

New York State Department of Environmental Conservation

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Joe Martens
Commissioner

October 17, 2013

[REDACTED] Project Director
The New NY Bridge Project
NYS Thruway Authority
303 South Broadway, Suite 413
Tarrytown, NY 10591

Re: The New NY Bridge / DEC Permit 3-9903-00043/00012
**Underwater Noise Attenuation System Main Span Design Unit for the
Tappan Zee Hudson River Crossing Revision 3 October 15, 2013**

Dear [REDACTED]

In accordance with condition 9 of the subject permit the Department hereby approves the subject Noise Attenuation System submitted via an October 16, 2013 email to me from [REDACTED] of your office.

As permit condition 76 states, with this approval the plan and its terms, conditions, schedule and requirements become an enforceable condition of the subject permit.

If you have any questions please feel free to contact me.

Respectfully,

[REDACTED]
Chief Permit Administrator

ecc: [REDACTED] NYSDEC
[REDACTED] NYSDEC
[REDACTED] NYSDOT

**Description of Underwater Noise Attenuation
System
Main Span Design Unit
for the
Tappan Zee Hudson River Crossing**

**Revision 3
October 15, 2013**

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Document History			
Issue Date	Description	By	Revision
9/16/2013	Issued to NYSDEC for permit condition 9.	VW	1
10/7/2013	Responded to NYSTA comments on Rev 1.	VW	2
10/15/2013	Responded to NYSTA comments on Rev 2.	VW	3

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Attachment 1 – Daily Memoranda for Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile Installation

Attachment 2 – Design Plans for the Multi-Tier Bubble Curtain (Drawings 1UBCR through 10UBCR)

Attachment 3 – Air Compressor Specifications

1.0 Introduction

The Pile Load Test (PLT) Program includes an underwater noise monitoring program for the installation of the test piles. The purpose of this noise monitoring program is to confirm that the underwater noise attenuation system (NAS) intended for use during production impact pile driving achieves its design goal of minimizing (to the maximum extent practicable) the effects of underwater sound upon fishes in the Hudson River. This program is being conducted pursuant to the following Tappan Zee Hudson River Crossing project requirements:

- New York State Thruway Authority (NYSTA) Tappan Zee Hudson River Crossing Project DB Contract Document Part 3 Project Requirements, Section 3 (P3PR3) Environmental Compliance, Conformed November 2012 and other applicable sections;
- New York State Department of Environmental Conservation (NYSDEC) DEC ID 3-9903-00043/00012-0014 (NYSDEC Permit); and
- National Marine Fisheries Service (NMFS) Biological Opinion (BO) April 10, 2013.

Underwater noise monitoring is conducted to verify that the NAS is deployed and operating in accordance with design specifications and determine compliance with underwater noise attenuation requirements.

Tappan Zee Constructors, LLC, (TZC) provided NYSTA and NYSDEC a report titled *Description of Pile Load Test Program and Underwater Noise Attenuation System for the Tappan Zee Hudson River Crossing (PLT-NAS Description)* in July 2013 that compared the NASs that were considered based on the 2012 Pile Installation Demonstration Program (PIDP) and described the multi-tier bubble curtain which was selected for further testing. The *PLT-NAS Description* indicates the following criteria are being used to determine the effectiveness of the NAS:

1. Attenuation – System has achieved at least a 10dB single strike sound exposure level (SEL) reduction or attenuation during impact pile driving;
2. Ensonified Area – System has attenuated underwater noise to achieve the distances to the required NMFS and NYSDEC thresholds during pile driving established by the BO Term and Condition 9 and NYSDEC Permit Condition 14; and
3. System Operation and Compatibility – System can be safely deployed and retrieved repeatedly during production piling without impact to pile driving requirements and project schedule.

That report demonstrated that the multi-tier bubble curtain can achieve at least a 10 dB SEL attenuation during impact pile driving and that the system could be safely deployed and retrieved repeatedly during production piling. As such, the multi-tier bubble curtain was selected for further testing during test pile installation. The *PLT-NAS Description* also provided a plan for testing the NAS, to determine whether or not the required distances to the NMFS and NYSDEC thresholds are being achieved.

Test pile installation monitoring results provide guidance on operational specifications of the underwater sound attenuation system monitoring, as well as the monitoring locations for production piling. The purpose of this report is to provide the results of the underwater noise monitoring of the installation of test piles for the main span design unit (see Attachment 1) and based on those results, provide the design plans and anticipated operational specifications for the noise attenuation system for the main span in accordance with the following NYSDEC Permit requirements:

8. The results of sound attenuation tests conducted during the 2012 Pile Installation Demonstration Program (PIDP); and any additional test results from underwater sound attenuation studies during the 2013 PIDP2 will be used to determine the most effective

underwater sound attenuation system. An underwater sound attenuation system or systems must be deployed during driving of steel piles four feet and larger in diameter to minimize to the maximum extent practicable the effects of underwater sound upon fishes in the Hudson River.

9. At least 30 days before starting installation of permanent piles four feet in diameter or more within each specific in-river design unit (as identified in the March 21, 2013 letter) the Permittee must give the Department design plans and operational specifications for the underwater sound attenuation system for that design unit. Except for piles installed during the 2013 PIDP2, installation of piles four feet and larger in diameter may begin when the Department has given written approval of the underwater sound attenuation system for each in-river design unit. Upon Department approval the final sound attenuation plan will be posted on the project website maintained by the Permittee.

2.0 Installation of Test Piles

The Pile Load Test Program utilize test piles in each of the ten (10) Design Units plus the Main Span (eleven [11] total design units), with the primary purpose to confirm pile load capacities. Test pile installation commenced at the Main Span Design Unit on July 24, 2013, when the PLT- [REDACTED] pile was installed with [REDACTED]. The first section of each test pile was installed with the [REDACTED]. The second section of each test pile was [REDACTED] and then driven with an [REDACTED]. A summary of the pile installation test piles at the Main Span Design Unit is provided in **Table 1**.

Table 1. Summary of Test Pile Installation for the Main Span Design Unit

Test Pile	Pile Diameter	Date	
		[REDACTED]	[REDACTED]
PLT- [REDACTED]	[REDACTED]	7/24/2013	7/31/2013
PLT- [REDACTED]		7/27/2013	8/3/2013
PLT- [REDACTED]		8/10/2013	8/19/2013

3.0 Unconfined Multi-tier Air Bubble Curtain NAS Design

Based on the NAS effectiveness determination in the *PLT-NAS Description*, the unconfined multi-tier bubble curtain was selected for further testing during test-pile installation. Refer to Attachment 2, Drawings 1UBCR through 10UBCR, for engineering details on the system.

3.1.1 NAS Components

The unconfined multi-tier bubble curtain consists of aluminum bubbler rings suspended from the pile-driving template at four points, spaced a maximum of 10 feet vertically, and connected to each other using ½"-diameter wire rope. See Drawing 7UBCR of Attachment 2 for bubbler ring dimensions and Drawing 7UBCR details including hole diameter, spacing, and orientation for the NAS for [REDACTED] piles.

Rather than connecting multiple rings to a single larger compressor and having one ring receiving more air than the rest, each ring was connected to its own compressor (Figures 1). Each compressor was connected to a reservoir tank to allow a continuous supply of air throughout pile driving (Figure 2). During the installation of test piles, a flow meter and air pressure gauge were used to measure air flow and air pressure (Figure 3). However, the air flow meter will not be available during production pile driving. The air compressor is capable of supplying an air pressure of up to 100 pounds per square inch (psi) or an air flow of 1600 cubic feet per meter (cfm) to each bubbler ring (Attachment 3). However, because of the reservoir

tank, the system is capable of supplying an air flow of up to 2000 cfm, to each bubbler ring, as was observed during testing.



Figure 1. Air Compressors and Reservoir Tanks on the Air Compressor Barge



Figure 2. Reservoir Tanks on the Air Compressor Barge

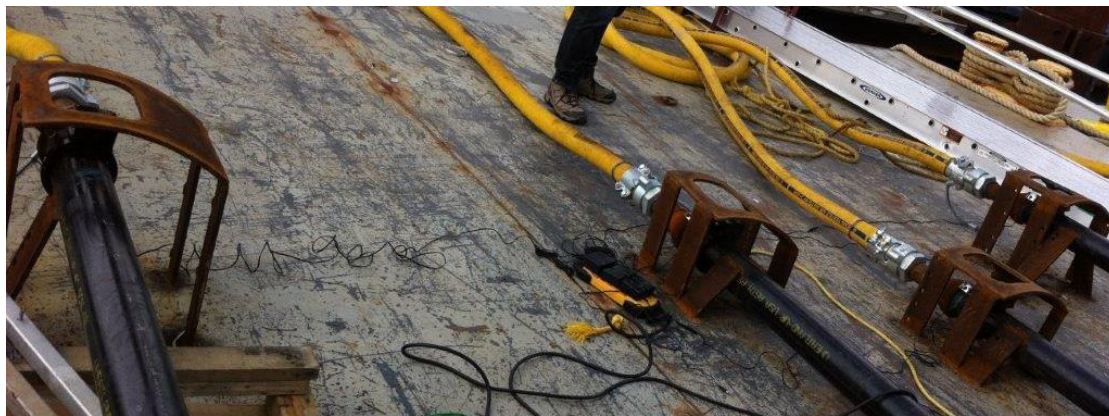
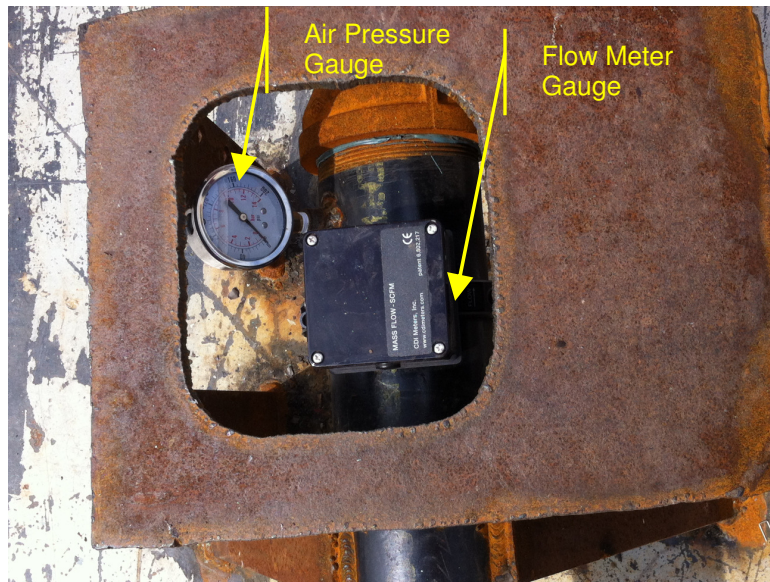


Figure 3. Flow Meters and Pressure Gauges on Outlets from the Reservoir Tank to the Bubbler Rings

3.1.2 NAS Deployment and Operation

The NAS deployment and operation proceeded as expected. After the piles were driven with the vibratory hammer, the bubble curtain rings were deployed around the perimeter of the piles with a crane and hung from the secondary template using wire rope slings and shackles (Figure 4). The air compressors/reservoir tanks pumped air into the rings, the impact hammer was lofted, the piles were tapped (i.e., a series of minimal energy strikes), and then driven to the required depth (Figure 5).



Figure 4. Deployment of the Unconfined Multi-tier Bubble Curtain



Figure 5. Operation of the Multi-Tier Bubble Curtain

4.0 Underwater Noise Monitoring During Test Pile Installation

4.4 Methods

Details of the equipment, the calibration of the equipment, the data collected, and the signal processing for underwater monitoring are included in the Underwater Noise Monitoring Plan. Details on the underwater noise monitoring for PLT [REDACTED] PLT [REDACTED] and PLT [REDACTED] are provided in the Daily Memoranda for each day of pile driving (Attachment 1).

