:** ~31 ft. **Ref. Elev.** ______ ft. **Tip Elev.** -44.26' ft. **Cutoff Elev.** +15'1" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: ______ **PanGEO Repr.:** S. Harrington

	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~22' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	0		Pushed w/ hammer	31			
	2	1/2		aligning 10:55 am	32			
25	3	1 1/2			33 55			
	4	2		10:58 am	34			
	5	3 blows			35			
	6				36			
	7	↓		Δ 11:04 aligning &	37			
30	8	3 blows		removing rigging	38			
	9				39			
	10	↓			40			
	11	1			41			
	12	1			42			
35	13	4	—	stopping to align	43			
	14	5			44			
	15	8			45			
	16	12			46			
	17	14			47			
40	18	11	48	~6.25' stroke height	48			
	19	12			49			
	20	12			50			
	21	13	44	~7.5' stroke hgt	51			
	22	17			52			
45	23	17	42	~8.17' stroke hgt	53			
	24	21			54			
	25	24			55			
	26	26	42	~8.17' stroke hgt	56			
	27	23			57			
50	28	27	40	~9' stroke hgt	58			
	29	30			59			
	30	31	40	– Stopped 11:15 am	60			

Δ Installed w/ bubble curtain

+16.74 butt elevation

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/10/21 **Weather:** 34° / Partly Cloudy **Start Time:** Driving 3:38 **Stop Time:** 3:48

Pile No.: P-09NW **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** —

Pile Length: 63 ft. **Length Driven:** ~29 ft. **Ref. Elev.** ____ ft. **Tip Elev.** -46.03 ft. **Cutoff Elev.** 15'11" ~~ft.~~

Steel Pile Grade/Heat: A252 Grade 3 **Wall Thickness:** 3/4 in. **Shoe:** N/A (open-ended)

~~**Precast Pile Mfr. Cert.**~~**/Pile No.:** ____ **Mfr.:** ____ ~~**Date Cast:**~~ ____ **Weight:** 5,500 lbs.

Hammer M&M: APE D62-22 **Helmet:** ____ lbs. **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: ____ **PanGEO Repr.:** S. Harrington

marking	Feet	Blows	Stroke/ Pressure/ Blows/min.	water line ~29' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
30	1	1		Setting up at 3:26	31			
	2	2		aligning	32			
	3	2		↓	33			
	4	2			34			
	5	2		Start driving 3:38	35			
35	6	3		↓	36			
	7	2			37			
	8	2			38			
	9	2			39			
	10	3		Stop to align 3:40	40			
40	11	3			41			
	12	4			42			
	13	6			43			
	14	5			44			
	15	7			45			
45	16	10			46			
	17	12			47			
	18	12	44	~7.5' stroke hgt	48			
	19	12			49			
	20	16			50			
50	21	17	42		51			
	22	18			52			
	23	19			53			
	24	19			54			
	25	18			55			
55	26	18	42		56			
	27	24			57			
	28	25	42	~9' stroke hgt	58			
	29	28	42	~9' stroke hgt	59			
	30	Stopped @	3:48 pm		60			

Butt elevation +16.97'
Installed w/ bubble curtain

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/1/21 **Weather:** Low 30s - overcast **Start Time:** 9:12 am **Stop Time:** 9:32 am

Pile No.: P-09NE **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** —

Pile Length: 63 ft. **Length Driven:** ~29 ft. **Ref. Elev.** — ft. **Tip Elev.** -46,22 ft. **Cutoff Elev.** 15'11" ft.

Steel Pile Grade/Heat: A52 Grd 3 **Wall Thickness:** 3/4 in. **Shoe:** N/A (open-ended)

~~**Precast Pile** Mfr. Cert./Pile No.:~~ ______ ~~**Mfr.:**~~ ______ **Date ~~Cast~~:** ______ **Weight:** 5,500 lbs.

Hammer M&M: APE D62-22 **Helmet:** ______ lbs. **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

~~**Pile Cushion**~~ thickness/material: ______ **PanGEO Repr.:** S. Harrington

mudline	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~27' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	0		Aligning	31			
	2	2			32			
30	3	3		9:12 driving	50 33			
	4				34			
	5		18 total		35			
	6		blows		36			
	7				37			
35	8	↓		stopping to remove	38			
	9	2		rigging 9:21	39			
	10	2			40			
	11	3			41			
	12	3			42			
40	13	4			43			
	14	7			44			
	15	6			45			
	16	7			46			
	17	8			47			
45	18	16			48			
	19	10	42	~9' Stroke Hgt	49			
	20	13			50			
	21	14			51			
	22	14			52			
50	23	15			53			
	24	17	42	~9' Stroke Hgt	54			
	25	17			55			
	26	19			56			
	27	19			57			
55	28	23			58			
	29	28	40	~stopped at ~29' embed	59			
	30			@ 9:32 am	60			

Butt elevation +16,78'

☆ Installed w/ bubble curtain

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/11/21 **Weather:** Low 30s. overcast **Start Time:** 11:24 **Stop Time:** 12:06

Pile No.: P-095 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 24 in. **Batter:** —

Pile Length: 61 ft. **Length Driven:** -27' ft. **Ref. Elev.** ____ ft. **Tip Elev.** -44.16 ft. **Cutoff Elev.** 15'11" ~~ft.~~

Steel Pile Grade/Heat: A252 Grade 3 **Wall Thickness:** 3/4 in. **Shoe:** N/A (open-ended)

Precast Pile Mfr. Cert./Pile No.: ____ **Mfr.:** ____ **Date Cast:** ____ **Weight:** 5,500 lbs.

Hammer M&M: APE D62-22 **Helmet:** ____ lbs. **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,082 ft.-lbs.

Pile Cushion thickness/material: ____ **PanGEO Repr.:** S. Herrington

mudline	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~ 26' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	1		aligning at 11:24	31			
	2	2		*stopping after ever	32			
	3	2		blows to align	33			
30	4	1			60 34			
	5	1			35			
	6	2			36			
	7	1			37			
	8	1			38			
35	9	1			39			
	10	2		Removing rigging 11:47am	40			
	11	2			41			
	12	2			42			
	13	3			43			
40	14	7			44			
	15	7			45			
	16	7			46			
	17	7	44		47			
	18	9			48			
45	19	10	42		49			
	20	11			50			
	21	13	42		51			
	22	14			52			
	23	17	41		53			
50	24	19			54			
	25	28	41		55			
	26	27	40		56			
	27	2	—	Stopped just past 52'	57			
	28			mark at 12:06 pm	58			
55	29				59			
	30				60			

Butt elev. +16.84'

* Installed w/ bubble curtain

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration Project No: 20-478

Date: 2/11/21 Weather: 30's - Snowing Start Time: 2:37 pm Stop Time: 2:53 pm

Pile No.: P-10N Pile Type: Open-ended Tip Ø: 24 in. Butt Ø: 24 in. Batter: —

Pile Length: 63 ft. Length Driven: ~26 ft. Ref. Elev. ____ ft. Tip Elev. -46.22 ft. Cutoff Elev. 15'11" ft.

Steel Pile Grade/Heat: A52 Grd 3 Wall Thickness: 3/4 in. Shoe: N/A (open-ended)

~~**Precast Pile** Mfr. Cert./Pile No.:~~ ____ ~~Mfr.:~~ ____ ~~Date Cast:~~ ____ Weight: 5,500 lbs.

Hammer M&M: APE D62-22 Helmet: — lbs. Ram Wt.: 13,671 lbs. Rated Energy: 164,052 ft.-lbs.

