Final Interim Report

# Underwater and Airborne Acoustic Monitoring for the U.S. Navy Elevated Causeway (ELCAS) Removal at the JEB Little Creek Naval Station: 10-11 September 2015

***Submitted to:***

Naval Facilities Engineering Command Atlantic under
HDR Environmental, Operations and Construction, Inc.
Contract No. N62470-10-D-3011, Task Order CTO33

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December 2015

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# Interim Summary

This report summarizes underwater and airborne acoustic monitoring results for removal of piles associated with the training exercise related to the removal of the Elevated Causeway (ELCAS) at Joint Expeditionary Base (JEB) Little Creek, Norfolk, Virginia. On 10 and 11 September 2015, multiple 61-centimeter diameter (24-inch) steel pipe piles were removed. All pile-extractions were accomplished using an APE 150 Vibratory Driver Extractor; which has an eccentric moment of 23.35 kilogram-force-meter (2,200 pound-force inch). Noise levels were measured for 13 piles. The hydroacoustic monitoring took place at three distances from the pile removal—near, mid-range, and distant—which all varied between and within days. The near and mid-range positions were manned, and the distant position had an autonomous recording system in place. Three different measures of sound were made—root mean square (RMS) sound pressure level (SPL), sound exposure level (SEL), and cumulative SEL. The compiled hydroacoustic data also allowed estimation of sound attenuation with range (propagation rate). **Table 1** is a summary of the average noise levels and range of noise levels measured during the pile-extraction monitoring. During the extraction of the piles, it was not possible to maintain a constant near-range distance of 10 meters (33 feet) from the pile; the distances ranged from 9 to 17 meters (30 to 56 feet). Measurements for these distances were normalized to 10 meters. **Table 2** shows the calculated normalized data for the 12 piles that were measured at distances greater and less than the 10-meter standard. **Appendix A** shows the time history and one-third octave band spectra for all measurements. These data were supplied to the Navy under a separate cover in a spreadsheet format.

On 10 September, sound measurements were completed on the removal of eight piles. The average extraction time per pile was approximately 2 minutes and 24 seconds. The near position ranged from 9 to 17 meters (30 to 56 feet), mid-range measurements were conducted at ranges between 79 and 87 meters (259 and 285 feet), and the distant monitoring site was at approximately 300 meters (1,000 feet). The anchoring system used when the distant system was deployed failed, causing the autonomous recorder to float to the surface during the pile extractions; the data recorded at this location were not usable. The anchoring system was revised and successfully deployed on 11 September. The weather was good with a Beaufort sea state of 2, which has wind speeds between 4 and 6 knots (7–11 km/hr) and small waves from 1 to 2 feet (0.3 to .06 m) and no whitecaps.

On 11 September, noise monitoring was conducted on the removal of five piles. The average extraction time for the five piles was approximately 1 minute and 15 seconds. The near position ranged from 11 to 16 meters (36 to 52 feet), the mid-range position ranged between 78 and 82 meters (256 and 269 feet), and distant monitoring was approximately 300 meters (984 feet) from the source. The weather was significantly worse with a Beaufort sea state of 4, which has wind speeds between 11 and 16 knots (20–30 km/hr) and small waves up to 4 feet (1.2 m) and many whitecaps. This made the background noise levels much higher than those observed on 10 September.

1 **Table 1 – Data Summary of the Underwater Sound Levels**

| Start Time | Stop Time | Removal Duration | Distance (meters) | RMS SPL (dB re1µPa) | | SEL (dB re 1µPa) | | Cumulative SEL (dB re 1µPa$^2$-sec) |
|---|---|---|---|---|---|---|---|---|
| | | | | Average | Range | Average | Range | |
| **10 September 2015** | | | | | | | | |
| 10:14:14 | 10:18:49 | 00:04:35 | 10 | 148 | 139-170 | 147 | 136-169 | 172 |
| | | | 86 | 130 | 124-134 | 129 | 122-134 | -[B] |
| 10:28:14 | 10:31:50 | 00:03:36 | 12 | 146 | 142-169 | 146 | 140-164 | 166 |
| | | | 84 | 131 | 125-154 | 130 | 122-150 | -[B] |
| 10:45:01 | 10:47:54 | 00:02:53 | 16 | 143 | 137-162 | 143 | 136-160 | 166 |
| | | | 80 | 134 | 124-150 | 133 | 122-147 | -[B] |
| 11:05:17 | 11:06:35 | 00:01:28 | 16 | 140 | 139-159 | 139 | 138-153 | 153 |
| | | | 80 | 129 | 127-148 | 128 | 126-140 | -[B] |
| 12:32:24 | 12:33:50 | 00:01:26 | 9 | 147 | 123-156 | 146 | 122-155 | 163 |
| | | | 87 | 126 | 117-134 | 124 | 116-132 | -[B] |
| 12:43:05 | 12:46:34 | 00:03:29 | 13 | 142 | 121-172 | 141 | 119-169 | 173 |
| | | | 83 | 130 | 117-156 | 128 | 113-152 | -[B] |
| 13:00:27 | 13:02:15 | 00:01:48 | 17 | 141 | 128-163 | 140 | 126-162 | 164 |
| | | | 79 | 130 | 123-152 | 129 | 119-150 | -[B] |
| 13:10:43 | 13:11:43 | 00:01:00 | 12 | 145 | 136-158 | 144 | 133-155 | 159 |
| | | | 84 | 128 | 122-143 | 127 | 120-140 | -[B] |
| **11 September 2015** | | | | | | | | |
| 09:05:50 | 09:06:47 | 00:00:57 | 14 | 141 | 136-167 | 139 | 135-164 | 167 |
| | | | 81 | 128 | 123-149 | 126 | 122-147 | -[B] |
| | | | 300 | 124 | 117-144 | 122 | 116-143 | -[B] |
| 09:13:56 | 09:15:14 | 00:01:18 | 11 | 147 | 137-171 | 145 | 135-170 | 176 |
| | | | 78 | 133 | 125-155 | 131 | 122-154 | 159 |
| | | | 300 | 128 | 122-147 | 127 | 121-146 | -[B] |
| 09:24:59 | 09:26:35 | 00:01:36 | 16 | 140 | 136-164 | 139 | 135-158 | 158 |
| | | | 82 | 130 | 123-150 | 128 | 122-145 | -[B] |
| | | | 300 | 126 | 118-142 | 125 | 118-137 | -[B] |
| 09:42:38 | 09:43:58 | 00:01:20 | 11 | 148 | 143-166 | 147 | 140-163 | 169 |
| | | | 81 | 134 | 129-149 | 132 | 126-147 | -[B] |
| | | | 300 | 129 | 122-146 | 128 | 120-144 | -[B] |
| 09:51:35 | 09:52:41 | 00:01:06 | 11 | 147 | 141-169 | 145 | 140-167 | 170 |
| | | | 81 | 133 | 126-152 | 131 | 126-150 | 150 |
| | | | 300 | 130 | 122-146 | 128 | 120-145 | -[B] |

1 **Table 2 – Hydroacoustic Monitoring Data at the Near Position Normalized to 10 meters**

| Measured Distance (meters) | Measured RMS SPL | | RMS SPL Normalized to 10 meters | | Measured SEL | | SEL Normalized to 10 m | |
|---|---|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | Average | Range | Average | Range |
| **10 September 2015** | | | | | | | | |
| 12 | 146 | 142-169 | 147 | 143-170 | 146 | 140-164 | 147 | 141-165 |
| 16 | 143 | 137-162 | 146 | 140-165 | 143 | 136-160 | 146 | 139-163 |
| 16 | 148 | 139-170 | 151 | 142-173 | 147 | 136-169 | 150 | 139-172 |
| 9 | 147 | 123-156 | 146 | 122-155 | 146 | 122-155 | 145 | 121-154 |
| 13 | 142 | 121-172 | 144 | 123-174 | 140 | 126-162 | 142 | 128-164 |
| 17 | 141 | 128-163 | 145 | 132-167 | 140 | 126-162 | 144 | 130-166 |
| 12 | 145 | 136-158 | 146 | 137-159 | 144 | 133-155 | 145 | 134-156 |
| **11 September 2015** | | | | | | | | |
| 14 | 141 | 136-167 | 143 | 138-169 | 139 | 135-164 | 141 | 137-166 |
| 11 | 147 | 137-171 | 148 | 138-172 | 145 | 135-170 | 146 | 136-171 |
| 16 | 140 | 136-164 | 143 | 139-157 | 139 | 135-158 | 142 | 138-161 |
| 11 | 148 | 143-166 | 149 | 144-167 | 147 | 140-163 | 148 | 141-164 |
| 11 | 147 | 141-169 | 148 | 142-170 | 145 | 140-167 | 146 | 141-168 |

Airborne (AB) noise measurements were also made from fixed locations on both days at 10 to 15 meters (33 to 49 feet) from the pile removal. The objective was to place a sound level meter (SLM) as close as possible to the pile removal while remaining safely out of the way of construction. Unfortunately, noise from the power pack and other construction activities overpowered the noise from the vibratory hammer.

On 10 September, the SLM location was at a fixed position 10 to 15 meters (33 to 49 feet) from the pile-extraction operations. During the morning, the AB SLM was located on the southeastern corner of the pier near the crane at a range of approximately 15 meters (49 feet) from the pile removal and 15 meters (49 feet) from the power plant. In the afternoon, the AB SLM was moved for operational reasons to a location behind the power plant. The location was 15 meters (49 feet) from the power plant and 32 meters (105 feet) to the pile extraction location. On 11 September, high winds caused the background AB levels to be elevated due to the wind blowing across the microphone. Measurements were made at 10 to 15 meters (33 to 49 feet) from the piles and 10 meters (33 feet) from the power plant.

The airborne noise levels measured are shown in **Appendix B**.

The times to extract a pile ranged from just under a minute to 4 minutes and 35 seconds while the average time to extract a pile was a little over 2 minutes. The average underwater noise from the pile extraction was 146 dB RMS SPL and 145 dB SEL normalized to 10 meters.

# Measurement Equipment

Reson Model TC-4013 and TC-4033 hydrophones were used for the underwater sound measurements. The signal from the hydrophones was fed directly into a Larson Davis Model 831 Precision Sound Level Meter (LDL 831). The LDL 831 captures the signal and stores the measurement data to be downloaded for analysis at the end of each day.

During vibratory driving, the maximum peak sound pressures ($LZ_{peak}$), the SEL, and the fast RMS sound pressure level were measured “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 $LFZ_{max}$. Additional analyses of the acoustical impulses were performed using the LDL 831 SLMs as well.

Airborne measurements were made using a 0.5-inch G.R.A.S. Model 40AQ pre-polarized random-incidence microphone. The signal was fed into an LDL 831 SLM. The system was calibrated with a Larson Davis 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

Acoustic monitoring may report data in several formats, depending on the type of operation generating the noise and the type of acoustic measurement. Impact pile driving produces pulse-type sounds, while vibratory pile installation or removal produces a more continuous type of sound.

For vibratory extraction, data reporting included the RMS SPL, the SEL, cumulative SEL, and the $L_{max}$ average one-third octave band frequency spectrum over the entire pile-driving event.

# Airborne Sound Descriptors

A-weighted airborne data were collected for vibratory extraction. During data collection, 1-second and 1-minute intervals were used for measuring airborne sounds. The airborne data represent the 1-second “fast” Z-weighted RMS ($L_{max}$). Due to the short extraction periods for the piles, the data shown are for the driving period. The tables in **Appendix B** show the data including the $L_{eq}$ and $L_{max}$.

# Measurement Data Management

For each day of monitoring, digital data captured by the SLMs were downloaded to a computer. Some of the readings during the monitoring were recorded in field notebooks to track levels and assess the ranges needed for monitoring.

# Quality Control

The underwater and airborne measurement systems were calibrated prior to use in the field with a G.R.A.S. Type 42AA pistonphone and hydrophone coupler. For the underwater systems, the pistonphone calibrator produces a continuous 136.4 or 145.3 dB (referenced to one microPascal) tone at 250 Hertz (Hz). For the airborne system the pistonphone produces a continuous 114.0 dB (referenced to 20 microPascals) tone at 250 Hz. The SLMs are calibrated to this tone and it is measured as well as recorded by the SLM at the beginning of all the data files. The system calibration status was checked at the end of the measurement event by both measuring the calibration tone and recording the post-measurement tone on the media files. Signal analysis included the measurement of the calibration tone at the beginning and end of recording events. All systems were found to be within 0.5 dB of the calibration levels. The pistonphone output has been certified at an independent facility.

All field notes were recorded in water-resistant field notebooks. Notebook entries include calibration notes, measurement positions (i.e., distance from the source and depth of the 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.

# Propagation Rate

The propagation rate, or acoustic spreading loss, was calculated for the pile extraction. The term “rate” applies to the logarithmic attenuation of noise levels as sound propagates away from the source. Empirically derived propagation rates like these provide a valuable utility in estimating sound harassment areas for future projects. The average RMS SPL and SEL propagation curves are shown in **Figures 1 and 2,** these acoustic spreading-loss curves can be used to calculate the overall distances to the various regulatory threshold levels for both RMS SPL and SEL. The dataset of measurement distances for the piles ranged from 9 to 300 meters

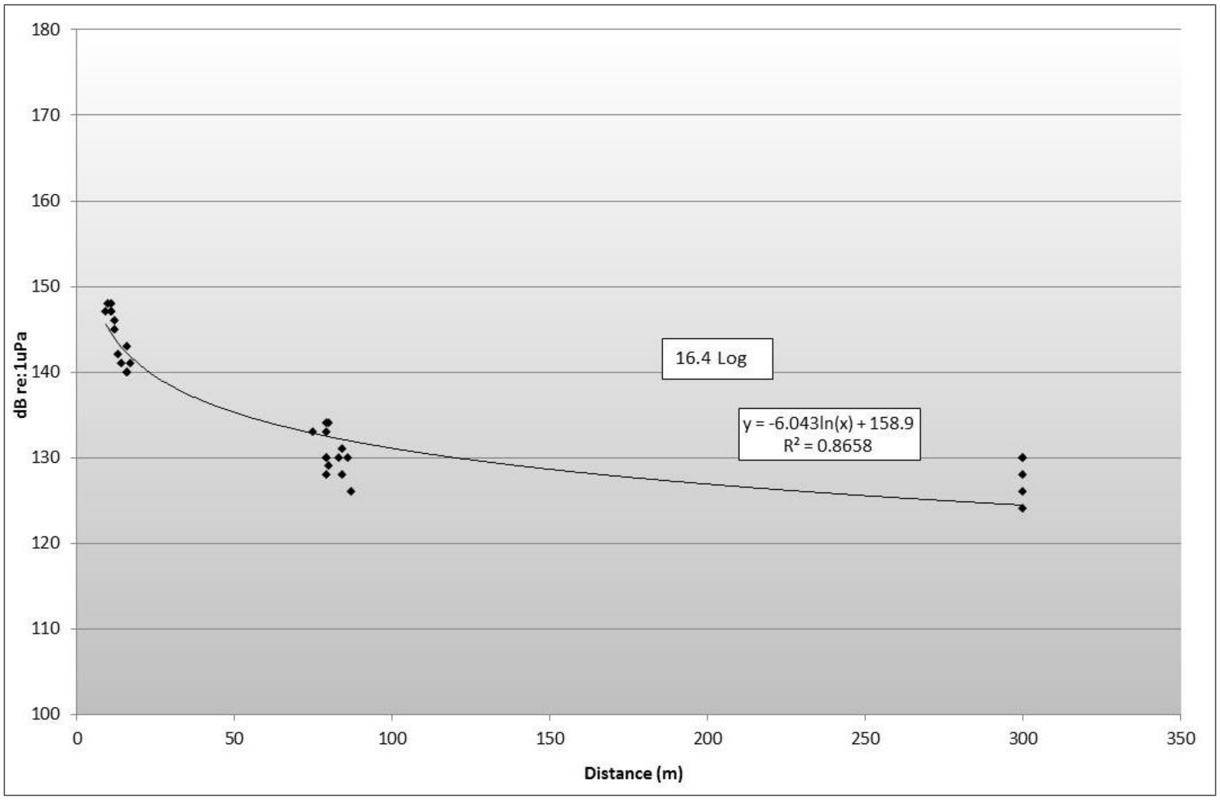


**Figure 1 – Acoustic Spreading Loss of Average RMS SPL Levels.**

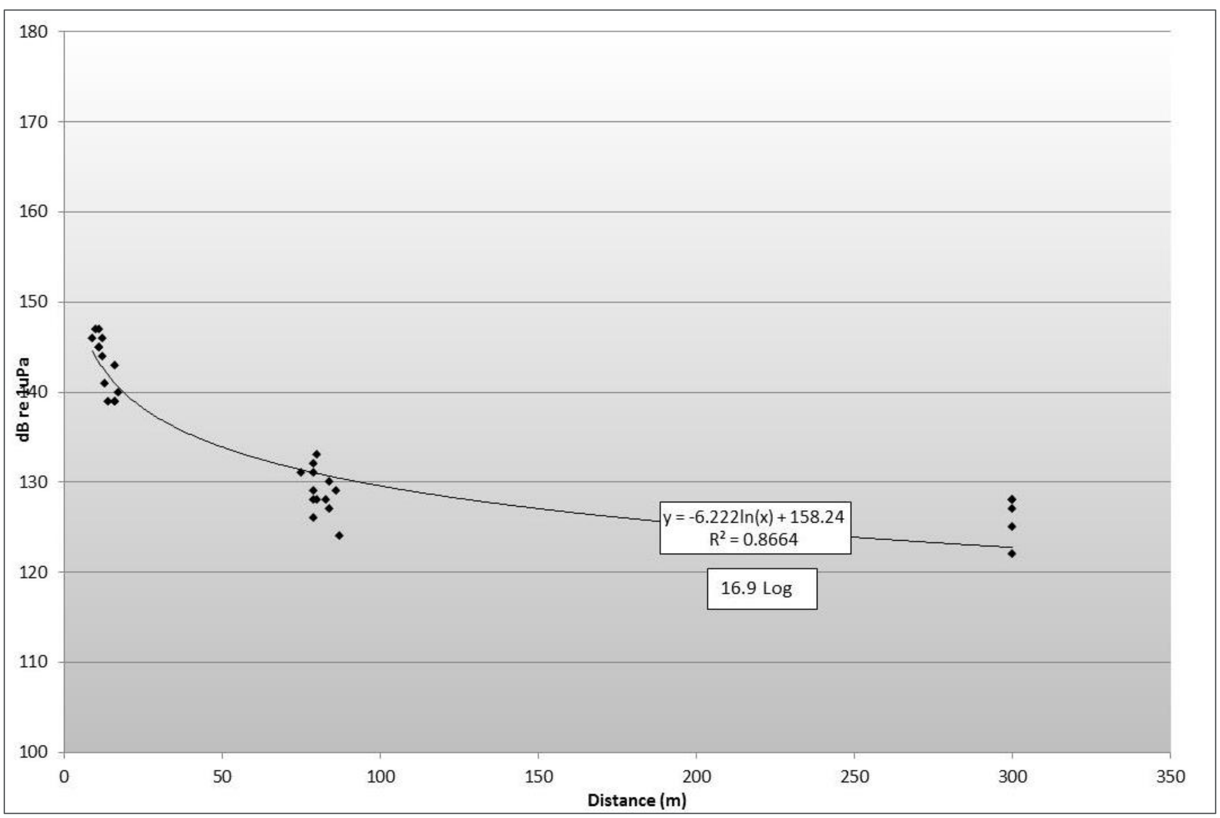


**Figure 2 – Acoustic Spreading Loss of Average SEL.**

(29 to 984 feet). The average propagation loss for the piles was 16.4 $Log_{10}$ for the RMS SPL values and 16.9 $Log_{10}$ for the SEL values, which is within the expected range for these types of piles.[1]

# Spectrum Analysis

On 10 September the measurement systems were programed to measure a wide range of levels due to the uncertainty in the expected noise levels from the pile extractions. The equipment used for the measurements has a limited dynamic range, due to the uncertainty of the expected noise levels and so as to not overload the system while measuring, the range was set to capture levels higher potential levels. After a review of the measured levels and spectra on 10 September it was determined that the dynamic range could be adjusted down and measure the low ambient level while not overloading on the high end. This was accomplished by adding 20 dB of gain to the system. **Figures 3** and **4** shows the differences between the gain on and off (note the differences between the background levels at the lower and higher frequencies with the gain on and off). With the 20-dB gain on at the low frequencies, there were between 5 and 14-dB reductions in the measured levels between 6.3 Hz and 80 Hz, and at the higher frequencies, there was approximately a 3 to 20-dB reduction in the measured noise levels between 1.6 kilohertz (kHz) and 20 kHz. With the 20-dB gain turned on in the meter there are no adjustments in the recorded data required, all that occurred is the dynamic range was lowered 20 dB. For analysis purposes only, the spectra data that had the 20-dB gain added on the second day should be used.