Figure 6 provides standard barge and hydrophone set up. As illustrated in Figure 6, hydrophones were generally placed at the distances of the noise level thresholds predicted in the NMFS BO (although locations varied based on conditions, such as vessel traffic and tides), as follows:

- peak SPL (sound pressure level) – located on the barge or survey vessel, approximately 100 feet from the pile, based on the distance from the pile to the 206 re 1 μPa peak SPL isopleth for [REDACTED] piles
- cSEL (cumulative Sound Exposure Level) - located approximately 505 feet from the pile, based on the distance from the pile to the 187 dB re 1 $\mu\text{Pa}^2\text{-s}$ cSEL isopleth for [REDACTED]
- rms SPL (root mean square SPL) – located approximately 800 feet from the pile, based on the distance from the pile to the 150 dB re 1 μPa rms SPL

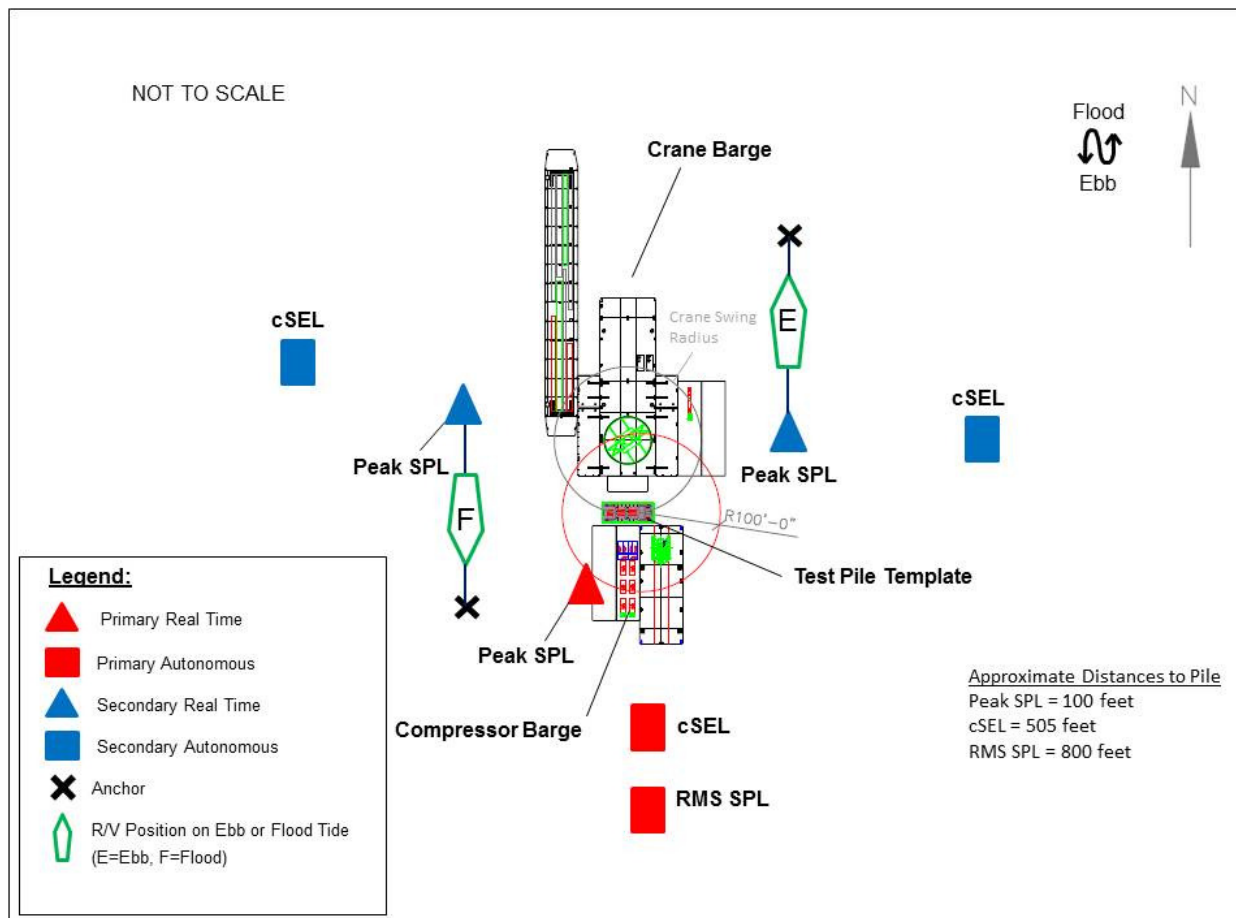


Figure 6. Plan View of a Typical Test Pile Barge Arrangement and Hydrophone Locations

Test pile installation for the Main Span occurred during a variety of current conditions (ebb, flood, and slack tide). Hydrophones were placed to capture variation in the performance of the NAS relative to the river current and barge placement. PLT [REDACTED] tested the NAS up-current in a 1-2 knot flood tide. The hydrophones completely surrounded the test piles during PLT [REDACTED] and PLT [REDACTED] to test the NAS down current, cross current, and up current. PLT [REDACTED] occurred during an ebb current of 1 to 1.5 knots. [REDACTED] occurred during flood and slack currents, which ranged from 0 to 1.6 knots. Table 2 provides a summary of the underwater noise monitoring equipment deployment and position relative to the current for the driving of the three test piles.

Table 2. Equipment Deployment and Position Relative to Current for PLT [REDACTED] PLT [REDACTED]

and PLT [REDACTED]

Date/Test Pile No.	Hydrophone ID	Location Relative to Pile*	Location Relative to Current	Current During Pile Driving	Distance to Pile (ft)	Water depth (ft)
7/31/2013 PLT [REDACTED]	[REDACTED]	Peak SPL- Barge	Up-current	Flood tide (1 – 2 knots)	95.4	[REDACTED]
		Peak SPL- Vessel	Cross-current		270	
		cSEL South	Up-current		556	
		cSEL East	Cross-current		598	
		RMS SPL East*	Cross-current		776	
8/3/201 PLT [REDACTED]	[REDACTED]	Peak SPL- Barge	Down-current, position 1	Ebb tide (1 – 1.5 knots)	100	
		Peak SPL- Vessel	Cross-current		170	
		cSEL East	Cross-current		282	
		cSEL North	Up-current		365	
		cSEL South	Down-current		238	
8/19/201 PLT [REDACTED]	[REDACTED]	Peak SPL- Barge	Up-current	Flood to slack tide (0 – 1.6 knots)	141	
		Peak SPL- Vessel	Cross-current		168	
		cSEL South	Up-current		396	
		cSEL West	Cross-current		268	
		cSEL North	Down-current		502	

*Locations correspond to the hydrophone locations labeled in Figure 5 and are based on the following:

- peak SPL – located on the barge or survey vessel, approximately 100 feet from the pile, based on the distance from the pile to the 206 re 1 μ Pa peak SPL isopleth for [REDACTED] piles
- cSEL- located approximately 505 feet from the pile, based on the distance from the pile to the 187 dB re 1 μ Pa²-s cSEL isopleth for [REDACTED] piles
- rms SPL – located approximately 800 feet from the pile, based on the distance from the pile to the 150 dB re 1 μ Pa rms SPL

In order to test the performance of the NAS, air flow was varied from 800 to 2200 cfm and air pressure from 35 to 100 psi throughout the three PLTs. Table 3 provides operation of the NAS during the installation of the three test piles.

Table 3. Description of NAS during PLT [REDACTED] PLT [REDACTED] and PLT [REDACTED]

Date/ Test Pile No.	Water Depth [REDACTED]	Number of Rings*	Air Flow (cfm) per Bubbler Ring	Air Pressure (psi)
7/31/2013 PLT [REDACTED]	[REDACTED]	5	900-2000	35-80
8/3/201 PLT [REDACTED]	[REDACTED]	5	900-2000	40-70
8/19/2013 PLT [REDACTED]	[REDACTED]	5	800-2200	40-100

* Ring spacing is presented in presented in Attachment 2, Drawing 1UBCR.

4.5 Results

4.5.1 NMFS Physiological and Behavioral Thresholds

In accordance with the NMFS BO Term and Condition Number 6, the monitoring program estimated (i) the peak sound level (peak SPL in dB re 1 μ Pa) at each recorder and the distance from the pile at which the peak SPL exceeds the 206 dB re 1 μ Pa, (ii) the cSEL at each recorder and the distance from the pile at which the cSEL exceeds 187 dB re 1 μ Pa²-s at the end of pile driving, and (iii) the rms SPL at each recorder and the distance from the pile at which rms SPL exceeds 150 dB re 1 μ Pa.

Table 4 provides a summary of the underwater sound levels measured at each recorder during the test pile installation. Table 5 provides the distances to each of the NMFS BO thresholds (Attachment 1 provides additional detail). **These results show that the distance to the 206 dB re 1 μ Pa peak SPL did not exceed NMFS requirement of 200 ft for [REDACTED] piles at the Main Span Design Unit.** The longest distance to the 206 dB re 1 μ Pa peak SPL isopleth was 7.5 ft, which is the same as the shortest distance to the 206 dB re 1 μ Pa peak SPL for the NASs tested during the 2012 PIDP. Specifically, during the 2012 PIDP the distances to the 206 dB re 1 μ Pa peak SPL isopleth was 7.5 – 20 ft for [REDACTED] piles, 37.8 ft for the [REDACTED] pile, and 14.4 ft for the [REDACTED] (Jasco 2012)¹.

Furthermore, the estimated diameter of the isopleth at the end of installation of test piles that corresponded to 187 dB re 1 μ Pa²-s cSEL never exceeded 420 ft. The river width is approximately 15,000 ft; therefore a fish movement corridor of more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving, in accordance with New York State Department of Environmental Conservation Permit Condition 14.

¹ Jasco. 2012. Underwater Acoustic Monitoring of the Tappan Zee Bridge Pile Installation Demonstration Project.

Table 4. Summary of the Measured Sound Levels at Each Recorder During the PLT [REDACTED] PLT [REDACTED] and PLT [REDACTED]

Date/ Test Pile No.	Location*	Max. peak SPL (dB re 1 μ Pa)	cSEL (dB re 1 μ Pa ² -s)**
7/31/2013 PLT [REDACTED]	Peak SPL- Barge	180	180
	Peak SPL- Vessel	171	166
	cSEL South	169	170
	cSEL East	163	159
	RMS SPL East	157	150
8/3/201 PLT [REDACTED]	Peak SPL- Barge	182	185
	Peak SPL- Vessel	180	179
	cSEL East	179	176
	cSEL North	180	175
	cSEL South	175	177
8/19/2013 PLT [REDACTED]	Peak SPL- Barge	192	188
	Peak SPL- Vessel	191	192
	cSEL South	184	184
	cSEL West	186	183
	cSEL North	181	181

*Locations correspond to the hydrophone locations labeled in Figure 5 and are based on the following:

- peak SPL – located on the barge or survey vessel, approximately 100 feet from the pile, based on the distance from the pile to the 206 re 1 μ Pa peak SPL isopleth for [REDACTED] piles
- cSEL- located approximately 500 feet from the pile, based on the distance from the pile to the 187 dB re 1 μ Pa²-s cSEL isopleth for [REDACTED] piles
- rms SPL – located approximately 800 feet from the pile, based on the distance from the pile to the 150 dB re 1 μ Pa rms SPL

**At the completion of pile driving.

**Description of Underwater Noise Attenuation
System (NAS) – Main Span Design Unit****Table 5. Estimated Distance from Pile Driving to the Noise Levels that Represent NMFS Thresholds**

Measurement		PLT [REDACTED]	PLT [REDACTED]	PLT [REDACTED]
Pile Installation Duration (hh:mm:ss)		00:04:27	00:26:00	00:20:28
Approximate Distance in feet to Threshold	206 dB re 1 μ Pa peak SPL	7.5	<3	3
	187 dB re 1 μ Pa ² -s cSEL f	52.5	95	198
	150 dB re 1 μ Pa rms SPL	355	462	3498

4.5.2 NAS Performance

The NAS was tested in a variety of river current conditions including flood, ebb, and slack tide, with hydrophones at various locations relative to the current (Table 2). Current speed ranged from 0 to 2 knots. Results for [REDACTED] indicate the received sound levels varied depending on direction. Sound levels recorded during a full flood tide were slightly higher at the 500-600-ft upstream recorder compared to the 500-600-ft cross current recorder (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT [REDACTED]). Changes in tidal state during the ebb tide did not appear to affect sound levels for PLT [REDACTED] (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT [REDACTED]). Some variation in sound levels was noted in flood versus slack tide during the installation of PLT [REDACTED] (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT [REDACTED]). In all cases, the NAS proved to be effective at attaining the required NMFS threshold of 206 dB re 1 μ Pa at 100 ft during all tide conditions.

Air flow varied from 800 to 2200 cfm and air pressure from 35 to 100 psi throughout the three PLTs. Insufficient data was collected during the installation of PLT [REDACTED] for a reliable statistical analysis of the NAS air flow settings. Air flow was never altered independently of other variables, such as increased hammer energy or tidal condition during the installation of PLT [REDACTED] and PLT [REDACTED]. At PLT [REDACTED] sound levels appear to be negatively correlated with the NAS air flow (measured sound levels increase as air flow decreases) or positively correlated with the strikes per foot (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT [REDACTED]). For PLT [REDACTED] changes in air flow settings at slack tide were compared. Neither hammer energy nor the increase in air flow had a predictable effect on the measured sound levels. Additionally, the inconsistency of the air flow, the rapidly changing hammer energies, and the low number of strikes mean that the effects of changes in air flow at PLT [REDACTED] can not be conclusively determined (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT [REDACTED]). However, the NMFS threshold of 206 dB re 1 μ Pa at 100 ft was not exceeded despite variation in air flow.

4.6 Conclusions

In accordance with NYSDEC Permit Condition 8, “an underwater noise attenuation system or systems must be deployed during the driving of steel piles [REDACTED] and larger in diameter to minimize to the maximum extent practicable the effects of underwater sound upon fishes in the Hudson River.” The PLT-NAS Description concludes that the most effective system is the one that will be capable of attenuating noise to achieve the distance thresholds required by NMFS in the BO and that can be safely deployed and retrieved repeatedly during production piling without affecting pile driving requirements and project schedule.

