January

2015

Hydroacoustic and Airborne Noise Monitoring at the Philadelphia Naval Shipyard during Pile Driving – Interim Report

30 September through 2 October 2014

Philadelphia Naval Shipyard, Philadelphia, PA

Interim Report Prepared by

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Acoustics • Air Quality

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Under Contract to

HDR

Environmental, Operations and Construction, Inc.

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Summary

This report summarizes the underwater and airborne noise monitoring results for (36-inch [91.4 cm] and 48-inch [121.2 cm]) steel shell piles at the Philadelphia Naval Shipyard Annex in Philadelphia, Pennsylvania (**Figure 1**). The piles driven were structural piles being driven to reinforce the existing Pier. The water depth at the pile locations was approximately 40 feet deep. Pier 4 (where the pile driving occurred) is set between Pier 2 to the east and Pier 5 to the west, there is approximately 600 to 650 feet between the piers. On the west side of Pier 4 there was an aircraft carrier and on the east side of Pier 2 there was a large ship. The piles were being driven through holes cut in the existing pier deck. For measurement locations, please refer to **Figure 2**.

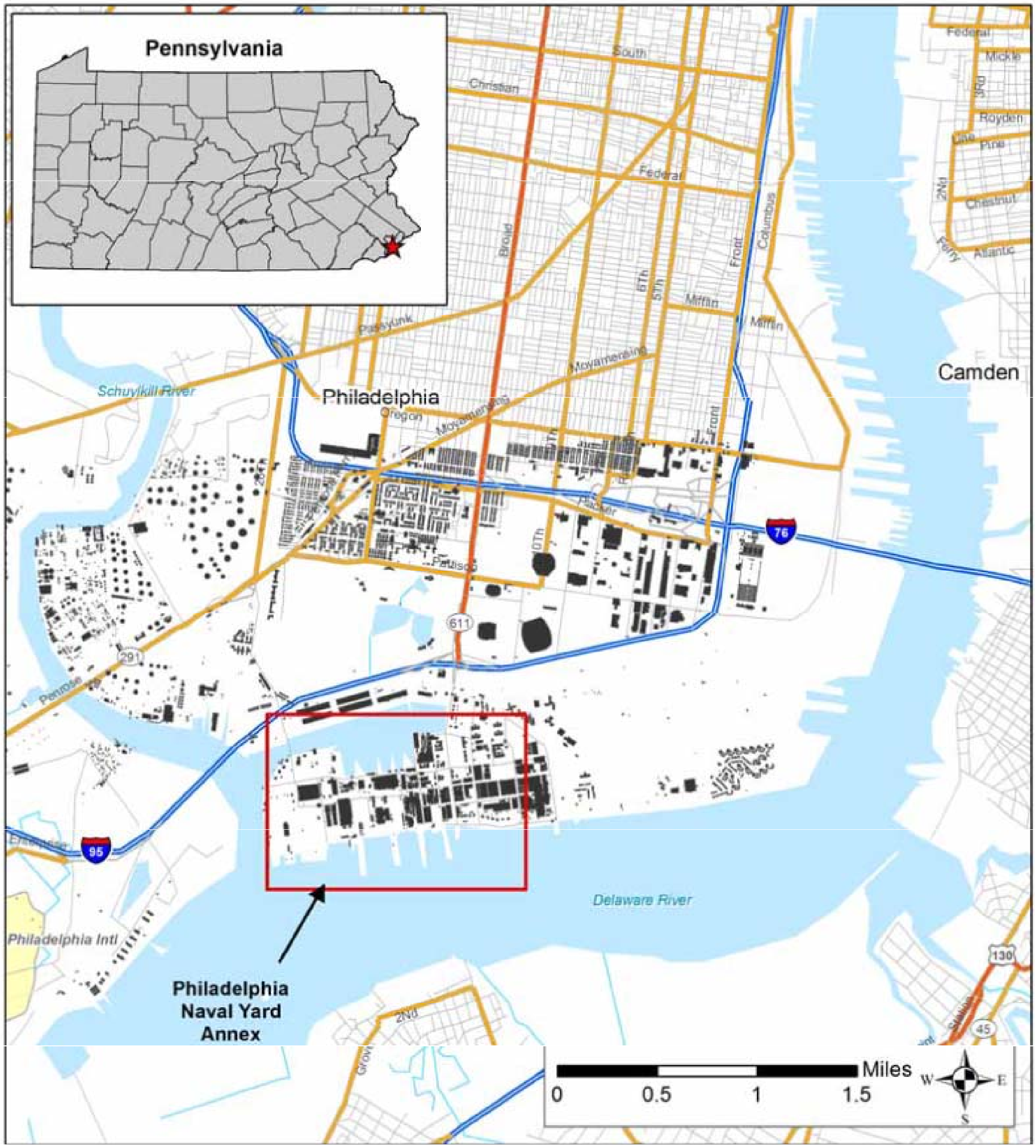

Figure 1: Study Location Map

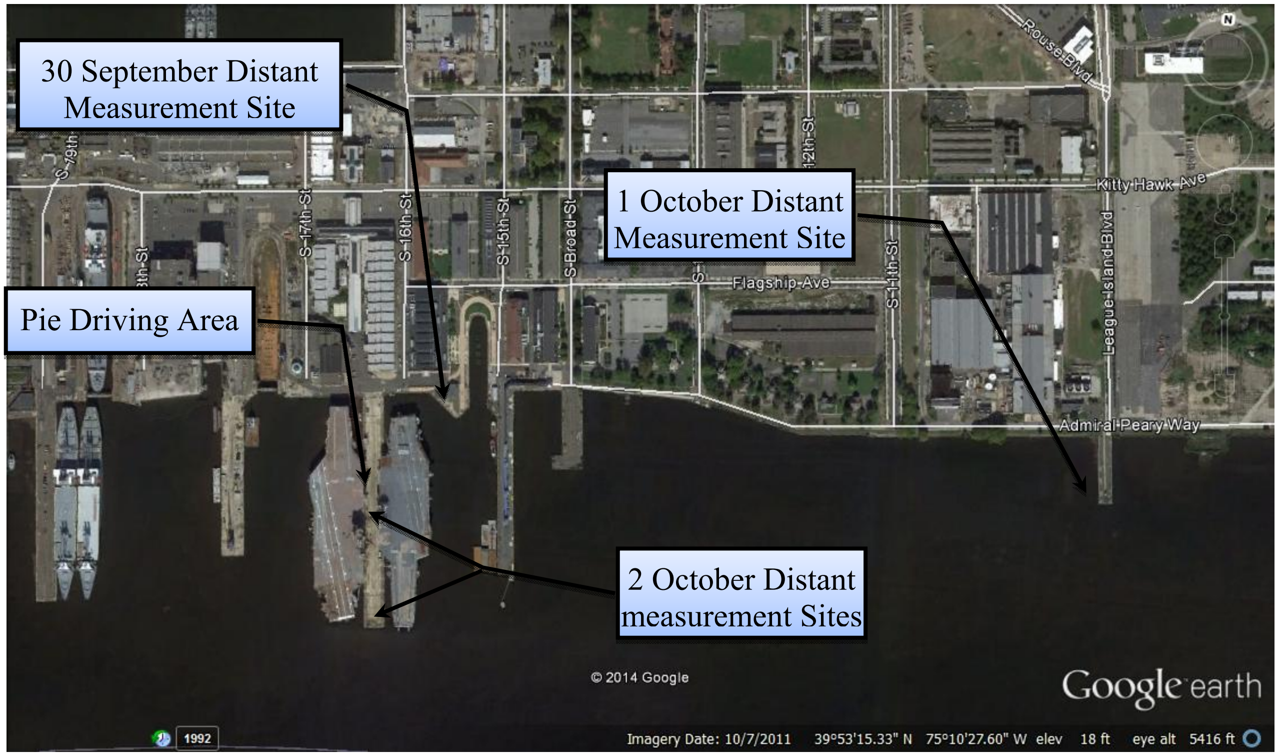

Figure 2: Measurement Locations

On 30 September, noise monitoring was conducted on three 48-inch steel shell piles (Piles A-3, B-3, and C-3). Both vibratory and impact measurements were made. All the piles were first installed using an American Piledriving Equipment (APE) Model 200 vibratory hammer with an eccentric moment of 50.69 kilograms per meter (kgm) (4,400 inch pounds [in-lbs.]). The piles were then driven to their finial tip elevation using an APE D70-52 diesel impact hammer with an energy rating between 117.21 kilometer newton (kNm) (86,822 foot-pounds [ft-lbs.]) and 234.42 kNm (173,644 ft-lbs.). The peak sound pressure level (SPL), root mean square (RMS) level, sound exposure level (SEL), and cumulative SEL (cSEL) sound levels were measured at two locations: 33 feet (10 meters) and approximately 410 feet (125 meters). Underwater sound levels are reported as Z-weighted[1] levels in decibels (dB) referenced to one micro pascal (µPa) with the exception of SEL and cSEL that is referenced to 1 μPa^2-sec. Airborne sounds are A-weighted levels in dB referenced to 20 µPa.

On 1 October, sound measurements were conducted on four 36-inch steel shell piles (Piles D-4, E-4, F-4, and G-4). Both vibratory and impact measurements were conducted. All the piles were first installed using an APE Model 200 vibratory hammer and then the piles were driven to their finial tip elevation using an APE D70-52 diesel impact hammer. The peak, RMS, SEL, and cumulative SEL were recorded at three locations: 33 feet (10 meters), 656 feet (200 meters), and approximately 3,610 feet (1.1 kilometers [km]). The 3,610-foot (1.1 km) monitoring distance

[1] Z-weighting is a flat response applied to underwater sound measurements made over the frequency range of 10 to 20,000 Hz. A-weighting includes adjustments to measured airborne sounds over the same frequency range, adjusted to reflect the perceived loudness to humans.

was established to represent a distance where the received sound during the vibratory driving was estimated to be at the Level B Harassment Zone. However, there appears to have been some acoustic shielding between the measurement site and the pile driving which caused the levels at the second site to be below the detection threshold of the sound level meter (SLM). The shielding may have been from the large ship that was moored at the pier between the pile driving and the measurement site or there may have been an area of that was not dredged between the measurement site and the pile driving. The 656-foot (200 meter) location was an unmanned autonomous recorder that was downloaded at the end of the day. At this location, which was at the end of the dock, it also appeared to have some acoustic shielding from the existing piers for the dock; Attachment D shows the existing pile layout. The only reliable data were from the 33-foot (10 meter) measurement site.

On 2 October, there were five 36-inch steel shell piles installed (D-3, E-3, G-3, H-4, and I-4). Both vibratory and impact measurements were made. All the piles were first installed using an APE Model 200 vibratory hammer and then the piles were driven to their finial tip elevation using an APE D70-52 diesel impact hammer. The peak, RMS, SEL, and cSEL were recorded at three locations, 33 feet (10 meters), 165 feet (50 meters), and 656 feet (200 meters), in an attempt to get better data for calculating the attenuation rate from the pile driving. While this method generally works effectively, the excess attenuation continued to be a problem with the existing pier layout. At the 165-foot (50 meter) location, there may not have been as much attenuation from the existing piers, but there was a hammer hoe doing demolition work on the existing deck. The noise from this operation appeared to be louder than the pile driving sounds. The unmanned autonomous system was not deployed because a suitable location where there was a clean line of sight to the pile driving could not be identified.

Table 1 provides a data summary of maximum sound pressure levels at 33 feet (10 meters) for the impact pile driving measured on 30 September and 1-2 October. **Table 2** provides a data summary of maximum and average 1-second RMS and the maximum and average 10-second average RMS sound pressure levels for the vibratory pile driving measured during the same period. **Attachment A** shows the time history of the pile driving and typical one-third octave band spectra.

Airborne measurements were also conducted at a fixed location from the pile driving. On 1 and 2 October the distance to the pile driving was maintained at 50 feet (15 meters). A Larson Davis 831 SLM was used to measure the airborne noise from the pile driving. On 30 September, the airborne system was not deployed due to technical errors in the system; these errors were corrected and the system was deployed on the following days. These measured levels are shown in **Attachment B**.

Attachment C shows a summary of the raw data from the three days of pile driving.

Measurement Equipment

Reson Model TC-4013 and Reson Model TC-4033 hydrophones were used. The signal from the hydrophones was fed directly into a Larson Davis Laboratories (LDL) Model 831 Precision Sound Level Meters (LDL 831).

Table 1: Data Summary of Maximum Levels from Impact Driving at 33 feet (dB re: 1µPa)

Pile Size	Pile ID	Date	Number of Blows	Peak		RMS		SEL		cSEL [1]
				Average	Range	Average	Range	Average	Range	
48-inch	A3	9/30/2014	939	200	197 - 204	183	180 - 187	173	169 - 175	202
48-inch	B3	9/30/2014	928	200	196 – 205	185	108 - 189	174	171 - 177	204
48-inch	C3	9/30/2014	969	203	197 -208	187	182 - 191	176	171 - 178	206
36-inch	D4	10/01/2014	723	199	195 - 203	185	181 - 189	174	171 - 177	203
36-inch	E4	10/01/2014	473	200	195 - 205	186	180 - 191	175	168 - 179	202
36-inch	F4	10/01/2014	574	200	195 - 206	185	179 - 191	174	169 - 178	202
36-inch	G4	10/01/2014	583	200	195 - 206	184	181 - 189	173	169 - 177	201
36-inch	D3	10/02/2014	526	203	198 - 207	185	183 - 189	174	171 - 176	201
36-inch	E3	10/02/2014	551	200	193 - 206	183	178 - 188	172	168 - 175	200
36-inch	G3	10/02/2014	635	199	192 - 207	183	177 - 189	172	167 - 176	200
36-inch	H4	10/02/2014	546	199	195 - 204	184	181 - 189	173	169 - 178	201
36-inch	I4	10/02/2014	640	198	191 - 205	183	177 - 190	172	167 - 177	201

[1] dB re:1µPa^2-sec

Table 2: Data Summary of Maximum RMS Vibratory Driving Levels at 33 feet (dB re: 1μPa)

Pile Size	Pile ID	Date	Duration (mm:ss)	1-second RMS		10-second RMS	
				Range	Average	Range	Average
48-inch	A3	9/302014	16:16	151 - 167	162	160 - 167	162
48-inch	B3	9/30/2014	7:23	148 - 160	157	142 - 160	157
48-inch	C3	9/30/2014	4:08	144 - 163	157	144 - 162	156
36-inch	D4	10/01/2014	[1]	[1]	[1]	[1]	[1]
36-inch	E4	10/01/2014	2:53	142 - 166	153	149 - 162	156
36-inch	F4	10/01/2014	3:53	131 - 169	157	155 - 164	157
36-inch	G4	10/01/2014	7:19	134 - 158	148	143 - 157	149
36-inch	D3	10/02/2014	5:20	140 - 158	151	143 - 156	151
36-inch	E3	10/02/2014	5:30	139 - 157	151	140 -154	151
36-inch	G3	10/02/2014	6:38	138 - 154	147	143 - 152	147
36-inch	H4	10/02/2014	2:55	137 - 156	146	138 - 154	147
36-inch	I4	10/02/2014	3:47	143 - 159	154	151 - 157	154

[1] Setting up equipment and missed the drive.

Airborne measurements were made using a 0.5-inch (1.3 cm) G.R.A.S. Model 40AQ pre-polarized random-incidence microphone. The signal was fed into an LDL Model 820 Sound Level Meter. The system was calibrated with a LDL Model CAL200 Acoustic Calibrator. The microphone was calibrated at the beginning and end of each day. Pre-event and post-event calibration levels were within 0.1 dB.

Underwater Sound Descriptors

The acoustic monitoring for this project reports data in several formats, depending on the type of pile driving and the type of acoustic measurement. Impact pile driving produces pulse-type sounds, while vibratory pile installation produces a more continuous type of sound.