~~**Pile Cushion**~~ thickness/material: ____ PanGEO Repr.: S. Herrington

marking	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks Water line ~27'	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
	1	0		aligning	31			
	2	1		" "	32			
30	3	2		" "	60 33			
	4	2		" "	34			
	5	6-7 blows/ft			35			
	6				36			
	7				37			
35	8				38			
	9				39			
	10	2		aligning & removing	40			
	11	2		rigging at 2:44 pm	41			
	12	4			42			
40	13	5			43			
	14	6			44			
	15	8			45			
	16	11			46			
	17	11	44		47			
45	18	13			48			
	19	16			49			
	20	17			50			
	21	18	42		51			
	22	15			52			
50	23	19	41		53			
	24	22			54			
	25	23	41		55			
	26	3		- stopped just past 52'	56			
	27			mark @ 2:53 pm	57			
55	28				58			
	29				59			
	30				60			

Butt elev: +16.78'

✱ Installed w/ bubble curtain

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration Project No: 20-478

Date: 2/11/21 Weather: 30's - Snowing Start Time: 3:40 pm Stop Time: 4:18 pm

Pile No.: P-105 Pile Type: Open-ended Tip Ø: 24 in. Butt Ø: 24 in. Batter: ——

Pile Length: 63 ft. Length Driven: ____ ft. Ref. Elev. ____ ft. Tip Elev. -46.15 ft. Cutoff Elev. 15'11" ~~ft.~~

Steel Pile Grade/Heat: A252 Grd 3 Wall Thickness: 3/4 in. Shoe: N/A (open-ended)

~~**Precast Pile** Mfr. Cert./Pile No.:~~ ____ ~~Mfr.:~~ ____ ~~Date Cast:~~ ____ Weight: 5,500 lbs.

Hammer M&M: APE D62-22 ~~Helmet:~~ ____ lbs. Ram Wt.: 13,671 lbs. Rated Energy: 164,052 ft.-lbs.

Pile ~~Cushion~~ thickness/material: ____ PanGEO Repr.: S. Herrington

	Feet	Blows	Stroke/ Pressure/ Blows/min.	Water line ~26' Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
Mudline →								
	1	2		Aligning @ 3:40pm	31			
	2	1		" "	32			
	3	1		" "	33			
30	4	2		" "	34			
	5	↓			35			
	6		5-6		36			
	7		blows		37			
	8		total		38			
35	9	↓		Removing rigging @ 4:00pm	39			
	10	3			40			
	11	4			41			
	12	6			42			
	13	7			43			
40	14	7			44			
	15	7			45			
	16	10	48		46			
	17	11			47			
	18	11			48			
45	19	14	46		49			
	20	16			50			
	21	17			51			
	22	17	42		52			
	23	19			53			
50	24	20			54			
	25	22	41		55			
	26	15		← stopped ~6' past	56			
	27			51' mark @ 4:18pm	57			
	28				58			
55	29				59			
	30				60			

Butt elev: +16.85'

* Installed w/ bubble curtain

Attachment 3

Histograms (measured PPVs vs. time) and pile driving records for Reinhall piles (P-02N and P-03) and non-Reinhall piles (P-01S, P-02S, P-01NA)

P-02N (@15 ft) - Delmag D62-22 Diesel Hammer
Reinhall

Histogram Start Time	08:39:02 February 8, 2021
Histogram Finish Time	10:35:31 February 8, 2021
Number of Intervals	3494.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17963 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	October 7, 2020 by Instantel
File Name	S963IUD1.D20

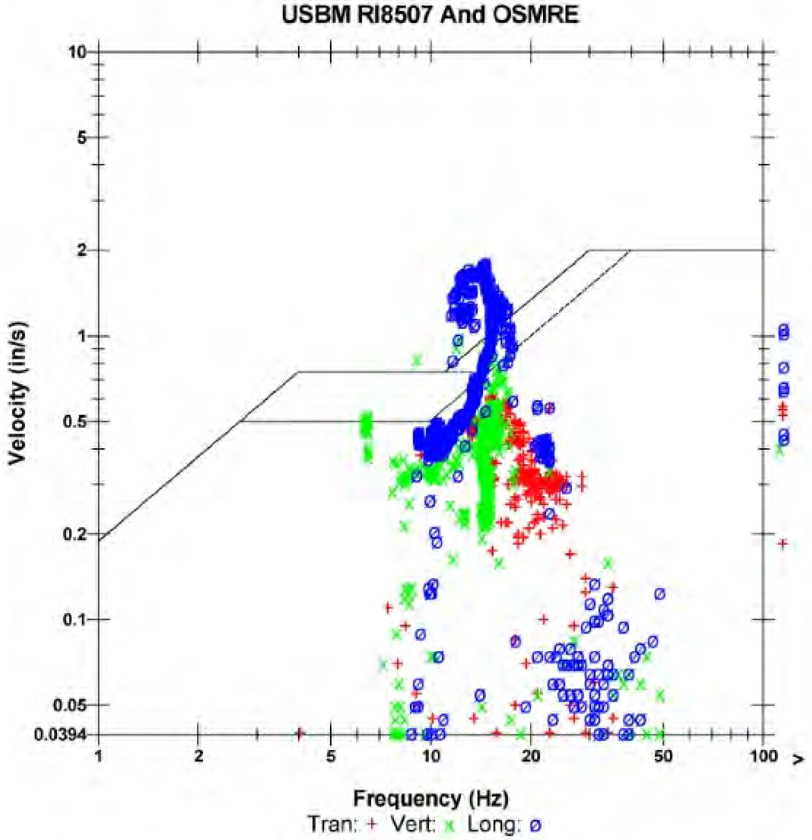
Notes

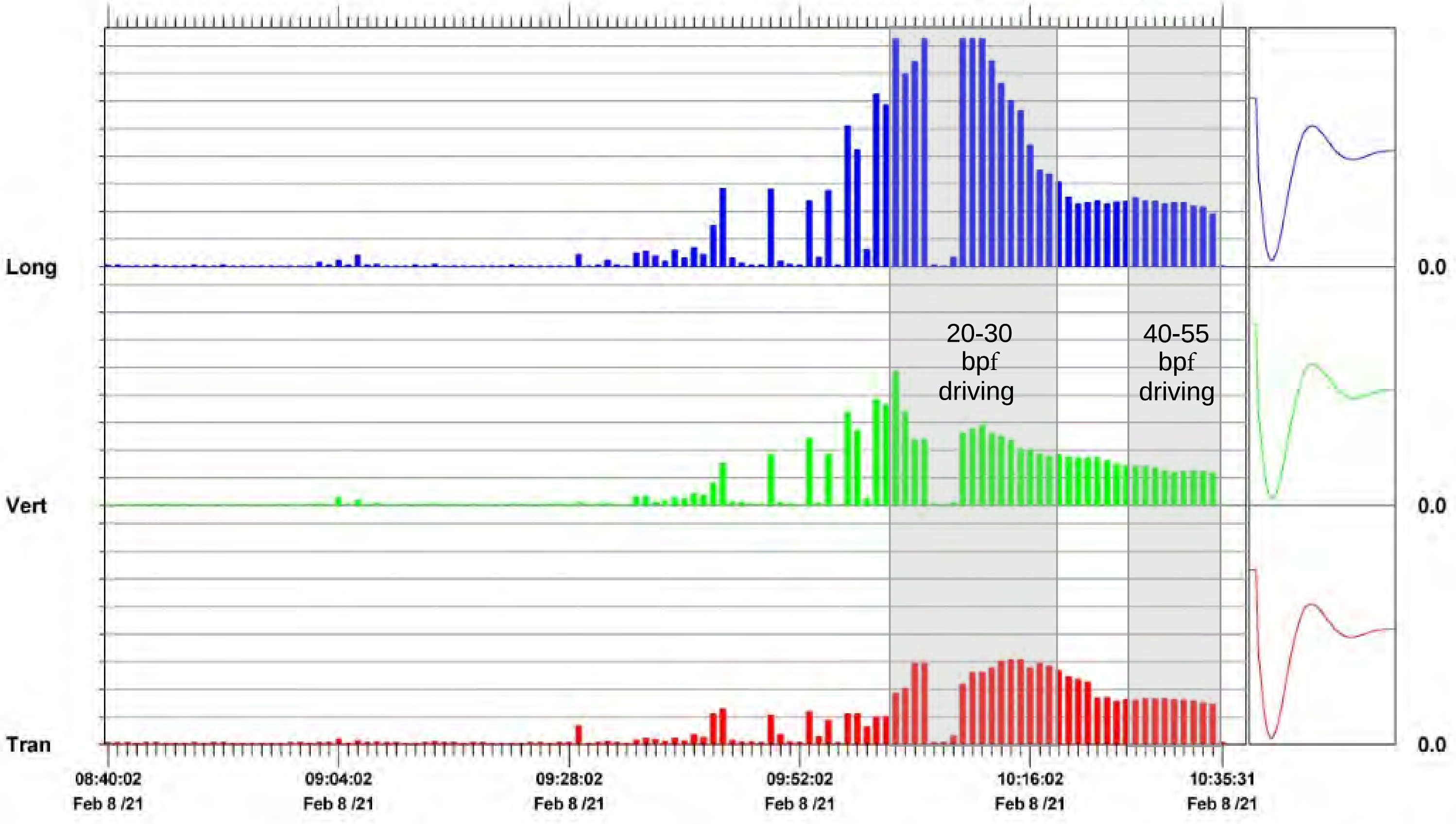
Location:	Seattle, WA
Client:	Port of Seattle
Monitored By:	PanGeo, Inc. 206-262-0370
Unit Location:	VM-3