Results of test pile installation indicate that the unconfined multi-tier bubble curtain is effective in minimizing noise in order to meet the NMFS and NYSDEC requirements. Not only did the multi-tier bubble curtain meet the requirements in full ebb and flood tides and for NAS settings evaluated the, underwater sound was reduced beyond NMFS and NYSDEC requirements. Results indicate that the unconfined multi-tier bubble curtain is effective at constraining the 206 dB re 1 μ Pa peak SPL isopleth to distances of 7.5 feet from the pile for [REDACTED] piles at the Main Span sites. That is, the largest estimated width of the 206 dB re 1 μ Pa peak SPL isopleth was measure at 15 ft, as compared to the 100 ft allowed by the NMFS BO.

These results indicate that the radii of the 206 dB re 1 μ Pa isopleth measured for the [REDACTED] of water with the 5-tier bubble curtains was smaller than any of the radii measured during the 2012 PIDP.

Furthermore, the diameter of the 187 dB re 1 μ Pa²-s cSEL isopleth at the end of installation of each pile was never estimated to be more than 420 ft. Therefore, the majority of the width of the river at the construction site would be an acoustic-free movement corridor for fish.

5.0 NAS Design Plan and Operational Specifications

The installation of the three test piles also demonstrated the unconfined multi-tier bubble curtain to be readily and safely deployable and retrievable. Given these logistical attributes, combined with the proven effectiveness at obtaining required distances to NMFS and NYSDEC thresholds, the unconfined multi-tier bubble curtain is considered most effective to minimize harm to fish in the Hudson River, to the maximum extent practicable.

During production piling for the main span, the unconfined multitier bubble curtain will be deployed and retrieved in a similar manner to the PLT [REDACTED] PLT [REDACTED] and PLT [REDACTED] pile installations. Water depth was approximately [REDACTED] feet for each of these tests. One bubble curtain ring will be deployed for every 8 to 10 feet of water depth. Table 6 provides the range of water depths at each main span pier and the number of bubble curtain rings to be deployed for pile driving at that pier. The NAS will be deployed according to the Construction Work Plan.

Table 6. Range of Water Depths at Each Main Span Pier and the Number of Bubble Curtain Rings to be Deployed

Pier	Water Depth (feet)	Number of Bubble Curtain Rings
[REDACTED]	[REDACTED]	4
	[REDACTED]	4
	[REDACTED]	5
	[REDACTED]	5
	[REDACTED]	3
	[REDACTED]	2

The NAS system contains three valves at the:

1. air compressor outlet to the reservoir tank (Figure 7),
2. reservoir tank inlet (Figure 8),
3. reservoir tank outlet (Figure 9) to the bubbler ring.

Prior to impact pile driving, the compressor will be turned on and the valves will be open such that air will be supplied to the bubbler rings. The valves will remain open during the operation of the bubble curtain. The bubble curtain will remain on during periods of active pile driving. Air pressure at the outlet from the reservoir tank will be maintained at a target pressure of between 60 and 80 psi with a minimum pressure of 40 psi to each bubbler ring (Figure 10).

The NAS operator will check the following (as outlined in the Construction Work Plan):

- Reservoir tank is pressurized prior to pile driving.
- The tank inlet and outlet valves are open immediately prior to starting the pile driving.

- Air pressure at each reservoir tank outlet approximately 5 minutes after pile driving begins.



Figure 7. Valve at the Air Compressor Outlet to the Reservoir Tank



Figure 8. Valve at the Reservoir Tank Inlet



Figure 9. Valve at the Outlet from the Reservoir Tank to the Bubble Curtain



Figure 10. Air Compressor Controls

**Attachment 1 – Daily Memoranda for Underwater
Acoustic Monitoring of the Tappan Zee Bridge Test
Pile Installation**



Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile Installation

Daily Memorandum for 31 July 2013

Submitted to:

[REDACTED]
HDR

Authors:

[REDACTED]
2 August 2013
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1. Summary

1.1. Pile Location and Monitoring Summary

PLT [REDACTED] was a [REDACTED] pile driven at the site of the New NY Bridge on the east side of the main river channel on 31 July 2013 from [REDACTED] Eastern Daylight Time (EDT) (Table 1). Two real-time acoustic monitoring systems and 3 autonomous acoustic monitoring systems deployed by JASCO (Section 4) at ranges of 95 – 776 ft from the pile on behalf of Tappan Zee Constructors LLC (TZC) to measure sound levels (Figure 1, Table 2). Full flood tide occurred at 18:30 EDT.

Table 1. Summary of PLT-[REDACTED] activities, 31 July 2013

Date:	31 July 2013
Pile-Driving Activity	
Test pile identifier:	PLT-[REDACTED]
Pile diameter:	[REDACTED]
Water Depth	[REDACTED]
Hammer type:	[REDACTED]
Total hammer strikes	[REDACTED]
Total penetration (ft)	[REDACTED]
Net duration of pile driving (hh:mm:ss)	[REDACTED]
Maximum single strike energy	[REDACTED] kip-ft ([REDACTED] kJ)
Total energy transferred	[REDACTED] kip-ft ([REDACTED] MJ)
Noise Attenuation System	
Five-tier unconfined bubble curtain airflow rate	900 – 2000 cubic feet minute (cfm), 35 – 80 psi
River conditions during piling	Flood tide, 1 - 2 knots (0.5 – 1 m/s), depth dependent, Figure 3)

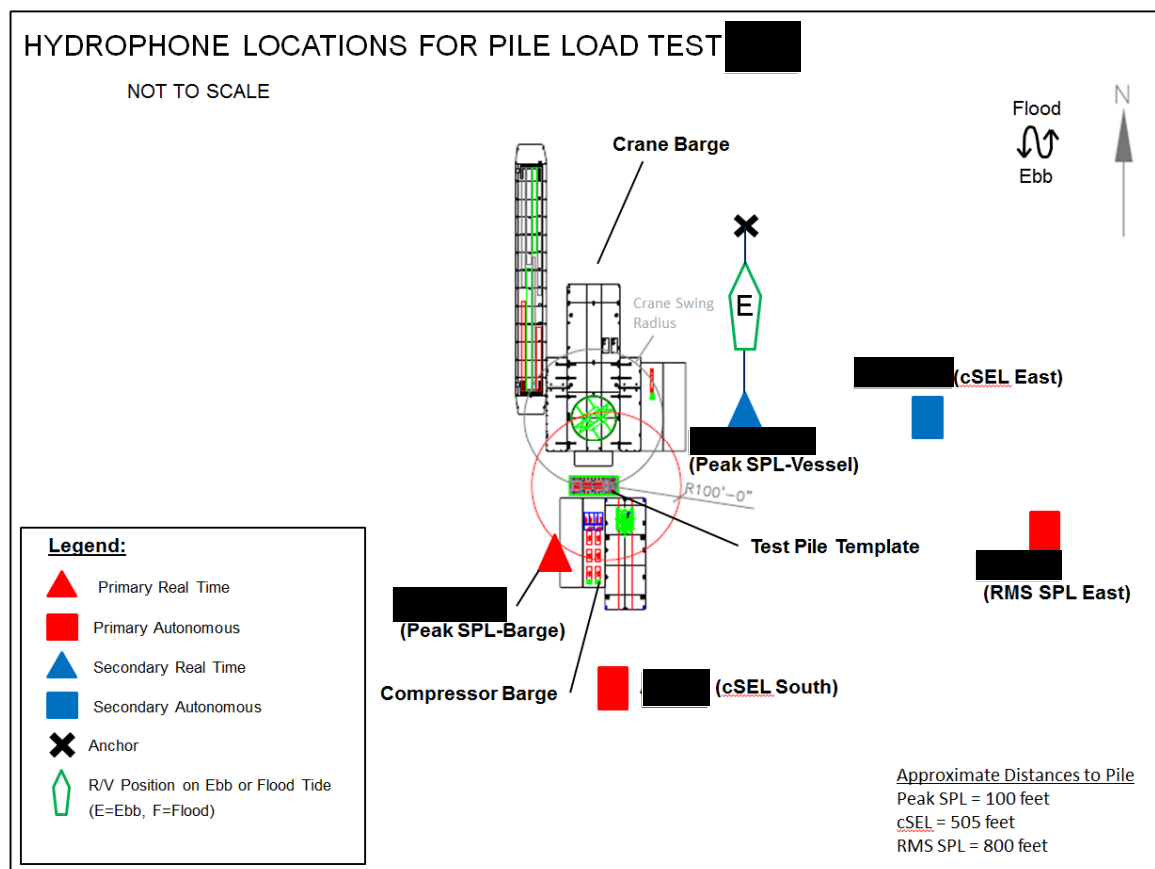


Figure 1. Plan view of pile and barge layout, 31 July 2013, PLT- [REDACTED]

Table 2. Summary of Autonomous Multichannel Acoustic Recorders (AMAR) locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	AMAR ID	Distance to Pile (ft)	Water depth (ft)	Max. peak SPL (dB re 1 μ Pa)	cSEL (dB re 1 μ Pa ² s)*
Peak SPL- Barge (Up-current)	[REDACTED]	95.4	[REDACTED]	179.8	180.1
Peak SPL- Vessel (Cross-current)	[REDACTED]	270		170.5	166
cSEL South (Up-current)	[REDACTED] 1	556		169.1	169.6
cSEL East (Cross-current)	[REDACTED]	598		163.4	159.3
RMS SPL East (Cross-current)	[REDACTED]	776		157	149.9

*Estimated at each recorder by multiplying the mean of the per-strike SEL by the number of strikes reported by the pile driving contractor, for the final value at the recorder, representing the total energy at the end of pile driving.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3-octave-band single-strike sound exposure levels (SELs), and sound level statistics for the distribution of the measured data are presented in Appendix A.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure level (SPL), rms SPL, and single strike SELs from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 μ Pa peak SPL was approximately 15 ft and did not exceed NMFS criteria of a diameter of 100 ft for [REDACTED] piles. The diameter of the 187 dB re 1 μ Pa²·s cumulative sound exposure level (cSEL) isopleth was estimated to be 105 ft at the end of pile driving. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore a fish movement corridor more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth radii for the NMFS physiological and behavioral thresholds.

Criteria	Estimated Radius (ft)
206 dB re 1 μ Pa peak SPL	7.5
187 dB re 1 μ Pa ² ·s cSEL	52.5*
150 dB re 1 μ Pa rms SPL (one second integration time)	355

*At the end of pile driving.

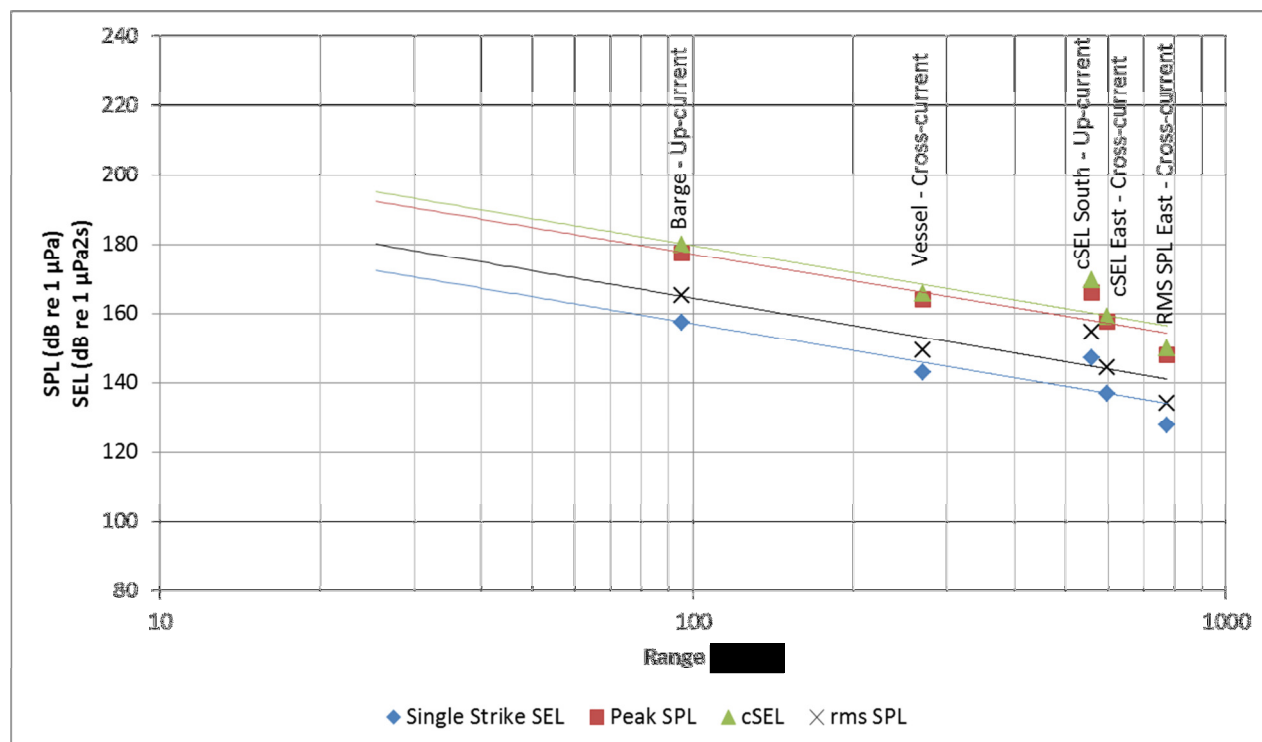


Figure 2. Regression based on mean values of the peak SPL, rms SPL, and single strike SELs from each recorder from pile driving of PLT-█████ 31 July 2013. Single Strike SEL, Peak SPL, and rms SPL are instantaneous values. cSEL, represents the cumulative Sound Exposure Level at the end of pile driving.