During impact driving, the maximum peak sound pressures (LZ_{peak}), impulse RMS sound pressure level (LZI), and the 1-second SEL (LZ_{eq}) were measured underwater "live" using the LDL 831. During vibratory driving, the maximum peak sound pressures (LZ_{peak}) and the fast RMS sound pressure level (LZF) were measured underwater "live" using the LDL 831. The LDL 831 SLM provided measurements of the un-weighted results for each data type, including the one-third octave band spectra for the 1-second LZ_{max}. Additional analyses of the acoustic impulses were performed using the LDL 831 SLMs as well. The LDL 831 captures the signal and stores the measurement data retrieved at the completion of a day of measurements.

Airborne Sound Descriptors

A-weighted airborne data were collected for both impact and vibratory driving. During data collection, 1-second and 1-minute intervals were used for measuring airborne data. The airborne data shown on the various time history charts represent the 1-second "fast" A-weighted RMS (L_{max}), which uses a 125-millisecond time constant for RMS averaging. The tables shown in **Attachment B** show the 1-minute data including the 1-minute LA_{eq} and 1-minute LA_{max}, and the peak sound pressure level.

Underwater Sound Data Management

Data were collected from hydrophones and recorded on Larson Davis 831 SLMs. The measurements of peak, RMS, and SEL sound pressures for each second were recorded. For each day of measurements, digital data captured by the SLMs were downloaded to a computer. The SLMs were used to provide accurate live readings and spectra data. These readings were recorded in field notebooks from time to time.

Quality Control

The measurement system was calibrated prior to use in the field with a G.R.A.S. Type 42AA pistonphone and hydrophone coupler. The pistonphone, when used with the hydrophone coupler, produces a continuous 136.4 or 145.3 dB (referenced to 1 μPa) tone at 250 hertz. The SLM is calibrated to this tone prior to use in the field. The tone is then measured by the SLM and is recorded onto the beginning of the digital audiotapes that were used in the field. The system calibration status was checked at the end of the measurement event by measuring the calibration tone and recording the post-measurement tone. Signal analysis included the measurement of the calibration tone at the beginning and end of recording events. All systems were found to be within 0.1 dB of the calibration levels. The pistonphone output was certified at an independent facility.

All field notes were recorded in water-resistant field notebooks. Such notebook entries include calibration notes, measurement positions (i.e., distance from source, depth of sensor), system gain settings, and the equipment used to make each measurement. Notebook entries were copied after each measurement day and filed for safekeeping. Recorded media were labeled and stored for subsequent analysis.

Discussion and Recommendations

Upon analyzing the data in detail, it appeared that an excess amount of sound attenuation was present, particularly when compared with values obtained from similar projects in other locations. For example, in San Francisco Bay, impact pile driving attenuation rates for 48-inch and 36-inch piles are approximately between $12*Log_{10}$ and $17*Log_{10}$ (unpublished data). On this project, the attenuation rates ranged from $18*Log_{10}$ to $23*Log_{10}$. These are extremely high attenuation rates that could only result from a couple of factors; very shallow water and/or obstructions in the water. Because this is a working dock with some of the largest naval ships present, the water is not deemed particularly shallow. After a thorough review of the site, there were an extremely high number of existing piles present (approximately 34 wood piles in each pile row and approximately 105 rows of piles spaced approximately 10 feet apart under the existing Pier 4) that could have caused the high rates attenuation, see Attachment D for pile layout.

These issues may potentially be avoided with additional planning prior to commencement of field work (e.g. set of as built plans for areas of proposed work). If these plans were available before the monitoring rather than afterwards, the placement of the distant and close hydrophones could have taken this into account. Additionally, greater access to the site would make it easier to get the hydrophones in more optimal locations. If a boat were made available, the flexibility would be ideal in order to ensure that there is a clear "line of sight" to pile driving activities.

Glossary

acoustical pulse – Integral over time of the initial positive acoustic pressure pulse. This metric has been used by researchers to evaluate the effects of blast signals on fish where the signal is typically characterized by a single positive peak pressure pulse.

acoustic energy flux – The work done per unit area and per unit time by a sound wave on the medium as it propagates. The units of acoustic energy flux are joules per square meter per second (J/m^2-s) or watts per square meter (W/m^2). The acoustic energy flux is also called acoustic intensity.

air bubble curtain – A device that infuses the area surrounding a pile with air bubbles, creating a bubble screen that reduces peak underwater sound pressure levels.

ambient sound – Normal background noise in the environment that has no distinguishable sources.

ambient sound level – The background sound level, which is a composite of sound from all sources near and far. The normal or existing level of environmental sound at a given location. Distribution of sound pressure versus frequency for a waveform, dimension in root mean square pressure, and defined frequency bandwidth.

amplitude – The maximum deviation between the sound pressure and the ambient pressure.

background Level – Is similar to Ambient Sound Level with the exception that is a composite of all sound measured during the consstruct5ion period minus the pile driving.

bandwidth – The range of frequencies over which a sound is produced or received.

cumulative sound exposure level ($SEL_{cumulative}$) – In an evaluation of pile driving impacts on fish, it may be necessary to estimate the cumulative SEL associated with a series of pile strike events. $SEL_{cumulative}$ can be estimated from the single-strike SEL and the number of strikes that likely would be required to place the pile at its final depth by using the following equation:

$$SEL_{cumulative} = SEL_{single\ strike} + 10*\log(\#\ of\ pile\ strikes)$$

dead blow – An ineffective hammer strike on the pile when the pile is advancing through soft soil.

decibel (dB) – A customary scale most commonly used for reporting levels of sound. A difference of 10 dB corresponds to a factor of 10 in sound power. A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for water is 1 micro-Pascal (µPa), and for air is 20 micro-Pascals (the threshold of healthy human audibility).

frequency – The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 and 20,000 hertz (Hz). Infrasonic sounds are below 20 Hz and ultrasonic sounds are above 20,000 Hz. Measured in cycles per second (hertz [Hz]).

frequency spectrum – The distribution of frequencies from low to high that comprise a sound. Frequency spectra are important because the frequency content of the sound may affect the way the fish responds to the sound (in terms of physical injury as well as hearing loss). From an engineering perspective, the frequency spectrum is important because it affects the expected sound propagation and the performance of a sound attenuation (i.e., reduction) system, both being frequency dependent.

hertz (Hz) – The units of frequency where 1 hertz equals 1 cycle per second.

impulse level – Integral over time of the initial positive acoustic pressure pulse. A graphical plot illustrating the time history of positive and negative sound pressure of individual pile strikes shown as a plot of µPa versus time. Measured in Pascals milliseconds (Pa msec).

intensity (I) –The product of sound pressure and acoustic particle velocity divided by the acoustic impedance of the medium; also referred to as the acoustic energy flux density.

peak sound pressure level (L_{PEAK}) – The largest absolute value of the instantaneous sound pressure. This pressure is expressed as a decibel (referenced to a pressure of 1 micro-Pascal [µPa] for water and 20 µPa for air) or in units of pressure, such as µPa or PSI.

project action area – The area experiencing direct and indirect project-related effects.

root mean square (RMS) sound pressure level –Decibel measure of the square root of mean square (RMS) pressure. For impulses, the average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy of the impulse.

sound – small disturbances in a fluid from ambient conditions through which energy is transferred away from a source by progressive fluctuations of pressure (or sound waves).

sound exposure – The integral over all time of the square of the sound pressure of a transient waveform.

sound exposure level (SEL) –The time integral of frequency-weighted squared instantaneous sound pressures. Proportionally equivalent to the time integral of the pressure squared and can be described manual, sound energy associated with a pile driving pulse, or series of pulses, is characterized by the SEL. SEL is the constant sound level in one second, which has the same amount of acoustic energy as the original time-varying sound (i.e., the total energy of an event). SEL is calculated by summing the cumulative pressure squared over the time of the event.

sound pressure level (SPL) – An expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 micro-Pascal (μPa) for water and biological tissues, and 20 μPa for air and other gases. Sound pressure is the sound force per unit area, usually expressed in micro-Pascals (or micro-Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The SPL is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressure exerted by the sound to a reference sound pressure (e.g., 20 micro-Pascals). SPL is the quantity that is directly measured by a sound level meter. Measured in decibels (dB).

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ATTACHMENT A:

TIME HISTORY OF PILE DRIVING AND 1/3 OCTAVE BAND SPECTRA

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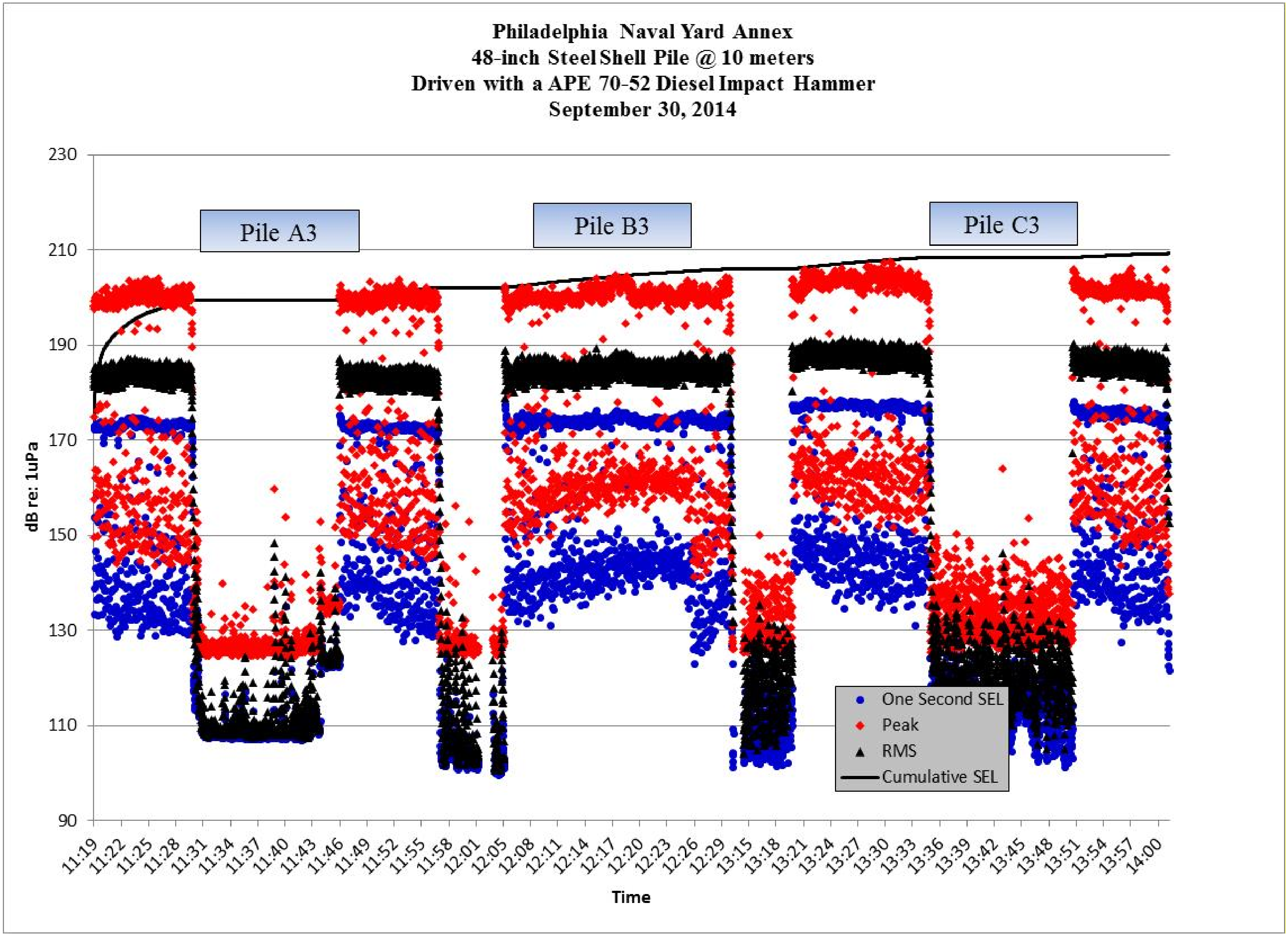
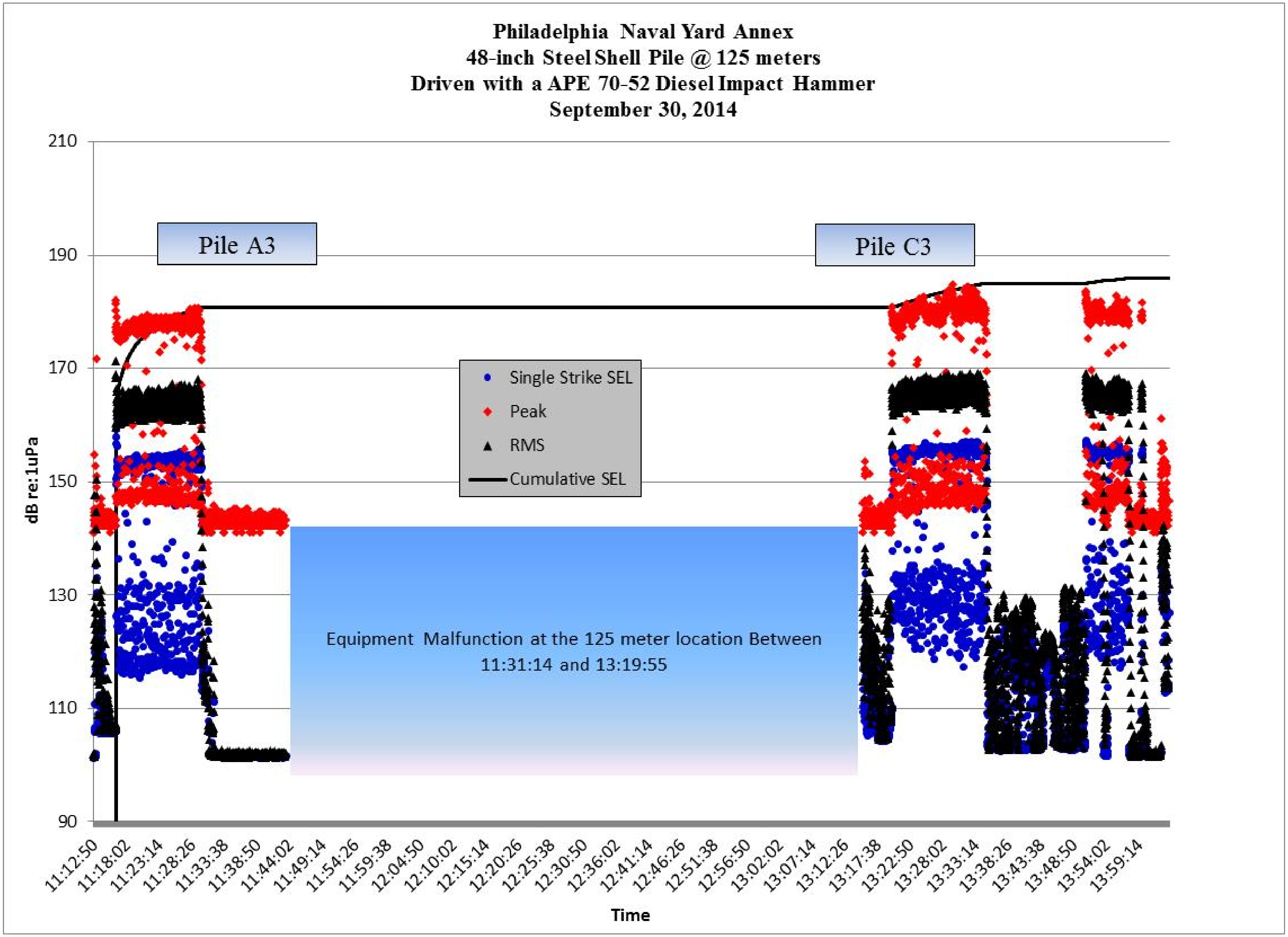

Philadelphia Naval Yard Annex
48-inch Steel Shell Pile @ 10 meters
Driven with a APE 70-52 Diesel Impact Hammer
September 30, 2014
Pile A3
Pile B3
Pile C3
dB re: 1uPa
230
210
190
170
150
130
110
90
11:19
11:22
11:25
11:28
11:31
11:34
11:37
11:40
11:43
11:46
11:49
11:52
11:55
11:58
12:01
12:05
12:08
12:11
12:14
12:17
12:20
12:23
12:26
12:29
13:15
13:18
13:21
13:24
13:27
13:30
13:33
13:36
13:39
13:42
13:45
13:48
13:51
13:54
13:57
14:00
Time
One Second SEL
Peak
RMS
Cumulative SEL