Extended Notes:
Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.610	0.970	1.815	in/s
ZC Freq	15.1	12.2	14.6	Hz
Date	Feb 8 /21	Feb 8 /21	Feb 8 /21	
Time	10:13:38	10:01:32	10:01:36	
Sensor Check	Passed	Passed	Passed	
Frequency	7.6	7.3	7.5	Hz
Overswing Ratio	4.1	4.0	4.0	

Peak Vector Sum 1.970 in/s on February 8, 2021 at 10:01:36





Time Scale: 1 minute /div **Amplitude Scale:** Geo: 0.200 in/s/div Plot Clipped

Sensor Check

Printed: February 12, 2021 (V 10.74)

Format © 1995-2015 Xmark Corporation

P-01S (@15 ft) - Delmag D62-22 Diesel Hammer

Histogram Start Time	08:40:09 January 20, 2021
Histogram Finish Time	09:11:24 January 20, 2021
Number of Intervals	937.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17963 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	October 7, 2020 by Instantel
File Name	S963ITDU.QX0

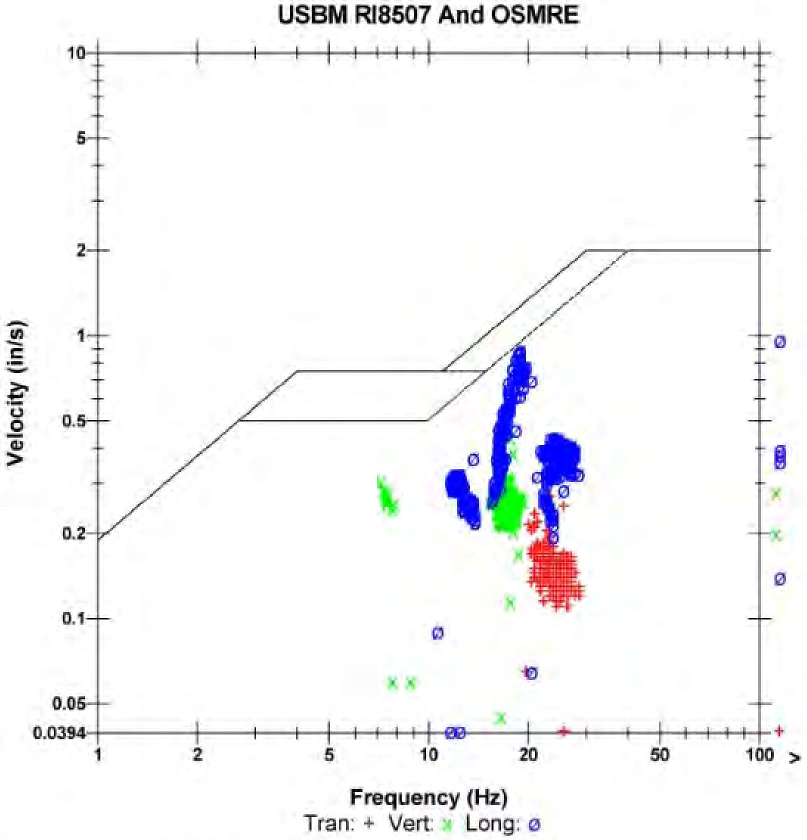
Notes

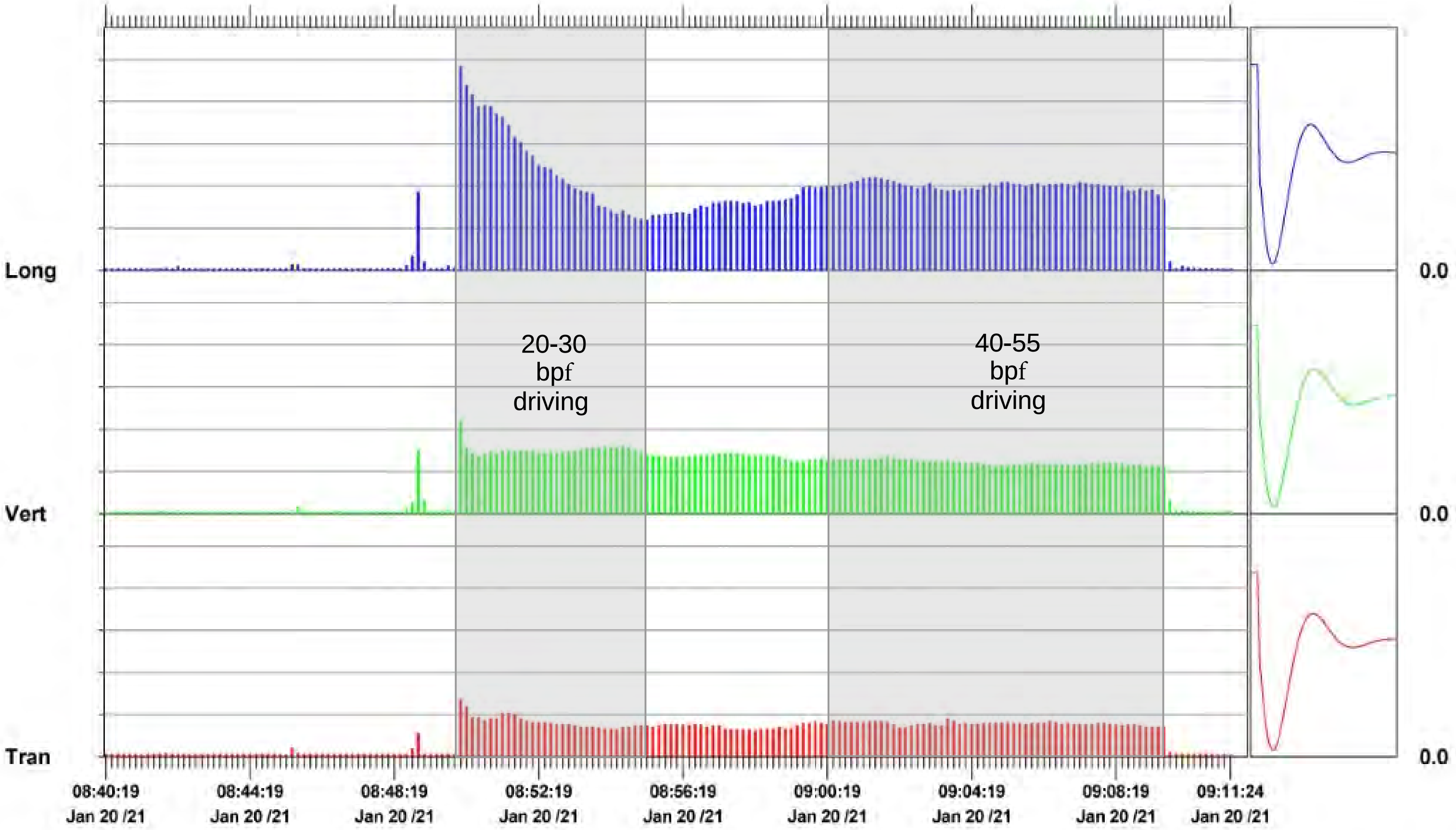
Location:	Seattle, WA
Client:	Port of Seattle
Monitored By:	PanGeo, Inc. 206-262-0370
Unit Location:	VM-3

Extended Notes:
Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.270	0.435	0.965	in/s
ZC Freq	23	17.7	N/A	Hz
Date	Jan 20 /21	Jan 20 /21	Jan 20 /21	
Time	08:50:05	08:50:05	08:50:05	
Sensor Check	Passed	Passed	Passed	
Frequency	7.6	7.5	8.1	Hz
Overswing Ratio	4.1	3.8	3.7	