1.3. Observations

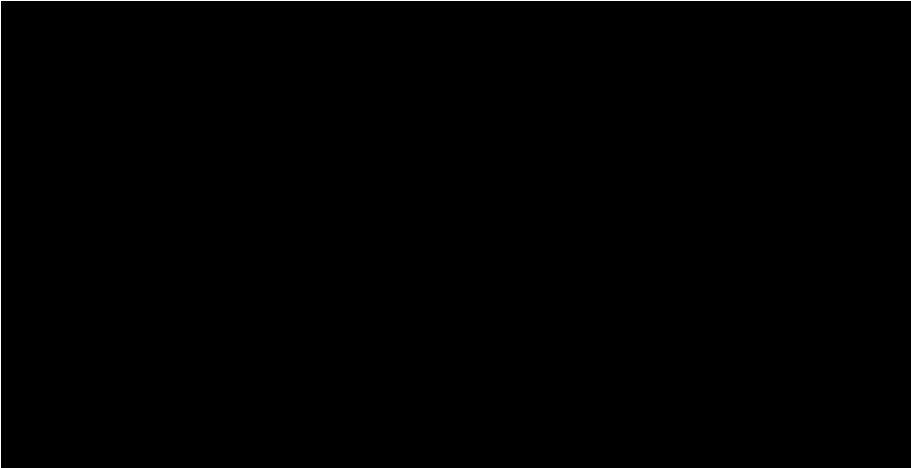
The impact hammer was operated at a maximum of █████ kJ, which is less than one-half of its maximum. PLT-█████ was driven at near full flood-tide for the 31 July 2013. The 'cSEL South' autonomous recorder was directly upstream of the pile and recorded sound levels that were higher than the autonomous recorder that was cross-current to the pile driving at a similar range (cSEL East) (i.e., both recorders were 500-600 ft from the pile). The differences were (Table 2):

- rms SPL – 11.4 dB
- peak SPL – 6.3 dB
- cSEL – 10.6 dB

The results indicate the received sound levels varied depending on direction. The Acoustic Doppler Current Profiler (ADCP) measurements showed flood (northerly) currents of up to 2 knots (1 m/s) at depths of █████ ft (Figure 3). Recorder 'cSEL South' was at a water depth of █████ ft and cSEL East was at a water depth of █████ ft. Therefore, two variables that may contribute to the different received sound levels are orientation to the current and bathymetry. There is no indication that the required NMFS and NYSDEC thresholds were exceeded in any direction.

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Time (EDT)	Activity
08:45	Safety meeting on shore.
08:50	Performed hydrophone calibration on AMAR-RT.
10:20	Transited to barge spread
10:25	Begin deploying AMARs
	
19:21	All AMARs retrieved
19:30	AMAR-RT retrieved
19:45	Alpine vessel at dock




2.2. Pile Driving Logs

2.2.1. Noise Attenuation System

NAS Used: 5-tier unconfined bubble curtain.

NAS Settings: 900 – 2000 cfm, 35 – 80 psi

Table 4. NAS Setting recorded by HDR during piling at PLT- 31 July 2013

Time (EDT)	Volume/min (cfm)	Pressure (psi)
	1800 – 2000	80
	1200 – 1700	50
	900 – 1100	35

2.2.2. Impact Hammering Log:

Total Energy: [REDACTED]

Total number of strikes: [REDACTED]

Maximum per-strike energy: [REDACTED] kJ

Net piling duration (hh:mm:ss): [REDACTED]

3. Weather and River Conditions

Table 5 and provide the predicted currents on the project site for 31 July 2013. Figure 3 provides the ADCP-measured currents.

Figure 4 provides the speed of sound in water, based on salinity and temperature measured using the conductivity/temperature/depth (CTD) meter.

Table 5. Weather conditions, predicted local tide times, and water depth.

Weather conditions:	Sunny, wind gusts to 5 mph
Full ebb current:	12:30 EDT
Slack current:	15:30 EDT
Full flood current:	18:30 EDT
Maximum ADCP-logged water depth	12 m
Minimum ADCP-logged water depth	12 m

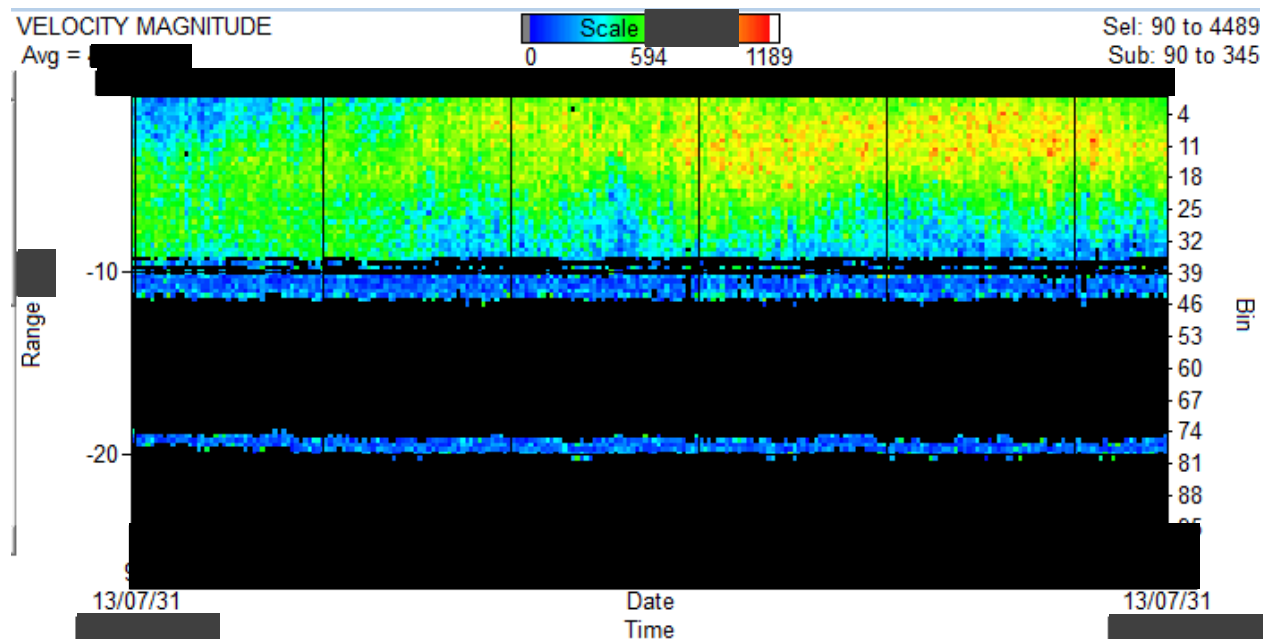


Figure 3. ADCP data from 2013 07 31 during pile driving. Times are in EDT.

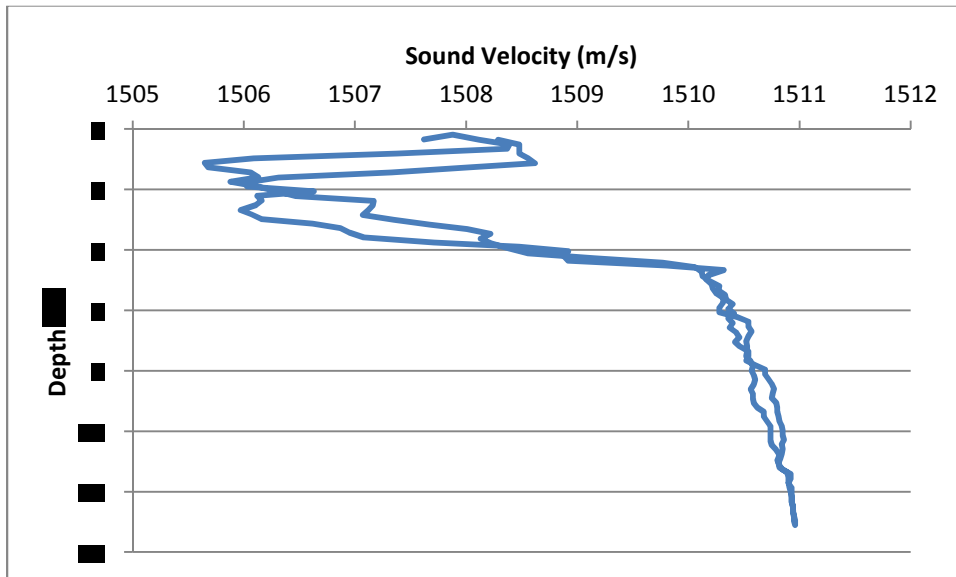


Figure 4. CTD Cast performed at Peak SPL- Barge location at 17:07 EDT.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 6 and Table 7 provide details on the real-time recording equipment used for PLT- [REDACTED]

Table 6. Information on the real-time monitoring equipment used on 31 July 2013.

Acoustic Data Logger		Units Deployed
Model:	AMAR RT (JASCO Applied Sciences)	2
<i>SpectroPlotter</i> version:	6.0.1	2
Hydrophone		
Model:	M8KC (GTI)	2
[REDACTED] Sensitivity:	-211.3 dB re 1 V/μPa	1
[REDACTED] Sensitivity:	-210.8 dB re 1 V/μPa	1
Other		
Hydrophone calibrator:	Pistonphone Type 42AC (G.R.A.S. Sound and Vibration)	1
CTD profiler:	Minos X (AML Oceanographic)	1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz	1

Table 7. Locations [REDACTED] and deployment times (EDT) of the AMAR-RT monitoring stations, 31 Jul 2013.

Station	Recorder ID	Latitude	Longitude	Deployment time	Water Depth (ft)	Distance to Pile (ft)
Peak SPL, Barge	[REDACTED]	[REDACTED]	[REDACTED]	16:10	[REDACTED]	95.4
Peak SPL, Vessel	[REDACTED]	[REDACTED]	[REDACTED]	15:30	[REDACTED]	270

4.2. Autonomous Monitoring Equipment

Table 8 and Table 9 provide details on the autonomous recording equipment used for PLT- [REDACTED]

Table 8. Information on the autonomous monitoring equipment used on 31 July 2013.

Acoustic Data Logger		Units Deployed
Model:	AMAR G3 (JASCO Applied Sciences)	3
<i>SpectroPlotter</i> version:	6.0.1	3
Hydrophone		

Model:	M8E-51-0dB (GTI)	3
Sensitivity:	-199.8 dB re 1 V/ μ Pa	1
Sensitivity:	-199.9 dB re 1 V/ μ Pa	1
Sensitivity:	-199.5 dB re 1 V/ μ Pa	1

Table 9. Locations (WGS84) and deployment times (EDT) of the autonomous monitoring AMAR stations currently deployed in the Hudson River.