Philadelphia Naval Yard Annex
48-inch Steel Shell Pile @ 125 meters
Driven with a APE 70-52 Diesel Impact Hammer
September 30, 2014
Pile A3
Pile C3
Single Strike SEL
Peak
RMS
Cumulative SEL
Equipment Malfunction at the 125 meter location Between 11:31:14 and 13:19:55
dB re:1uPa
Time
210
190
170
150
130
110
90
11:12:50
11:18:02
11:23:14
11:28:26
11:33:38
11:38:50
11:44:02
11:49:14
11:54:26
11:59:38
12:04:50
12:10:02
12:15:14
12:20:26
12:25:38
12:30:50
12:36:02
12:41:14
12:46:26
12:51:38
12:56:50
13:02:02
13:07:14
13:12:26
13:17:38
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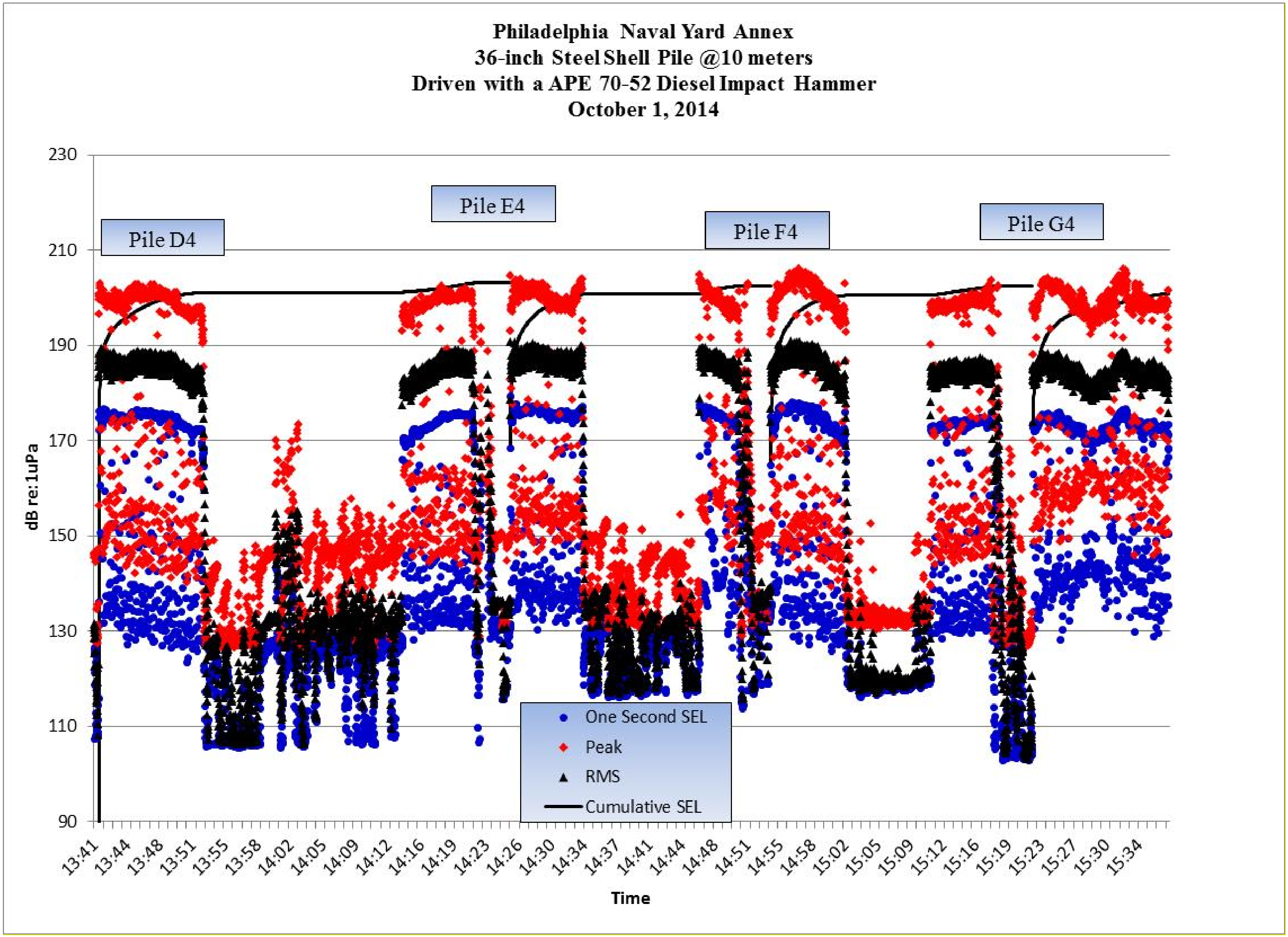
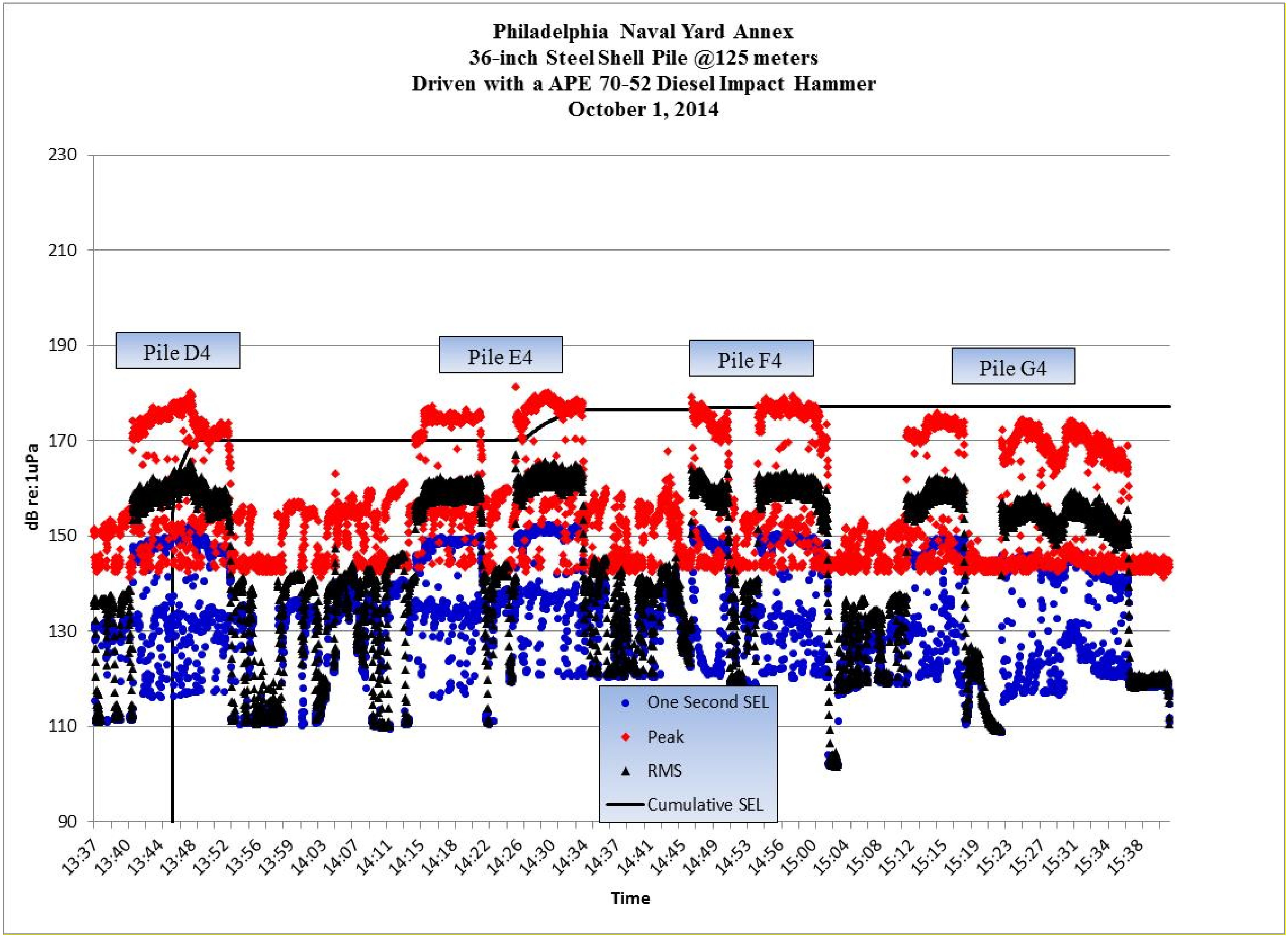
13:48:50
13:54:02
13:59:14


Philadelphia Naval Yard Annex
36-inch Steel Shell Pile @10 meters
Driven with a APE 70-52 Diesel Impact Hammer
October 1, 2014
Pile D4
Pile E4
Pile F4
Pile G4
230
210
190
170
150
130
110
90
dB re:1uPa
13:41
13:44
13:48
13:51
13:55
13:58
14:02
14:05
14:09
14:12
14:16
14:19
14:23
14:26
14:30
14:34
14:37
14:41
14:44
14:48
14:51
14:55
14:58
15:02
15:05
15:09
15:12
15:16
15:19
15:23
15:27
15:30
15:34
Time
One Second SEL
Peak
RMS
Cumulative SEL