# Discussion

The combination of shallow water and low noise levels during the extraction of the piles made it difficult to obtain data at the near location. Ideally, the measurements would have been made from a boat 10 meters (33 feet) from the piles being pulled; however, due to safety concerns, this was not a practicable option. There was no safe way to maintain a 10-meter distance from the piles being pulled, even from the pier. A similar condition was true for the airborne measurements; there was no convenient location on the end of the decking to place the airborne system where it was not in the way and able to measure the noise primarily from the vibratory extractor. There were three separate noise-generating components from this operation - the crane, the power plant that provided power to the vibratory extractor, and the actual vibratory extractor. The power plant was in a fixed position, and the crane, while it did not change position, did rotate, causing the primary noise (from the engine) as it rotated. The vibratory extractor was moved from pile to pile; there were times when the power plant was closer to the measurement site, and there were times that the vibratory extractor was closer. This made it difficult to separate the noise of the vibratory extractor from the other sources. On 11 September, the wind was blowing from the north at approximately 11 to 16 knots with gusts up to 18 knots (33 km/hr) and this caused an increase in the low-end frequencies. The A-weighted data show an approximate 10-dB increase between the background levels and the times that the pile was being extracted, while the Z-weighted frequencies show a 0 to 3 dB

[1] Caltrans' *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* Nov 2015, **http://www.dot.ca.gov/hq/env/bio/fisheries_bioacoustics.htm**.

difference. As the day progressed, the wind speeds increased so that on the last pile removed it was not possible to detect the noise of the activity based on the Z weighted data (see time histories in **Appendix B**).

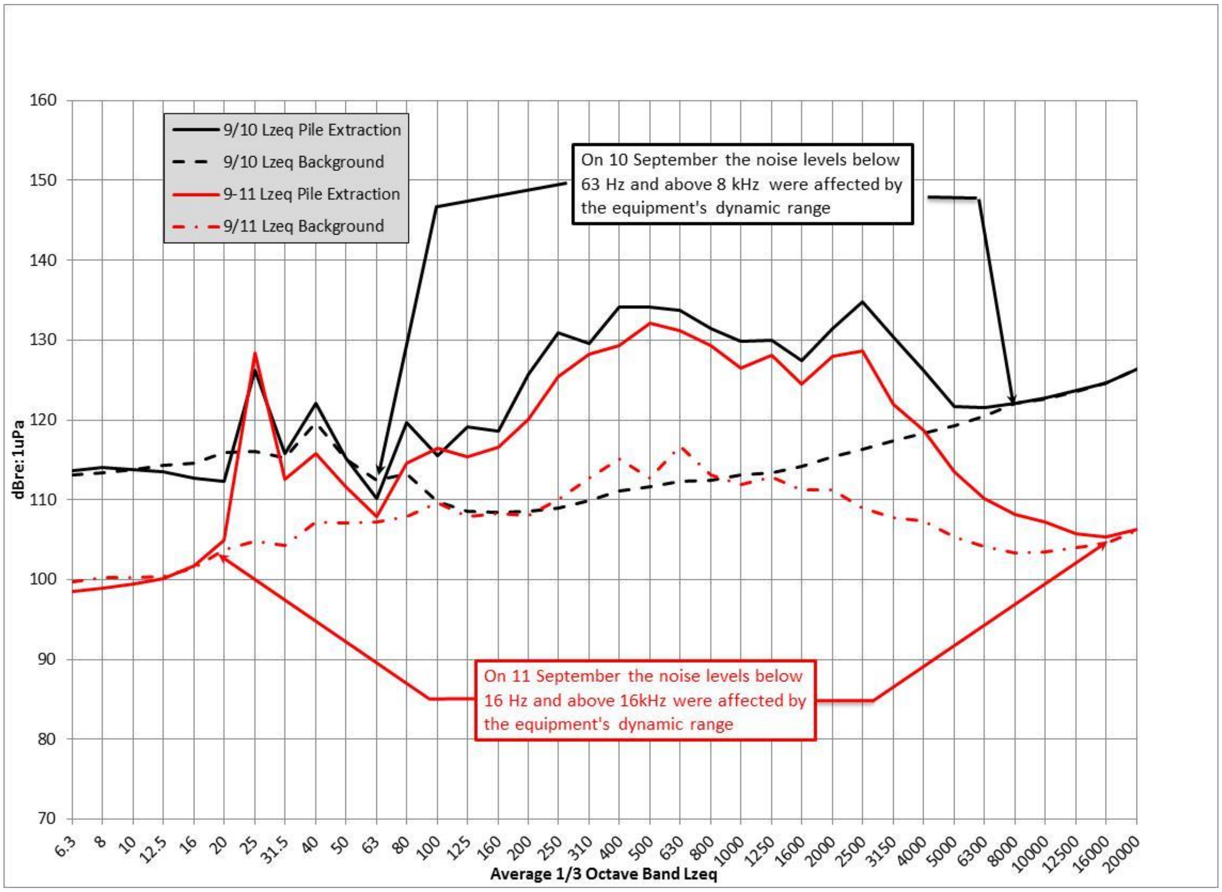


**Figure 3 – Comparison of Pile Driving Spectra and Background Noise (9/10 Lzeq without gain; 9/11 Lzeq with 20 dB gain applied).**

# Glossary

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

**Ambient sound level** – The background sound pressure level at a given location, normally specified as a reference level to study a new intrusive sound source.

**Background level** – Similar to ambient sound level with the exception that is a composite of all sound measured during the construction period minus the pile removal.

**Amplitude –** The maximum deviation between the sound pressure and the ambient pressure.

**Cumulative sound exposure level ($SEL_{cumulative}$)** – In an evaluation of pile-driving impacts, 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:

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

**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 microPascal (μPa), and for air it is 20 microPascals (the threshold of healthy human auditory sensitivity).

**dBA** – A frequency-weighted decibel scale that approximates the relative sensitivity of human hearing to different frequency bands of audible sound.

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

**Frequency spectrum** – The distribution of frequencies that comprise a sound.

**Fast, Slow and Impulse** – Most sound level meters have two conventional time weightings, F = Fast and S = Slow with time constants of 125 milliseconds (ms) and 1000 ms respectively. Some also have I = Impulse time weighting, which is a quasi-peak detection characteristic with rapid rise time (35 ms) and a much slower 1.5-second decay.

- F = 125 ms up and down
- S = 1 second up and down
- I = 35 ms while the signal level is increasing or 1,500 ms while the signal level is decreasing

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

**Kilohertz (kHz)** – 1,000 Hertz

**Leq** – *Equivalent Average Sound Pressure Level (or Energy-Averaged Sound Level).* The decibel level of a constant noise source that would have the same total acoustical energy over the same time interval as the actual time-varying noise condition being measured or estimated. Leq values must be associated with an explicit or implicit averaging time in order to have practical meaning. The use of A-weighted, C-weighted, or Z-weighted (flat) decibel units sometimes is indicated by $LA_{eq}$, $LC_{eq}$, or $LZ_{eq}$, respectively

**LZF** – Z-weighted Fast RMS Sound Pressure Level

**$LZF_{max}$** – Maximum Z-weighted Fast RMS Sound Pressure Level

**$LZ_{eq}$** – Z-weighted, Leq, sound pressure level

**$LZ_{max}$** – Maximum Sound Pressure level during a measurement period or a noise event.

**$LZ_{peak}$** – Z-weighted peak sound pressure level

**microPascal (µPa)** – The pascal (symbol Pa) is the SI unit of pressure. It is equivalent to one newton per square meter. There are 1,000,000 mircoPascals in one Pascal.

**milliseconds (ms)** – A thousandth (0.001 or $10^{-3}$ or $^{1}/_{1,000}$) of a second.

**Peak sound pressure level ($L_{PEAK}$)** – The largest absolute value of the instantaneous sound pressure. This pressure is expressed in decibels (referenced to a pressure of 1 microPascal [µPa] for water and 20 µPa for air) or in units of pressure, such as µPa or Pounds per Square Inch.

**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. 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 Level Meter (SLM)** – An instrument that can measure sound level, commonly used in noise pollution studies for the quantification of different kinds of noise.

**Sound pressure level (SPL)** – An expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 microPascal (μPa) for water, and 20 μPa for air and other gases. Sound pressure is the sound force per unit area, usually expressed in microPascals (or microNewtons 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. SPL is the quantity directly measured by a sound level meter.

**Z-weighted –** Z-weighting is a flat frequency response of 10 Hz to 20 kHz ±1.5 dB. This response replaces the older "Linear" or "Unweighted" responses as these did not define the frequency range over which the meter would be linear.

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# A

# Time History of Pile Removals and One-Third Octave Band Spectra

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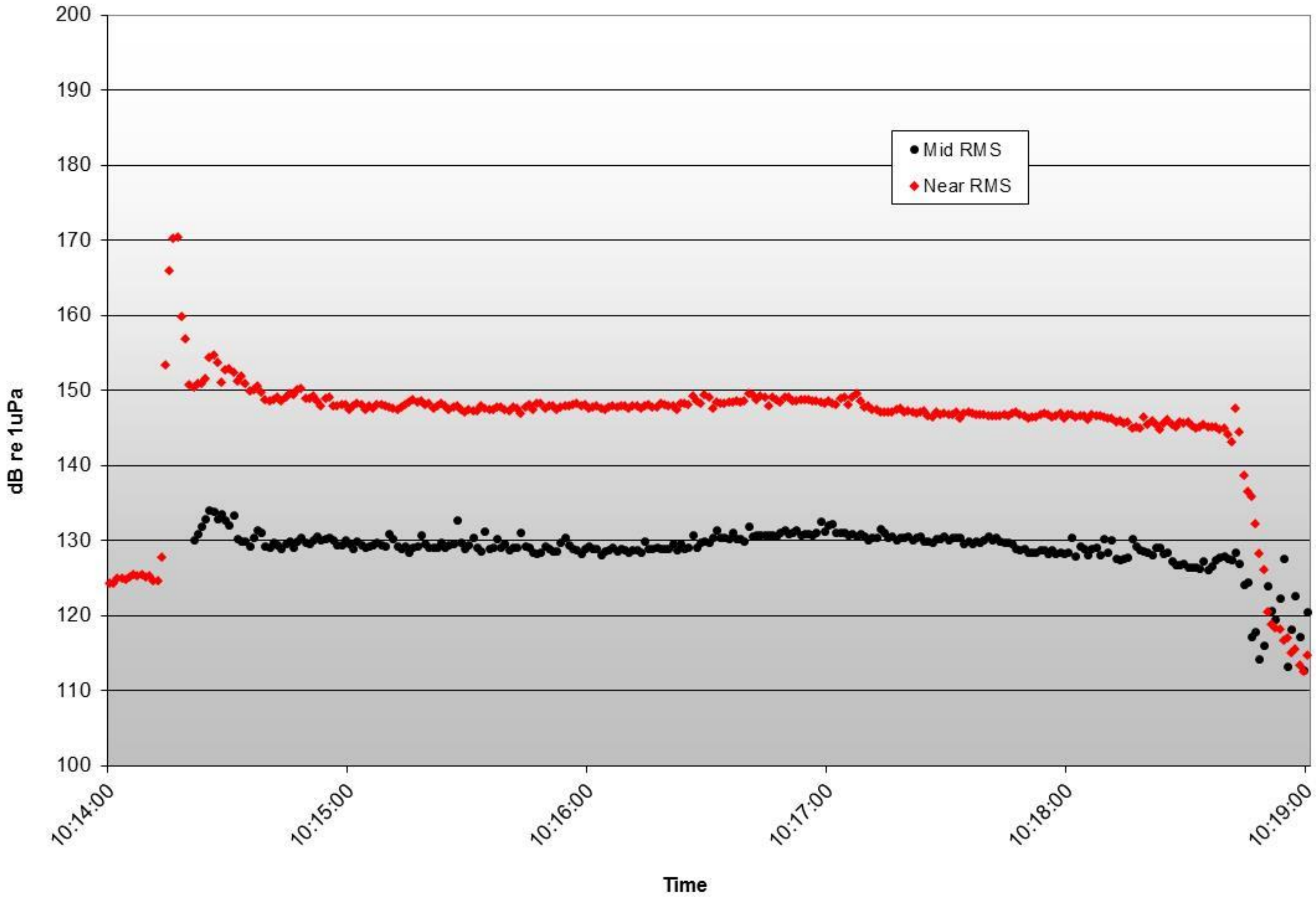