Station	Recorder ID	Latitude	Longitude	Deployment time	Water Depth (ft)	Distance to Pile (ft)
RMS SPL East (Cross-current)				11:05		775.5
cSEL East (Cross-current)				10:57		597.5
cSEL South (Upstream)				10:49		559.8

5. Daily Monitoring Close-out

Raw data archived to disk:	<u>2013-08-01 11:30</u>
Raw data transferred to data-warehouse:	<u>archived locally</u>
Logs, CTD data & ADCP data transferred to project server:	<u>2013-08-11</u>
CSV and XLSX analysis files and scripts transferred to project server:	<u>2013-08-11</u>
Photos transferred to project server:	<u>2013-08-11</u>

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels From Barge

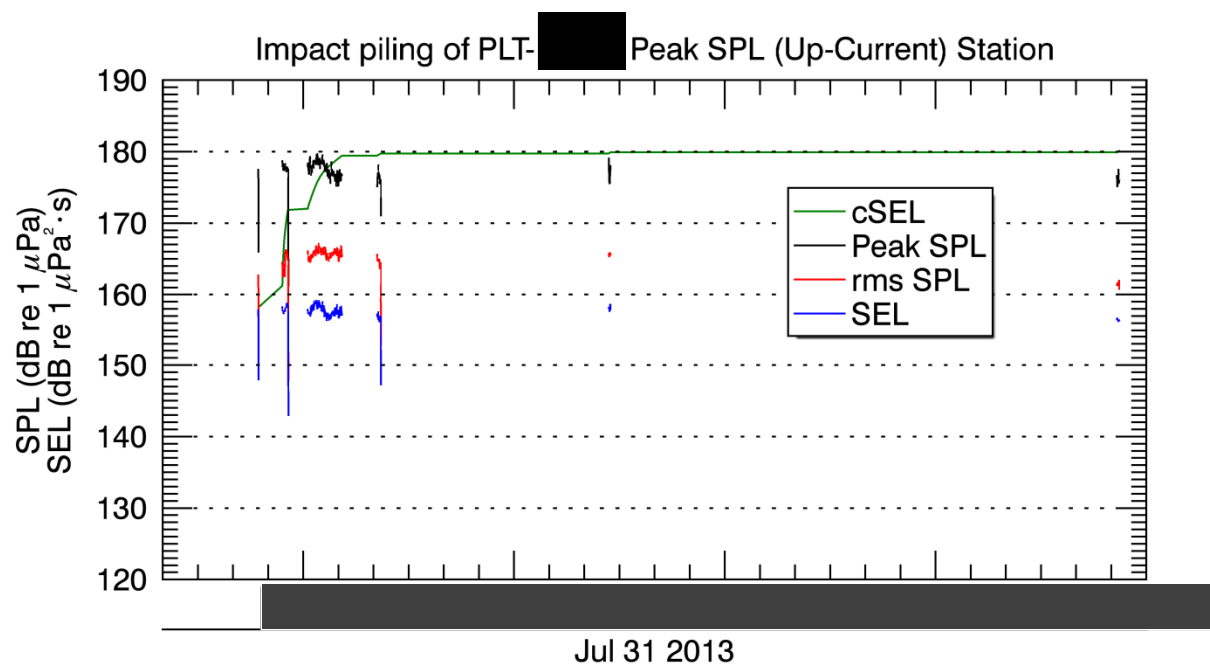


Figure 5. Impact Pile Driving: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location Peak SPL – Barge during pile driving at PLT- [REDACTED] (95 ft from pile PLT- [REDACTED]).

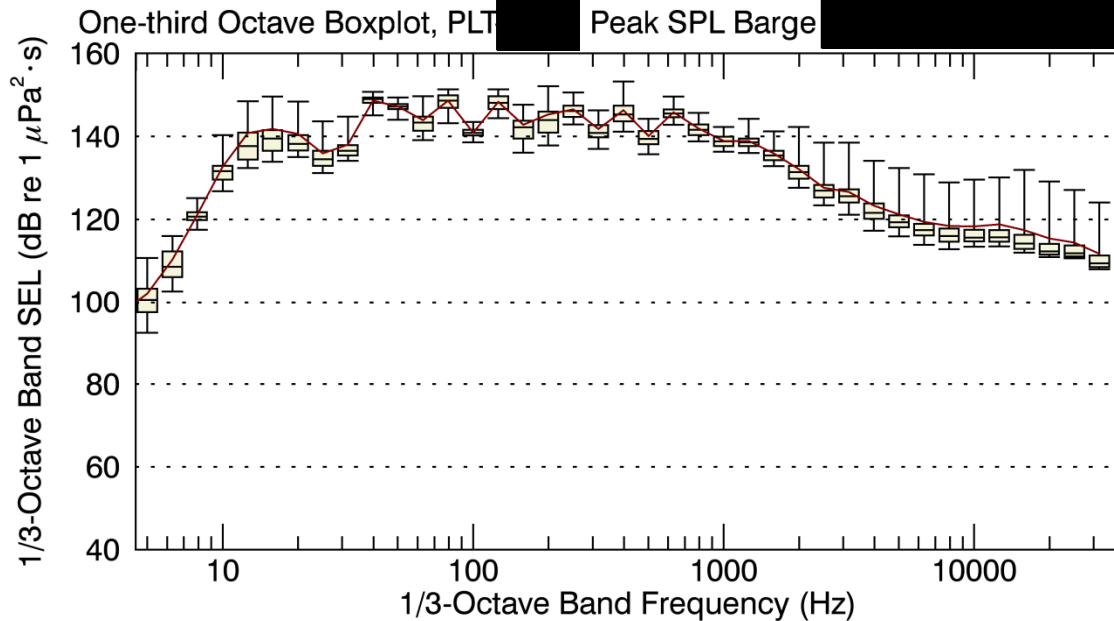


Figure 6. Distribution of one-second 1/3-Octave single-strike SELs measured 95 ft from Test Pile PLT-[REDACTED] on [REDACTED]

Table 10. Sound levels for the measurements at Peak SPL - Barge during pile driving of PLT-[REDACTED] (95 ft from pile PLT-[REDACTED])

Sound Level Statistic*	Peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{max}	179.8	167.2	159.2
L_5	179	166.6	158.8
L_{25}	178.2	166	158.2
L_{50}	177.4	165.6	157.7
L_{75}	176.6	165	157.1
L_{95}	175.4	161.6	156.4
L_{mean}	177.4	165.3	157.6

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

A.2. Impact Pile-Driving Sound Levels From Vessel

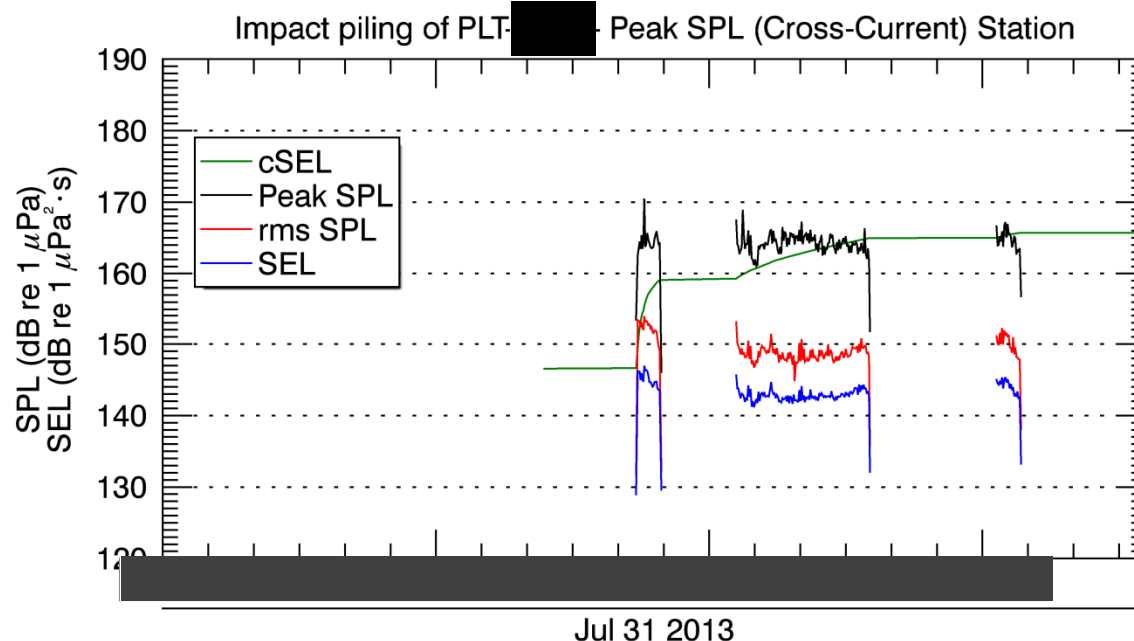


Figure 7. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location Peak SPL – Vessel during pile driving at PLT- [REDACTED] (270 ft from pile PLT- [REDACTED])

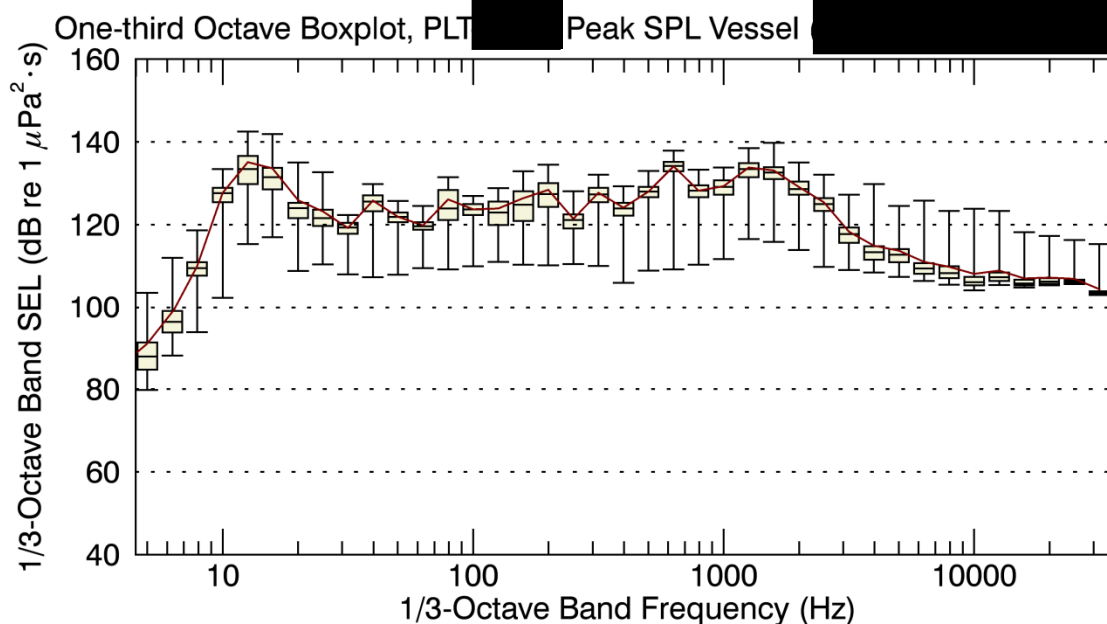


Figure 8. Distribution of one-second 1/3-Octave single-strike SELs measured 270 ft from Test Pile PLT- [REDACTED] on [REDACTED]

Table 11. Sound levels for the measurements at Peak SPL - Vessel during pile driving of PLT- (270 ft from pile PLT-)

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{max}	170.5	154.1	147
L_5	166.9	153.1	145.9
L_{25}	165.1	150	143.9
L_{50}	164.1	148.8	142.9
L_{75}	163.4	147.9	142.3
L_{95}	148.6	128.4	126
L_{mean}	164.2	149.4	143.1

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

A.3. Impact Pile-Driving Sound Levels cSEL South

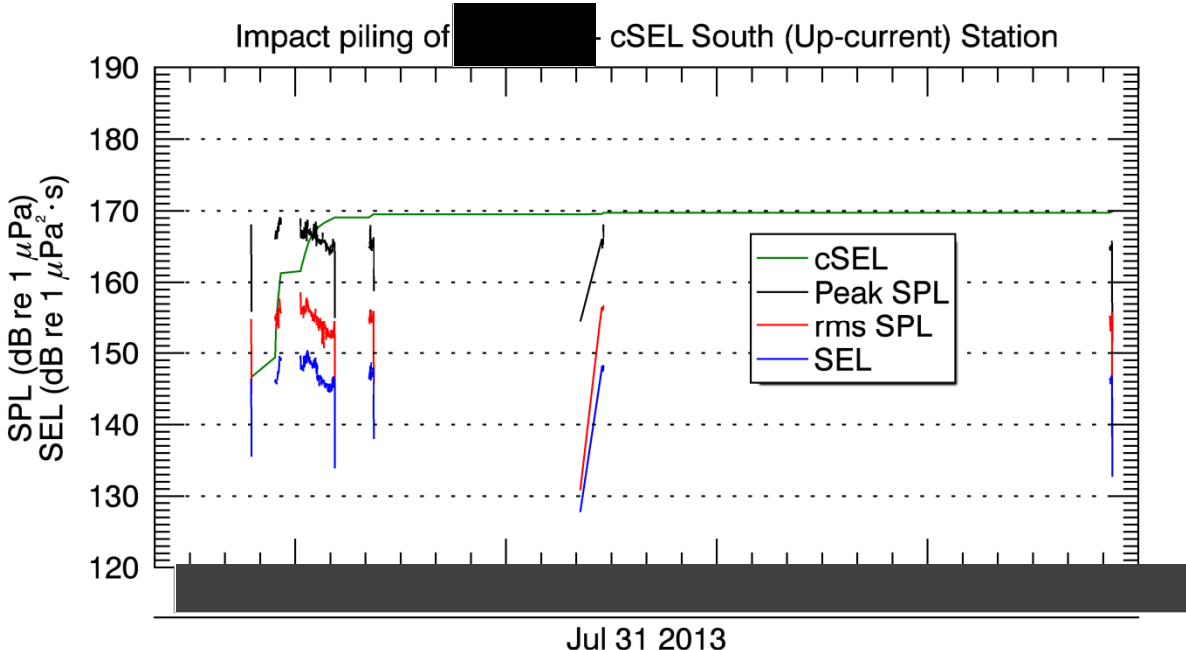


Figure 9. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location Peak SPL – Vessel during pile driving at PLT- (560 ft from pile PLT-).