Peak Vector Sum 0.990 in/s on January 20, 2021 at 08:50:05
N/A: Not Applicable


USBM RI8507 And OSMRE



Time Scale: 10 seconds /div **Amplitude Scale:** Geo: 0.200 in/s/div

Sensor Check

P-03 (@25 ft) - Delmag D62-22 Diesel Hammer Reinhall

Histogram Start Time	12:33:16 February 8, 2021
Histogram Finish Time	14:31:04 February 8, 2021
Number of Intervals	3534.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17963 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	October 7, 2020 by Instantel
File Name	S963IUDC.7G0

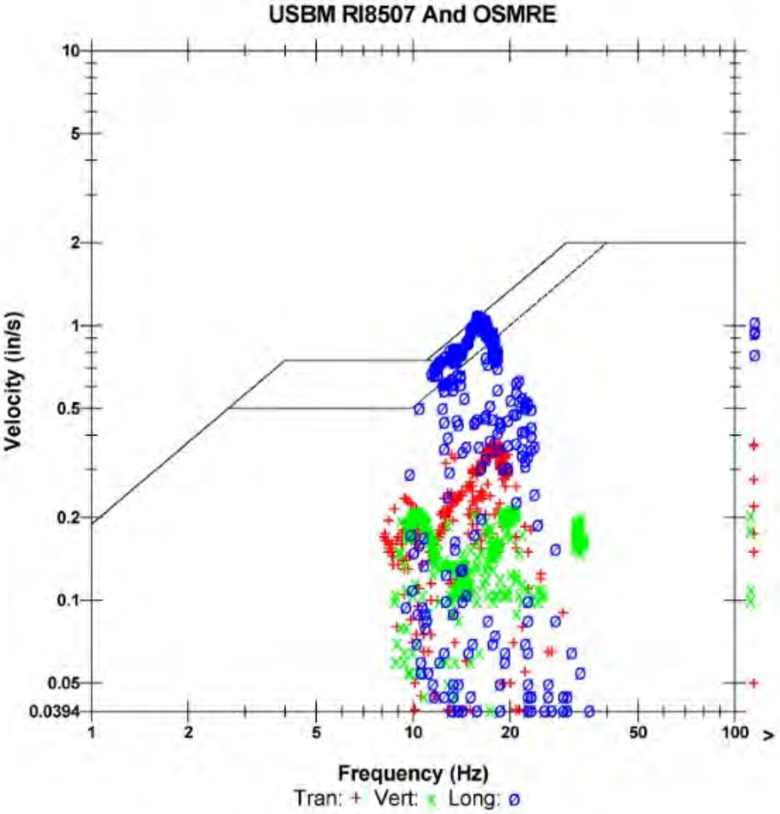
Notes

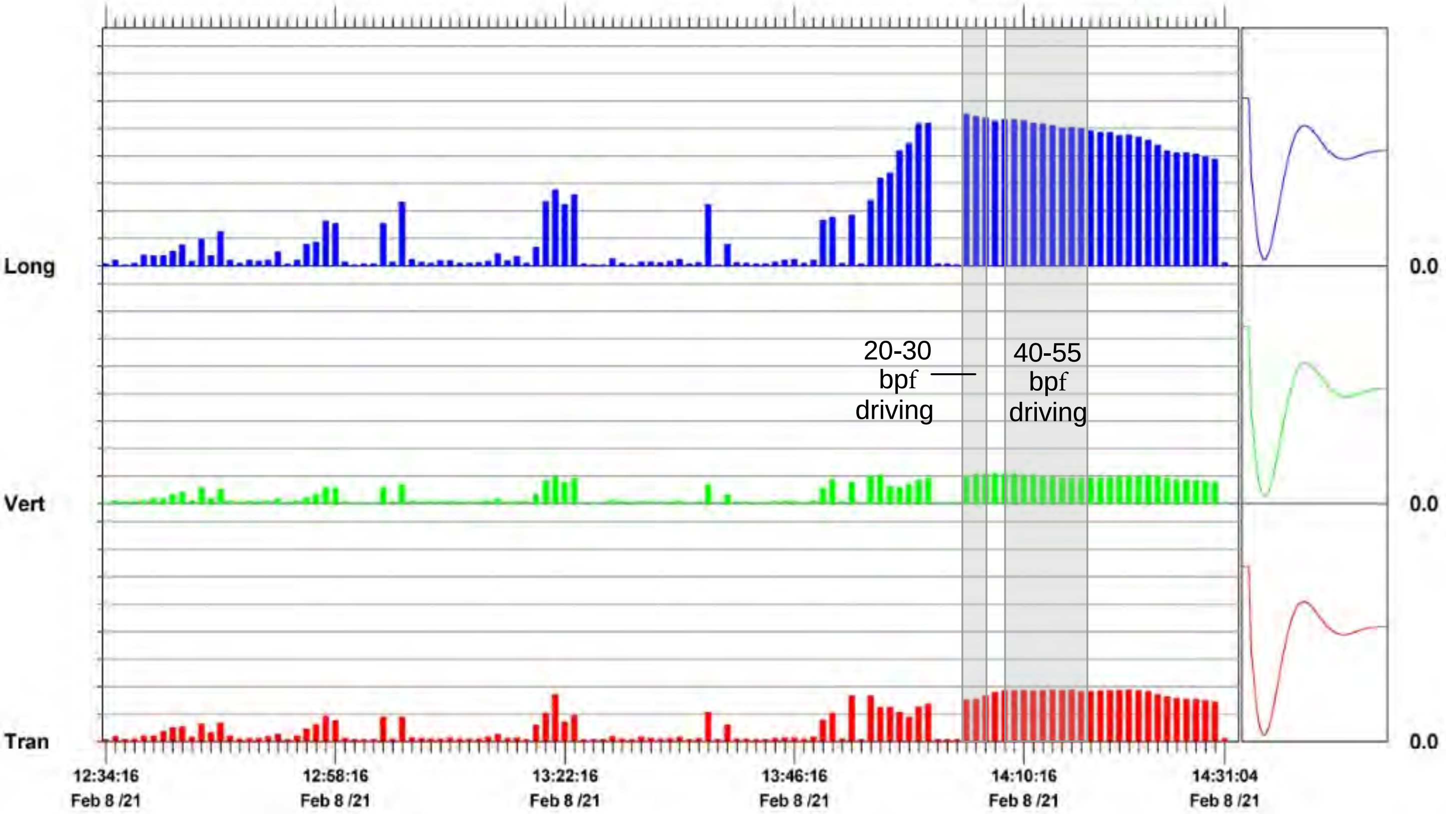
Location:	Seattle, WA
Client:	Port of Seattle
Monitored By:	PanGeo, Inc. 206-262-0370
Unit Location:	VM-3

Extended Notes:
Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.375	0.215	1.100	in/s
ZC Freq	18.0	21	15.8	Hz
Date	Feb 8 /21	Feb 8 /21	Feb 8 /21	
Time	14:12:18	14:06:22	14:04:02	
Sensor Check	Passed	Passed	Passed	
Frequency	7.6	7.3	7.5	Hz
Overswing Ratio	4.1	3.9	4.0	

Peak Vector Sum 1.116 in/s on February 8, 2021 at 14:04:02





Time Scale: 1 minute /div **Amplitude Scale:** Geo: 0.200 in/s/div

Sensor Check

Printed: February 12, 2021 (V 10.74)

Instantel P-02S (@25 ft) - Delmag D62-22 Diesel Hammer

Histogram Start Time	14:11:30 January 19, 2021
Histogram Finish Time	14:41:07 January 19, 2021
Number of Intervals	888.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17963 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	October 7, 2020 by Instantel
File Name	S963ITCF.F60