**Figure A-1 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #1 at JEB Little Creek, 10 September 2015.**

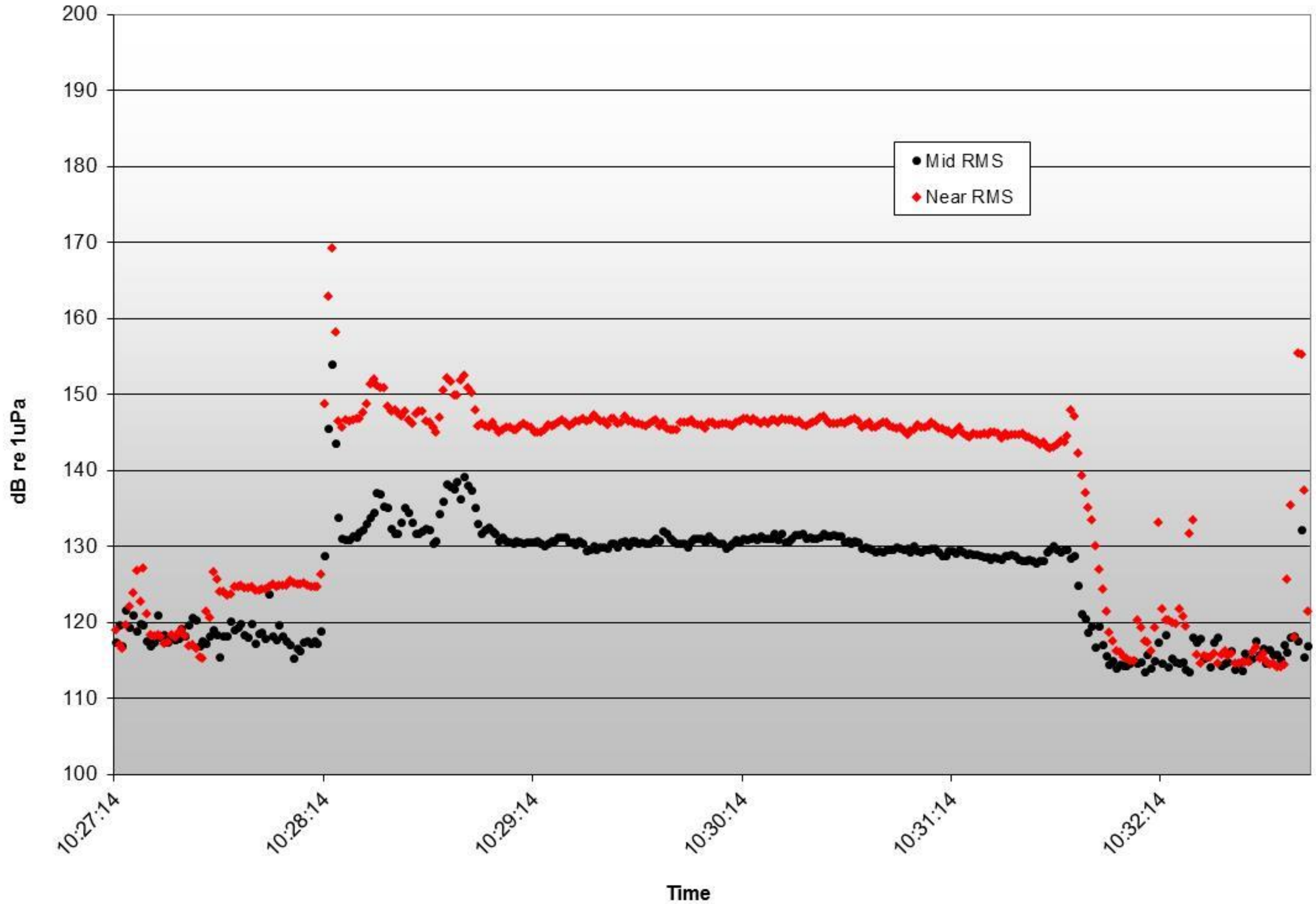


**Figure A-2 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #2 at JEB Little Creek, 10 September 2015.**

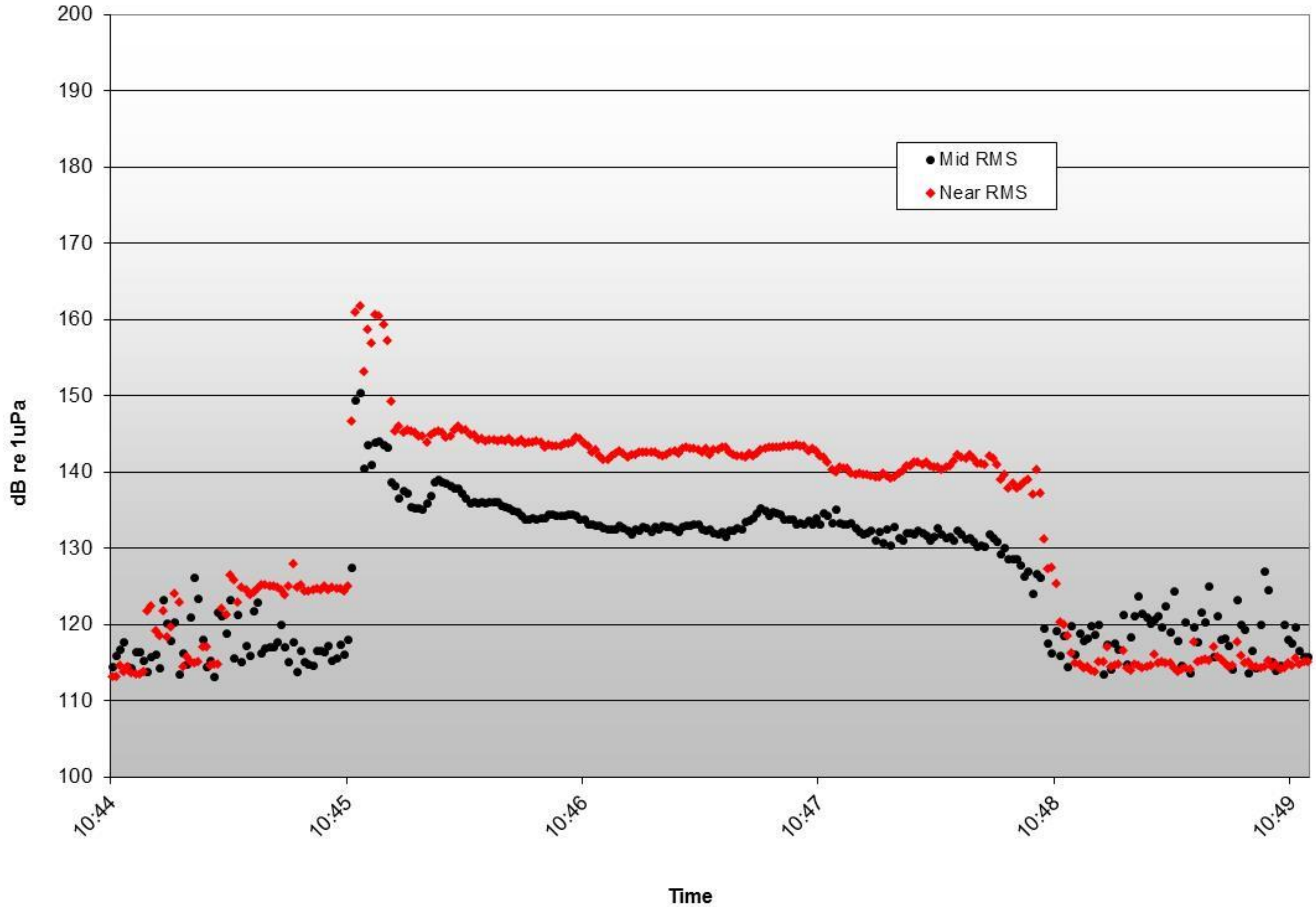


**Figure A-3 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #3 at JEB Little Creek, 10 September 2015.**

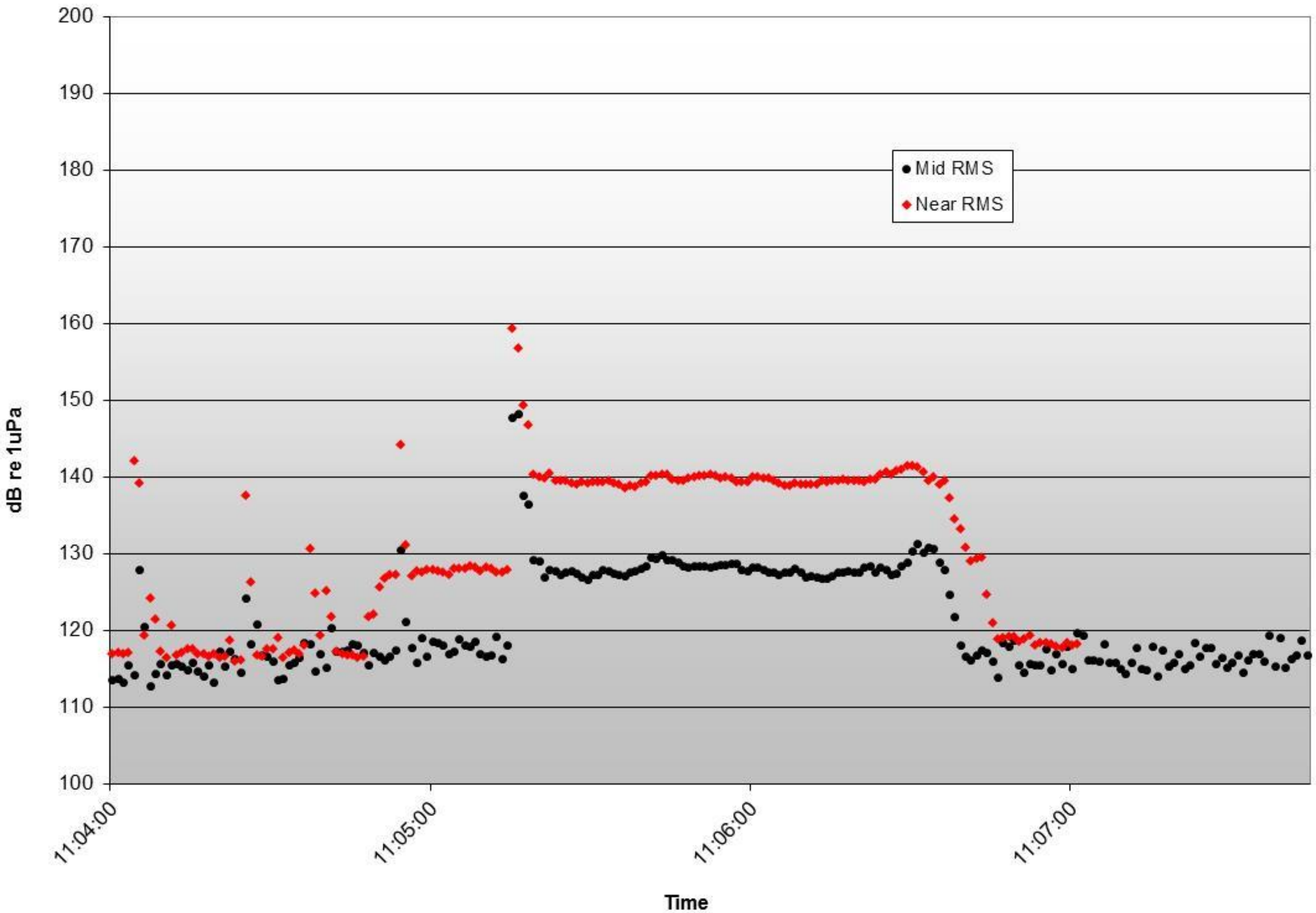


**Figure A-4 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #4 at JEB Little Creek, 10 September 2015.**

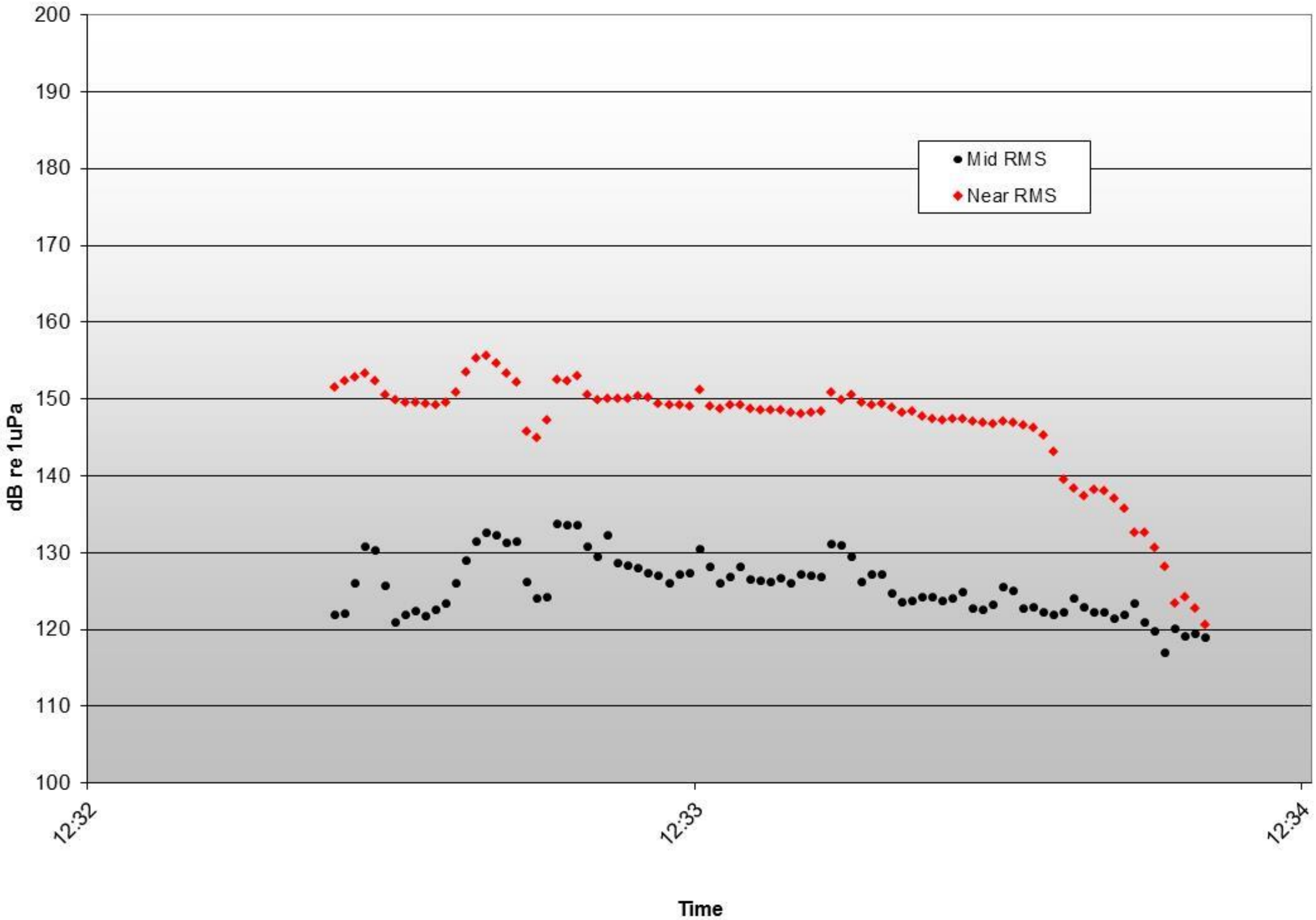


**Figure A-5 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #5 at JEB Little Creek, 10 September 2015.**

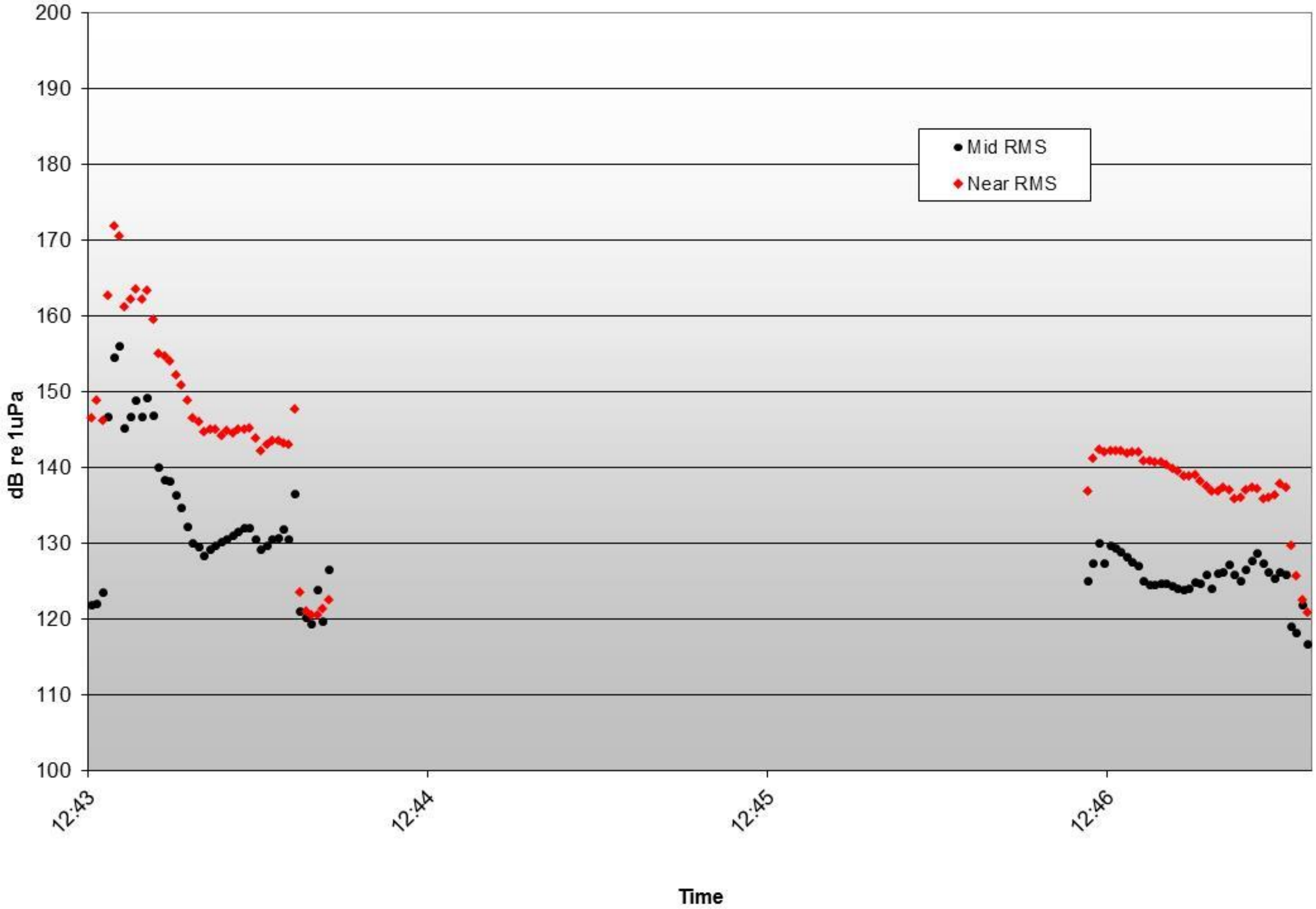


**Figure A-6 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #6 at JEB Little Creek, 10 September 2015.**

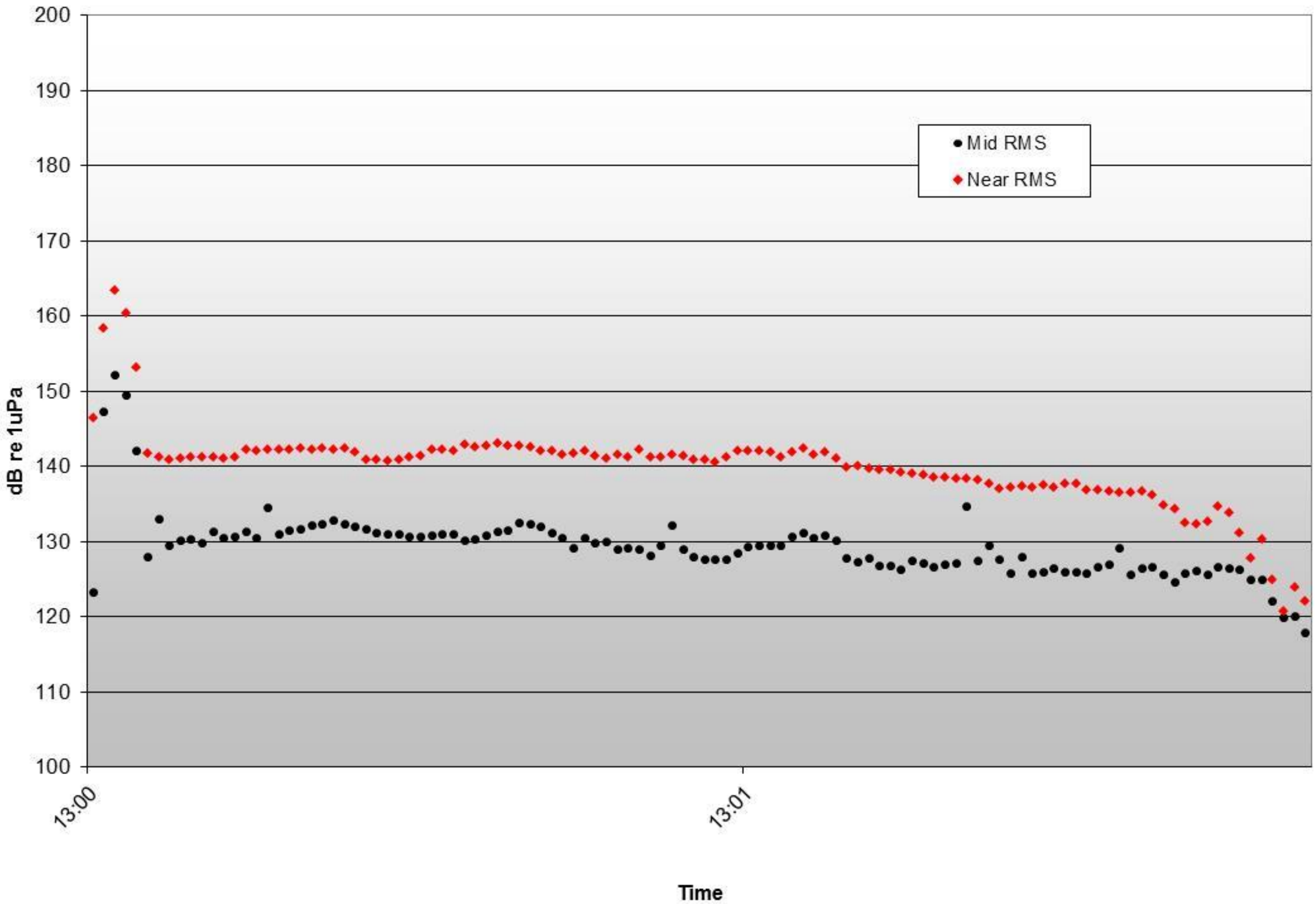