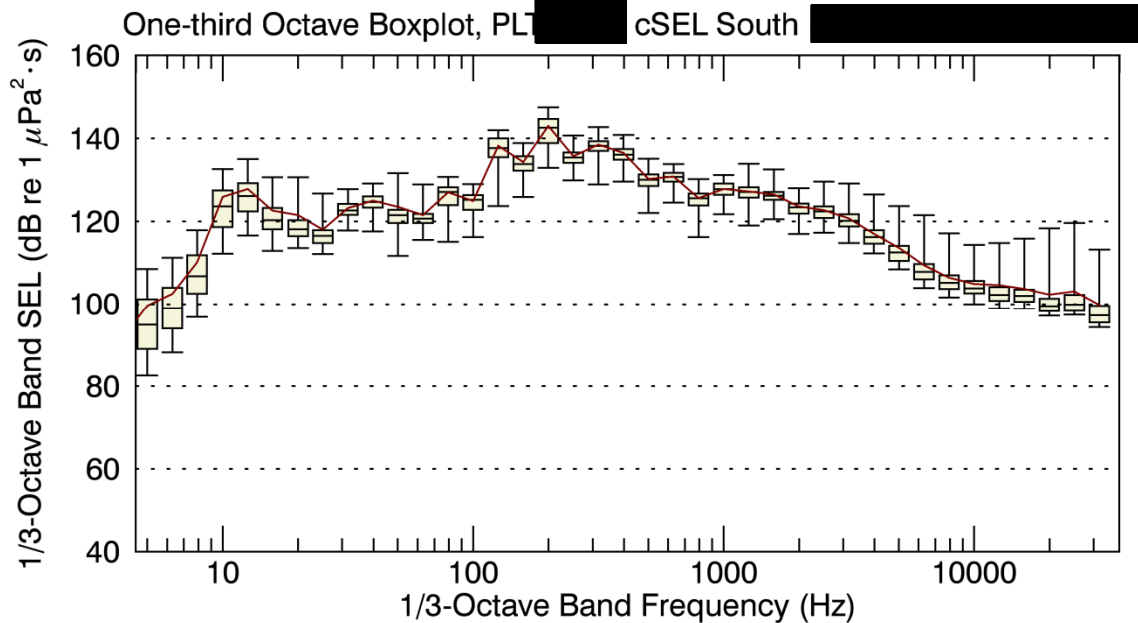


Figure 10. Distribution of one-second 1/3-Octave single-strike SELs measured 560 ft from Test Pile PLT-[REDACTED] on [REDACTED] R [REDACTED]

Table 12. Sound levels for the measurements at Peak SPL - Vessel during pile driving of PLT-[REDACTED] (560 ft from pile PLT-[REDACTED] [REDACTED])

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{max}	169.1	158.5	150.4
L_5	168.4	156.8	149.6
L_{25}	166.8	155.9	148.4
L_{50}	166	155	146.8
L_{75}	165.2	153.2	145.8
L_{95}	158.9	145.8	138.1
L_{mean}	166.1	154.7	147.2

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

A.4. Impact Pile-Driving Sound Levels cSEL East

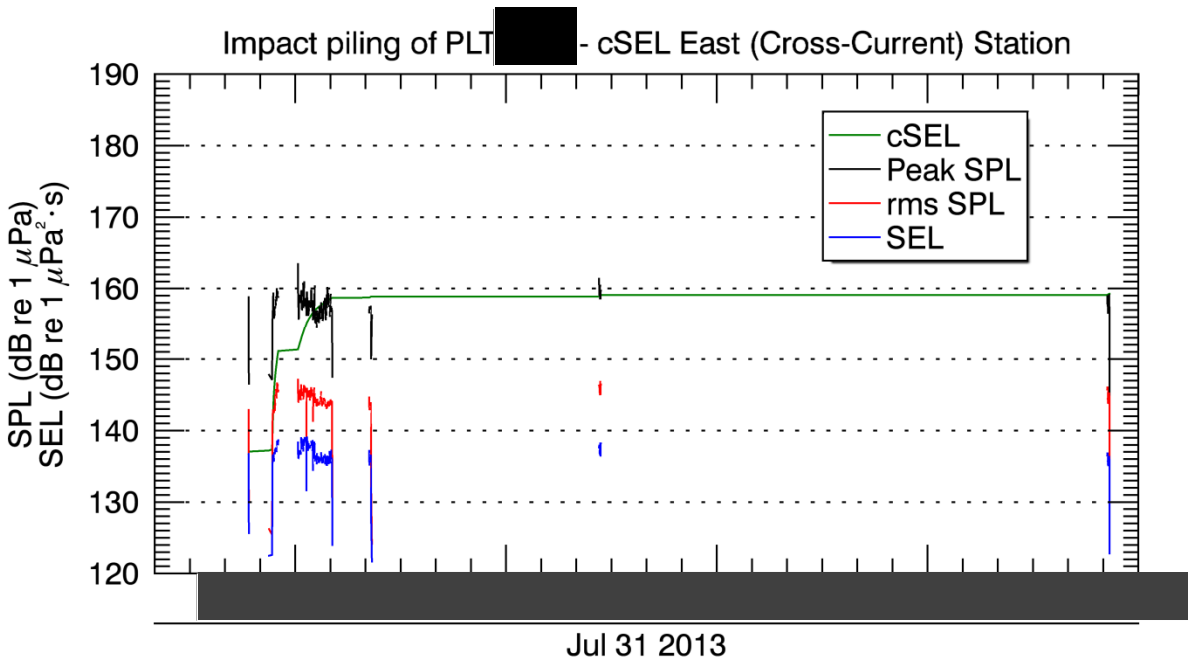


Figure 11. Impact Pile Driving: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location cSEL East during pile driving at PLT- [REDACTED] (598 ft from pile PLT- [REDACTED])

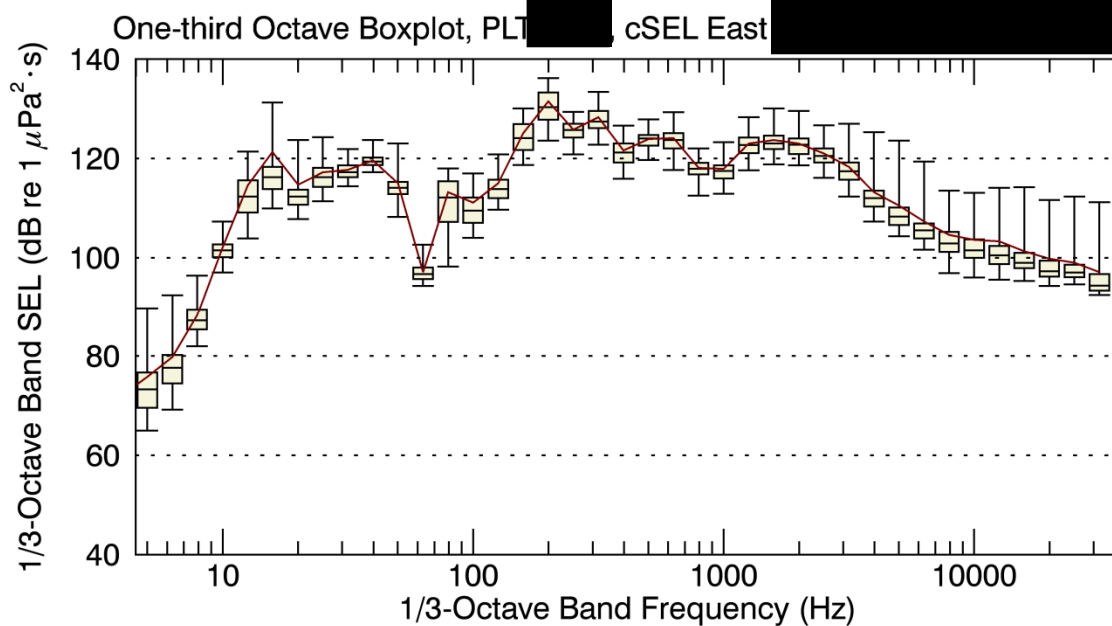


Figure 12. Distribution of one-second 1/3-Octave single-strike SELs measured 598 ft from Test Pile PLT- [REDACTED] on [REDACTED]

Table 13. Sound levels for the measurements at cSEL East during pile driving of PLT- (598 ft from pile PLT-).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{\max}	163.4	147.1	139.1
L_5	159.9	146.3	138.7
L_{25}	158.5	145.3	137.7
L_{50}	157.5	144.3	136.6
L_{75}	156.7	143.6	135.9
L_{95}	155.2	142.1	135
L_{mean}	157.8	144.4	136.8

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

A.5. Impact Pile-Driving Sound Levels RMS SPL East

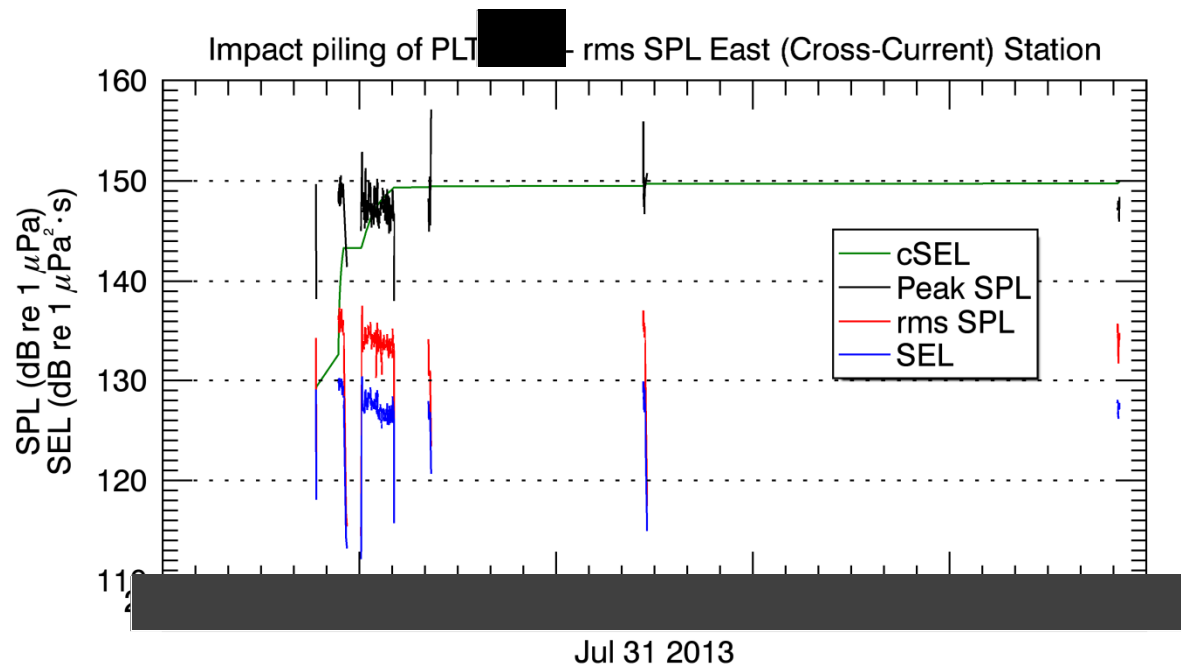


Figure 13. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location rms SPL East during pile driving at PLT- [REDACTED] (776 ft from pile PLT- [REDACTED] A [REDACTED])

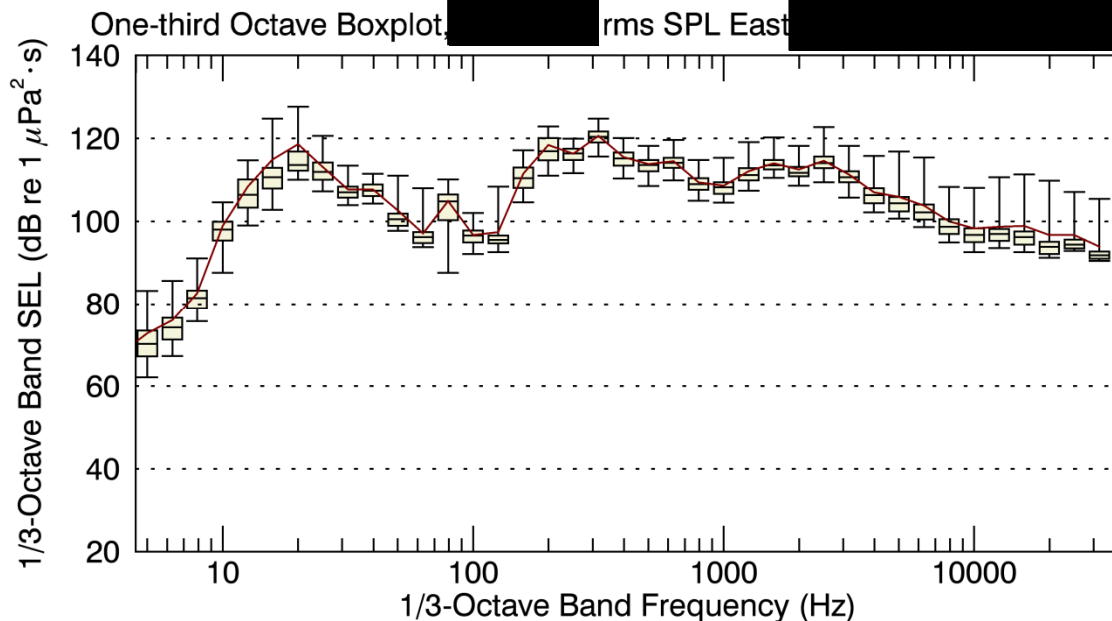


Figure 14. Distribution of one-second 1/3-Octave single-strike SELs measured 776 ft from Test Pile PLT- on A