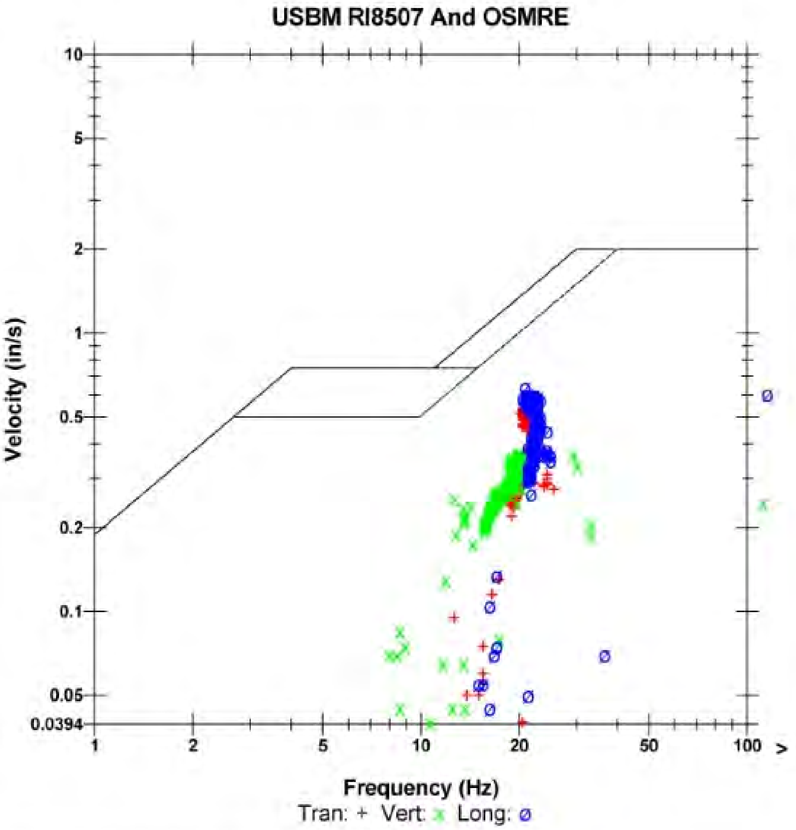
Notes

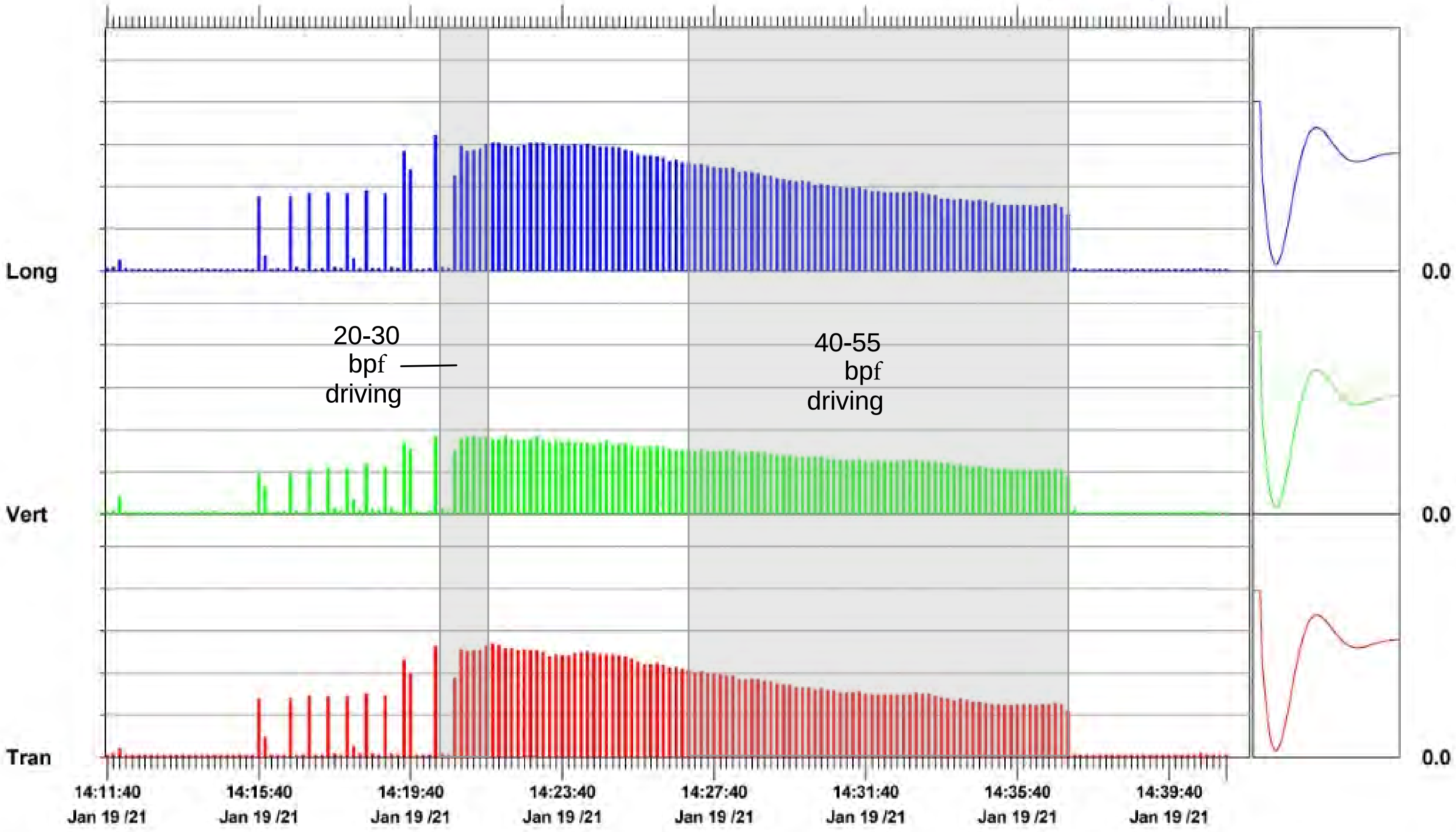
Location:	Seattle, WA
Client:	Port of Seattle
Monitored By:	PanGeo, Inc. 206-262-0370
Unit Location:	VM-3

Extended Notes:
Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.535	0.370	0.640	in/s
ZC Freq	20	20	21	Hz
Date	Jan 19 /21	Jan 19 /21	Jan 19 /21	
Time	14:21:46	14:21:16	14:20:16	
Sensor Check	Passed	Passed	Passed	
Frequency	7.4	7.4	7.4	Hz
Overswing Ratio	4.2	3.9	4.0	

Peak Vector Sum 0.852 in/s on January 19, 2021 at 14:20:16





Time Scale: 10 seconds /div **Amplitude Scale:** Geo: 0.200 in/s/div Sensor Check

Printed: January 19, 2021 (V 10.74)

P-02N (@35 ft) - Delmag D62-22 Diesel Hammer
Reinhall

Histogram Start Time	08:38:31 February 8, 2021
Histogram Finish Time	10:34:51 February 8, 2021
Number of Intervals	3490.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17964 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	October 6, 2020 by Instantel
File Name	S964IUD1.C70

Notes

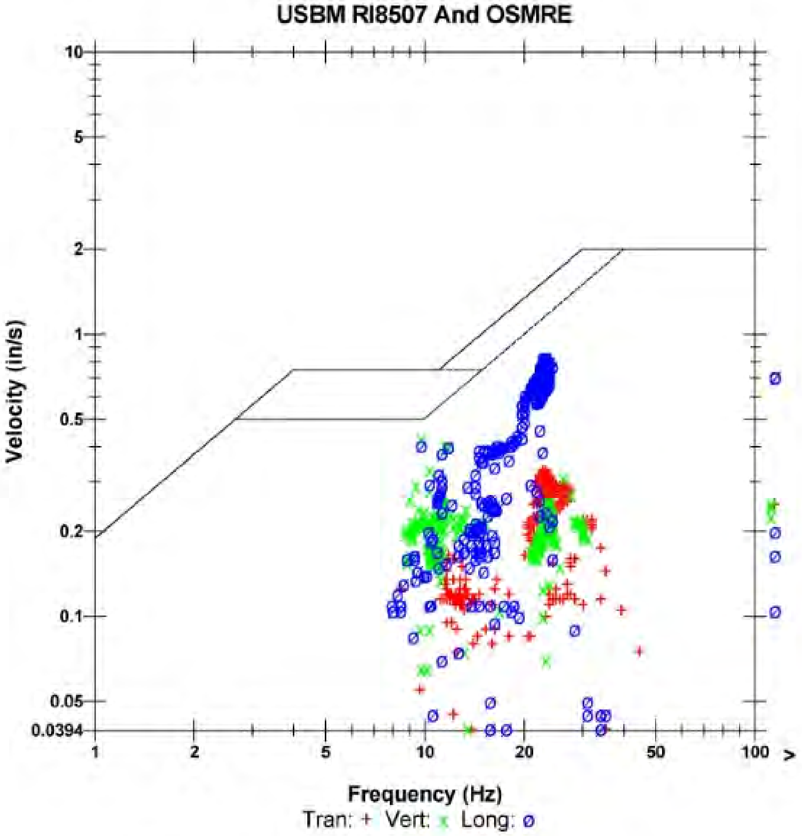
Location: Seattle, WA
Client: Port of Seattle
Monitored By: PanGeo, Inc. 206-262-0370
Unit Location: VM-4