**Figure A-7 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #7 at JEB Little Creek, 10 September 2015.**

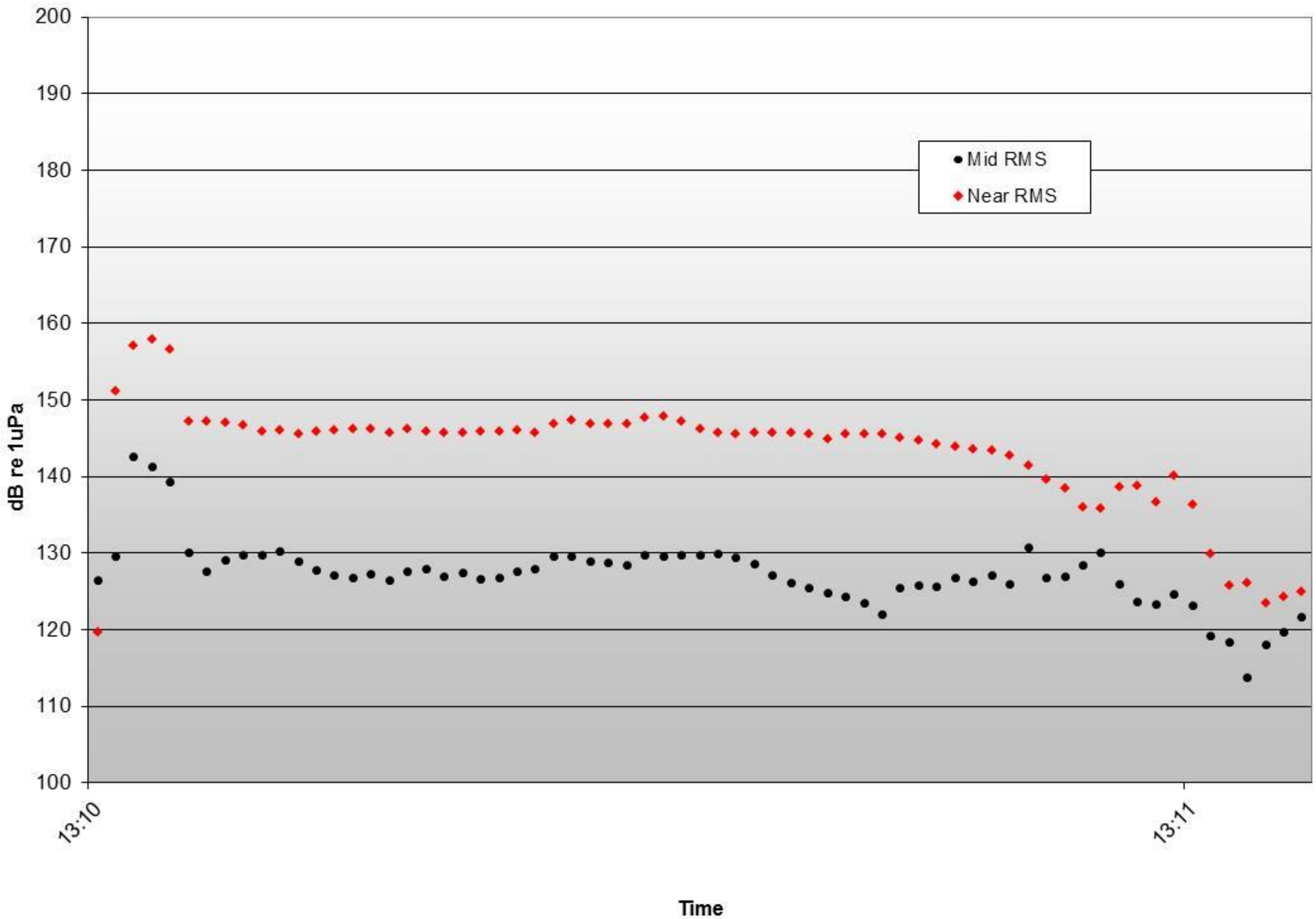


**Figure A-8 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #8 at JEB Little Creek, 10 September 2015.**

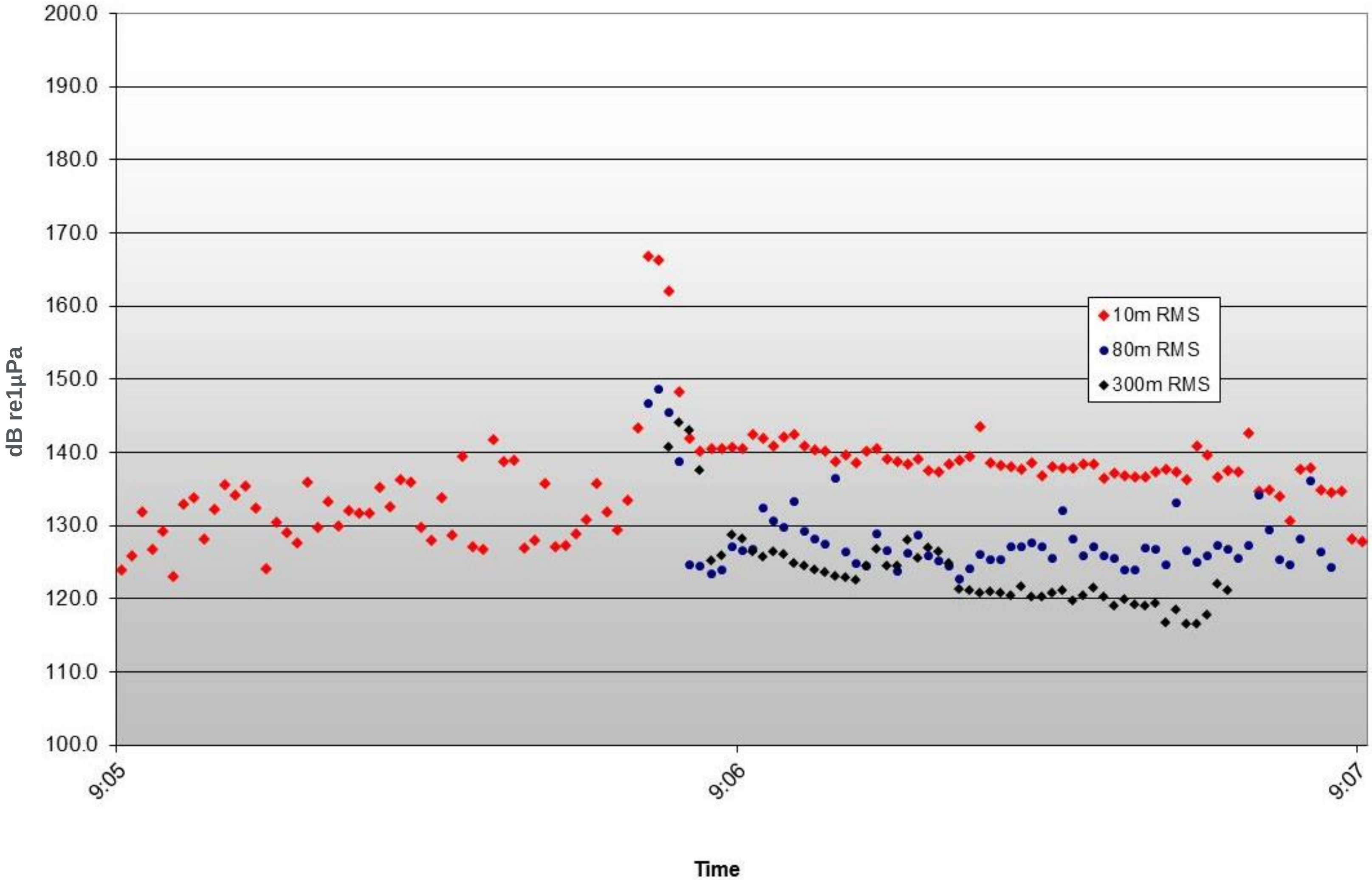


Figure A-9 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #1-A at JEB Little Creek, 11 September 2015.

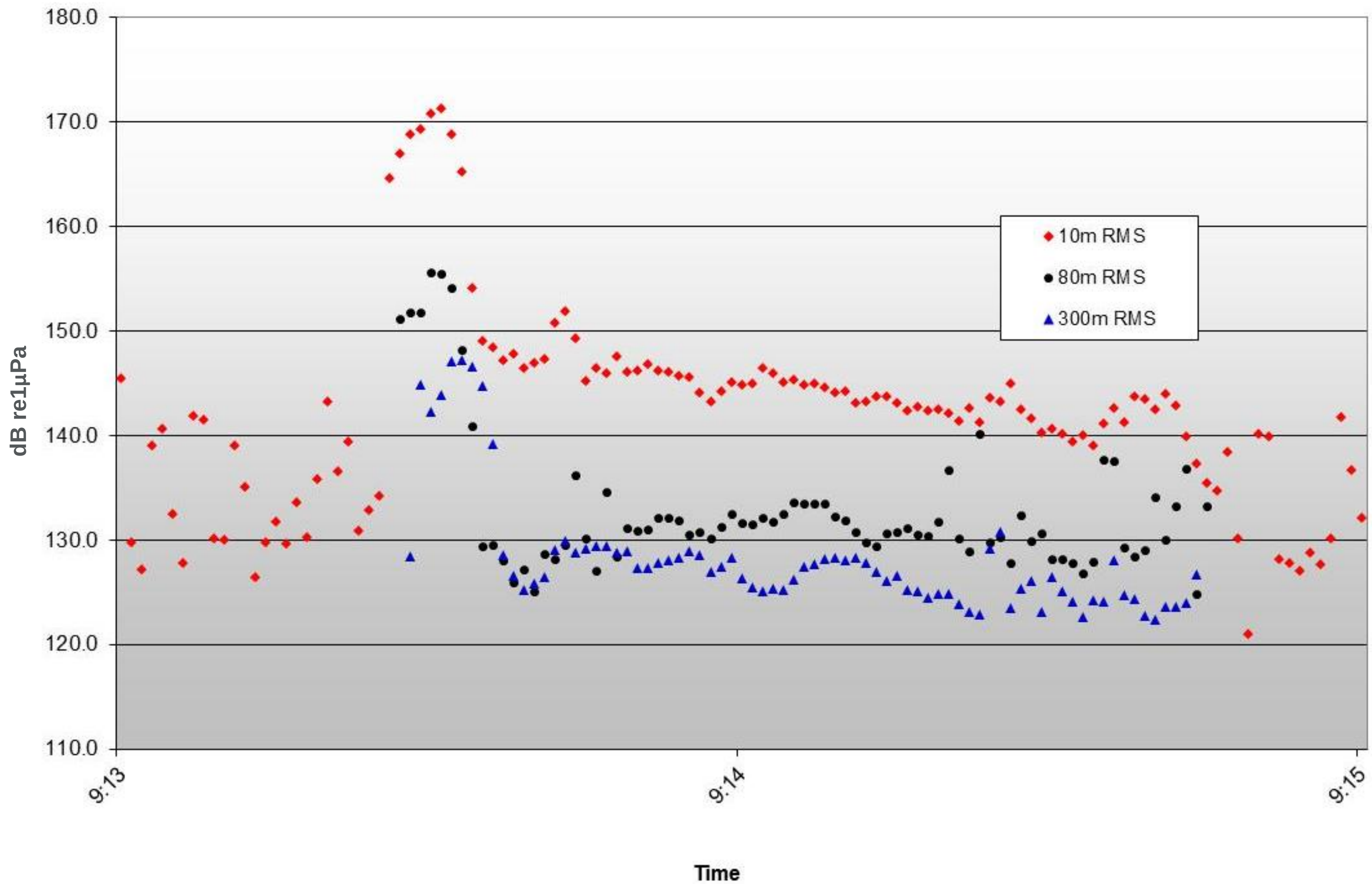


**Figure A-10 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #2-A at JEB Little Creek, 11 September 2015.**

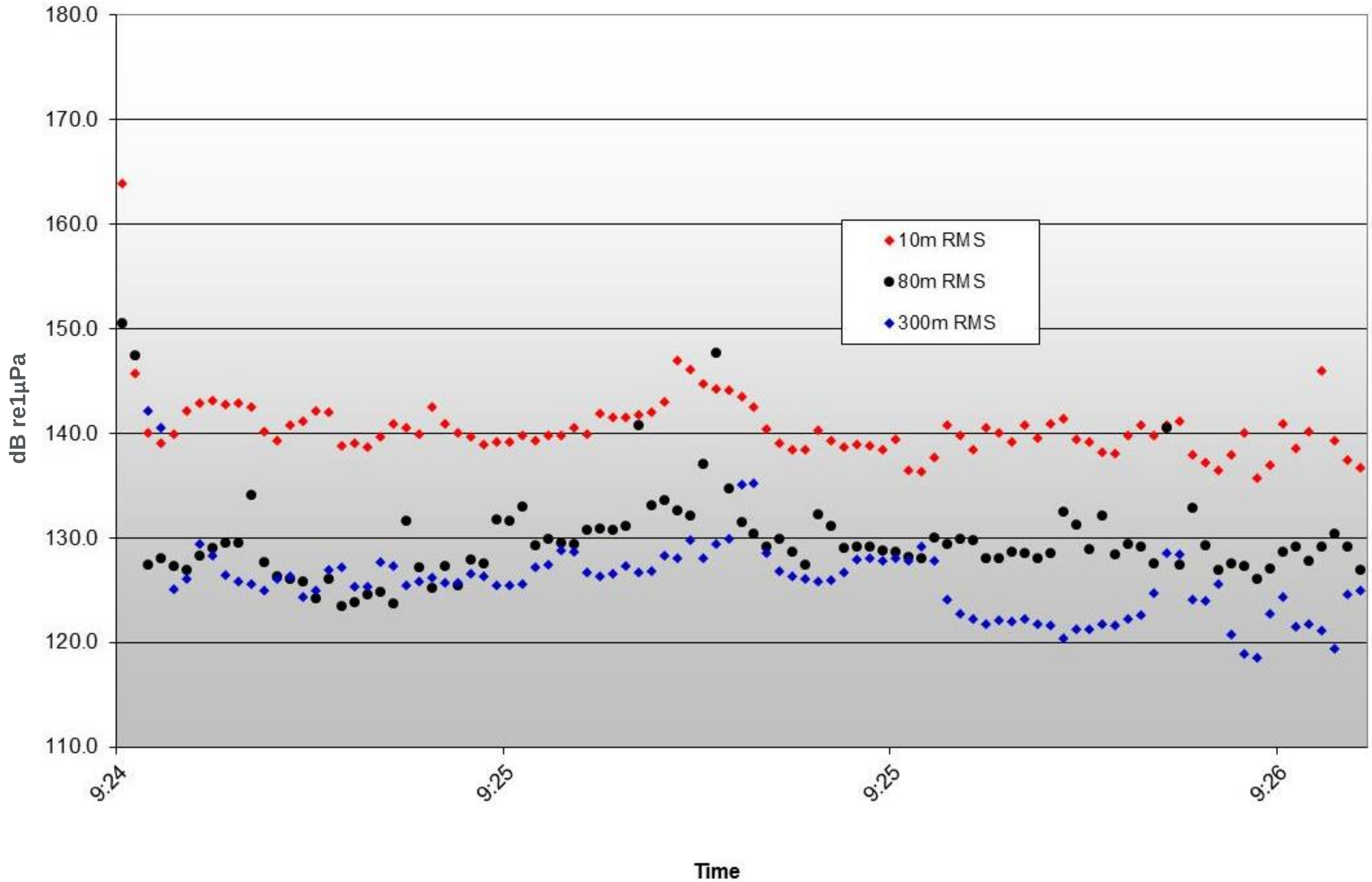


**Figure A-11 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #3-A at JEB Little Creek, 11 September 2015.**

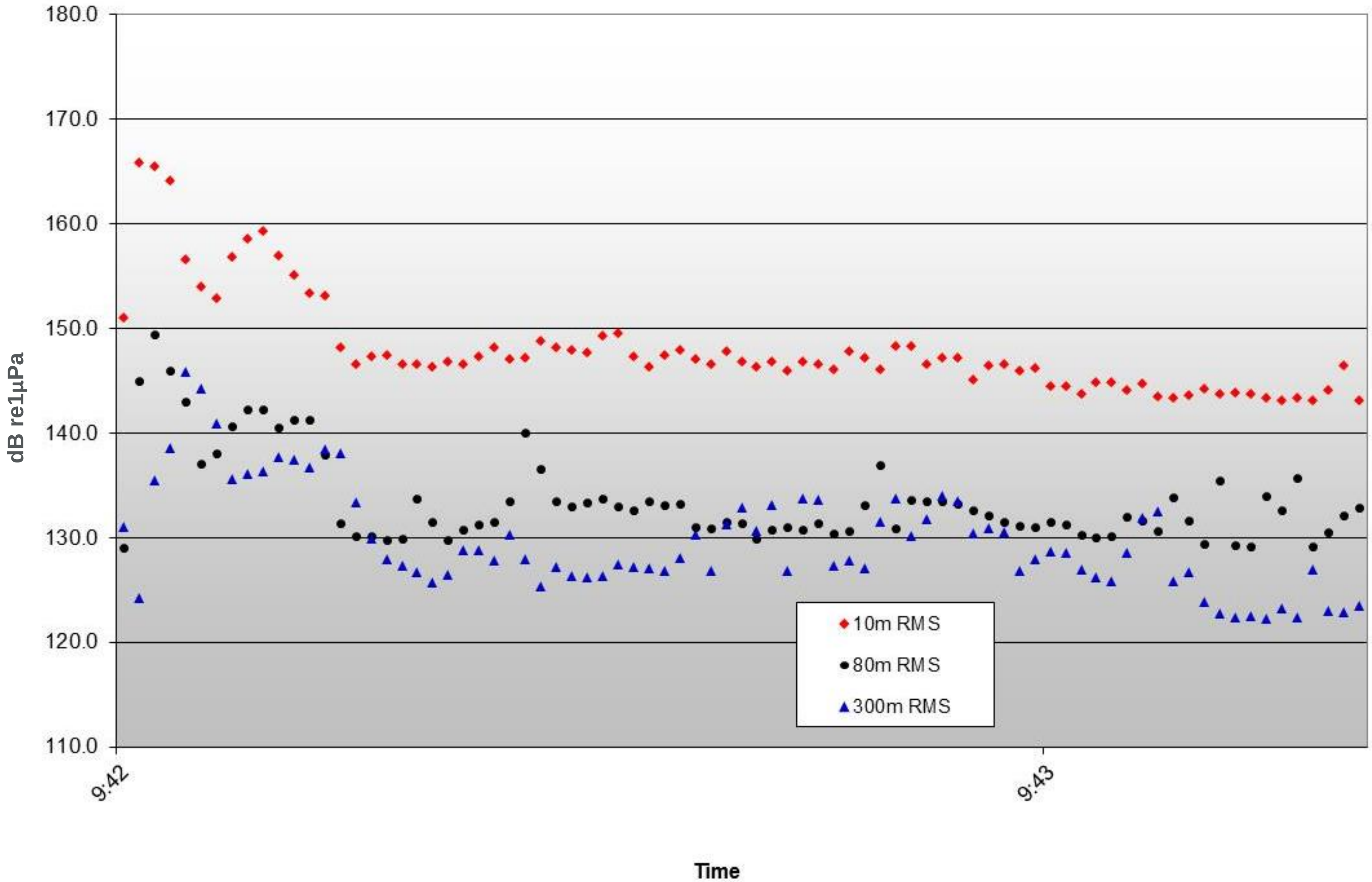


**Figure A-12 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #4-A at JEB Little Creek, 11 September 2015.**

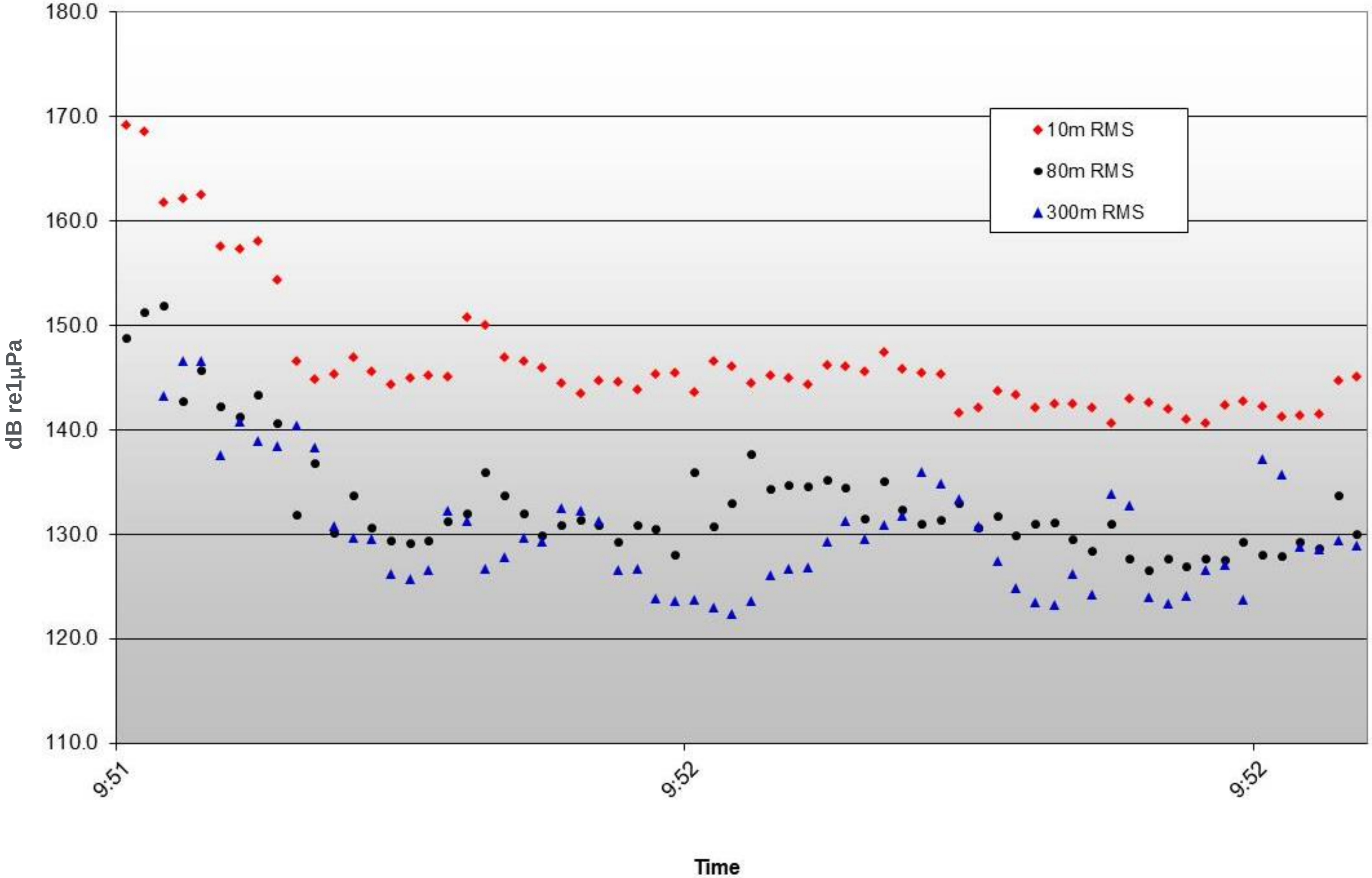


**Figure A-13 – Underwater Noise SPLs Recorded During Removal of ELCS Pile #5-A at JEB Little Creek, 11 September 2015.**