Table 14. Sound levels for the measurements at location rms SPL East during pile driving of PLT- (776 ft from pile PLT-)

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{max}	157	137.6	130.4
L_5	150.4	136.2	129.8
L_{25}	148.5	134.9	128.3
L_{50}	147.5	134	127.2
L_{75}	146.6	133.3	126.7
L_{95}	145.2	130.6	125.6
L_{mean}	148.1	134.2	127.6

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



Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile Installation

Daily Memorandum for 03 August 2013

Submitted to:

[REDACTED]
HDR

Authors:

[REDACTED]
7 August 2013
[REDACTED]

JASCO Applied Sciences
Suite 202, 32 Troop Ave.
Dartmouth, NS, B3B 1Z1, Canada
[REDACTED]
[REDACTED]
[REDACTED]



1. Summary

1.1. Pile Location and Monitoring Summary

PLT [REDACTED] was a [REDACTED] pile driven at the site of the New NY Bridge on the east side of the navigation channel on 03 Aug 2013 (Table 1). Two real-time acoustic monitoring systems and 3 autonomous acoustic monitoring systems deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors LLC measured sound levels at ranges of 100 – 365 ft from the pile (Figure 1, Table 2). Piling driving occurred between [REDACTED] EDT and full ebb tide occurred at 14:53 EDT.

Table 1. Summary of PLT [REDACTED] activities, 03 August 2013

Date:	03 August 2013
Pile-Driving Activity	
Test pile identifier:	PLT-[REDACTED]
Pile diameter:	[REDACTED]
Water depth	[REDACTED] ft
Hammer type:	[REDACTED]
Total hammer strikes	[REDACTED]
Total penetration (ft)	[REDACTED]
Net duration of pile driving (hh:mm:ss)	[REDACTED]
Maximum single strike energy	[REDACTED] kip·ft [REDACTED] kJ)
Total energy transferred	[REDACTED] kip·ft [REDACTED] MJ)
Noise Attenuation System	
Five-tier unconfined bubble curtain airflow rate	900 – 2000 cfm, 40 – 70 psi
River conditions during piling	Ebb tide, 1 - 1.5 knots (0.5 – 0.8 m/s depth dependent, Figure 5)

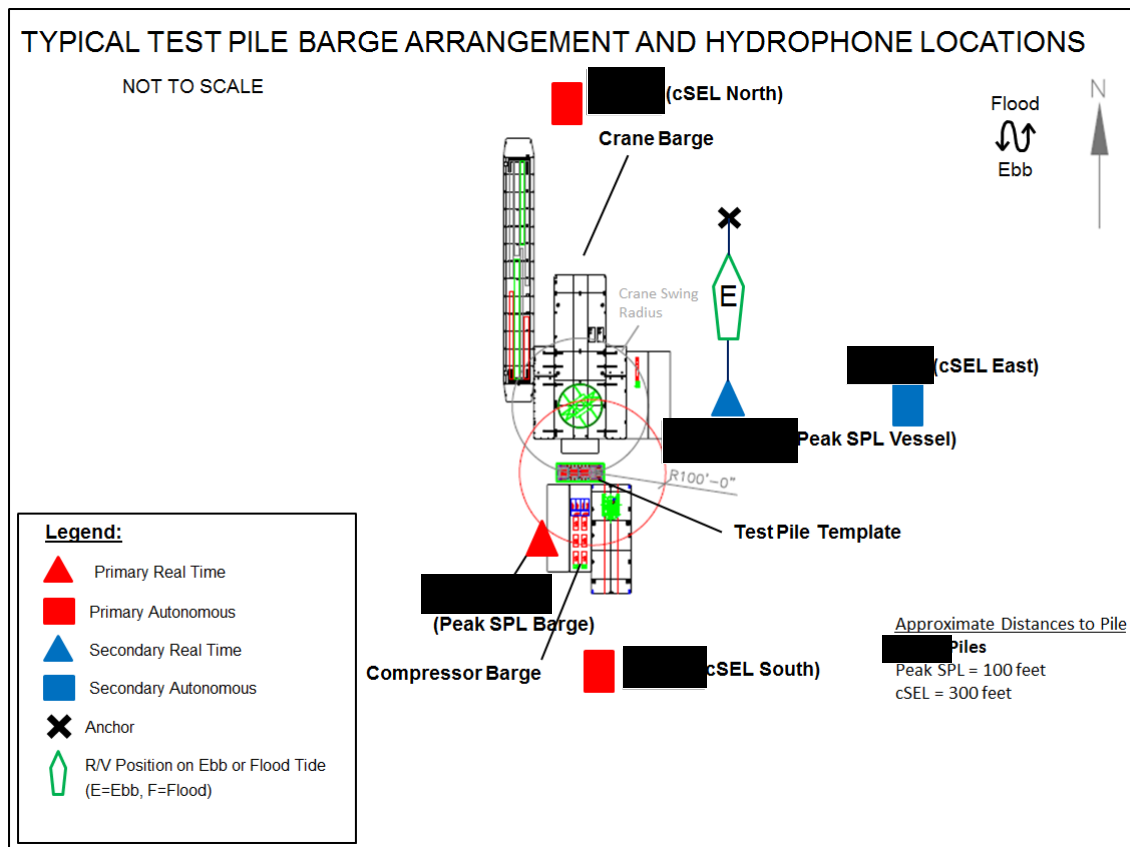


Figure 1. Plan view of pile and barge layout, 3 August 2013, PLT- [REDACTED]

Table 2. Summary of Autonomous Multichannel Acoustic Recorder (AMAR) locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	AMAR ID	Distance to Pile (ft)	Water depth (ft)	Max. peak SPL (dB re 1 μ Pa)	cSEL (dB re 1 μ Pa ² s)*
Peak SPL- Barge (down-current, pos 1)	[REDACTED]	100	[REDACTED]	182	185
Peak SPL- Vessel (Cross-current)	[REDACTED]	170		180	179
cSEL East (cross-current)	[REDACTED]	282		179	176
cSEL North (up-current)	[REDACTED]	365		180	175
cSEL South (down-current)	[REDACTED]	238		175	177

*Estimated at each recorder by multiplying the mean of the per-strike SEL by the number of strikes reported by the pile driving contractor, for the final value at the recorder, representing the total energy at the end of pile driving.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3 octave single-strike SELs, and sound level statistics for the distribution of the measured data are presented in Appendix A.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure level (SPL), root mean square (rms) SPL, and single strike sound exposure levels (SELs) from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated radius of the 206 dB re 1 μ Pa peak SPL was approximately <5 ft and did not exceed NMFS criteria of a diameter of 100 ft for [REDACTED] piles. The diameter of the 187 dB re 1 μ Pa²·s cumulative sound exposure level (cSEL) isopleth was estimated to be 190 ft at the end of pile driving. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore a fish movement corridor more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth radii for the NMFS physiological and behavioral thresholds.

Criteria	Estimated Radius (ft)
206 dB re 1 μ Pa peak SPL	<3
187 dB re 1 μ Pa ² ·s cSEL	95*
150 dB re 1 μ Pa rms SPL (one second integration time)	462

*At the end of pile driving.

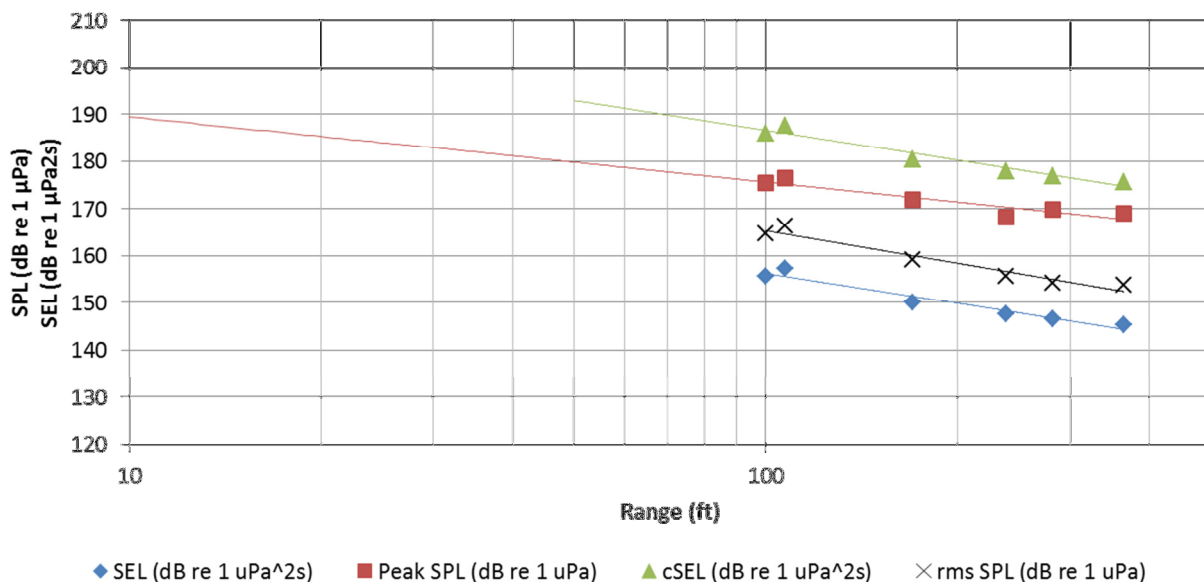


Figure 2. Regression based on mean values of the peak SPL, rms SPL, and single strike SELs from each recorder from pile driving of PLT- [REDACTED] 03 August 2013. Single Strike SEL, Peak SPL, and rms SPL are instantaneous values. cSEL, represents the cumulative Sound Exposure Level at the end of pile driving.

1.3. Observations

Sound levels appear to be negatively correlated with the noise attenuation system (NAS) air flow (measured sound levels increase as air flow decreases) or positively correlated with the hammer energy. The effects of tidal state do not appear to affect the sound levels. To demonstrate this relationship Figure 3 presents the sound measurements at the location Peak SPL Barge annotated with the following NAS air pressure settings and hammer energy states:

- 70 psi & [REDACTED] kip-ft;
- 50 psi & [REDACTED] kip-ft; and
- 40 psi & [REDACTED] kip-ft.

The sound level statistics and a regression of the radii to the NMFS thresholds was performed for each of measurement state. There are 5 – 9 dB differences in the peak SPL, 4-6 dB differences in the rms SPL, and 4-6 dB differences in the single-strike SELs at each recorder among the three measurements states (Table 4). The sound levels were higher when the NAS setting was lower, however, the strikes/ft were higher, and the river current was also higher during the measurements with lower NAS air flow. The distances to each NMFS threshold meet the BO thresholds in all measurements states (Table 5).

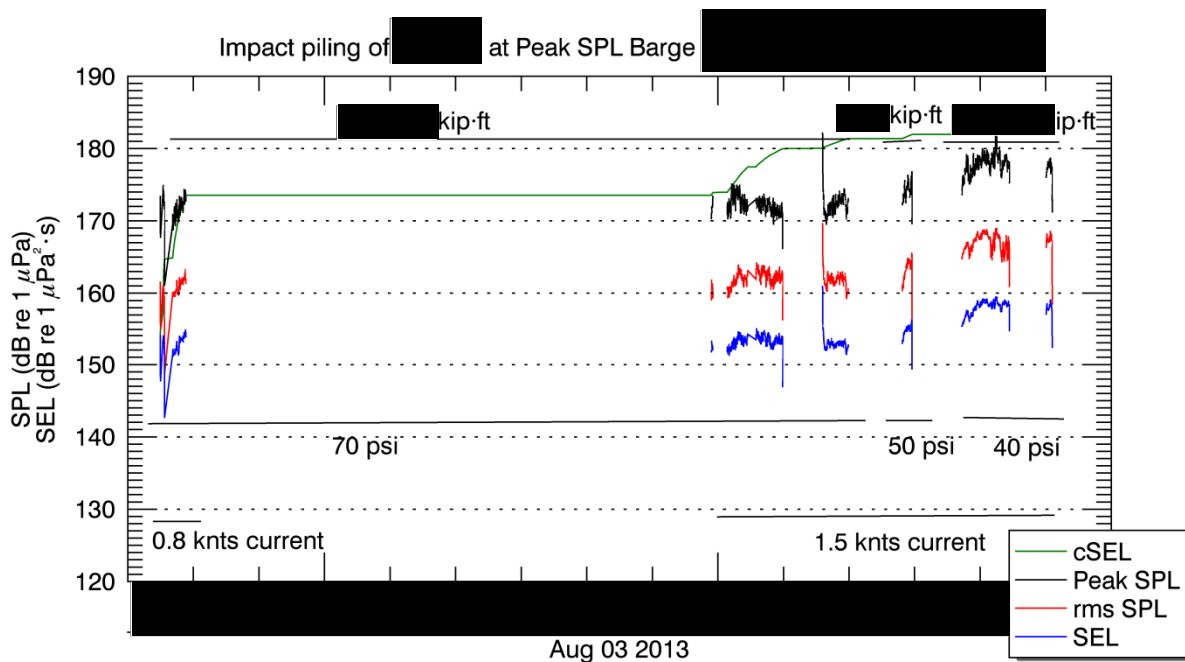


Figure 3. Annotated plot of measured sound levels versus time (in EDT), hammer energy per strike, noise-attenuation system pressure settings, and river current (in knots). The measurements were made at location Peak SPK Barge, 100 ft down-current from the pile.