Philadelphia Naval Yard Annex
36-inch Steel Shell Pile @125 meters
Driven with a APE 70-52 Diesel Impact Hammer
October 1, 2014
Pile D4
Pile E4
Pile F4
Pile G4
dB re:1uPa
230
210
190
170
150
130
110
90
One Second SEL
Peak
RMS
Cumulative SEL
13:37
13:40
13:44
13:48
13:52
13:56
13:59
14:03
14:07
14:11
14:15
14:18
14:22
14:26
14:30
14:34
14:37
14:41
14:45
14:49
14:53
14:56
15:00
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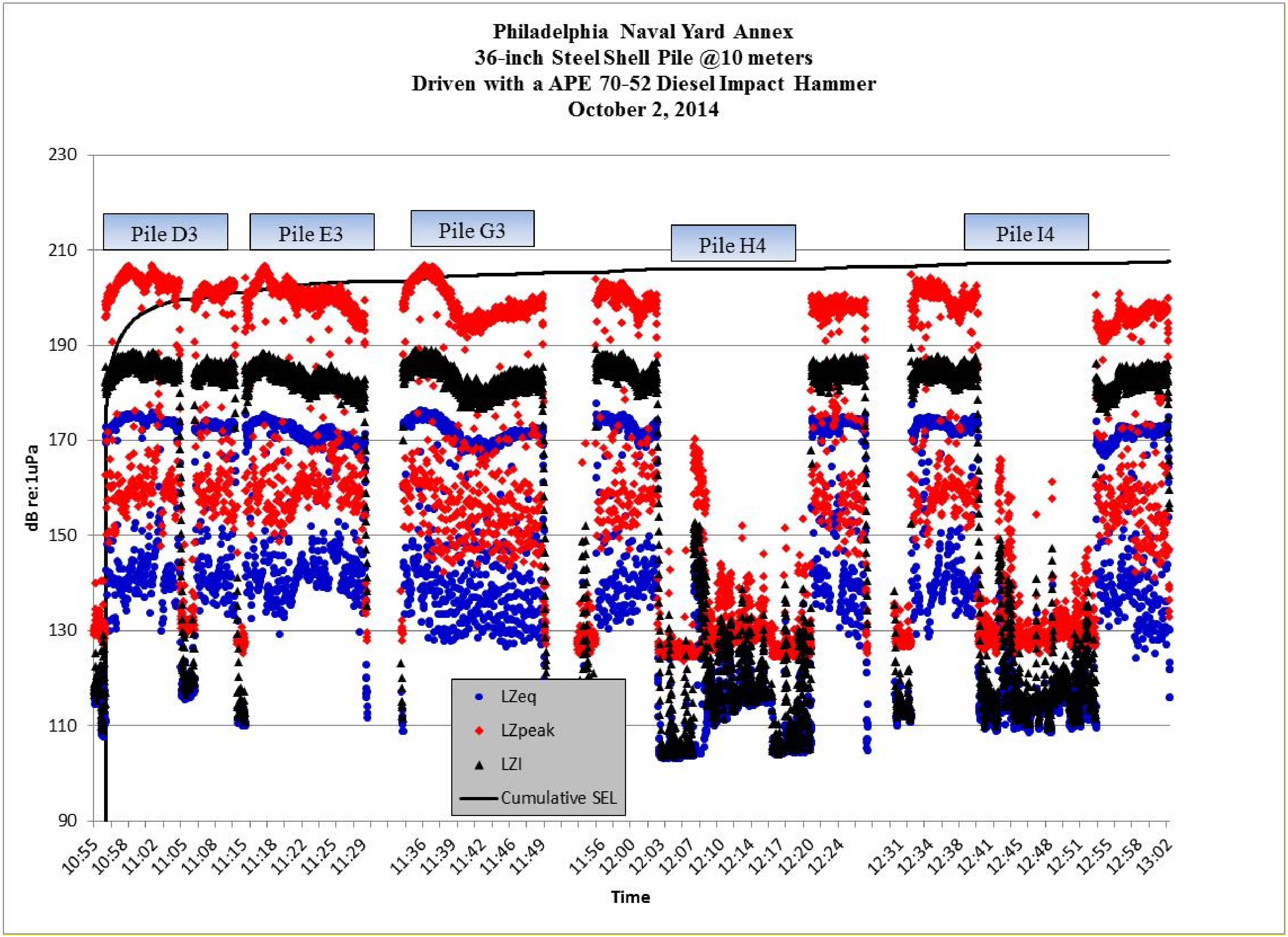
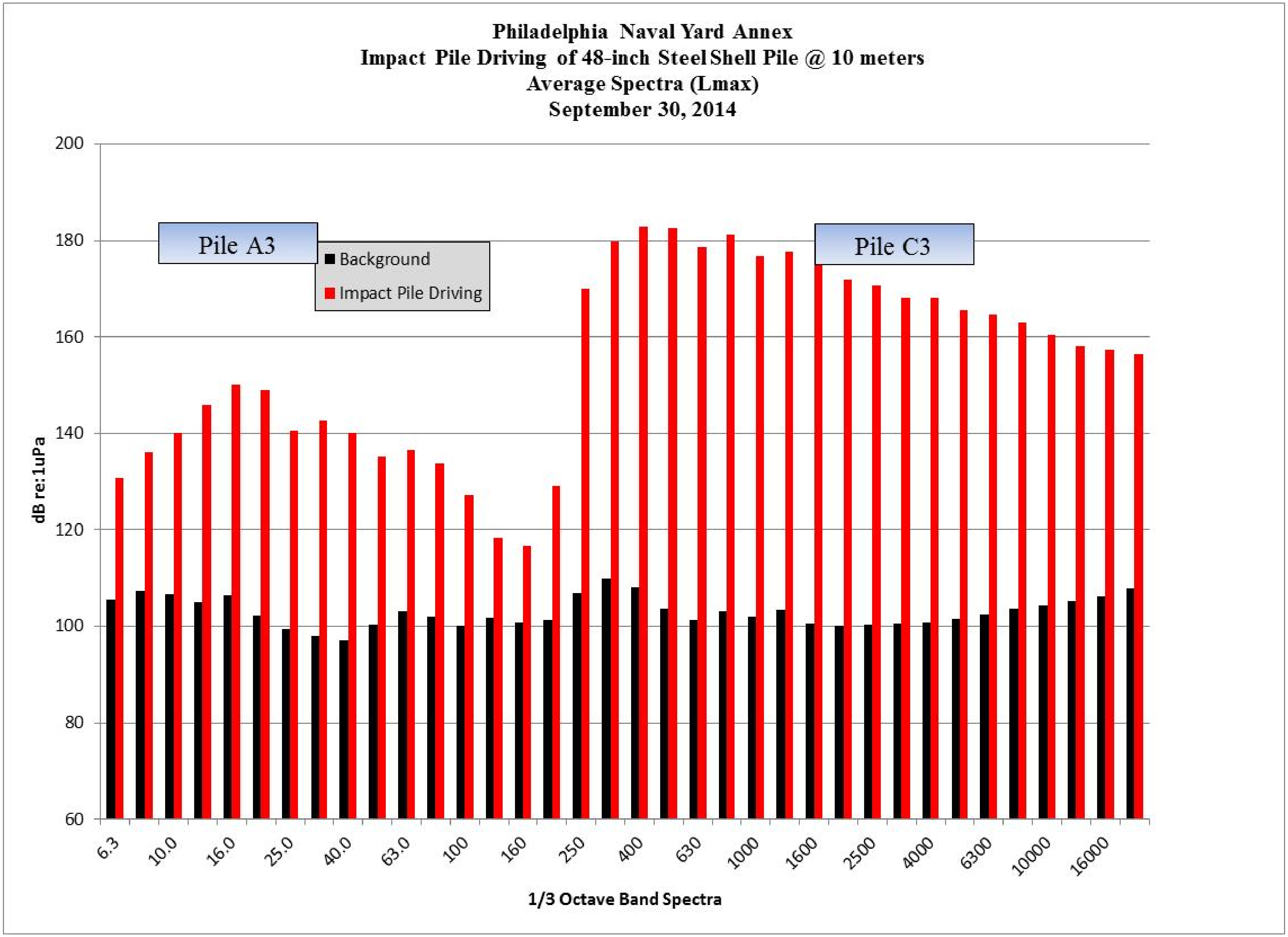
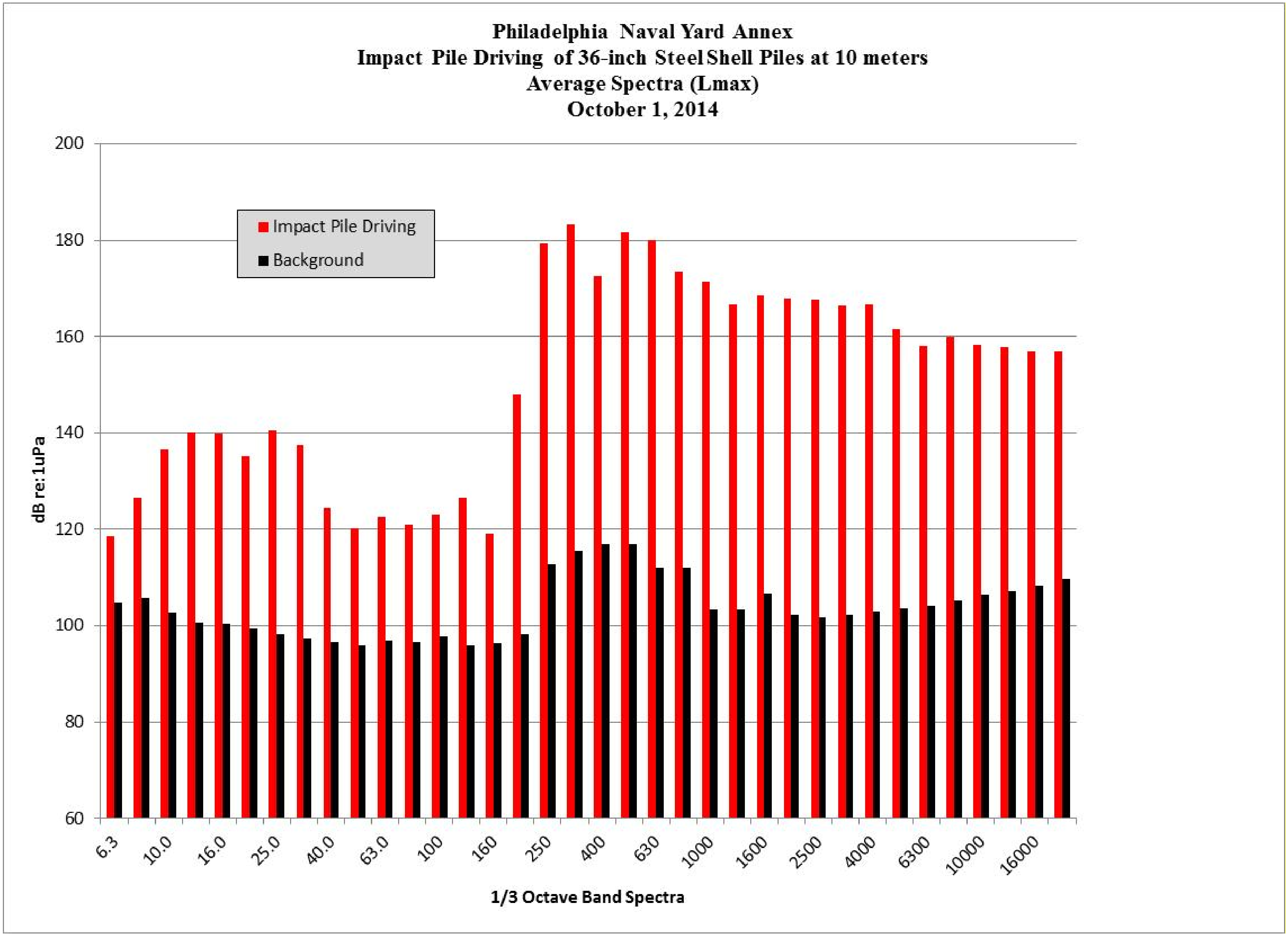
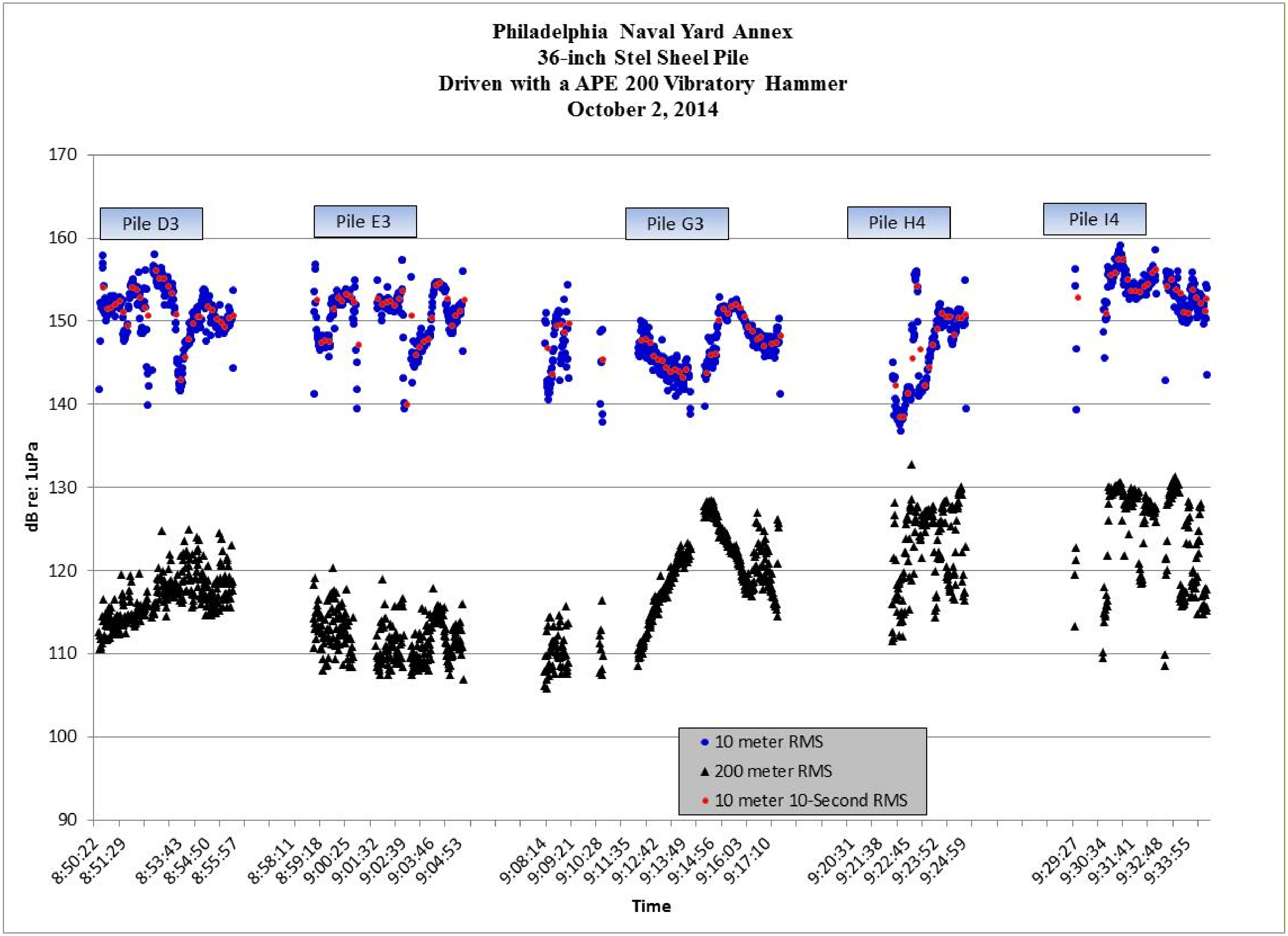
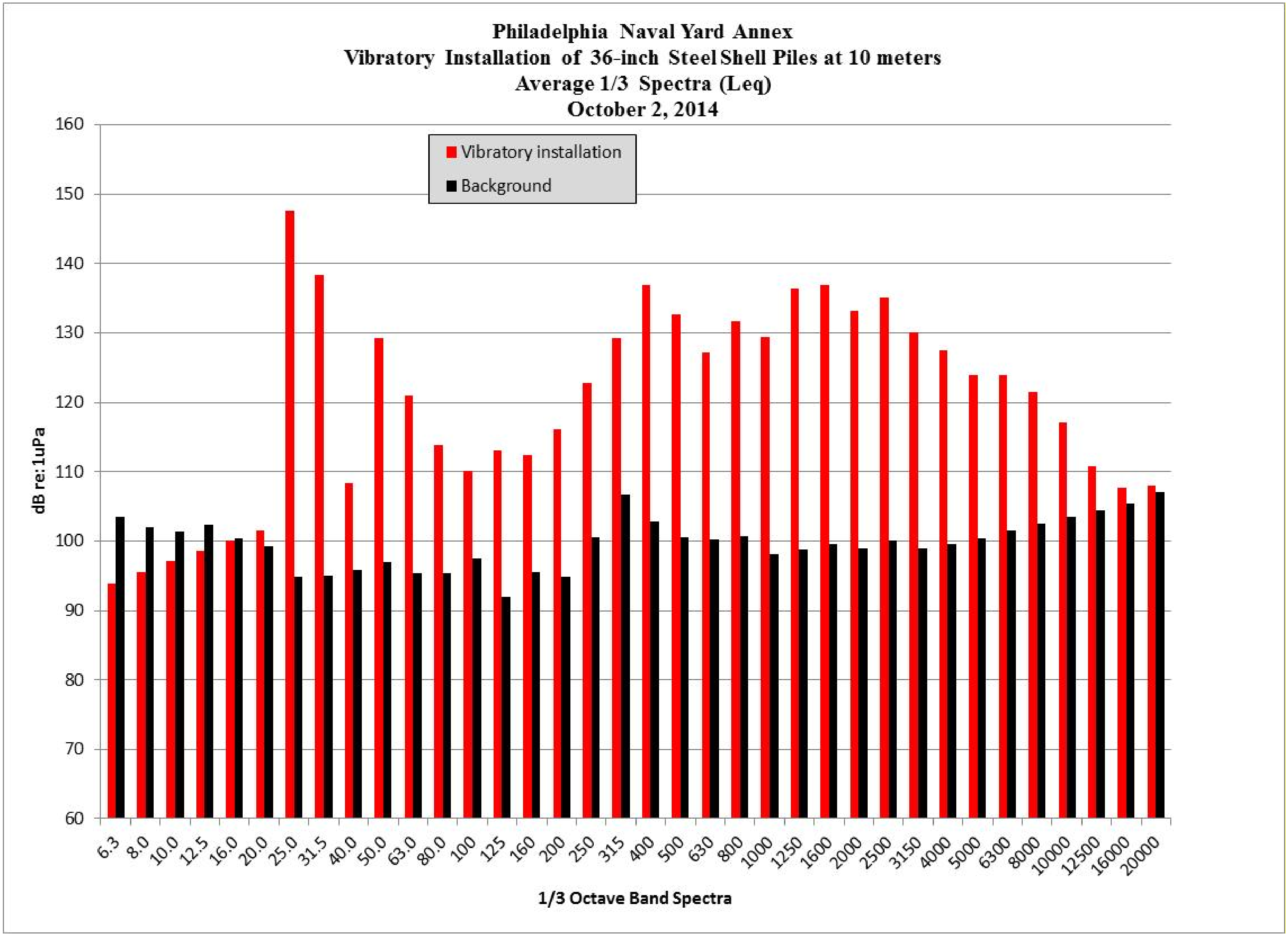
15:19
15:23
15:27
15:31
15:34
15:38
Time

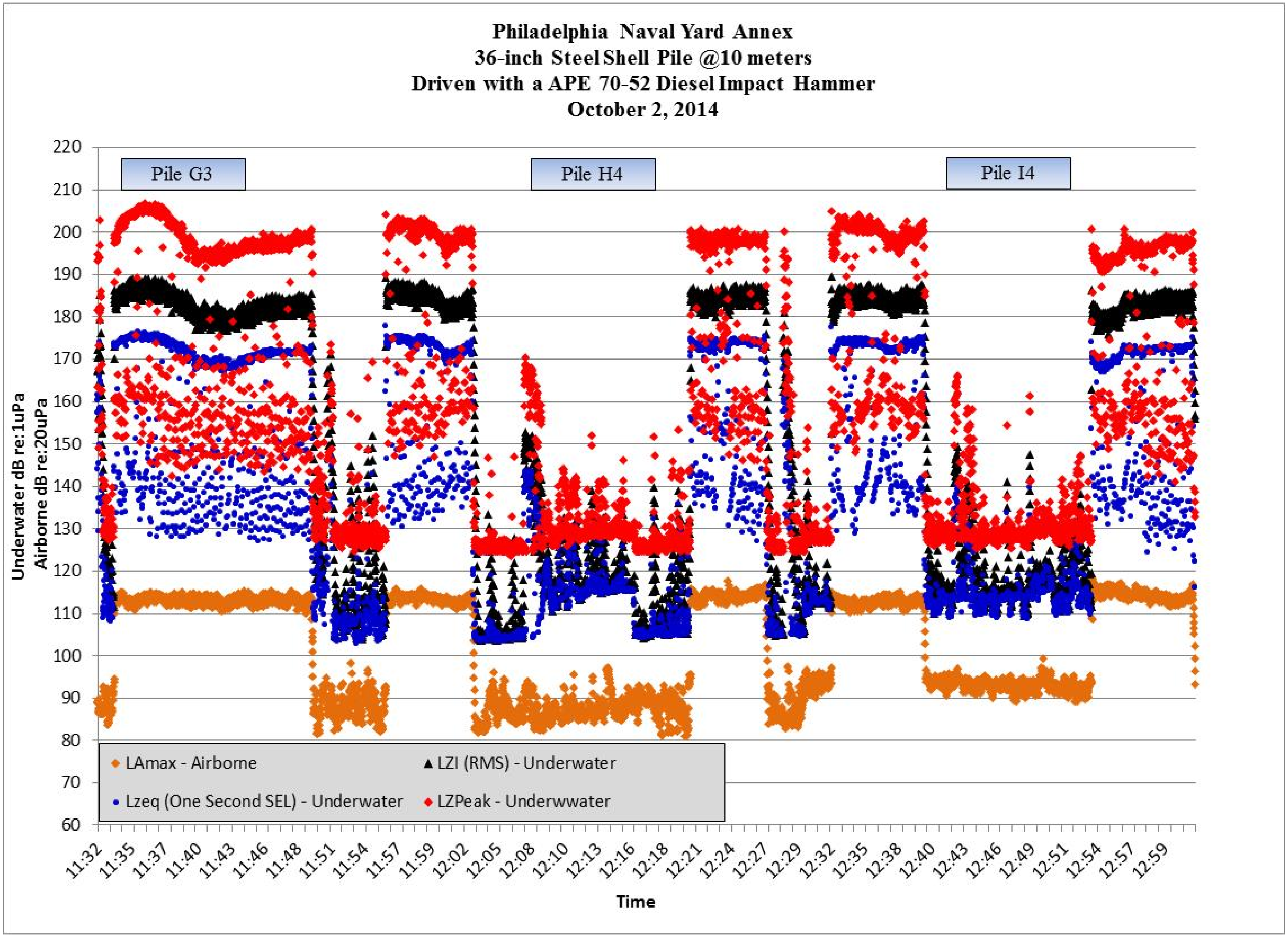

Philadelphia Naval Yard Annex
36-inch Steel Shell Pile @10 meters
Driven with a APE 70-52 Diesel Impact Hammer
October 2, 2014
Pile D3
Pile E3
Pile G3
Pile H4
Pile I4
dB re:1uPa
230
210
190
170
150
130
110
90
LZeq
LZpeak
LZI
Cumulative SEL
10:55
10:58
11:02
11:05
11:08
11:15
11:18
11:22
11:25
11:29
11:36
11:39
11:42
11:46
11:49
11:56
12:00
12:03
12:07
12:10
12:14
12:17
12:20
12:24
12:31
12:34
12:38
12:41
12:45
12:48
12:51
12:55
12:58
13:02
Time