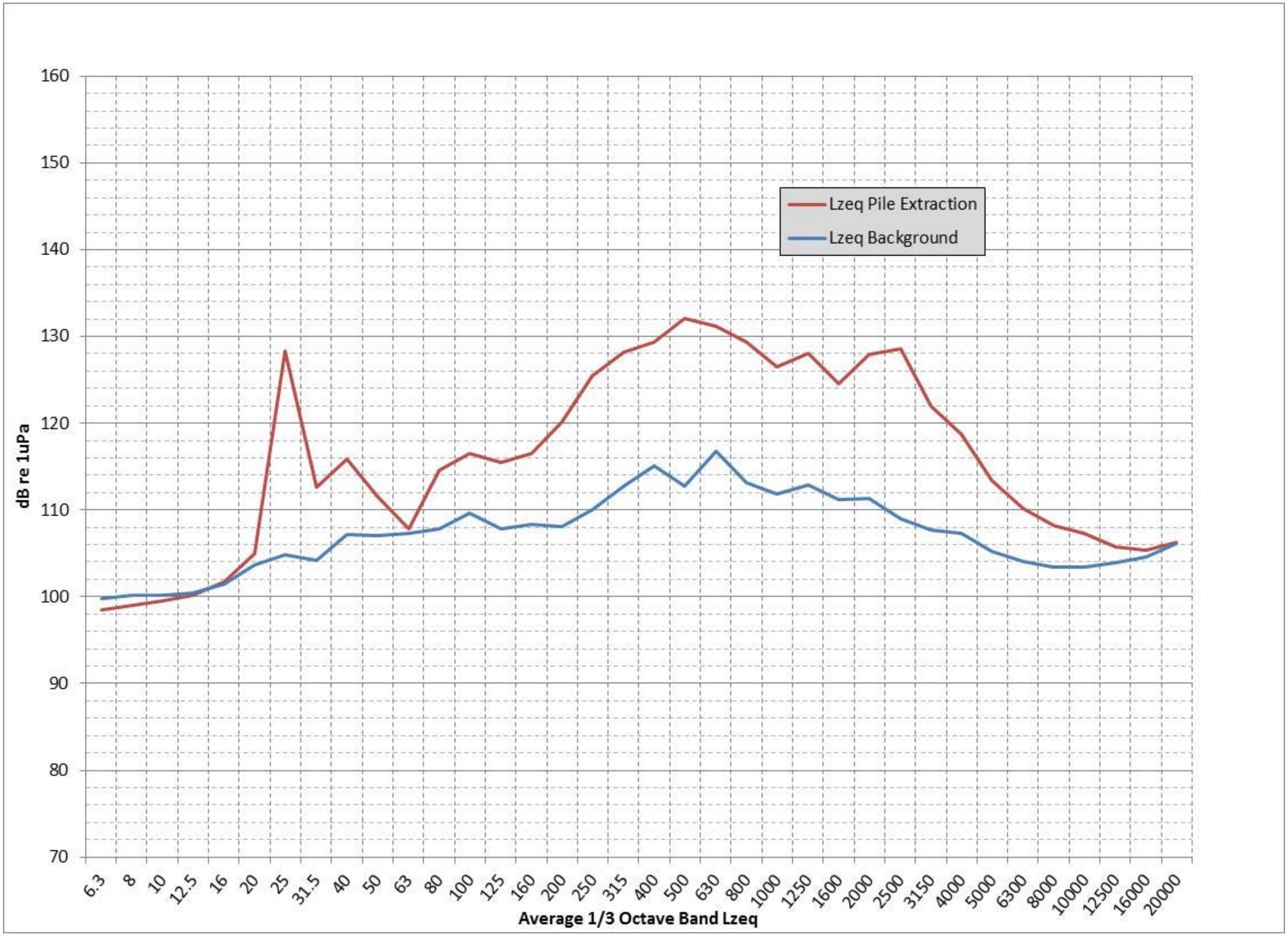


**Figure A-14 – Average LZeq one-third octave Band Spectra September 11, 2015 near location**


**Figure A-15 – Average LZmax one-third octave Band Spectra September 11, 2015 near location**

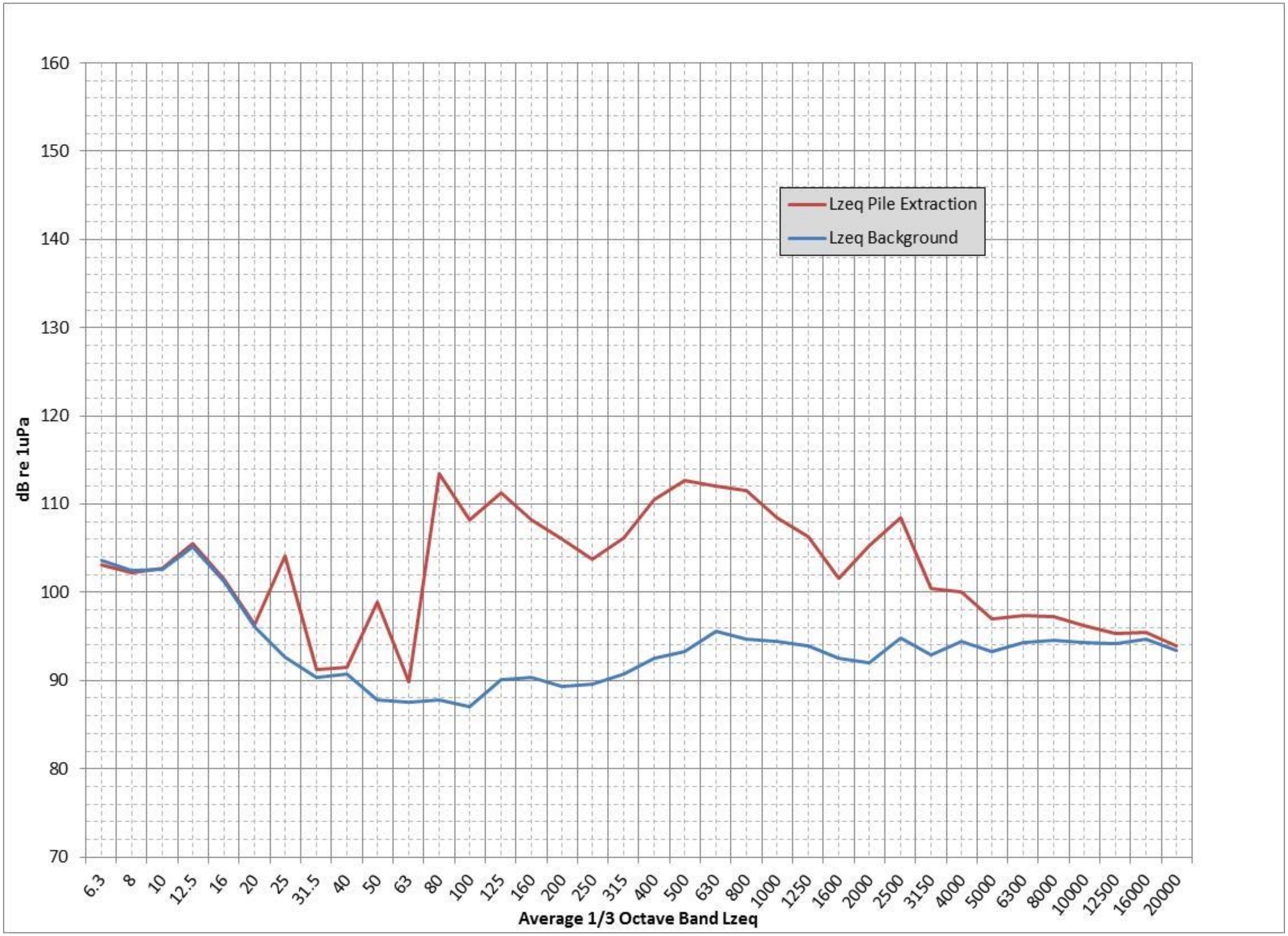


**Figure A-16 – Average LZeq one-third octave Band Spectra September 11, 2015 300-meter location**

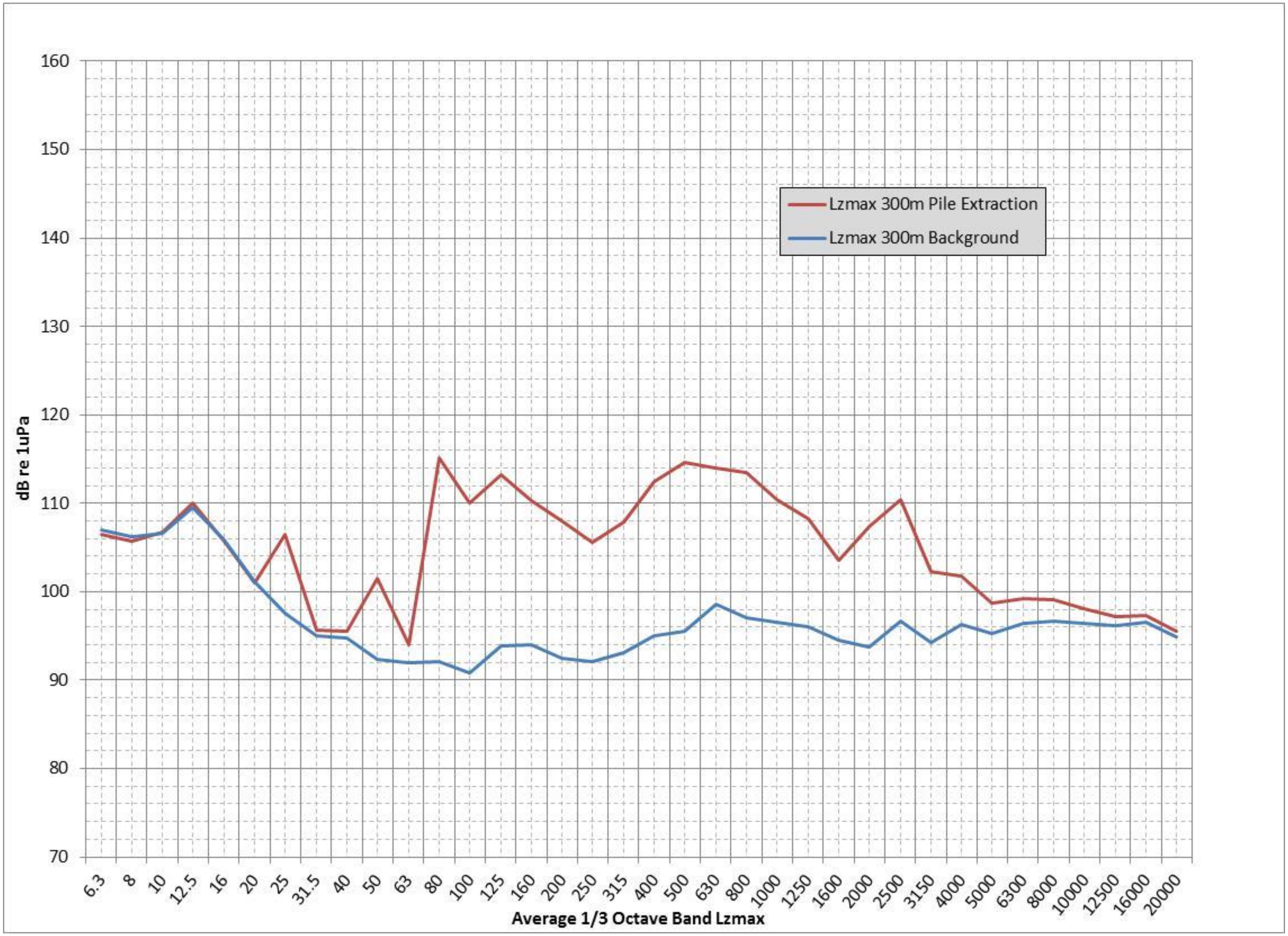


**Figure A-17 – Average LZmax one-third octave Band Spectra September 11, 2015 300-meter location**

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# B

## Time History and One-Minute Airborne Data

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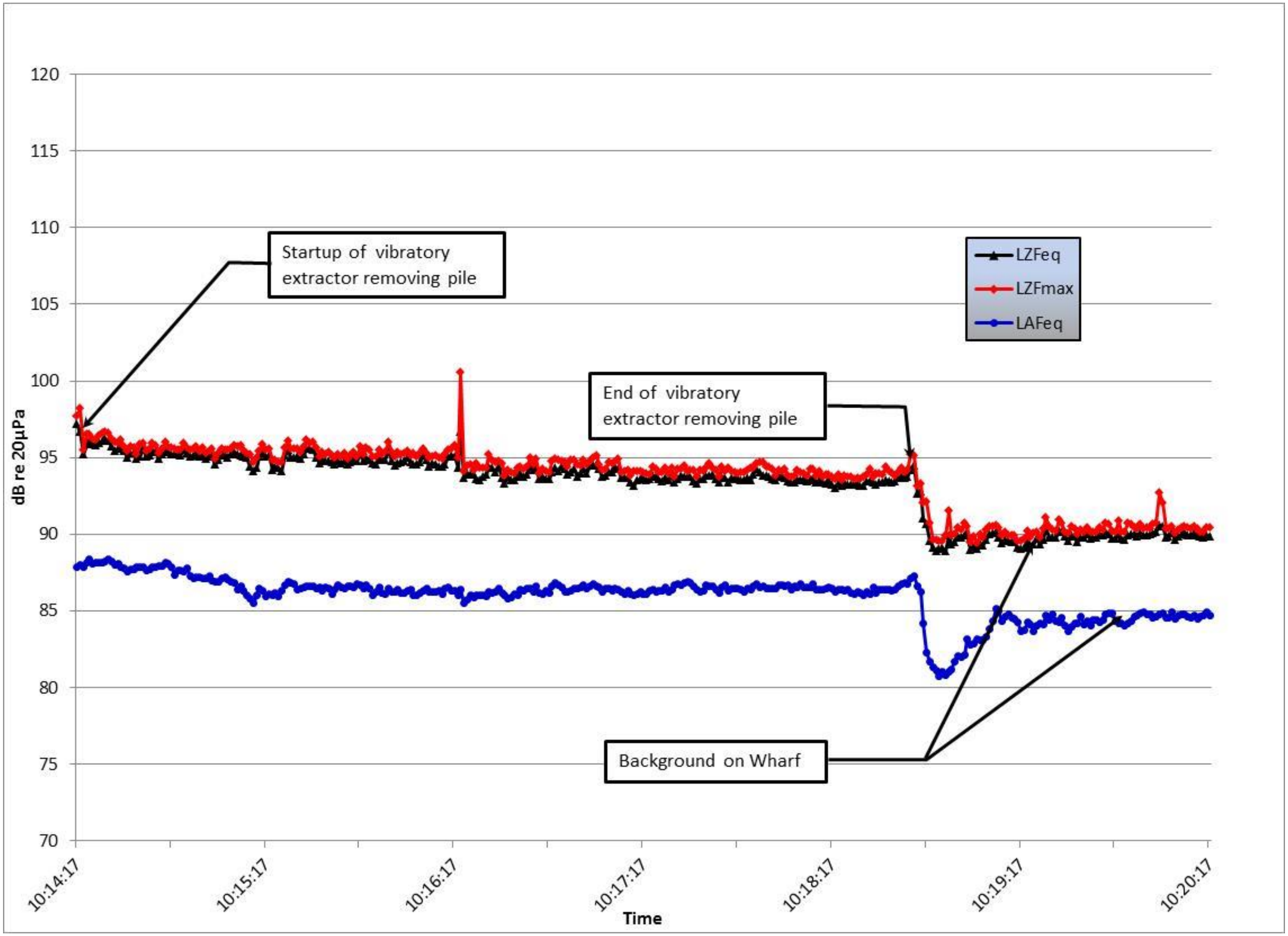


**Figure B-1 – Pile 1 Airborne Noise SPLs Recorded During Removal of ELCS Pile #1 at JEB Little Creek, 10 September 2015.**