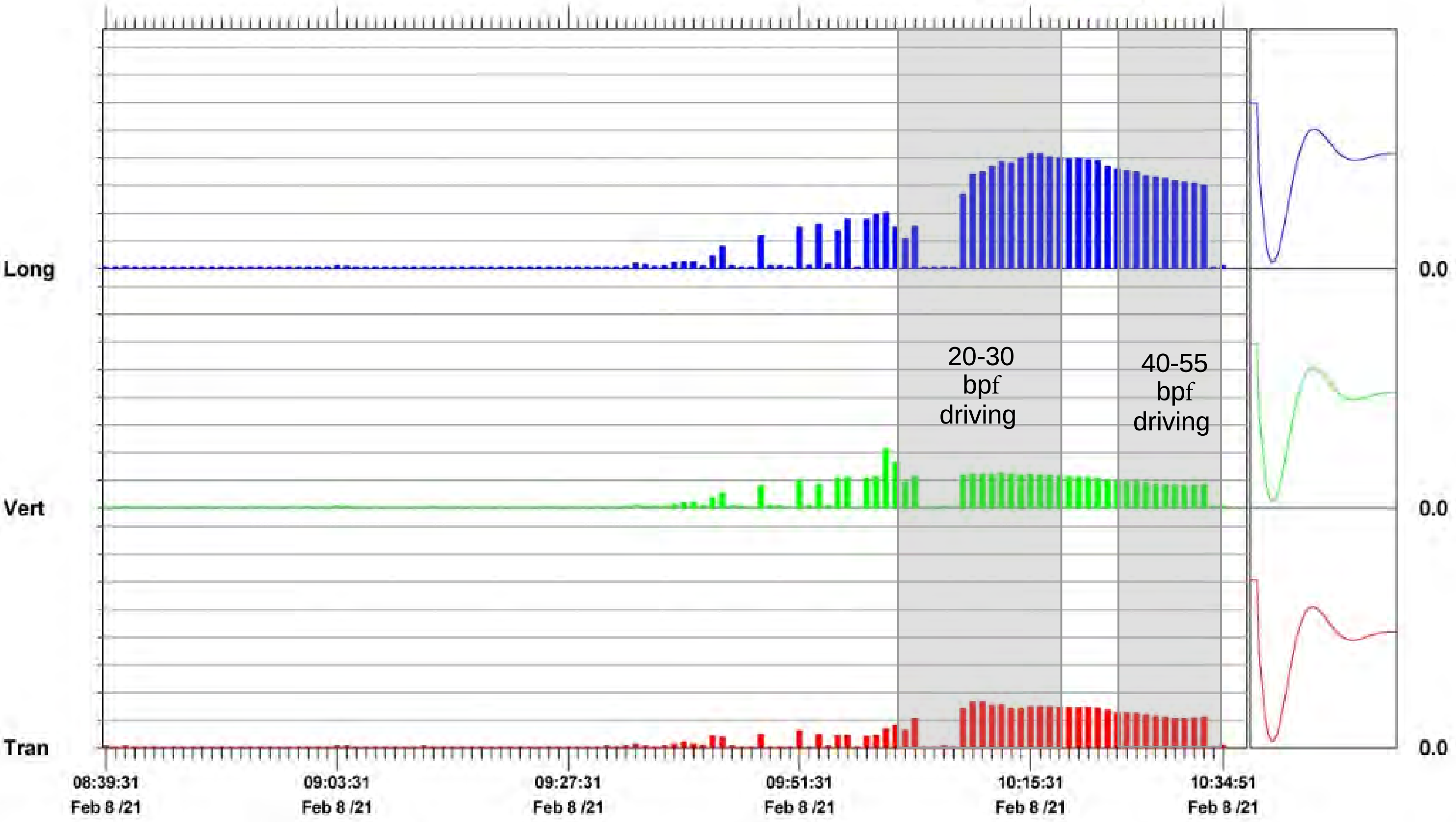
Extended Notes:

Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.330	0.425	0.830	in/s
ZC Freq	23	9.8	23	Hz
Date	Feb 8 /21	Feb 8 /21	Feb 8 /21	
Time	10:09:11	10:00:23	10:14:57	
Sensor Check	Passed	Passed	Passed	
Frequency	7.6	7.5	7.4	Hz
Overswing Ratio	4.0	4.2	4.3	

Peak Vector Sum 0.860 in/s on February 8, 2021 at 10:15:07





Time Scale: 1 minute /div **Amplitude Scale:** Geo: 0.200 in/s/div

Sensor Check

Printed: February 12, 2021 (V 10.74)

Format © 1995-2015 Xmark Corporation

Instantel

P-01NA (@35 ft) - Delmag D62-22 Diesel Hammer

Histogram Start Time	09:16:36 January 20, 2021
Histogram Finish Time	09:42:19 January 20, 2021
Number of Intervals	771.00 at 2 seconds
Range	Geo:10.000 in/s
Sample Rate	2048sps

Serial Number	BE17964 V 10.72-8.17 MiniMate Plus
Battery Level	6.2 Volts
Unit Calibration	October 6, 2020 by Instantel
File Name	S964ITDW.FO0