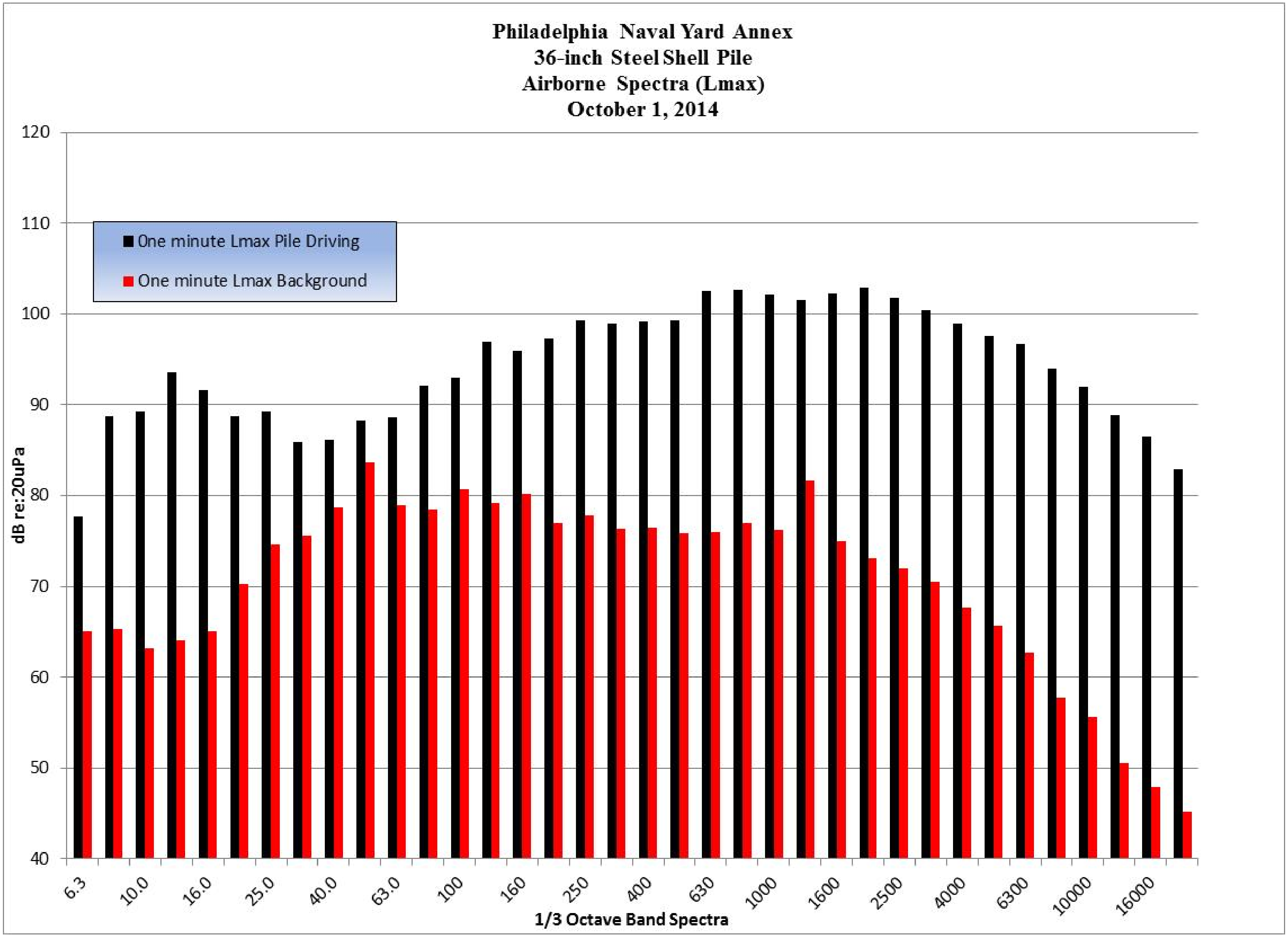

Philadelphia Naval Yard Annex
Impact Pile Driving of 48-inch Steel Shell Pile @ 10 meters
Average Spectra (Lmax)
September 30, 2014
Pile A3
Pile C3
Background
Impact Pile Driving
dB re:1uPa
200
180
160
140
120
100
80
60
6.3
10.0
16.0
25.0
40.0
63.0
100
160
250
400
630
1000
1600
2500
4000
6300
10000
16000
1/3 Octave Band Spectra

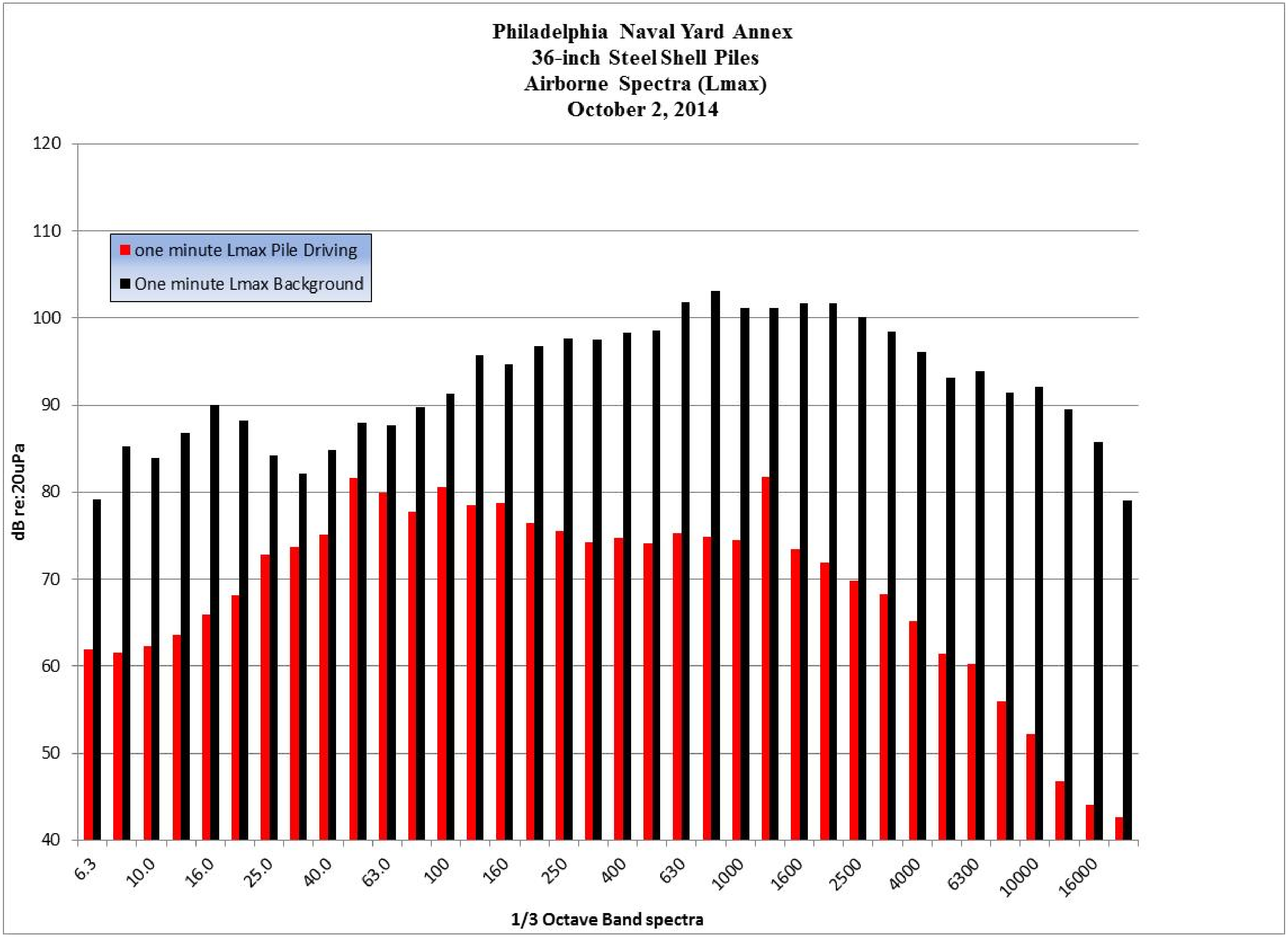

Philadelphia Naval Yard Annex
Impact Pile Driving of 36-inch Steel Shell Piles at 10 meters
Average Spectra (Lmax)
October 1, 2014
Impact Pile Driving
Background
dB re:1uPa
200
180
160
140
120
100
80
60
6.3
10.0
16.0
25.0
40.0
63.0
100
160
250
400
630
1000
1600
2500
4000
6300
10000
16000
1/3 Octave Band Spectra


Philadelphia Naval Yard Annex
36-inch Stel Sheel Pile
Driven with a APE 200 Vibratory Hammer
October 2, 2014
Pile D3
Pile E3
Pile G3
Pile H4
Pile I4
dB re: 1uPa
170
160
150
140
130
120
110
100
90
10 meter RMS
200 meter RMS
10 meter 10-Second RMS
8:50:22
8:51:29
8:53:43
8:54:50
8:55:57
8:58:11
8:59:18
9:00:25
9:01:32
9:02:39
9:03:46
9:04:53
9:08:14
9:09:21
9:10:28
9:11:35
9:12:42
9:13:49
9:14:56
9:16:03
9:17:10
9:20:31
9:21:38
9:22:45
9:23:52
9:24:59
9:29:27
9:30:34
9:31:41
9:32:48
9:33:55
Time


Philadelphia Naval Yard Annex
Vibratory Installation of 36-inch Steel Shell Piles at 10 meters
Average 1/3 Spectra (Leq)
October 2, 2014
Vibratory installation
Background
dB re:1uPa
160
150
140
130
120
110
100
90
80
70
60
6.3 8.0 10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500 16000 20000
1/3 Octave Band Spectra


Philadelphia Naval Yard Annex
36-inch Steel Shell Pile @10 meters
Driven with a APE 70-52 Diesel Impact Hammer
October 2, 2014
Pile G3
Pile H4
Pile I4
Underwater dB re:1uPa
Airborne dB re:20uPa
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
LAmax - Airborne
LZI (RMS) - Underwater
Lzeq (One Second SEL) - Underwater
LZPeak - Underwwater
11:32
11:35
11:37
11:40
11:43
11:46
11:48
11:51
11:54
11:57
11:59
12:02
12:05
12:08
12:10
12:13
12:16
12:18
12:21
12:24
12:27
12:29
12:32
12:35
12:38
12:40
12:43
12:46
12:49
12:51
12:54
12:57
12:59
Time


Philadelphia Naval Yard Annex
36-inch Steel Shell Pile
Airborne Spectra (Lmax)
October 1, 2014
One minute Lmax Pile Driving
One minute Lmax Background
dB re:20uPa
120
110
100
90
80
70
60
50
40
6.3
10.0
16.0
25.0
40.0
63.0
100
160
250
400
630
1000
1600
2500
4000
6300
10000
16000
1/3 Octave Band Spectra


Philadelphia Naval Yard Annex
36-inch Steel Shell Piles
Airborne Spectra (Lmax)
October 2, 2014
one minute Lmax Pile Driving
One minute Lmax Background
dB re:20uPa
120
110
100
90
80
70
60
50
40
6.3
10.0
16.0
25.0
40.0
63.0
100
160
250
400
630
1000
1600
2500
4000
6300
10000
16000
1/3 Octave Band spectra

ATTACHMENT B:

ONE-MINUTE AIRBORNE DATA

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Table B-1.1. One Minute A-Weighted Airborne Data

Date	Time	L_{eq}	L_{max}	Pile ID
10/01/2014	13:41:00	102	113	Pile D4
10/01/2014	13:42:00	105	112	
10/01/2014	13:43:00	105	113	
10/01/2014	13:44:00	105	113	
10/01/2014	13:45:00	105	113	
10/01/2014	13:46:00	105	113	
10/01/2014	13:47:00	105	113	
10/01/2014	13:48:00	105	113	
10/01/2014	13:49:00	105	112	
10/01/2014	13:50:00	104	112	
10/01/2014	13:51:00	105	113	
10/01/2014	13:52:00	104	113	
10/01/2014	14:15:00	103	111	
10/01/2014	14:16:00	104	112	
10/01/2014	14:17:00	105	112	
10/01/2014	14:18:00	105	112	
10/01/2014	14:19:00	105	113	
10/01/2014	14:20:00	105	113	
10/01/2014	14:21:00	105	112	
10/01/2014	14:26:00	107	115	Pile E4
10/01/2014	14:27:00	108	116	
10/01/2014	14:28:00	108	116	
10/01/2014	14:29:00	108	116	
10/01/2014	14:30:00	108	116	
10/01/2014	14:31:00	108	116	
10/01/2014	14:32:00	107	116	
10/01/2014	14:33:00	107	116	
10/01/2014	14:46:00	106	117	
10/01/2014	14:47:00	109	117	
10/01/2014	14:49:00	109	116	
10/01/2014	14:50:00	108	116	

Date	Time	L_{eq}	L_{max}	Pile ID
10/01/2014	14:54:00	107	115	Pile F4
10/01/2014	14:55:00	104	112	
10/01/2014	14:56:00	105	113	
10/01/2014	14:57:00	106	114	
10/01/2014	14:58:00	106	113	
10/01/2014	14:59:00	106	114	
10/01/2014	15:00:00	105	113	
10/01/2014	15:01:00	105	114	
10/01/2014	15:02:00	101	114	
10/01/2014	15:11:00	100	111	
10/01/2014	15:12:00	104	112	
10/01/2014	15:13:00	104	112	
10/01/2014	15:14:00	104	112	
10/01/2014	15:15:00	105	112	
10/01/2014	15:16:00	105	113	
10/01/2014	15:17:00	105	113	
10/01/2014	15:23:00	102	109	Pile G4
10/01/2014	15:24:00	103	110	
10/01/2014	15:25:00	102	109	
10/01/2014	15:26:00	102	108	
10/01/2014	15:27:00	101	108	
10/01/2014	15:28:00	101	108	
10/01/2014	15:29:00	101	108	
10/01/2014	15:30:00	100	107	
10/01/2014	15:31:00	100	107	
10/01/2014	15:32:00	100	107	
10/01/2014	15:33:00	100	107	
10/01/2014	15:34:00	100	106	
10/01/2014	15:35:00	100	107	
10/01/2014	15:36:00	100	107	