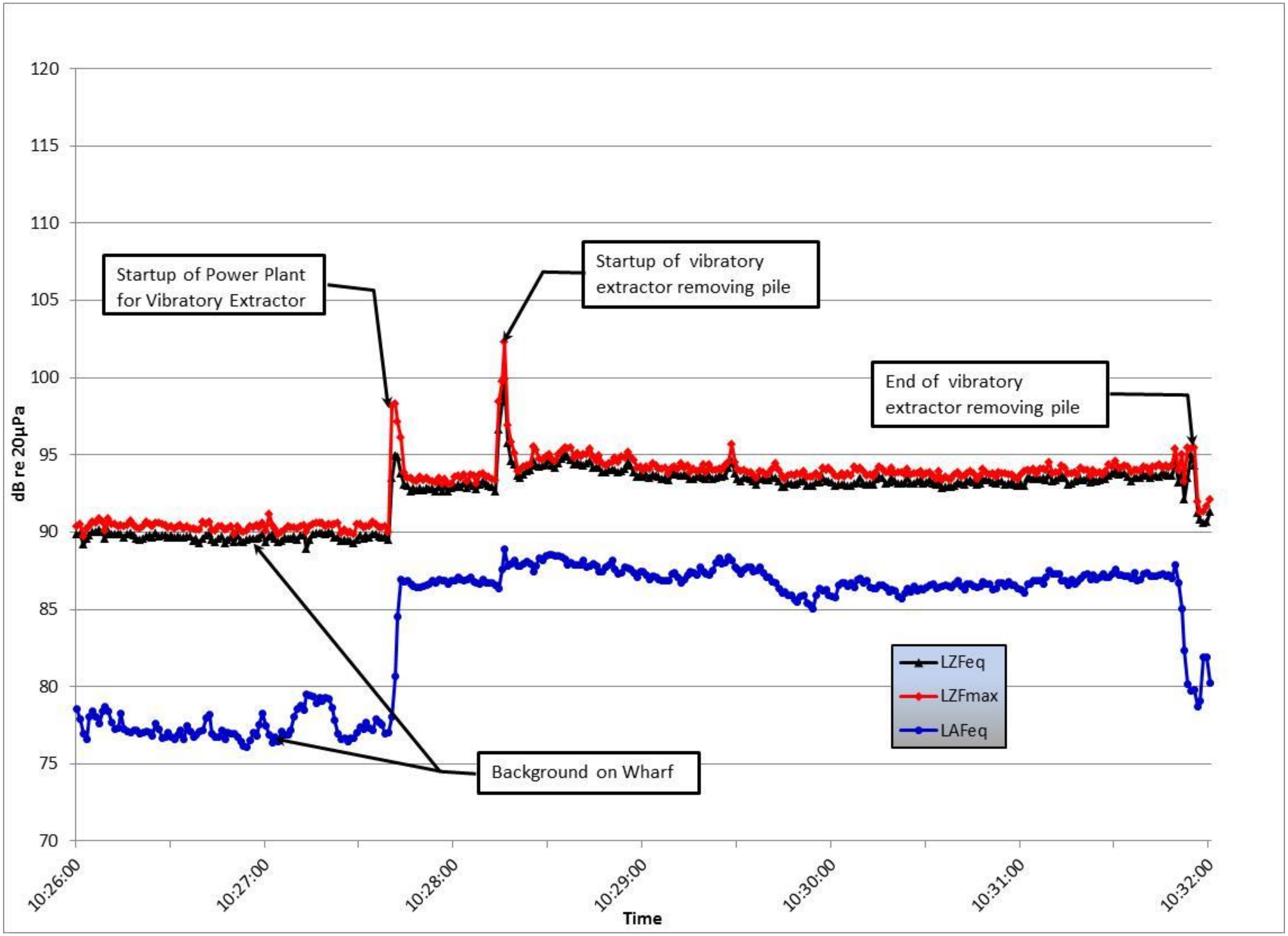


**Figure B-2 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #2 at JEB Little Creek, 10 September 2015.**

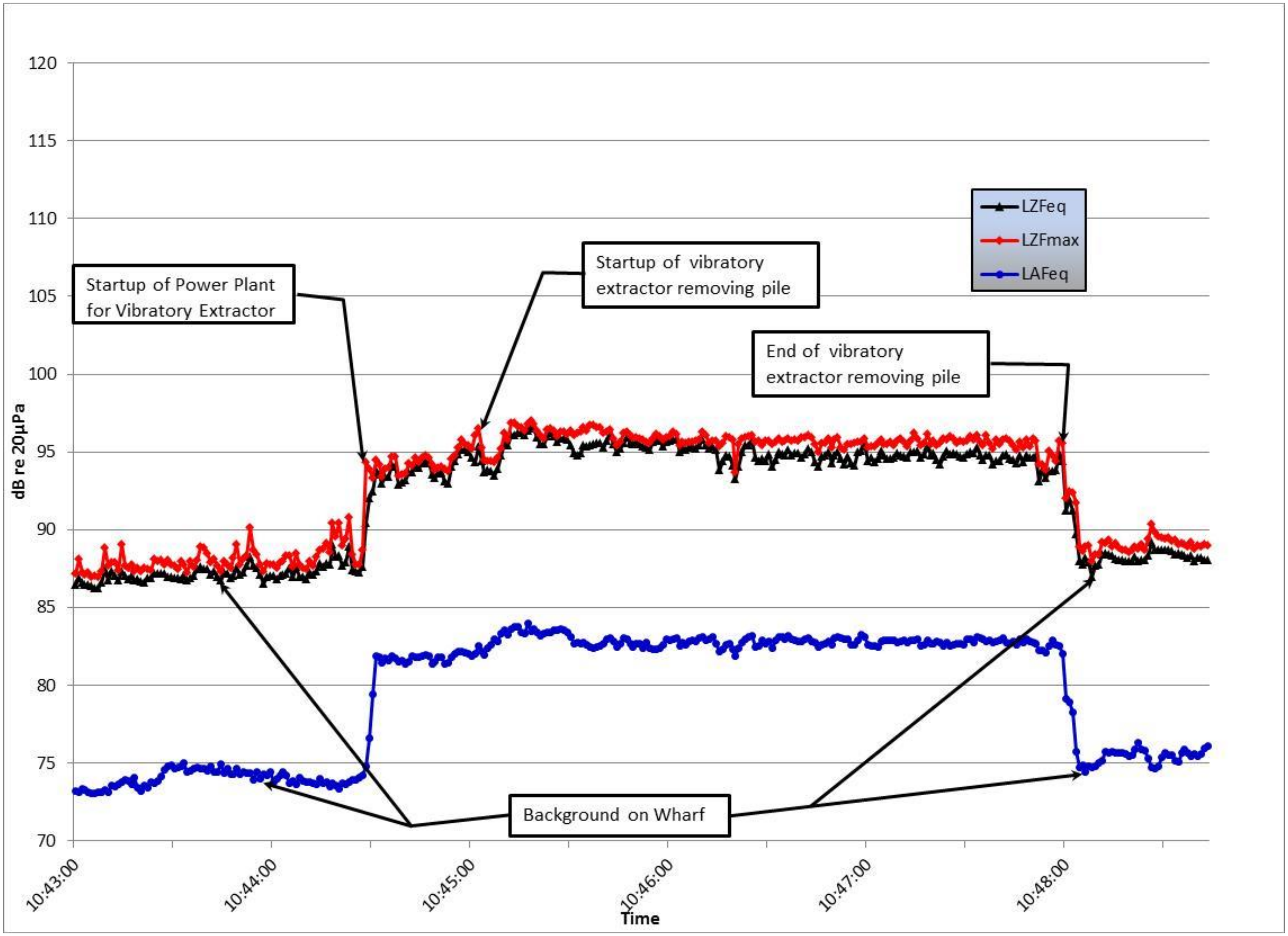


**Figure B-3 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #3 at JEB Little Creek, 10 September 2015.**

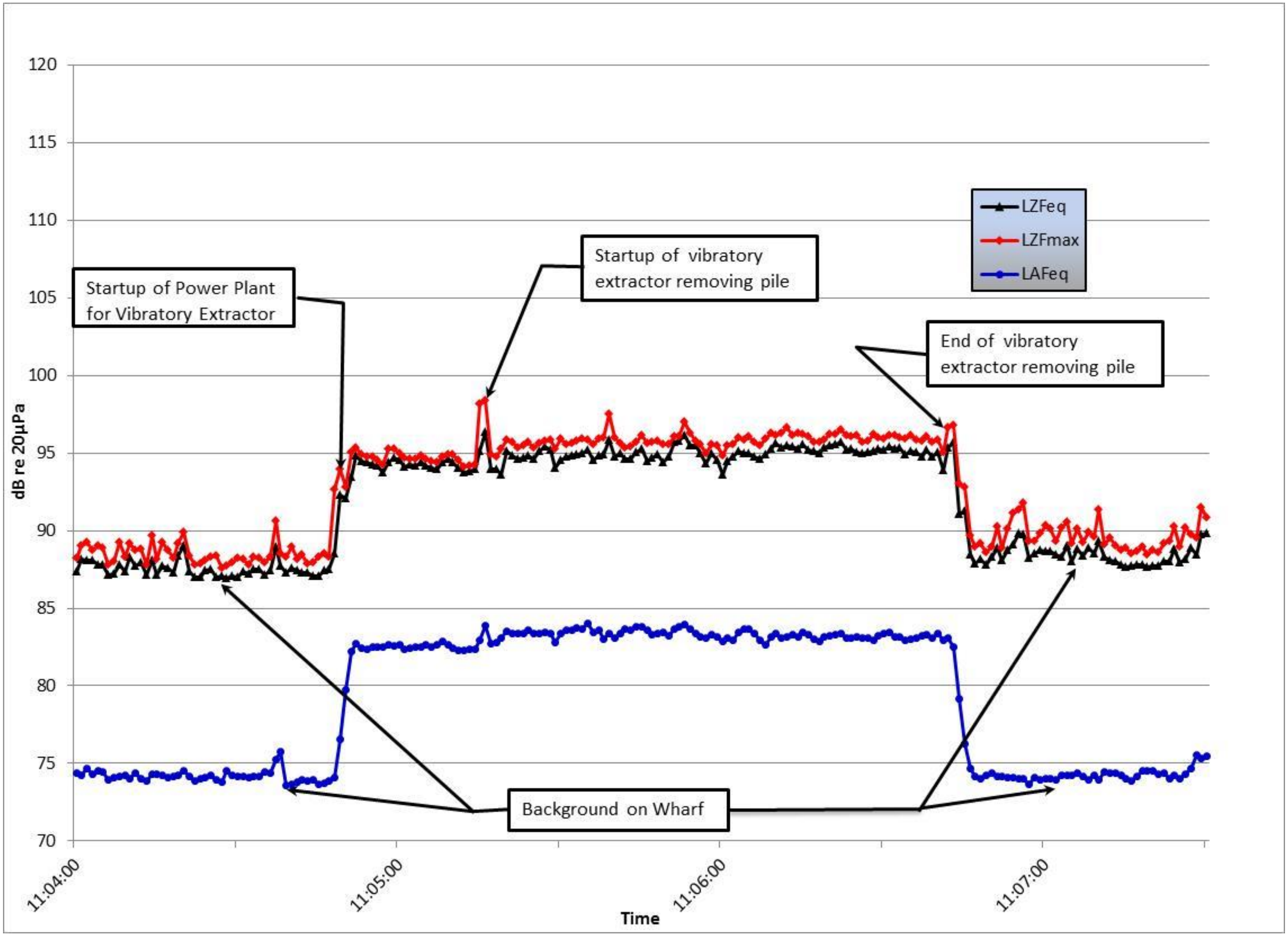


**Figure B-4 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #4 at JEB Little Creek, 10 September 2015.**

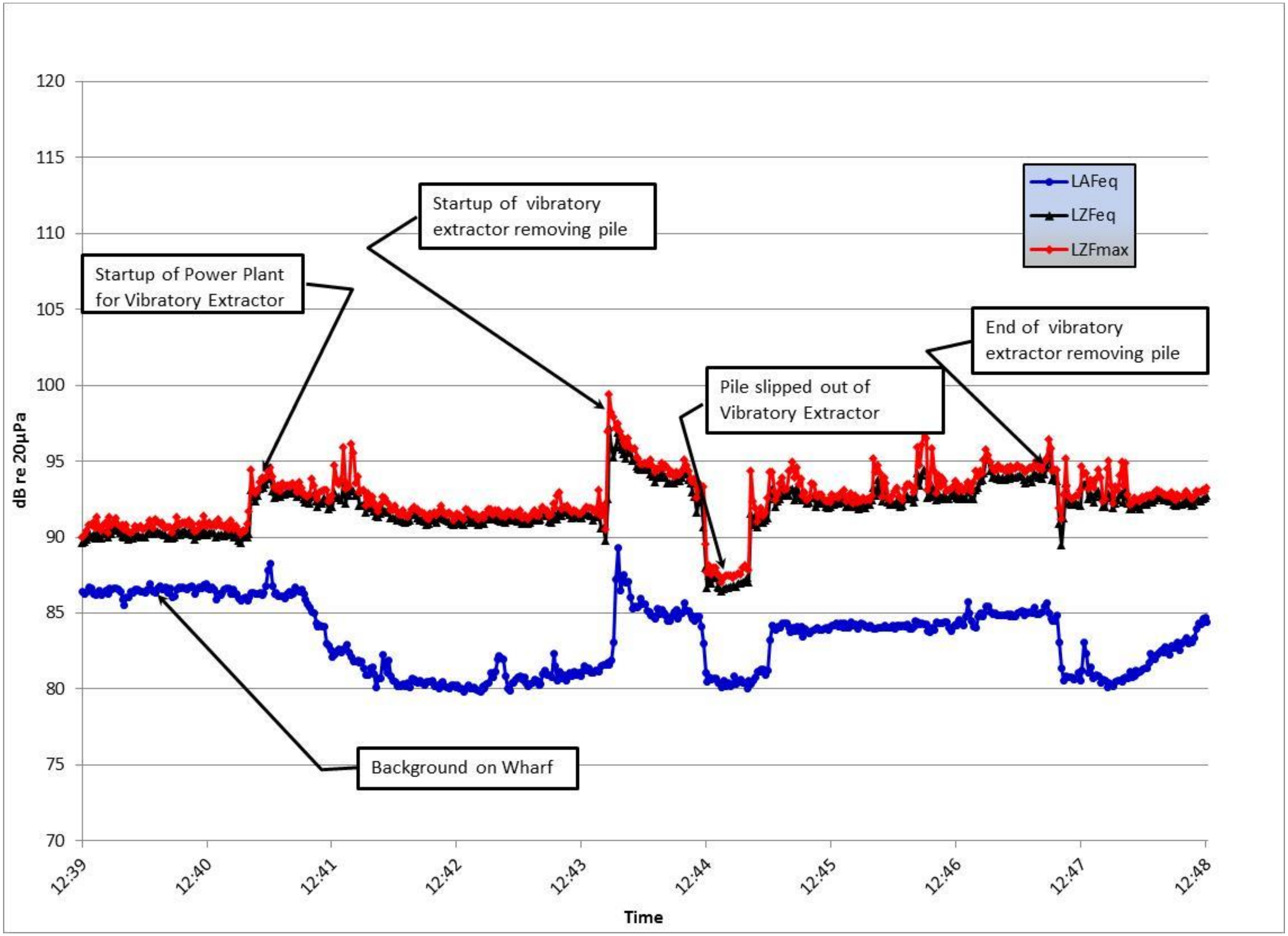


**Figure B-5 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #6 at JEB Little Creek, 10 September 2015.**

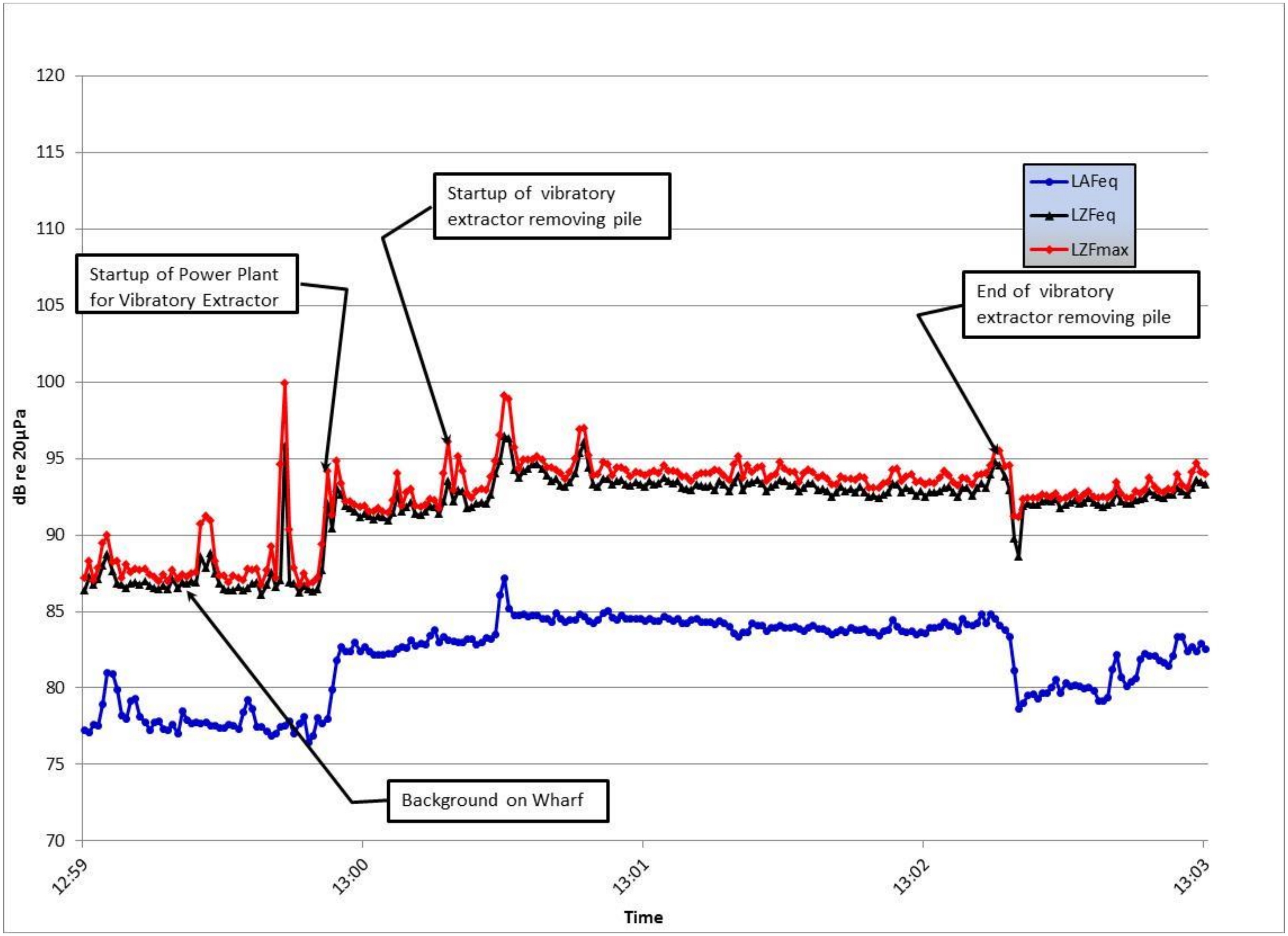


**Figure B-6 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #7 at JEB Little Creek, 10 September 2015.**

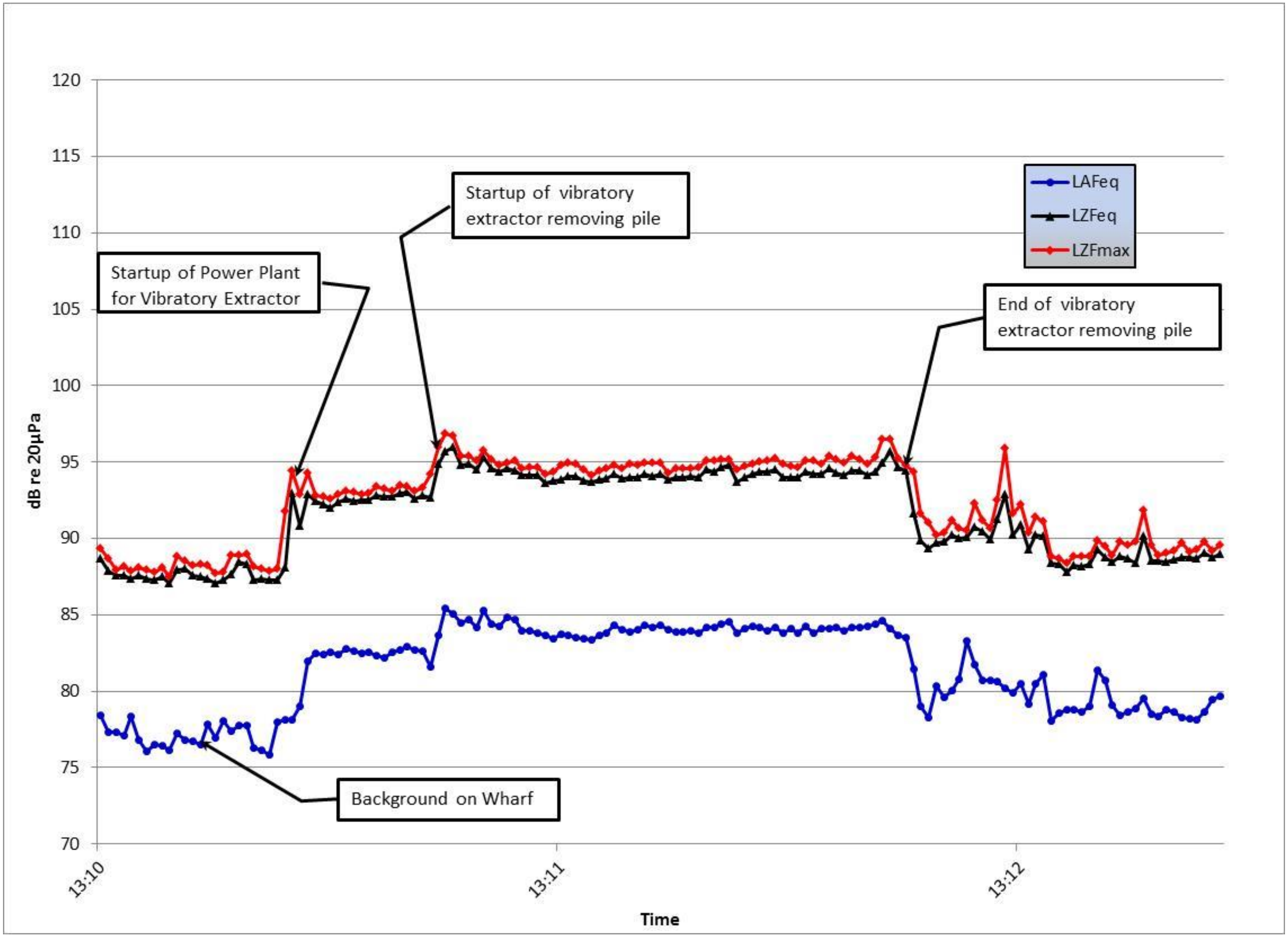


**Figure B-7 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #8 at JEB Little Creek, 10 September 2015.**

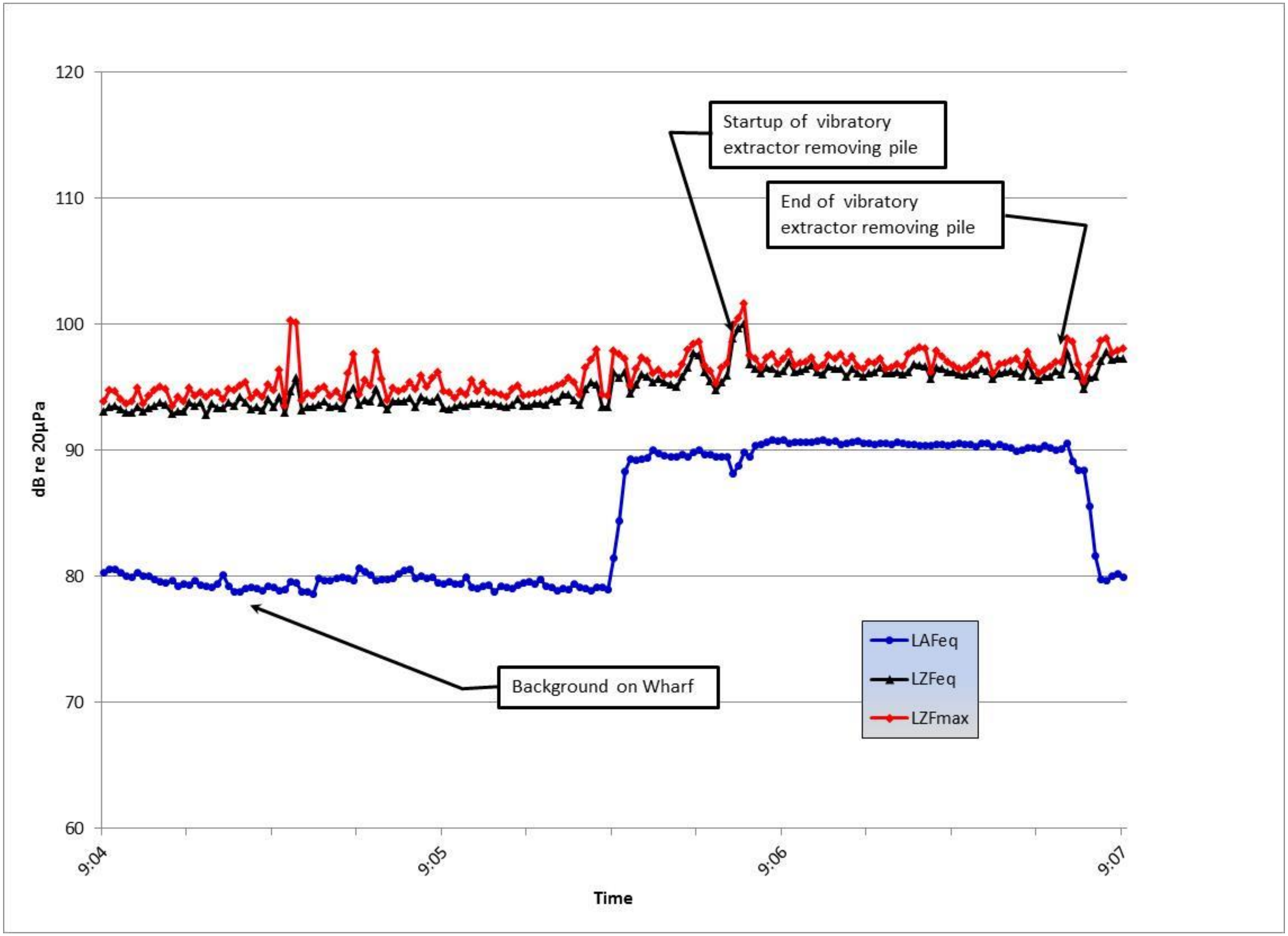


**Figure B-8 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #1-A at JEB Little Creek, 11 September 2015.**

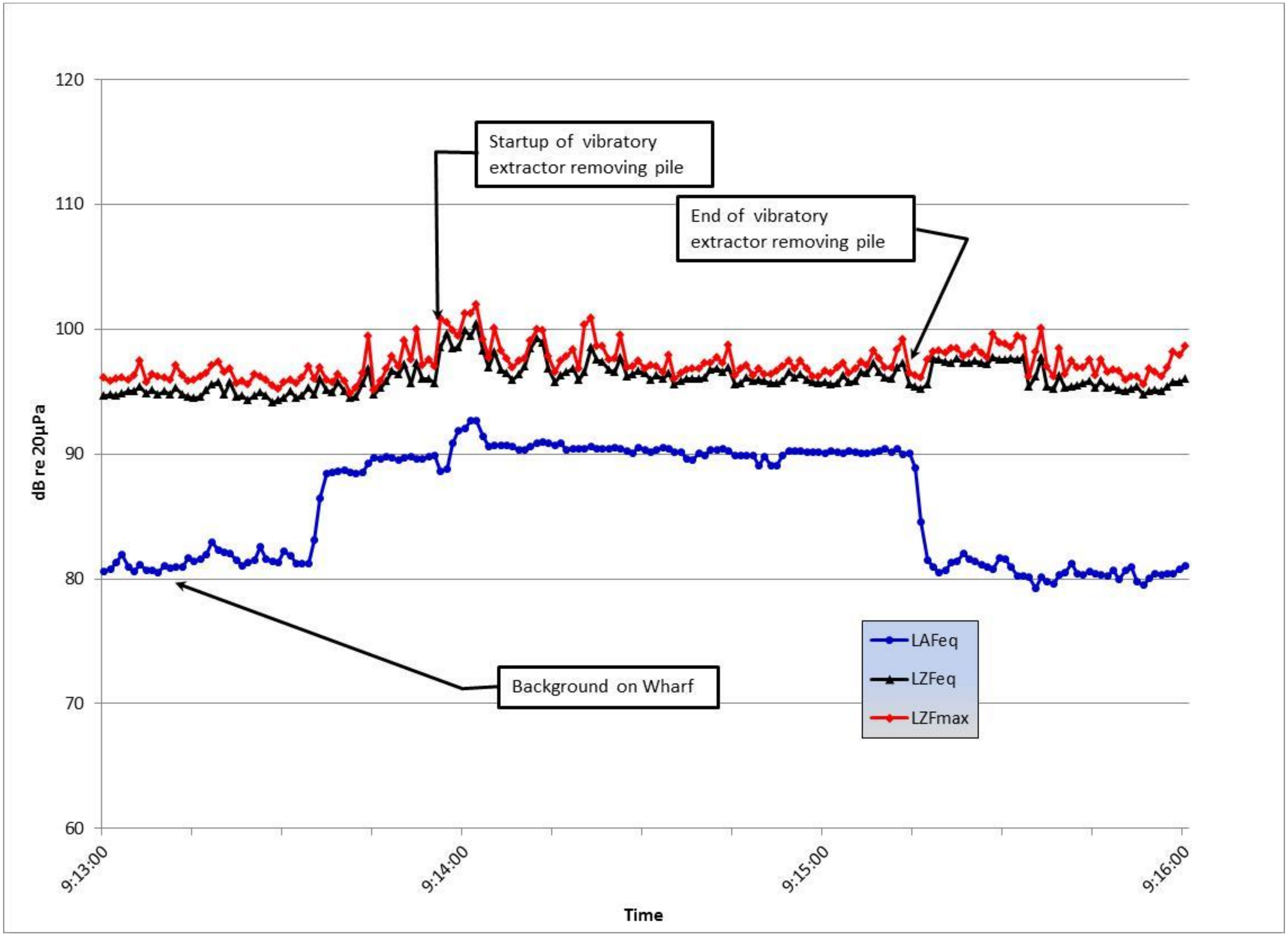


**Figure B-9 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #2-A at JEB Little Creek, 11 September 2015.**

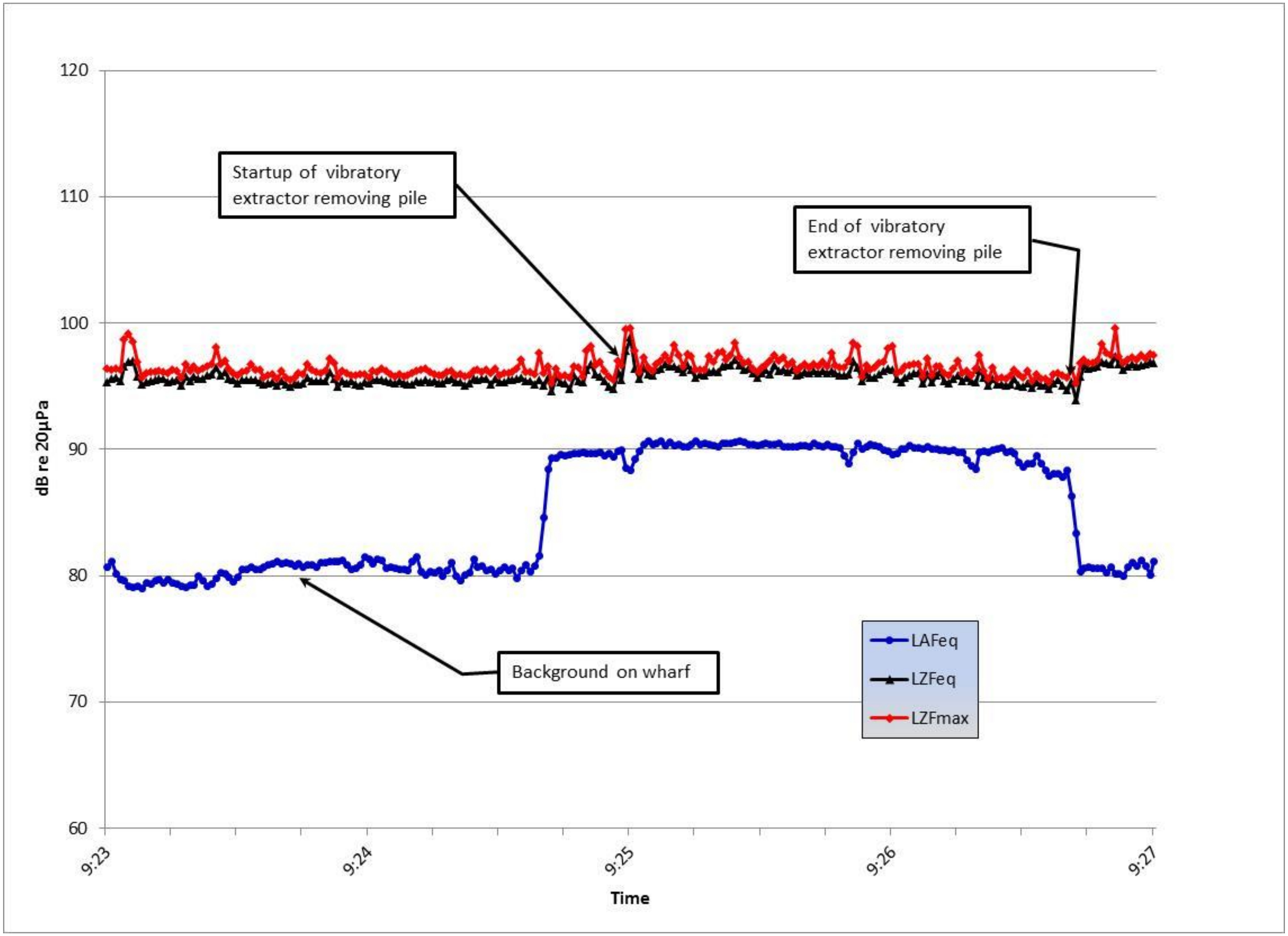


**Figure B-10 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #3-A at JEB Little Creek, 11 September 2015.**

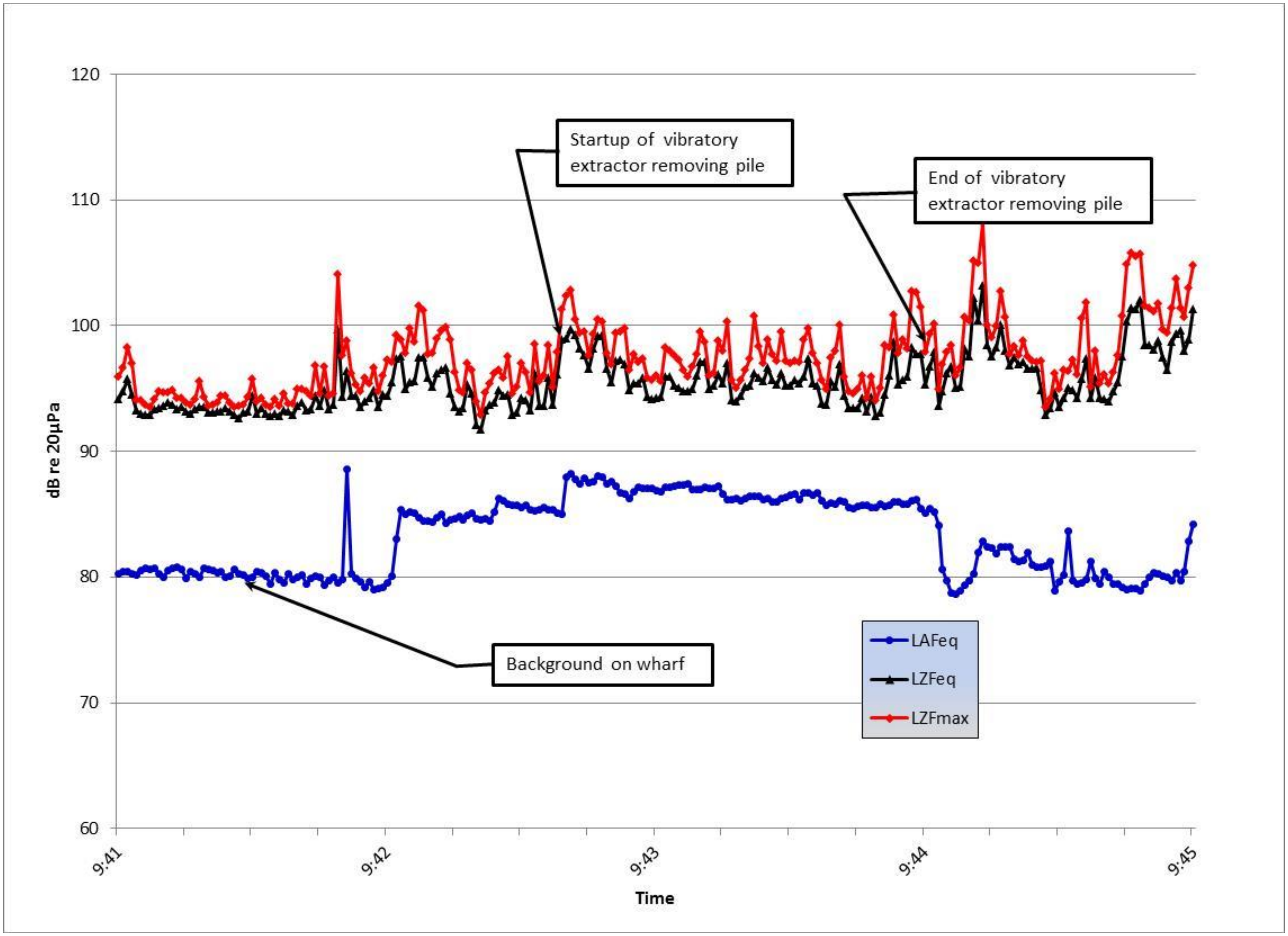


**Figure B-11 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #4A at JEB Little Creek, 11 September 2015.**

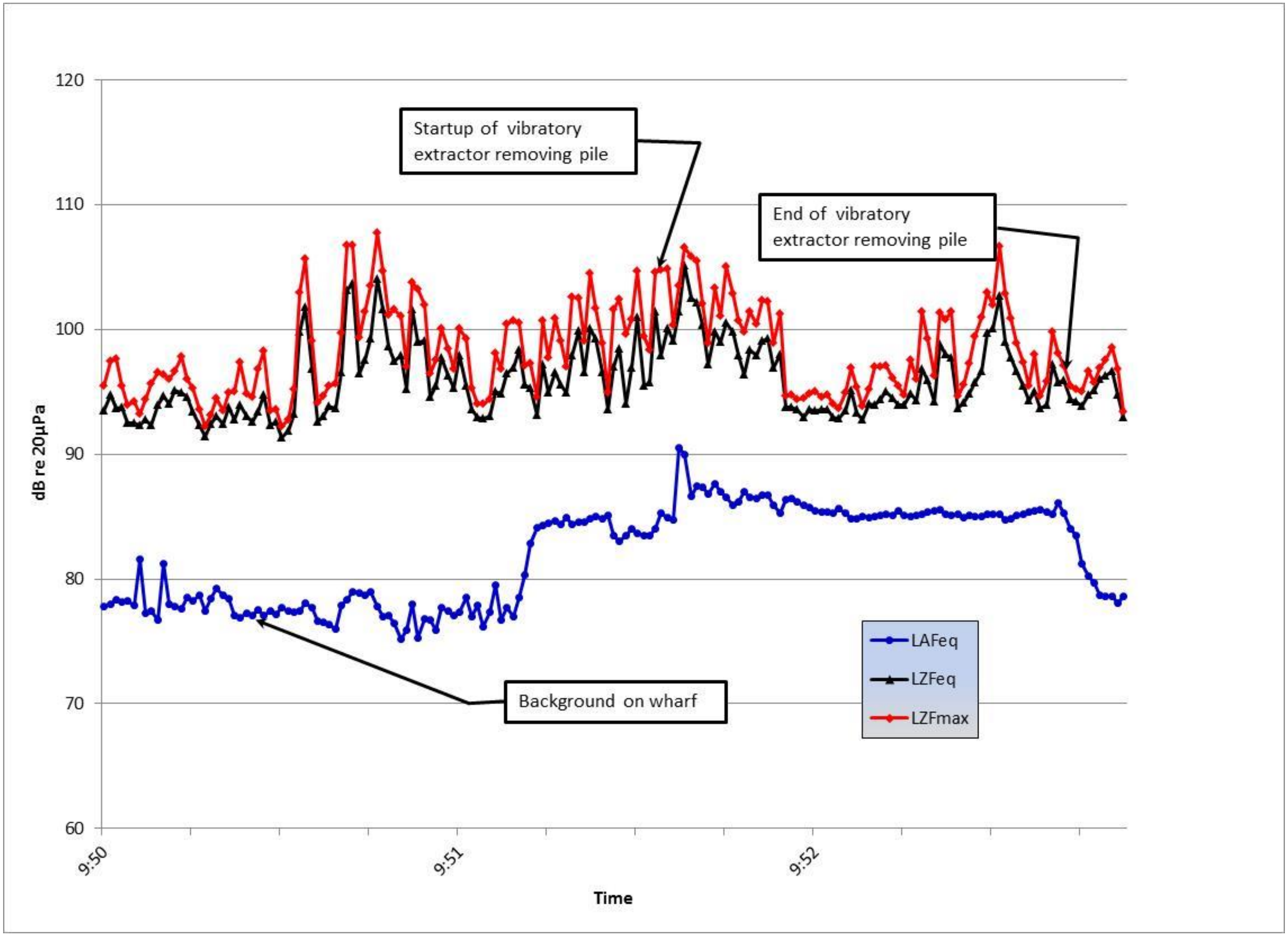


**Figure B-12 – Airborne Noise SPLs Recorded During Removal of ELCS Pile #5A at JEB Little Creek, 11 September 2015.**

**Table B-1 – Distances to Various Noise Sources (meters)**

| Pile | Distance to noise source in meters | | |
|---|---|---|---|
| | Power Plant | Crane | Vibratory Extractor |
| **10 September** | | | |
| 1 | 10 | 5 | 15 |
| 2 | 8 | 5 | 15 |
| 3 | 15 | 15 | 32 |
| 4 | 15 | 15 | 32 |
| 5 | ND | ND | ND |
| 6 | 10 | 5 | 15 |
| 7 | 10 | 5 | 17 |
| 8 | 10 | 5 | 14 |
| **11 September (Wind Contaminated)** | | | |
| 1A | 10 | 5 | 25 |
| 2A | 10 | 5 | 30 |
| 3A | 10 | 5 | 24 |
| 4A | 10 | 5 | 19 |
| 5A | 10 | 5 | 17 |

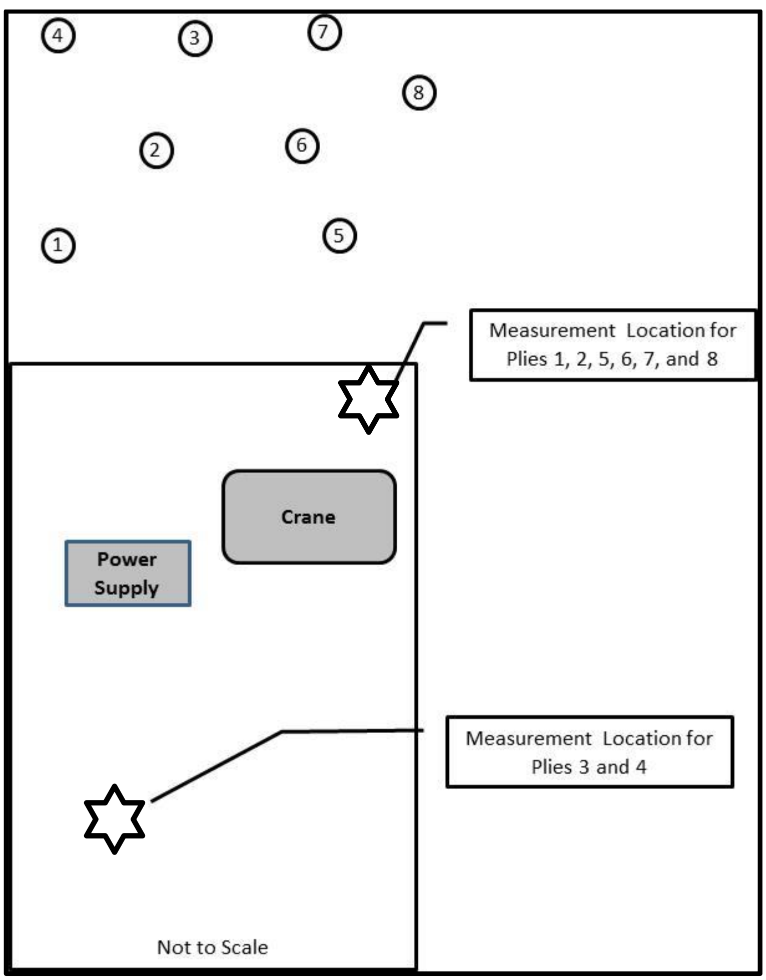


**Figure B-13 –Noise Source relative locations on Wharf**

**Table B-2 – Airborne Data for Sheet Piles (dBA)**

| Date | Pile ID | Start Time | End Time | Duration | LZFeq [1] | LZFmax [1] | LAFeq [1] | Notes |
|---|---|---|---|---|---|---|---|---|
| 9/10/2015 | 1 | 10:14:17 | 10:18:49 | 00:04:35 | 94 | 101 | 87 | Start times indicate when the power plant started. Vibratory extraction commenced approximately 15 to 45 secs following |
| | 2 | 10:27:42 | 10:31:50 | 00:04:08 | 94 | 102 | 87 | |
| | 3 | 10:44:31 | 10:47:54 | 00:03:23 | 95 | 97 | 83 | |
| | 4 | 11:04:51 | 11:06:35 | 00:01:44 | 95 | 98 | 83 | |
| | 5 | N/D | N/D | N/D | N/D | N/D | N/D | |
| | 6 | 12:43:15 | 12:46:34 | 00:03:29 | 94 | 97 | 84 | |