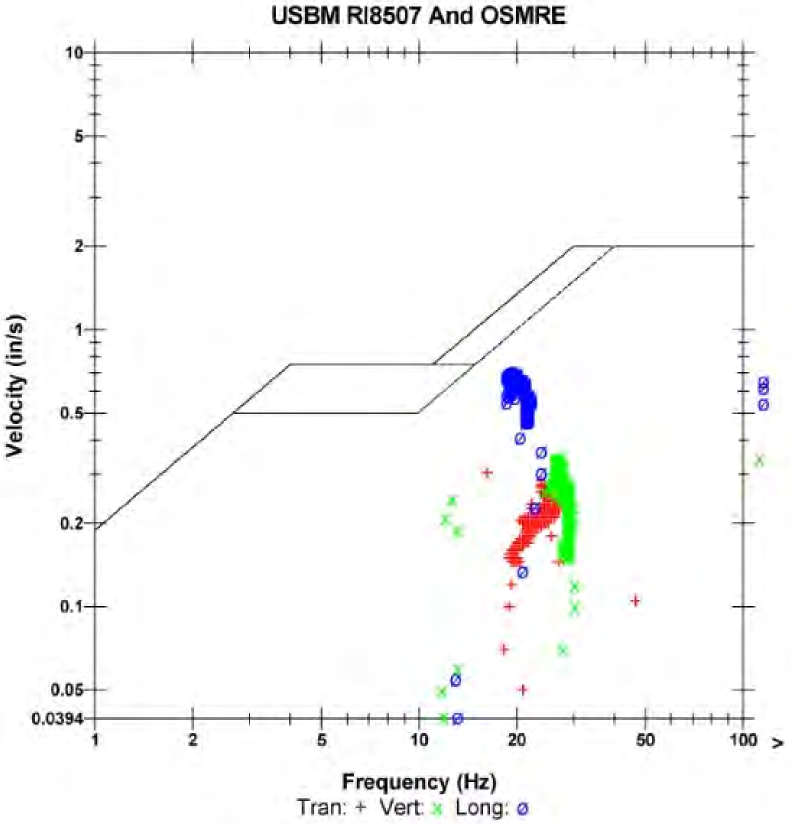
Notes

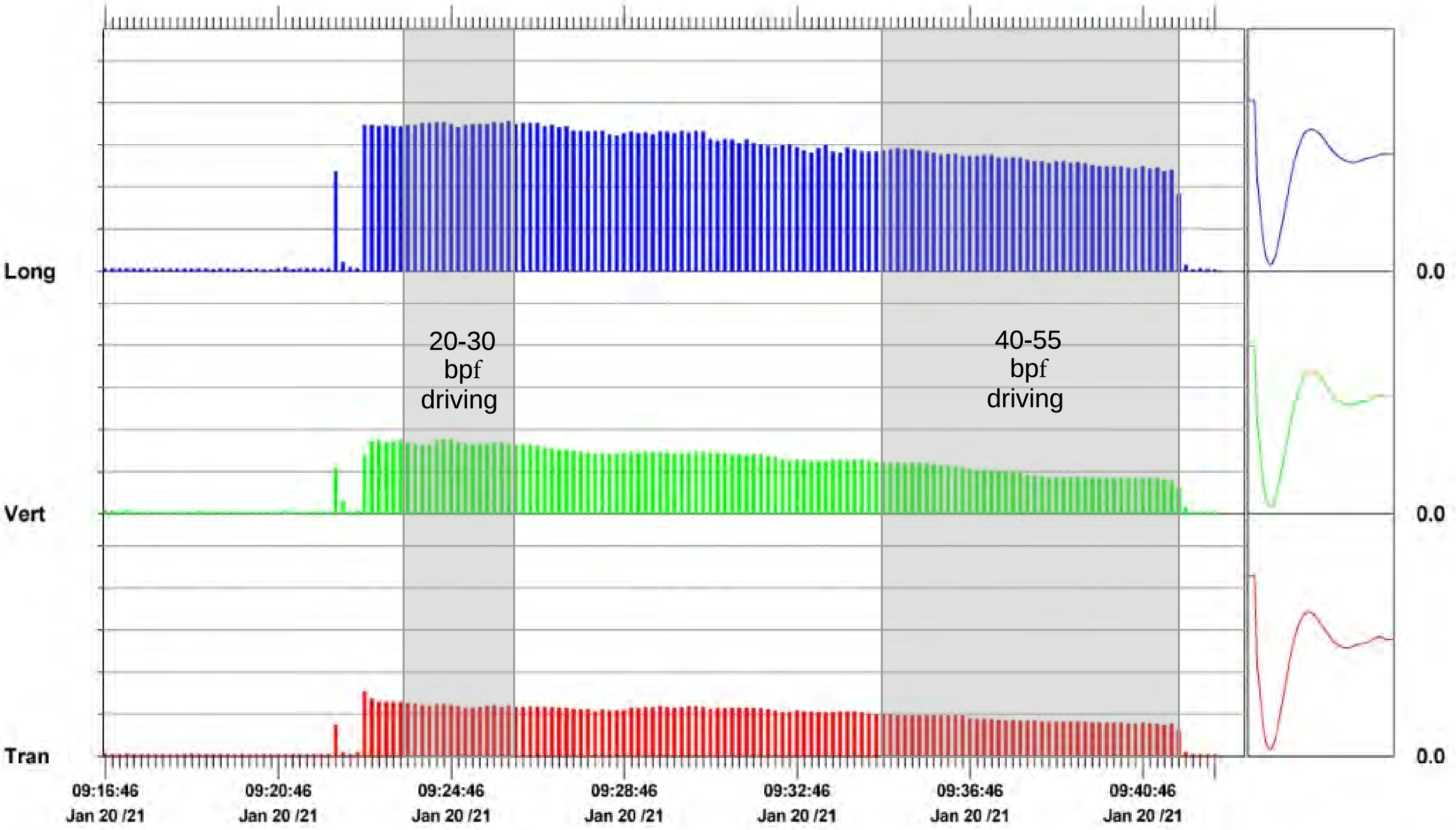
Location:	Seattle. WA
Client:	Port of Seattle
Monitored By:	PanGeo, Inc. 206-262-0370
Unit Location:	VM-4

Extended Notes:
Project: T117 Restoration Pile Driving

	Tran	Vert	Long	
PPV	0.305	0.350	0.710	in/s
ZC Freq	16.3	28	19.3	Hz
Date	Jan 20 /21	Jan 20 /21	Jan 20 /21	
Time	09:22:42	09:24:46	09:26:02	
Sensor Check	Passed	Passed	Passed	
Frequency	7.8	7.4	7.4	Hz
Overswing Ratio	3.9	4.1	4.2	

Peak Vector Sum 0.736 in/s on January 20, 2021 at 09:24:20


USBM RI8507 And OSMRE



Time Scale: 10 seconds /div **Amplitude Scale:** Geo: 0.200 in/s/div

Sensor Check

Printed: January 20, 2021 (V 10.74)

PanGEO
INCORPORATED

Reinhall

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration　**Project No:** 20-478
Date: 2/18/21　**Weather:** ~40°F　**Start Time:** 9:58 am　**Stop Time:** 10:35 am
Pile No.: P-02N　**Pile Type:** Open-ended　**Tip Ø:** 24 in.　**Butt Ø:** 18 in.　**Batter:** N/A
Pile Length: 63 ft.　**Length Driven:** ~60 ft.　**Ref. Elev.** — ft.　**Tip Elev.** -45.03' ft.　**Cutoff Elev.** 15'11"
Steel Pile Grade/Heat: A252 Grad. 3　**Wall Thickness:** 0.75 in.　**Shoe:** N/A (Open-ended)
Hammer M&M: ICE 44B Vibratory　**Hammer Wt.:** 5,500 lbs　**Driving Force:** 207 tons　**Frequency:** 900-1800 vpm
Hammer M&M: APE D62-22　**Ram Wt.:** 13,671 lbs.　**Rated Energy:** 164,052 ft.-lbs.
Pile Cushion thickness/material:　**PanGEO Repr.:** S. Harrington

Reinhall coupler (1–3)
19 (7–10)
24 (11–15)
25 (16–20)

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
1			Stabbed in ~1½'	31	8		
2			w/ just weight of hammer	32	11		
3	2		↑	33	12	42	
4	2		Aligning after every	34	16	42	
5	3		blow	35	17		
6	4		↓	36	18		
7				37	19		
8				38	21	44	
9				39	24		
10				40	24	40	
11				41	23		
12				42	25	40	
13				43	22		
14				44	25	46	
15				45	31		
16				46	35	40	~9' stroke
17				47	38	38	~10' stroke　10:20 am
18				48	38		
19				49	37		
20				50	38		
21	5			51	37		
22	7			52	39	38	~10' stroke
23	7			53	42		10:26 am
24	8			54	43		
25	7			55	44	38	~10' stroke
26	7			56	46		10:30 am
27	8			57	56		
28	8			58	56	38	~10' stroke
29	8			59	54		10:35 am
30	9			60	~19 blows		

+17.97' butt elevation

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 1/15/21 **Weather:** 50s - partly sunny **Start Time:** 1:47 pm **Stop Time:** ____

Pile No.: P-015 **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** ____ in. **Batter:** N/A

Pile Length: 61 ft. **Length Driven:** ____ ft. **Ref. Elev.** +14.5' ft. **Tip Elev.** -44 ft. **Cutoff Elev.** 15-4" ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: / **PanGEO Repr.:** S. Harrington

	Feet	Blows	sec/ft ~~Stroke/ Pressure/~~ Blows/min.	Remarks	Feet	Blows	sec/ft ~~Stroke/ Pressure/~~ Blows/min.	Remarks	
	1		↓		31		33		
Starting [illegible]	2				32		34		
1:51	3			Aligning	33	2:04	47		
	4		11		34	2:05	68		
	5		12		35	2:06	72		
	6		7		36	2:08	60		
	7		16		37		64		
	8		12		38		114		
	9		14		39		130		
	10		16		40	~40.5'	180	Stopped @ 2:14 pm	
	11		9		41	13		Impact 1/20/21 – 8:51 – 9:10 am	
	12		11		42	29			
	13		7		43	29			
	14		13		44	27	39s		
	15		14		45	27			
	16		7		46	30			44 bpm
	17		7		47	32			
	18		7		48	33			42 bpm
	19		11		49	35		8:58 am 1/20/21	
	20		9		50	36			42 bpm
	21		13		51	39			
1:58	22		12	Aligning	52	41		9:00 am	42 bpm
	23		13		53	42			
	24		12		54	46			
	25		12		55	47			40 bpm
	26		12		56	54			
	27		19		57	53			
	28		15	Bouncing	58	54			36 bpm
2:00	29		28		59	56	– Stopped at ~59' bgs @ 9:10 am		
	30		27		60	Tip	Elev:	- -44.10	

+36.40' top of can after vibrating

top of can after impact

Reinhall

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration Project No: 20-478

Date: 2/8/21 Weather: ~41° Partly Cloudy Start Time: 1:15 pm Stop Time: 2:29 pm

Pile No.: P-03 Pile Type: Open-ended Tip Ø: 24 in. Butt Ø: 18 in. Batter: N/A

Pile Length: 63 ft. Length Driven: ~55 ft. Ref. Elev. ______ ft. Tip Elev. -45.47 ft. Cutoff Elev. 15'11"

Steel Pile Grade/Heat: A252 Grad. 3 Wall Thickness: 0.75 in. Shoe: N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory Hammer Wt.: 5,500 lbs Driving Force: 207 tons Frequency: 900-1800 vpm

Hammer M&M: APE D62-22 Ram Wt.: 13,671 lbs. Rated Energy: 164,052 ft.-lbs.