Table B-1.2. One Minute A-Weighted Airborne Data

Date	Time	L_{eq}	L_{max}	Pile ID
Vibratory Driving				
10/02/2014	08:50:00	99	108	Pile D3
10/02/2014	08:51:00	99	103	
10/02/2014	08:52:00	96	104	
10/02/2014	08:53:00	98	101	
10/02/2014	08:54:00	95	102	
10/02/2014	08:55:00	95	101	
10/02/2014	08:56:00	87	91	No Driving
10/02/2014	08:57:00	83	86	
10/02/2014	08:58:00	83	86	
10/02/2014	08:59:00	97	103	Pile E3
10/02/2014	09:00:00	100	103	
10/02/2014	09:01:00	93	102	
10/02/2014	09:02:00	98	103	
10/02/2014	09:03:00	93	101	
10/02/2014	09:04:00	95	100	
10/02/2014	09:05:00	87	99	
10/02/2014	09:06:00	78	79	No Driving
10/02/2014	09:07:00	79	86	
10/02/2014	09:08:00	89	96	Pile G3
10/02/2014	09:09:00	86	95	
10/02/2014	09:10:00	82	91	
10/02/2014	09:11:00	78	79	
10/02/2014	09:12:00	91	94	
10/02/2014	09:13:00	91	94	
10/02/2014	09:14:00	88	94	
10/02/2014	09:15:00	92	95	
10/02/2014	09:16:00	92	94	
10/02/2014	09:17:00	91	96	
10/02/2014	09:18:00	79	81	No Driving
10/02/2014	09:19:00	78	81	
10/02/2014	09:20:00	78	82	
10/02/2014	09:21:00	80	92	
10/02/2014	09:22:00	82	86	

Date	Time	L_{eq}	L_{max}	Pile ID
Vibratory Driving (continued)				
10/02/2014	09:23:00	90	98	Pile H4
10/02/2014	09:24:00	93	96	
10/02/2014	09:25:00	85	96	
10/02/2014	09:26:00	81	83	No Driving
10/02/2014	09:27:00	80	81	
10/02/2014	09:28:00	80	83	
10/02/2014	09:29:00	83	96	Pile I4
10/02/2014	09:30:00	93	99	
10/02/2014	09:31:00	98	102	
10/02/2014	09:32:00	94	98	
10/02/2014	09:33:00	94	99	
10/02/2014	09:34:00	92	97	
10/02/2014	09:35:00	90	96	
Impact Driving				
10/02/2014	11:34:00	104	111	Pile G3
10/02/2014	11:35:00	104	111	
10/02/2014	11:36:00	104	112	
10/02/2014	11:37:00	104	112	
10/02/2014	11:38:00	104	112	
10/02/2014	11:39:00	103	112	
10/02/2014	11:40:00	103	111	
10/02/2014	11:41:00	103	111	
10/02/2014	11:42:00	102	111	
10/02/2014	11:43:00	102	110	
10/02/2014	11:44:00	103	111	
10/02/2014	11:45:00	102	110	
10/02/2014	11:46:00	103	112	
10/02/2014	11:47:00	103	111	
10/02/2014	11:48:00	103	111	
10/02/2014	11:49:00	102	111	
10/02/2014	11:50:00	92	110	No Driving
10/02/2014	11:51:00	79	86	
10/02/2014	11:52:00	79	88	
10/02/2014	11:53:00	78	93	
10/02/2014	11:54:00	78	88	
10/02/2014	11:55:00	75	86	

Date	Time	L_{eq}	L_{max}	Pile ID
Impact Driving (continued)				
10/02/2014	11:56:00	102	110	Pile H4
10/02/2014	11:57:00	103	111	
10/02/2014	11:58:00	104	111	
10/02/2014	11:59:00	104	111	
10/02/2014	12:00:00	103	111	
10/02/2014	12:01:00	103	110	
10/02/2014	12:02:00	103	111	
10/02/2014	12:03:00	98	112	
10/02/2014	12:04:00	77	86	Pause No Driving
10/02/2014	12:05:00	80	91	
10/02/2014	12:06:00	77	87	
10/02/2014	12:07:00	81	90	
10/02/2014	12:08:00	80	90	
10/02/2014	12:09:00	72	81	
10/02/2014	12:10:00	76	89	
10/02/2014	12:11:00	74	86	
10/02/2014	12:12:00	72	86	
10/02/2014	12:13:00	78	91	
10/02/2014	12:14:00	83	91	
10/02/2014	12:15:00	74	88	
10/02/2014	12:16:00	81	90	
10/02/2014	12:17:00	80	88	
10/02/2014	12:18:00	73	84	
10/02/2014	12:19:00	73	85	
10/02/2014	12:20:00	74	88	
10/02/2014	12:21:00	103	112	Pile H4 (cont.)
10/02/2014	12:22:00	105	112	
10/02/2014	12:23:00	105	112	
10/02/2014	12:24:00	104	111	
10/02/2014	12:25:00	103	111	
10/02/2014	12:26:00	104	111	
10/02/2014	12:27:00	98	110	

Date	Time	L_{eq}	L_{max}	Pile ID
Impact Driving (continued)				
10/02/2014	12:28:00	75	86	No Driving
10/02/2014	12:29:00	77	88	
10/02/2014	12:30:00	78	89	
10/02/2014	12:31:00	80	84	
10/02/2014	12:32:00	97	111	Pile I4
10/02/2014	12:33:00	102	109	
10/02/2014	12:34:00	102	110	
10/02/2014	12:35:00	102	110	
10/02/2014	12:36:00	103	110	
10/02/2014	12:37:00	103	111	
10/02/2014	12:38:00	103	110	
10/02/2014	12:39:00	103	111	
10/02/2014	12:40:00	98	110	
10/02/2014	12:41:00	80	85	Pause No Driving
10/02/2014	12:42:00	81	91	
10/02/2014	12:43:00	81	93	
10/02/2014	12:44:00	79	84	
10/02/2014	12:45:00	79	82	
10/02/2014	12:46:00	79	83	
10/02/2014	12:47:00	82	89	
10/02/2014	12:48:00	84	93	
10/02/2014	12:49:00	82	91	
10/02/2014	12:50:00	84	92	
10/02/2014	12:51:00	80	87	
10/02/2014	12:52:00	79	87	
10/02/2014	12:53:00	79	85	
10/02/2014	12:54:00	104	112	Pile I4 (cont.)
10/02/2014	12:55:00	105	112	
10/02/2014	12:56:00	105	113	
10/02/2014	12:57:00	104	112	
10/02/2014	12:58:00	104	112	
10/02/2014	12:59:00	103	111	
10/02/2014	13:00:00	103	111	
10/02/2014	13:01:00	103	111	
10/02/2014	13:02:00	99	111	

ATTACHMENT C:

SUMMARY OF RAW UNDERWATER DATA

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48" piles Impact Driven at HardPoint 1 Piles A3 - C3									
Pile A3									
			10 Meter					125 Meter	
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	204	187	175		182	171	159
		Min	197	180	169		180	159	151
		Average	200	183	173		180	164	153
		Cumulative SEL			202				181
	Attenuation Rate						20 Log	17 Log	18 Log
	Pile Strikes		939						
Pile B3									
			10 Meter					Bad Data	
			Peak	RMS	SEL				
		Max	205	189	177				
		Min	196	180	171				
		Average	200	185	174				
		Cumulative SEL			204				
	Attenuation Rate								
	Pile Strikes		928						
Pile C3									
			10 Meter					125 Meter	
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	208	191	178		185	169	157
		Min	197	182	171		177	163	153
		Average	203	187	176		180	166	155
		Cumulative SEL			206				184
	Attenuation Rate						21 Log	19 Log	19 Log
	Pile Strikes		969						
Daily Summary of Impact Driving									
			10 Meter					125 Meter	
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	208	191	178		185	171	159
		Min	196	180	169		177	159	151
		Average	201	185	175		180	165	155
		Cumulative SEL			209				186
	Attenuation Rate						21 log	18 Log	17 Log
	Pile Strikes		2836						
DISTANCES TO NMFS THRESHOLD - Impact									
	PEAK			RMS			Cumulative SEL		
	206	190	180	160	150	120	187	183	
	13	<10	19	245	880	N/A	178	298	

48" piles Vibratory Driven at HardPoint 1 Piles A3 - C3									
Pile A3									
		10 Meter					125 Meter		
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	182	168	167		160	146	146
		Min	158	146	145		145	126	126
		Average	171	162	162		151	134	134
		Cumulative SEL					18 Log	20 Log	20 Log
	Attenuation Rate								
	Driving Duration								
Pile B3									
		10 Meter					Distant		
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	173	161	160		161	140	140
		Min	156	144	144		145	123	124
		Average	169	157	157		150	137	137
		Cumulative SEL					17 Log	22 Log	21 Log
	Attenuation Rate								
	Driving Duration								
Pile C3									
		10 Meter					125 Meter		
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	177	165	163		164	142	141
		Min	156	144	144		145	123	123
		Average	170	157	157		150	135	135
		Cumulative SEL					18 Log	20 Log	20 Log
	Attenuation Rate								
	Driving Duration								
Daily Summary of Vibratory Pile Driving									
		10 Meter					125 Meter		
			Peak	RMS	SEL		Peak	RMS	SEL
		Max	182	168	167		164	146	146
		Min	156	144	144		145	123	123
		Average	170	158	158		150	135	135
		Cumulative SEL					18 Log	21 Log	21 Log
	Attenuation Rate								
	Driving Duration		24 min 38 sec (1,478 Seconds)						
DISTANCES TO NMFS THRESHOLD - Vibratory									
	PEAK	RMS					Cumulative SEL		
	206	190	180	160	150	120	187	183	
	N/A	>10	>10	N/A	25	794	N/A	N/A	

36" piles Impact Driven at HardPoint 2 Piles D4 -G4								
Pile D4								
			10 Meter			125 Meter		
			Peak	RMS	SEL	Peak	RMS	SEL
Total Drive		Max	203	189	177	180	165	153
		Min	192	178	168	168	152	144
		Average	199	185	174	174	159	148
		Cumulative SEL			203			
	Attenuation Rate					21log	22log	22log
Pile E4								
			10 Meter			Distant		
			Peak	RMS	SEL	Peak	RMS	SEL
		Max	205	191	179	181	167	155
		Min	192	178	168	167	152	144
		Average	200	186	175	176	161	150
		Cumulative SEL			202			
	Attenuation Rate					22log	22log	22log
Pile F4								
			10 Meter			125 Meter		
			Peak	RMS	SEL	Peak	RMS	SEL
Total Drive		Max	206	191	178	179	163	151
		Min	192	178	168	167	152	144
		Average	200	185	174	174	159	148
		Cumulative SEL			202			
	Attenuation Rate					24log	25log	25log
Pile G4								
			10 Meter			125 Meter		
			Peak	RMS	SEL	Peak	RMS	SEL
Total Drive		Max	206	189	177	174	159	147
		Min	192	178	168	163	149	139
		Average	199	184	173	169	154	143
		Cumulative SEL			201			
	Attenuation Rate					29log	27log	27log
		At the 125 meter location there was partial shielding from pier where hydrophone got pushed under Pier						

36" piles Vibratory Driven at HardPoint 2 Piles D4 -G4								
			10 Meter					
			Peak	RMS	SEL	Peak	RMS	SEL
Total Drive		Max	174	160	160	154	134	134
		Min	140	138	138	141	115	115
		Average	163	150	150	144	121	121
		Cumulative SEL						
	Attenuation Rate					18 Log	23 Log	23 Log

36" piles Impact Driven at HardPoint 2 Piles D3 - G3; H4-I4											
Pile D3											
			10 Meter			200 Meter					
			Peak	RMS	SEL	Peak	RMS	SEL			
Total Drive		Max	207	189	176	*	*	*			
		Min	193	177	165	*	*	*			
		Average	202	185	174	*	*	*			
		Cumulative SEL									
	Attenuation Rate										
Pile E3											
			10 Meter			100 meter					
			Peak	RMS	SEL	Peak	RMS	SEL			
		Max	206	188	175	*	*	*			
		Min	193	177	166	*	*	*			
		Average	200	183	172	*	*	*			
		Cumulative SEL									
	Attenuation Rate										
Pile G3											
			10 Meter			100 meter					
			Peak	RMS	SEL	Peak	RMS	SEL			
Total Drive		Max	207	189	176	*	*	*			
		Min	192	177	165	*	*	*			
		Average	199	183	172	*	*	*			
		Cumulative SEL									
	Attenuation Rate										
Pile H4											
			10 Meter			50 meter			100 meter		
			Peak	RMS	SEL	Peak	RMS	SEL	Peak	RMS	SEL
Total Drive		Max	204	189	178	*	*	*	*	*	*
		Min	192	178	165	*	*	*	*	*	*
		Average	199	184	173	*	**	*	*	*	*
		Cumulative SEL									
	Attenuation Rate										
Pile I4											
			10 Meter			50 meter					
			Peak	RMS	SEL	Peak	RMS	SEL			
Total Drive		Max	205	190	177	*	*	*			
		Min	192	177	165	*	*	*			
		Average	198	183	172	*	*	*			
		Cumulative SEL									
	Attenuation Rate				* Data at the distant location not valid, There must have been some shielding at the measurement sites					
36" piles Vibratory Driven at HardPoint 2 Piles D4 -G4											
			10 Meter			200 Meter					
			Peak	RMS	SEL	Peak	RMS	SEL			
Total Drive		Max	174	160	160	151	133	133			
		Min	149	138	138	141	115	115			
		Average	163	150	150	144	121	121			
		Cumulative SEL									
	Attenuation Rate					18 Log	21 Log	21 Log			

ATTACHMENT D:

EXISTING PILE LOCATIONS (AS BUILT DRAWINGS)