| | 7 | 12:59:53 | 13:02:15 | 00:02:12 | 93 | 99 | 84 | |
| | 8 | 13:10:27 | 13:11:43 | 00:01:16 | 93 | 97 | 85 | |
| 9/11/2015 | 1A | 09:05:50 | 09:06:47 | 00:00:57 | 96[2] | 97[2] | 90 | The high winds had an affect on the measured levels |
| | 2A | 09:13:56 | 09:15:14 | 00:01:18 | 97[2] | 98[2] | 90 | |
| | 3A | 09:24:59 | 09:26:35 | 00:01:36 | 96[2] | 97[2] | 90 | |
| | 4A | 09:42:38 | 09:43:58 | 00:01:20 | 96[2] | 98[2] | 87 | |
| | 5A | 09:51:35 | 09:52:41 | 00:01:06 | 97[2] | 99[2] | 85 | |

[1] LZeq and LAeq are the average over the whole event and the LZFmax is the maximum level during the event.
N/D – No Data due to battery problem with the SLM

### Table B-3 – One-Minute Data – The Areas Shaded Gray are When Pile Extractions Occurred (dBA)

| Time | Lzeq | Lzmax | Laeq |
|---|---|---|---|
| **10 September – 15 AM** | | | |
| 10:15:00 | 94.9 | 96.1 | 86.5 |
| 10:16:00 | 94.3 | 100.6 | 86.3 |
| 10:17:00 | 93.7 | 95.1 | 86.4 |
| 10:18:00 | 92.8 | 95.2 | 85.8 |
| 10:19:00 | 89.7 | 91.1 | 84.3 |
| 10:20:00 | 90.1 | 92.7 | 85.0 |
| 10:21:00 | 90.1 | 91.2 | 84.9 |
| 10:22:00 | 90.1 | 91.0 | 84.8 |
| 10:23:00 | 90.1 | 91.1 | 84.7 |
| 10:24:00 | 92.7 | 100.0 | 85.2 |
| 10:25:00 | 90.6 | 98.7 | 79.4 |
| 10:26:00 | 89.7 | 90.9 | 77.3 |
| 10:27:00 | 91.1 | 98.3 | 82.6 |
| 10:28:00 | 94.4 | 102.3 | 87.7 |
| 10:29:00 | 93.4 | 95.7 | 87.0 |
| 10:30:00 | 93.2 | 94.2 | 86.5 |
| 10:31:00 | 93.4 | 95.5 | 86.6 |
| 10:35:00 | 90.4 | 91.4 | 80.0 |
| 10:36:00 | 90.0 | 91.2 | 79.9 |
| 10:37:00 | 89.6 | 90.5 | 79.1 |
| 10:38:00 | 89.8 | 91.9 | 79.4 |
| 10:39:00 | 90.6 | 93.2 | 80.1 |
| 10:40:00 | 90.7 | 93.8 | 79.8 |
| 10:41:00 | 92.6 | 103.7 | 80.6 |
| 10:42:00 | 86.8 | 88.9 | 74.2 |
| 10:43:00 | 87.0 | 90.2 | 74.1 |
| 10:44:00 | 91.8 | 95.8 | 79.4 |
| 10:45:00 | 95.5 | 97.0 | 82.9 |
| 10:46:00 | 94.9 | 96.3 | 82.8 |
| 10:47:00 | 94.6 | 96.2 | 82.7 |
| 10:48:00 | 89.1 | 95.0 | 75.7 |
| 10:49:00 | 89.1 | 98.8 | 73.9 |
| 10:50:00 | 86.9 | 94.4 | 72.8 |
| 10:51:00 | 86.5 | 88.8 | 72.7 |
| 10:52:00 | 86.3 | 90.3 | 73.5 |
| 10:53:00 | 86.0 | 88.1 | 73.1 |
| 10:54:00 | 86.2 | 92.3 | 72.7 |
| 10:55:00 | 86.2 | 91.1 | 72.4 |
| 10:56:00 | 86.0 | 88.3 | 72.8 |
| 10:57:00 | 85.8 | 89.1 | 73.1 |
| 10:58:00 | 85.9 | 87.7 | 72.7 |
| 10:59:00 | 88.0 | 95.2 | 74.0 |
| 11:00:00 | 86.0 | 91.1 | 69.5 |
| 11:01:00 | 86.7 | 90.8 | 70.1 |
| 11:02:00 | 87.7 | 91.2 | 74.1 |
| 11:03:00 | 87.8 | 92.1 | 74.2 |
| 11:04:00 | 89.7 | 95.3 | 77.0 |
| 11:05:00 | 94.8 | 98.4 | 83.2 |
| 11:06:00 | 94.1 | 96.8 | 82.0 |
| 11:07:00 | 88.4 | 93.6 | 74.3 |
| 11:08:00 | 88.3 | 90.6 | 74.7 |
| 11:09:00 | 88.0 | 90.1 | 73.8 |
| 11:10:00 | 88.4 | 93.0 | 73.5 |
| **10 September – 15 PM** | | | |
| 12:36:00 | 90.3 | 95.5 | 86.1 |
| 12:37:00 | 89.9 | 91.1 | 86.3 |
| 12:38:00 | 90.1 | 91.4 | 86.4 |
| 12:39:00 | 90.2 | 91.4 | 86.5 |
| 12:40:00 | 92.0 | 94.6 | 86.1 |
| 12:41:00 | 91.7 | 96.1 | 81.1 |
| 12:42:00 | 91.2 | 93.0 | 80.7 |
| 12:43:00 | 93.8 | 99.4 | 84.7 |
| 12:44:00 | 91.0 | 94.9 | 82.6 |