~~Pile Cushion~~ thickness/material: ______ PanGEO Repr.: S. Harrington

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks
1			2' water at design location	31	13	44	7.5' stroke height
2				32	13		
3	1		Stabbed in 2' below grade w/ weight of hammer	33	14		
4	1			34	16		
5	1			35	21	40	9' stroke height
6	1 1/2'		– Aligning –	36	23		– stop to move straps
7	1		1:55 pm	37	31		2:04 pm
8	2			38	34		
9	2			39	37	40	
10	2			40	40		2:07 pm
11	2		– aligning – 1:57 pm	41	41	38	10' stroke height
12	2			42	46		
13	2			43	53		
14	2			44	50	39	~9.5' stroke height
15	2			45	56		
16	3			46	57		
17	4			47	58	38	~10' stroke height 2:17 pm
18	6			48	62		
19	7		Steady driving	49	63		
20	6			50	59	38	~10' stroke height
21	5			51	58		
22	5			52	59		
23	6			53	59	39	~9.5' stroke height
24	7			54	70		
25	8			55	63		~stopped ~3" shy of 55' mark
26	9			56			
27	10			57			
28	10			58			
29	12			59			
30	13			60			

30'

+ 17.53' tip

PanGEO INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration Project No: 20-478

Date: 1/19/21 Weather: ~40° F, foggy & cold Start Time: 11:09 am Stop Time: 2:36 pm

Pile No.: P-025 Pile Type: Open-ended Tip Ø: 24 in. Butt Ø: ____ in. Batter: N/A

Pile Length: 61 ft. Length Driven: ____ ft. Ref. Elev. +15.5' ft. Tip Elev. -44 ft. Cutoff Elev. 15'11" ft.

Steel Pile Grade/Heat: A252 Grad. 3 Wall Thickness: 0.75 in. Shoe: N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory Hammer Wt.: 5,500 lbs Driving Force: 207 tons Frequency: 900-1800 vpm

Hammer M&M: APE D62-22 Ram Wt.: 13,671 lbs. Rated Energy: 164,052 ft.-lbs.

Pile Cushion thickness/material: / PanGEO Repr.: S. Harrington

Feet	Blows	sec/ft ~~Stroke/ Pressure/~~ Blows/min.	Remarks	Feet	Blows	sec/ft ~~Stroke/ Pressure/~~ Blows/min	Remarks	
1		↓	Couldn't time – too fast ↓	31		30	Slowing down	
2				32		24		
3				33		21		
4		8		34		31		
5		7		35		20		
6		10		36		22		
7		9		37		33		
8		9		38		49	V. dense/hard material/	
9		9	Aligning	39		60		
10		27		40		76		
11		14		41		130	Stopping vibration 11:45 am	
12		9		42	40	2:16 pm	2:16 – 2:36 impact	
13		9		43	25			
14		9	Aligning – bent up to ...	44	24			
15		12		45	24			
16		12		46	27	2:20 pm		46 bpm
17		11		47	24			
18		18		48	35			
19		11		49	32			
20		11		50	31			
21		14		51	34			44 bpm
22		11		52	36			
23		11	aligning	53	37	2:25 pm		
24		13		54	42			40 bpm
25		13		55	41			
26		15		56	41			
27		25		57	47			40 bpm
28		13		58	47			40 bpm
29		14		59	47			40 bpm
30		17		60	—			40 bpm

11:11–11:14

+16.98' top

-44.02 tip

↑ Stopped at 59'8" ~42 blows

Stopped – 2:36 – Impact

PanGEO
INCORPORATED

Reinhall

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 2/8/21 **Weather:** ~40°F **Start Time:** 9:58 am **Stop Time:** 10:35 am

Pile No.: P-02N **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** 18 in. **Batter:** N/A

Pile Length: 63 ft. **Length Driven:** ~60 ft. **Ref. Elev.** — ft. **Tip Elev.** -45.03' ft. **Cutoff Elev.** 15'11"

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: **PanGEO Repr.:** S. Harrington

Reinhall coupler (ft 1–3)
17 (ft 7–10)
24 (ft 11–15)
25 (ft 16–20)

Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	Feet	Blows	Stroke/ Pressure/ Blows/min.	Remarks	
1			Stabbed in ~1/2'	31	8			
2			w/ just weight of hammer	32	11			
3	2		↑	33	12	42		
4	2		Aligning after every	34	16	42		
5	3		blow	35	17			
6	4		↓	36	18			
7				37	19			
8				38	21	44		
9				39	24			
10				40	24	40		
11				41	23			
12				42	25	40		
13				43	22			
14				44	25	46		
15				45	31			
16				46	35	40	~9' stroke	
17				47	38	38	~10' stroke	10:20 am
18				48	38			
19				49	37			
20				50	38			
21	5			51	37			
22	7			52	39	38	~10' stroke	
23	7			53	42			10:26 am
24	8			54	43			
25	7			55	44	38	~10' stroke	
26	7			56	46			10:30 am
27	8			57	56			
28	8			58	56	38	~10' stroke	
29	8			59	54			10:35 am
30	9			60	~19 blows			

+17.97' butt elevation

PanGEO
INCORPORATED

PILE INSTALLATION RECORD

Project Name/Location: T117 Habitat Restoration **Project No:** 20-478

Date: 1/15/21 **Weather:** ~50' - partly cloudy **Start Time:** 9:47 **Stop Time:** 10:33 am

Pile No.: P-01NA **Pile Type:** Open-ended **Tip Ø:** 24 in. **Butt Ø:** / in. **Batter:** N/A

Pile Length: 61 ft. **Length Driven:** ______ ft. **Ref. Elev.** +16.5 ft. **Tip Elev.** -44 ft. **Cutoff Elev.** +15.4' ft.

Steel Pile Grade/Heat: A252 Grad. 3 **Wall Thickness:** 0.75 in. **Shoe:** N/A (Open-ended)

Hammer M&M: ICE 44B Vibratory **Hammer Wt.:** 5,500 lbs **Driving Force:** 207 tons **Frequency:** 900-1800 vpm

Hammer M&M: APE D62-22 **Ram Wt.:** 13,671 lbs. **Rated Energy:** 164,052 ft.-lbs.

Pile Cushion thickness/material: / **PanGEO Repr.:** S. Harrington

30 sec

Feet	Blows	sec (ft) ~~Stroke/~~ Pressure/ Blows/min.	Remarks	Feet	Blows	sec/ft Stroke/ Pressure/ Blows/min.	Remarks
1		3		31		26	
2		4		32		32	
3		8		33		27	bouncing a lot
4		4		34		45	
5		6		35		39	
6	[illegible] 10	6		36		22	
7	9:46	9	Stopped to align	37		31	
8				38	10:28	62	- V. dense/hard ground
9				39		93	
10			- Slowed	40	10:33 am	240	Stopping
11				41	-		Inspect 1/20/21 - 9:24 am
12	9:52		Stopped to align	42	28	9:24 am	9:42 am
13		3		43	30		
14		7		44	30		
15		12		45	30		
16		5		46	32		44 bpm
17		7		47	33		
18		12	Slowed	48	33		
19		5		49	35		
20		4		50	35		40 bpm
21		6		51	38		
22		6		52	38		
23	9:55	9	- Lifting it up to 20'	53	38	9:34 am	
24		6		54	43		
25	10:01 - 10:09	8 8	- Aligning - lifting to 13'	55	45		40 bpm
26		7		56	44		
27		11		57	47		
28		17		58	53		
29		22		59	56		38 bpm
30		26		60	27		- Stopped 9:42 am

ordering 10:00 am → 24

10:20 — 28

* Spiral weld piles

Tip elevation -44.10'

Top elevation +16.9'

7.3 Appendix C – Photos of Mandrels After Driving