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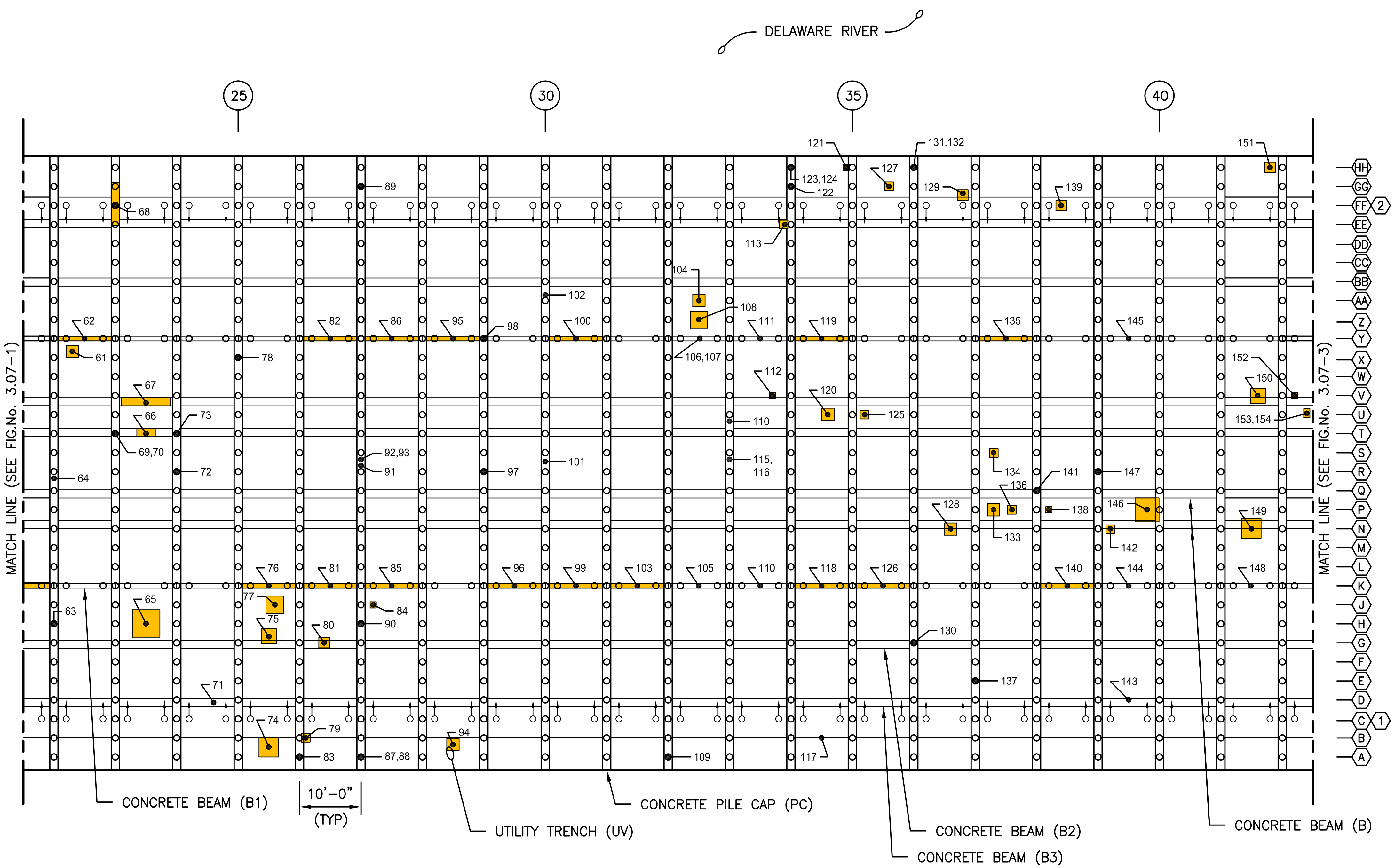
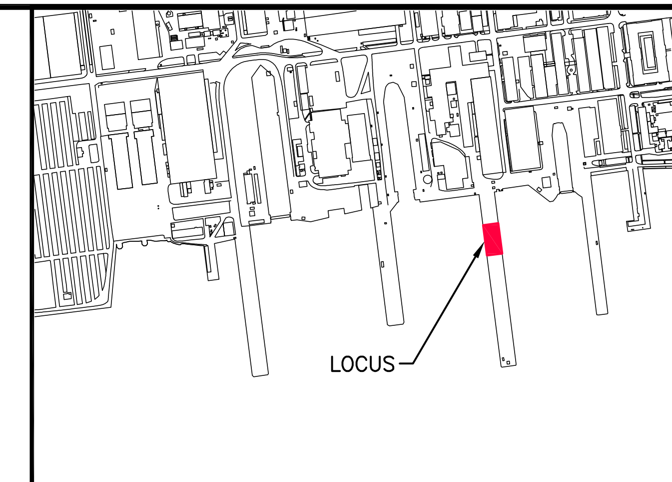


PLAN

SCALE: 1"=20'-0"



LOCUS PLAN

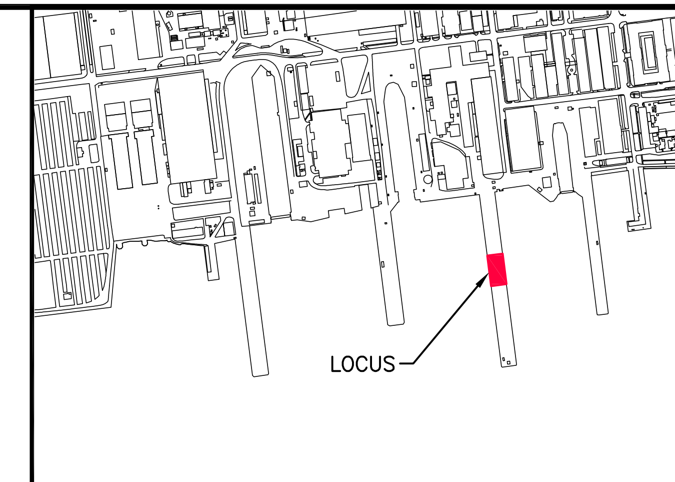
NO SCALE

LEGEND

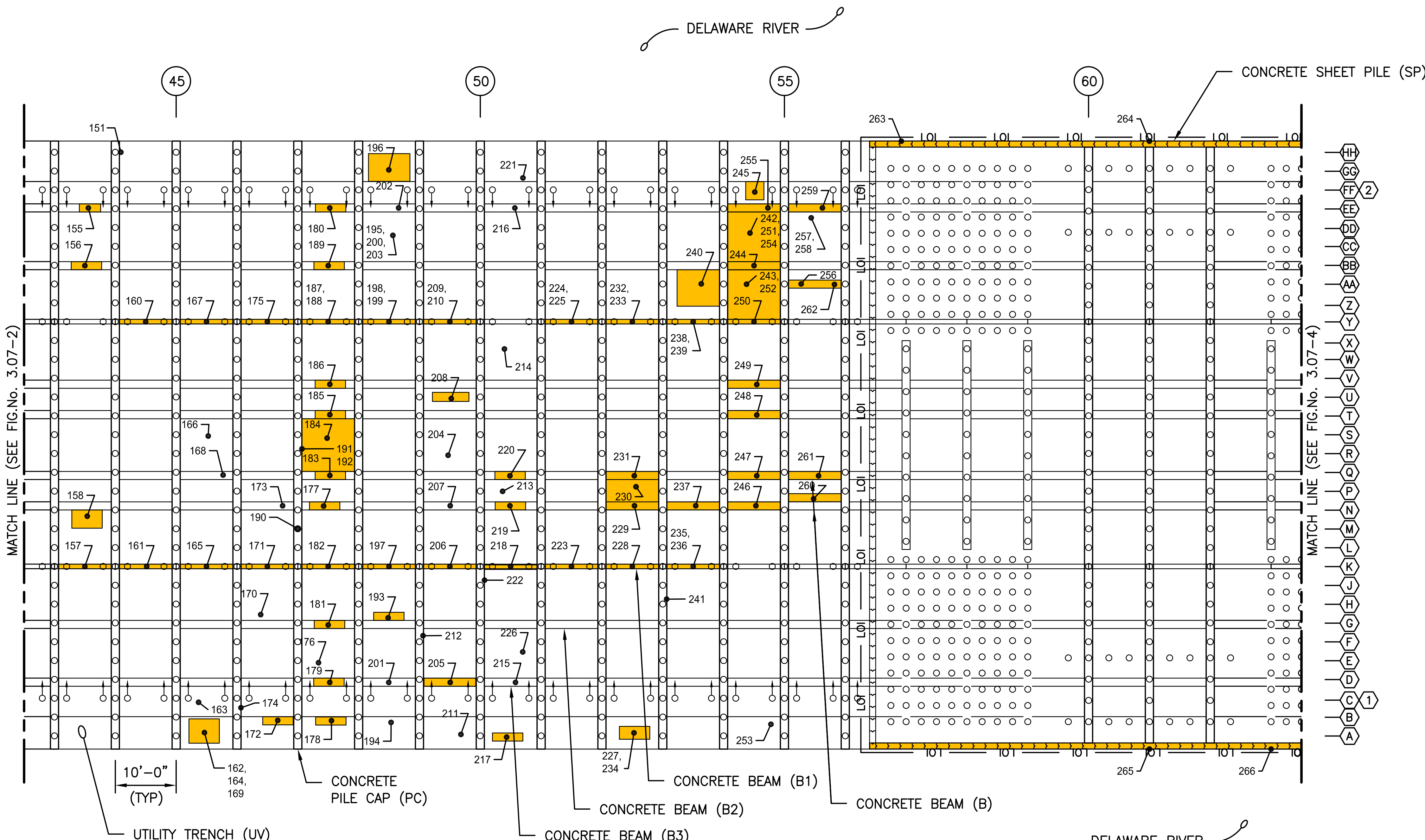
- (A) PILE ROW DESIGNATION
- (1) BATTER PILE ROW DESIGNATION
- (20) PILE BENT DESIGNATION
- TIMBER BATTER PILE (PB)
- TIMBER PILE (P)
- 55 INDICATES DEFECT ID No. SEE EMS DATA FOR DEFECT TYPE AND DIMENSIONS
- APPROXIMATE AREA OF DEFECT
- (PC) INDICATES ASSET TYPE

NOTE:
CONCRETE BEAMS AND UTILITY TRENCH ARE MIRRORED ABOUT THE CENTER OF THE PIER.

NAVFAC	DATE: APRIL, 2013 CONTRACT NUMBER N62583-12-D-0738 GRAPHIC SCALE 20 10 0 20 SCALE OF FEET	CHILDS ENGINEERING CORPORATION WATERFRONT STRUCTURAL ENGINEERING 34 William Way, Bellingham, MA 02019 Phone: (508) 966-9092 Fax: (508) 966-9096 http://www.childseng.com	NAVAL FACILITIES ENGINEERING AND EXPEDITIONARY WARFARE CENTER PORT HUENEME, CA NAVAL SUPPORT ACTIVITY MECHANICSBURG PHILADELPHIA, PA **PIER 4 UNDER DECK PLAN**	FIG.No. 3.07-2



LOCUS PLAN
NO SCALE



PLAN
SCALE: 1"=20'-0"

LEGEND

- (A) PILE ROW DESIGNATION
- (1) BATTER PILE ROW DESIGNATION
- (20) PILE BENT DESIGNATION
- TIMBER BATTER PILE (PB)
- TIMBER PILE (P)
- 149 INDICATES DEFECT ID No. SEE EMS DATA FOR DEFECT TYPE AND DIMENSIONS
- LOI — LIMIT OF INSPECTION
- APPROXIMATE AREA OF DEFECT
- (PC) INDICATES ASSET TYPE

DATE: APRIL, 2013

CONTRACT NUMBER N62583-12-D-0738

GRAPHIC SCALE
20 10 0 20
SCALE OF FEET

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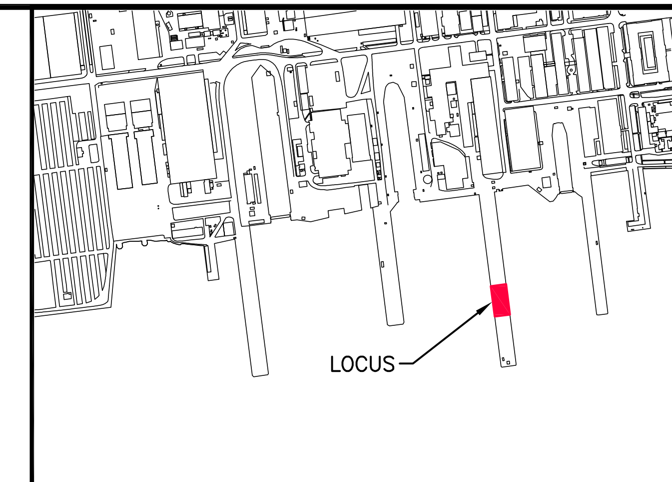
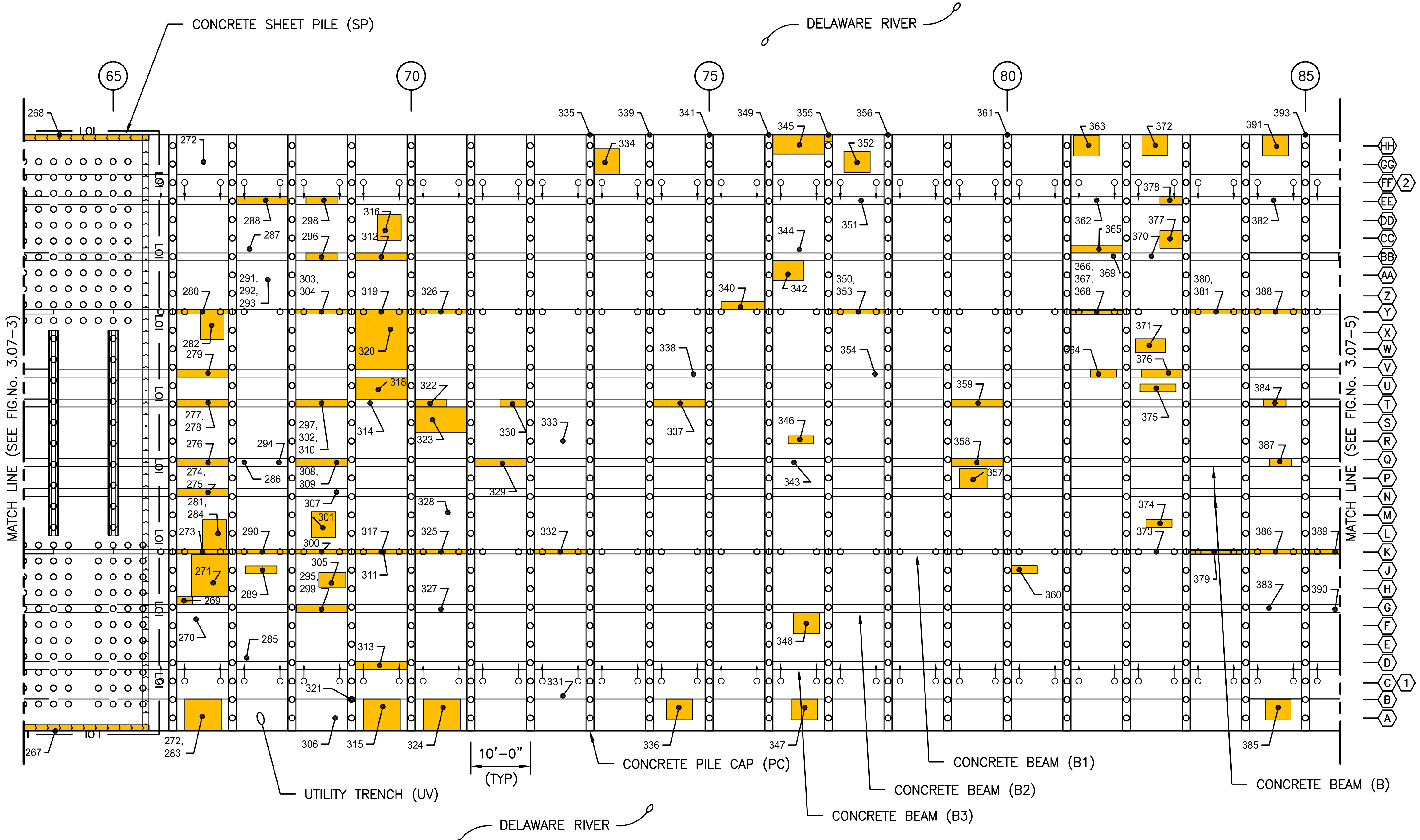
PIER 4
UNDER DECK PLAN

FIG.No. 3.07-3



LOCUS PLAN
NO SCALE



PLAN
SCALE: 1"=20'-0"

LEGEND

- (A) PILE ROW DESIGNATION
- (1) BATTER PILE ROW DESIGNATION
- (20) PILE BENT DESIGNATION
- TIMBER BATTER PILE (PB)
- TIMBER PILE (P)
- 33 INDICATES DEFECT ID No. SEE EMS DATA FOR DEFECT TYPE AND DIMENSIONS
- LOI LIMIT OF INSPECTION
- APPROXIMATE AREA OF DEFECT
- (PC) INDICATES ASSET TYPE