| 12:45:00 | 92.6 | 97.4 | 84.1 |
| 12:46:00 | 93.5 | 96.4 | 84.4 |
| 12:47:00 | 92.4 | 95.0 | 82.1 |
| 12:48:00 | 93.4 | 99.1 | 86.1 |
| 12:49:00 | 93.0 | 93.8 | 85.8 |
| 12:50:00 | 93.0 | 95.4 | 85.5 |
| 12:51:00 | 92.9 | 94.6 | 84.0 |
| 12:52:00 | 92.7 | 94.6 | 83.6 |
| 12:53:00 | 92.8 | 93.7 | 84.1 |
| 12:54:00 | 92.8 | 93.5 | 84.1 |
| 12:55:00 | 92.9 | 94.9 | 84.7 |
| 12:56:00 | 90.2 | 94.9 | 84.3 |
| 12:57:00 | 87.0 | 96.5 | 79.3 |
| 12:58:00 | 87.2 | 92.2 | 78.9 |
| 12:59:00 | 88.4 | 99.9 | 78.7 |
| 13:00:00 | 93.2 | 99.1 | 84.0 |
| 13:01:00 | 93.1 | 95.1 | 84.0 |
| 13:02:00 | 92.6 | 95.6 | 82.3 |
| 13:03:00 | 93.2 | 96.0 | 83.2 |
| 13:04:00 | 93.3 | 94.7 | 83.7 |
| 13:05:00 | 93.1 | 95.9 | 83.4 |
| 13:06:00 | 93.1 | 94.7 | 83.4 |
| 13:07:00 | 93.1 | 96.3 | 84.4 |
| 13:08:00 | 88.8 | 98.1 | 81.2 |
| 13:09:00 | 88.1 | 94.4 | 79.2 |
| 13:10:00 | 92.0 | 96.8 | 81.7 |
| 13:11:00 | 93.6 | 96.5 | 83.4 |
| **11-September-15** | | | |
| 8:52:00 | 91.9 | 94.3 | 81.6 |
| 8:53:00 | 93.0 | 99.7 | 86.3 |
| 8:54:00 | 95.8 | 105.9 | 90.4 |
| 8:55:00 | 92.7 | 96.3 | 85.6 |
| 8:56:00 | 92.3 | 95.8 | 80.2 |
| 8:57:00 | 91.9 | 96.7 | 79.9 |
| 8:58:00 | 93.4 | 105.1 | 80.1 |
| 8:59:00 | 92.9 | 103.5 | 80.4 |
| 9:00:00 | 91.8 | 94.7 | 79.9 |
| 9:01:00 | 92.1 | 95.8 | 79.9 |
| 9:02:00 | 92.5 | 99.9 | 84.6 |
| 9:03:00 | 93.6 | 99.7 | 80.3 |
| 9:04:00 | 93.7 | 100.3 | 85.6 |
| 9:05:00 | 95.4 | 101.6 | 90.3 |
| 9:06:00 | 96.3 | 98.8 | 88.1 |
| 9:07:00 | 95.6 | 99.1 | 80.6 |
| 9:08:00 | 93.5 | 98.1 | 80.7 |
| 9:09:00 | 93.5 | 100.8 | 80.7 |
| 9:10:00 | 93.1 | 99.3 | 81.3 |
| 9:11:00 | 96.3 | 105.1 | 82.3 |
| 9:12:00 | 95.2 | 98.9 | 82.1 |
| 9:13:00 | 95.6 | 100.9 | 81.7 |
| 9:14:00 | 96.9 | 101.9 | 81.8 |
| 9:15:00 | 96.3 | 100.0 | 81.5 |
| 9:16:00 | 96.3 | 100.8 | 81.7 |
| 9:17:00 | 94.5 | 102.4 | 81.0 |
| 9:18:00 | 95.4 | 102.5 | 80.2 |
| 9:19:00 | 95.0 | 101.9 | 83.2 |
| 9:20:00 | 93.9 | 97.8 | 80.6 |
| 9:21:00 | 93.7 | 97.9 | 80.5 |
| 9:22:00 | 94.5 | 98.4 | 85.9 |
| 9:23:00 | 95.5 | 99.2 | 86.4 |
| 9:24:00 | 95.5 | 99.5 | 81.1 |
| 9:25:00 | 96.2 | 99.5 | 81.2 |
| 9:26:00 | 95.8 | 99.5 | 81.9 |
| 9:27:00 | 97.2 | 103.2 | 81.9 |
| 9:28:00 | 96.0 | 98.8 | 80.7 |
| 9:29:00 | 94.8 | 100.2 | 82.2 |
| 9:30:00 | 97.6 | 106.1 | 77.8 |
| 9:31:00 | 99.0 | 106.3 | 85.0 |
| 9:32:00 | 96.9 | 106.2 | 81.6 |
| 9:33:00 | 98.5 | 105.4 | 86.3 |
| 9:34:00 | 96.7 | 101.2 | 90.4 |
| 9:35:00 | 96.0 | 98.8 | 85.6 |
| 9:36:00 | 96.5 | 99.6 | 80.2 |
| 9:37:00 | 96.6 | 104.3 | 79.9 |
| 9:38:00 | 96.5 | 101.3 | 80.1 |
| 9:39:00 | 94.3 | 98.6 | 80.4 |
| 9:40:00 | 95.4 | 102.1 | 79.9 |
| 9:41:00 | 93.9 | 104.1 | 79.9 |
| 9:42:00 | 96.0 | 102.8 | 84.6 |
| 9:43:00 | 95.5 | 102.7 | 80.3 |
| 9:44:00 | 97.7 | 108.2 | 85.6 |
| 9:45:00 | 98.9 | 107.7 | 90.3 |
| 9:46:00 | 101.2 | 108.0 | 88.1 |
| 9:47:00 | 101.8 | 111.6 | 80.6 |
| 9:48:00 | 95.6 | 109.5 | 80.7 |
| 9:49:00 | 93.7 | 100.6 | 80.7 |
| 9:50:00 | 96.8 | 107.7 | 81.3 |
| 9:51:00 | 98.1 | 106.6 | 82.3 |

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