DATE: APRIL, 2013

CONTRACT NUMBER
N62583-12-D-0738

GRAPHIC SCALE
20 10 0 20
SCALE OF FEET

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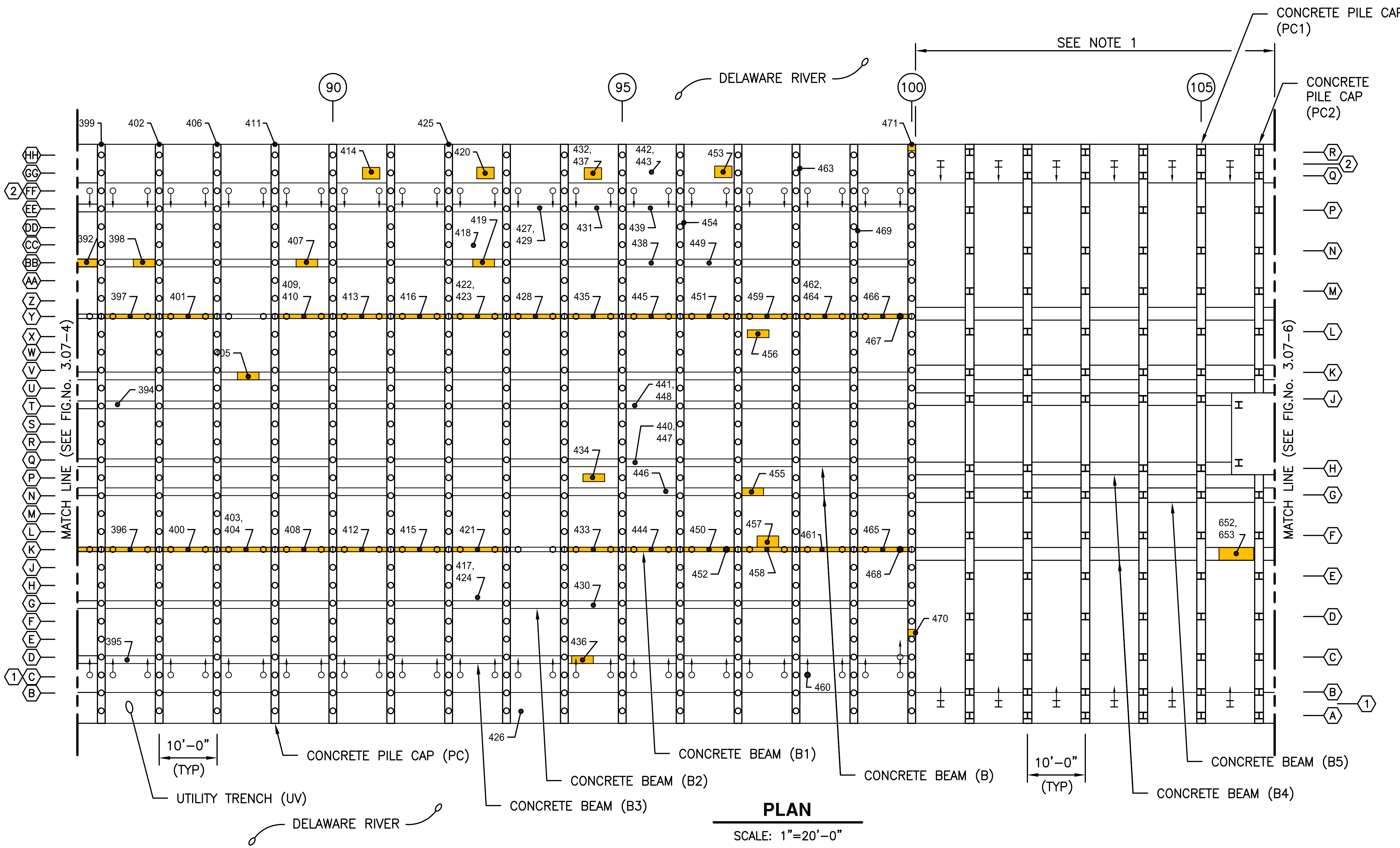
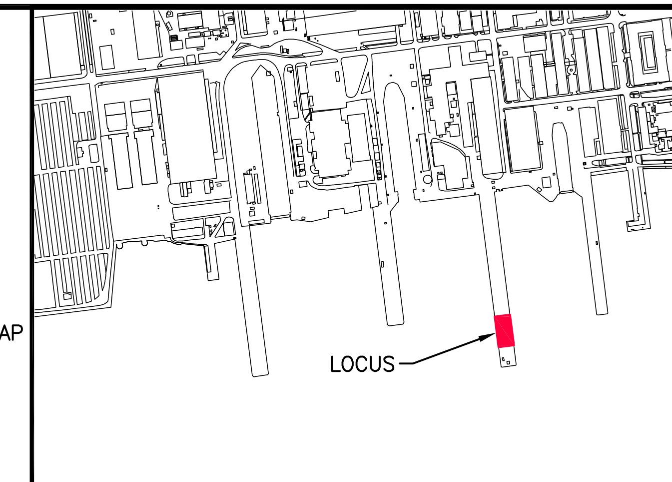
PIER 4
UNDER DECK PLAN

FIG.No. 3.07-4



PLAN

SCALE: 1"=20'-0"



LOCUS PLAN

NO SCALE

LEGEND

- (A) PILE ROW DESIGNATION
- (1) BATTER PILE ROW DESIGNATION
- (20) PILE BENT DESIGNATION
- TIMBER BATTER PILE (PB)
- TIMBER PILE (P)
- STEEL BATTER H PILE (PB1)
- STEEL H PILE (P1)
- 33 INDICATES DEFECT ID No. SEE EMS DATA FOR DEFECT TYPE AND DIMENSIONS
- LOI — LIMIT OF INSPECTION
- APPROXIMATE AREA OF DEFECT
- (PC) INDICATES ASSET TYPE

NOTE:
1. ASSETS P & P1 DEFECT ID No. 472-651 NOT SHOWN FOR CLARITY SEE APPENDIX B - STRUCTURAL DATA DEFECT SHEET.

NAVFAC

DATE: APRIL, 2013

CONTRACT NUMBER N62583-12-D-0738

GRAPHIC SCALE

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SCALE OF FEET

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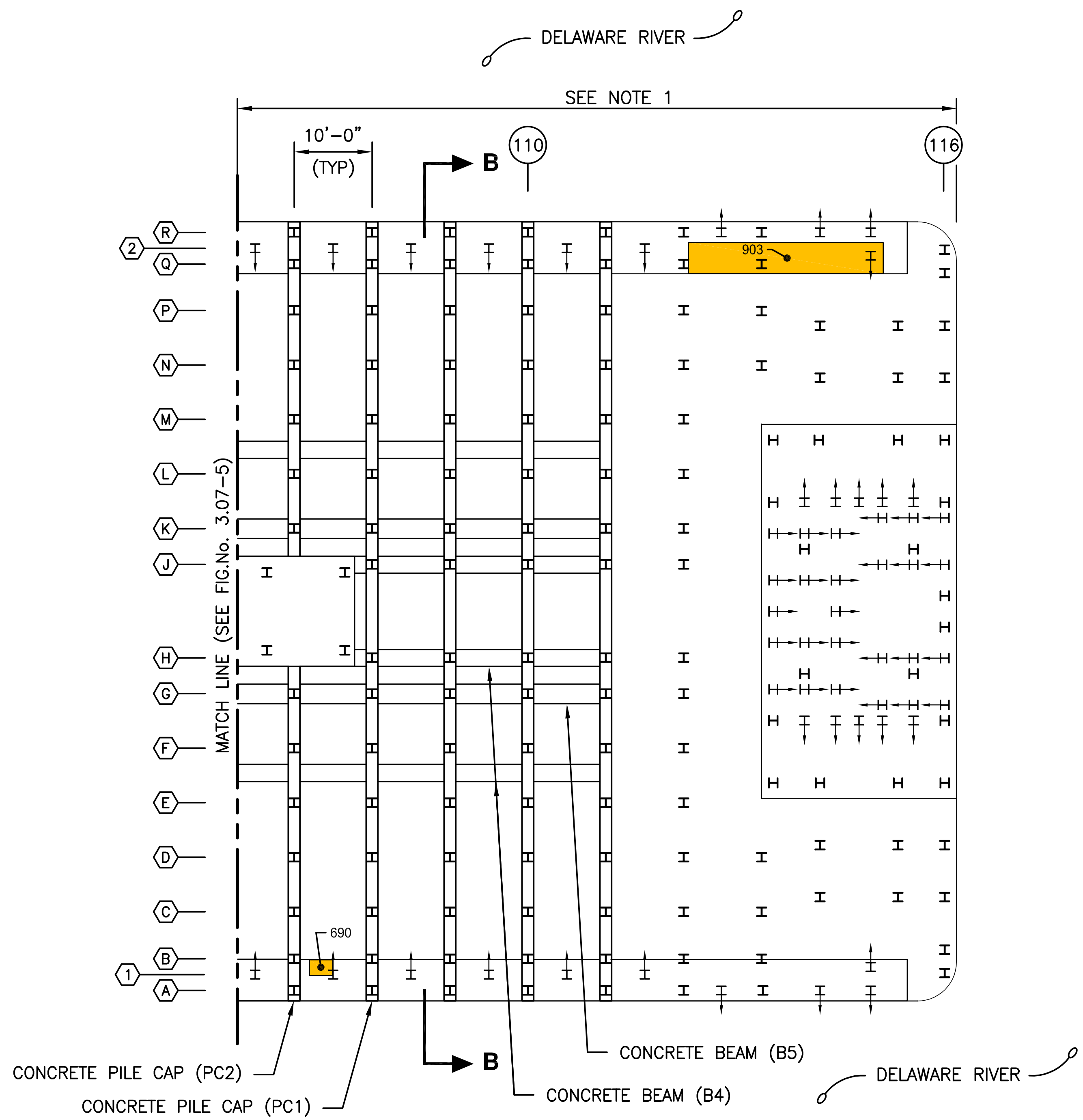
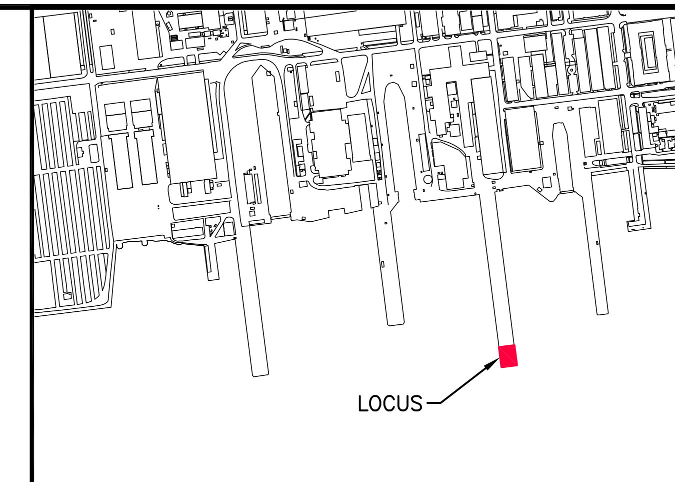
PIER 4
UNDER DECK PLAN

FIG.No. 3.07-5



PLAN

SCALE: 1"=20'-0"



LOCUS PLAN

NO SCALE

LEGEND

- (A) PILE ROW DESIGNATION
- (1) BATTER PILE ROW DESIGNATION
- (20) PILE BENT DESIGNATION
- STEEL BATTER H PILE (PB1)
- STEEL H PILE (P1)
- 33 INDICATES DEFECT ID No. SEE EMS DATA FOR DEFECT TYPE AND DIMENSIONS
- LOI LIMIT OF INSPECTION
- APPROXIMATE AREA OF DEFECT
- (PC) INDICATES ASSET TYPE

NOTE:
1. ASSETS P & P1 DEFECT ID No. 651-908 NOT SHOWN FOR CLARITY SEE APPENDIX B - STRUCTURAL DATA DEFECT SHEET.

DATE:	APRIL, 2013
CONTRACT NUMBER	N62583-12-D-0738

GRAPHIC SCALE

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SCALE OF FEET

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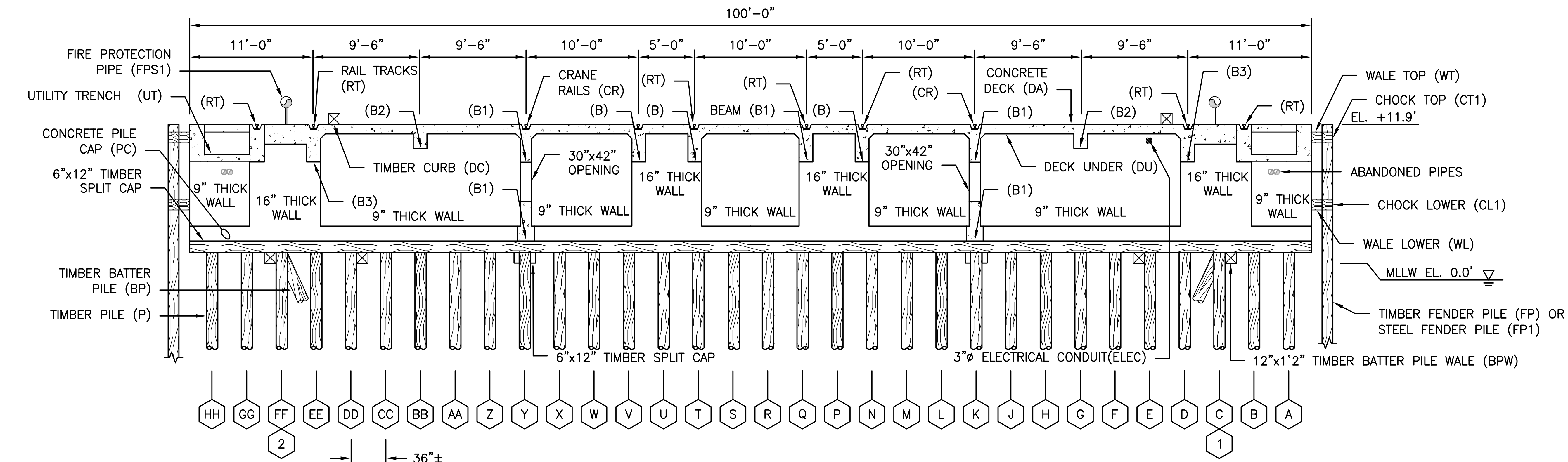
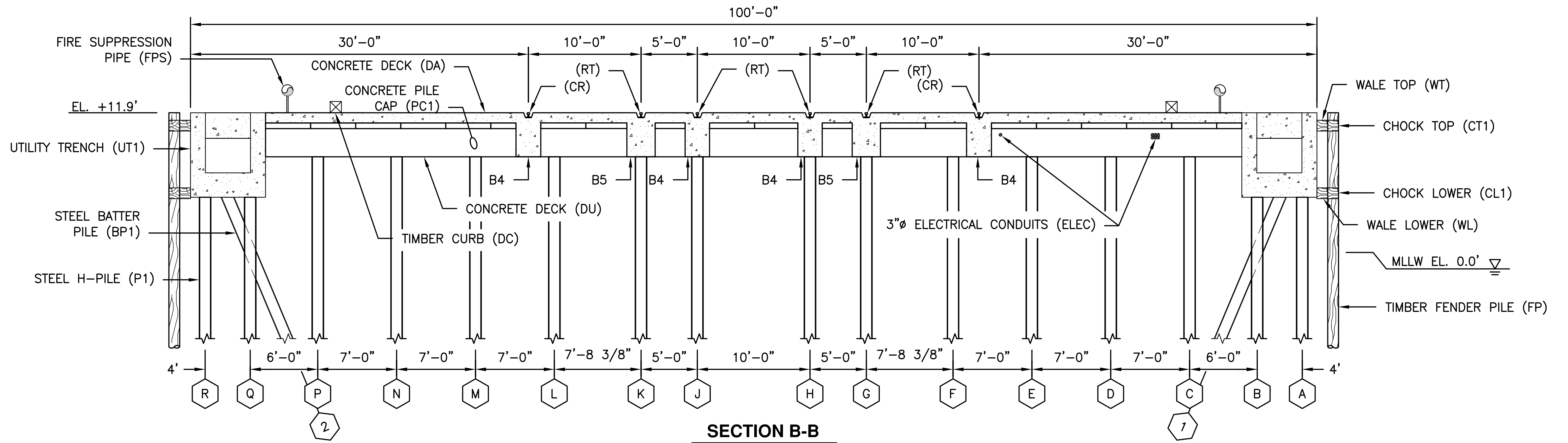
PIER 4
UNDER DECK PLAN

FIG.No. 3.07-6



SECTION A-A

SCALE: 1"=10'-0"



SECTION B-B

SCALE: 1"=10'-0"

DATE: APRIL, 2013

CONTRACT NUMBER N62583-12-D-0738

GRAPHIC SCALE

10 5 0 10

SCALE OF FEET

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PIER 4
TYPICAL SECTIONS

FIG.No. 3.07-19

TOM QUINN K:\2323-11.11 MECHANICSBURG WFI\CADD\CURRENT WORKING DWGS\3.7 PIER 4\PIER 4 SECTION.DWG May 30, 2013 - 2:41pm