Table 4. Median sound levels measured during each NAS air flow setting during piling of PLT-████ 3 August 2013. Peak SPL and rms SPL units are dB re 1 μ Pa. Single Strike (SS) SEL units are dB re 1 μ Pa²·s. Effects of changing settings are found by subtracting the sound levels from the 70 psi measurements from the levels on the same recorder at the other settings. For example, peak SPL at cSEL North was 163 dB at 70 psi, and 171 dB at 40 psi, for a difference of 8 dB.

Location	Distance to Pile (ft)	70 psi, █████ strikes)			50 psi, █████ strikes)			40 psi, █████ strikes)		
		Peak SPL	rms SPL	SS SEL	Peak SPL	rms SPL	SS SEL	Peak SPL	rms SPL	SS SEL
Peak SPL, Barge	100	172	162	153	174	163	155	177	167	158
Peak SPL, Vessel	170	168	156	147	171	159	150	174	161	152
cSEL East	282	164	151	143	168	154	146	173	156	148
cSEL North	365	163	151	142	164	151	143	171	155	147
cSEL South	238	164	152	144	166	155	147	170	158	150

Table 5. Estimated isopleth radii for the NMFS physiological and behavioral thresholds as a function of NAS air pressure. The cSEL radius is estimated for all states as if there were █████ strikes.

Criteria	Estimated Radius (ft),		
	70 psi, █████ kip-ft	50 psi, █████	40 psi, █████
206 dB re 1 μ Pa peak SPL	1.0	1.0	0.2
187 dB re 1 μ Pa ² ·s cSEL	58	80	112
150 dB re 1 μ Pa rms SPL (one second integration time)	387	441	610

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Time (EDT)	Activity
10:05	Safety meeting on shore.
10:13	Performed hydrophone calibration on AMAR-RT.
10:20	Transited to barge spread
10:25	Begin deploying AMARs
11:00	All autonomous AMARs deployed

Time (EDT)	Activity
[REDACTED]	[REDACTED]
18:00	Alpine vessel beginning retrieval of AMARs (ADCP shutdown)
18:38	All AMARs retrieved
18:58	Alpine vessel at dock
19:30	Downloading data and securing for the day

2.2. Pile Driving Logs

2.2.1. Noise Attenuation System

Noise Attenuation System (NAS) Used: 5-tier unconfined bubble curtain.

Table 6. NAS Setting recorded by HDR during piling at PLT- [REDACTED] 3 August 2013

Time (EDT)	Air Flow (cfm)	Air Pressure (psi)
[REDACTED]	1700 – 2000	70
[REDACTED]	1200 – 1300	50
[REDACTED]	900 – 1100	40

2.2.2. Impact Hammering Log:

Total Energy: [REDACTED] kip·ft [REDACTED] MJ)

Total number of strikes: [REDACTED]

Maximum per-strike energy: [REDACTED] kip·ft [REDACTED] kJ)

Net piling duration (hh:mm:ss): [REDACTED]

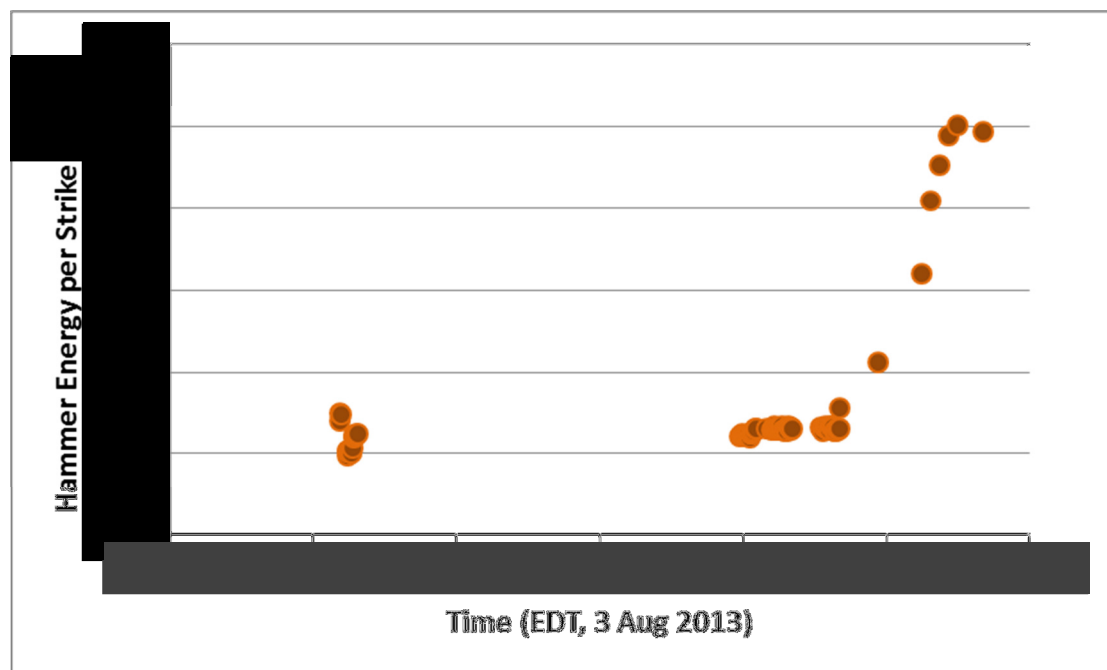


Figure 4. Hammer Energy per Strike for the impact piling of [REDACTED] 3 Aug 2013.

3. Weather and River Conditions

Table 7 provides the predicted currents at the project site on 3 August 2013. Figure 4 provides the Acoustic Doppler Current Profiler (ADCP)-measured currents. Figure 6 provides the speed of sound in water, based on salinity and temperature measured using the conductivity/temperature/depth (CTD) meter.

Table 7. Weather conditions, predicted local tide times, and water depth.

Weather conditions:	Clouds, rain, wind SW 5 knots building to 15 – 20 knots.
Full ebb current:	14:53 EDT
Slack current:	11:40 EDT
Full flood current:	09:08 EDT

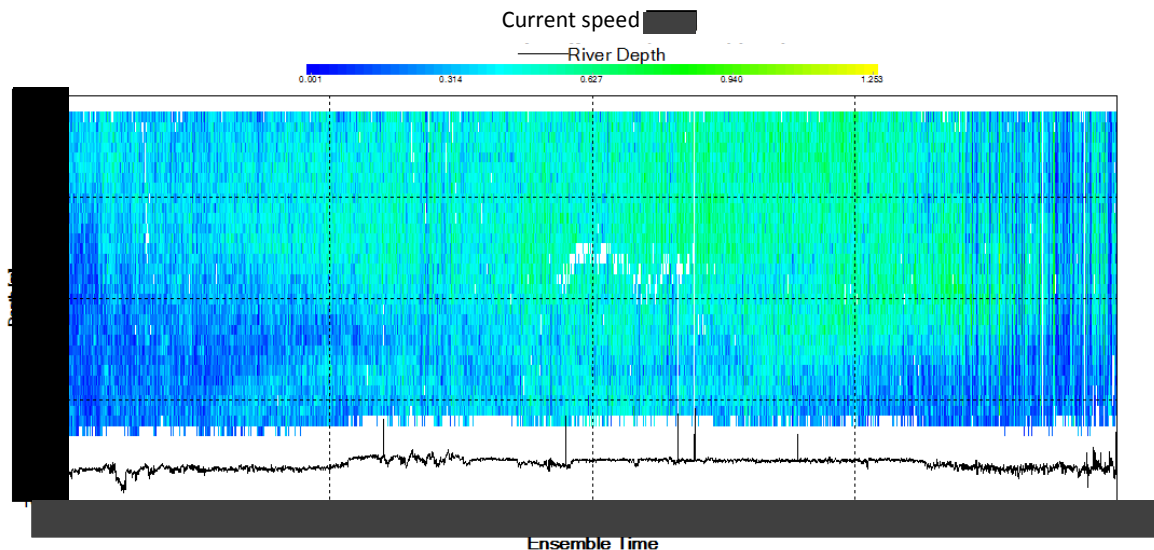


Figure 5. ADCP data from 2013 08 03 at the Peak SPL – Vessel location, times are in EDT

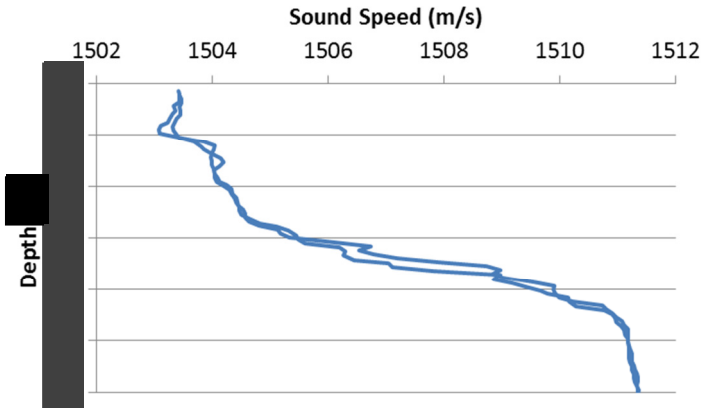


Figure 6. CTD Cast performed at 15:56 (EDT) at the Peak SPL – Barge location.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

The following provides information on the real-time monitoring equipment used on 03 August 2013. Table 8 provides location information on the real-time recorders

Acoustic Data Logger		Units Deployed
Model:	AMAR RT (JASCO Applied Sciences)	2
<i>SpectroPlotter</i> version:	6.0.1	2
Hydrophone		
Model:	M8KC (GTI)	2
██████████ Sensitivity:	-210.8 dB re 1 V/μPa	1
██████████ Sensitivity:	-210.9 dB re 1 V/μPa	1
Other		
Hydrophone calibrator:	42AC Pistonphone calibrator (G.R.A.S. Sound and Vibration)	1
CTD profiler:	Minos X (AML Oceanographic)	1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz	1

Table 8. Locations ██████████ and deployment times (EDT) of the AMAR-RT monitoring stations, 3 Aug 2013.

Station	Recorder ID	Latitude	Longitude	Deployment time	Water Depth (ft)	Distance to Pile (ft)
Peak SPL, Barge	██████████			12:22	██████████	100
Peak SPL, Vessel				12:30		170

4.2. Autonomous Monitoring Equipment

The following provides information on the autonomous monitoring equipment used on 03 August 2013. Table 9 provides the locations of the autonomous recorders.

Acoustic Data Logger		Units Deployed
Model:	AMAR G3 (JASCO Applied Sciences)	3
<i>SpectroPlotter</i> version:	6.0.1	3
Hydrophone		

Model:	M8E-51-0dB (GTI)	3
Sensitivity:	-199.7 dB re 1 V/ μ Pa	1
Sensitivity:	-199.8 dB re 1 V/ μ Pa	1
Sensitivity:	-199.6 dB re 1 V/ μ Pa	1

Table 9. Locations () and deployment times (EDT) of the long-range monitoring AMAR stations 3 Aug 2013

Station	Recorder ID	Latitude	Longitude	Deployment time	Water Depth	Distance to Pile (ft)
cSEL East (Cross-current)				10:53		282
cSEL North (down-current)				10:44		238
cSEL South (up current)				10:48		365

5. Daily Monitoring Close-out

Raw data archived to disk:	<u>2013-08-01 11:30</u>
Raw data transferred to data-warehouse:	<u>archived locally</u>
Logs, CTD data & ADCP data transferred to project server:	<u>archived locally</u>
CSV and XLSX analysis files and scripts transferred to project server:	<u>archived locally</u>
Photos transferred to project server:	<u>archived locally</u>

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels From Vessel

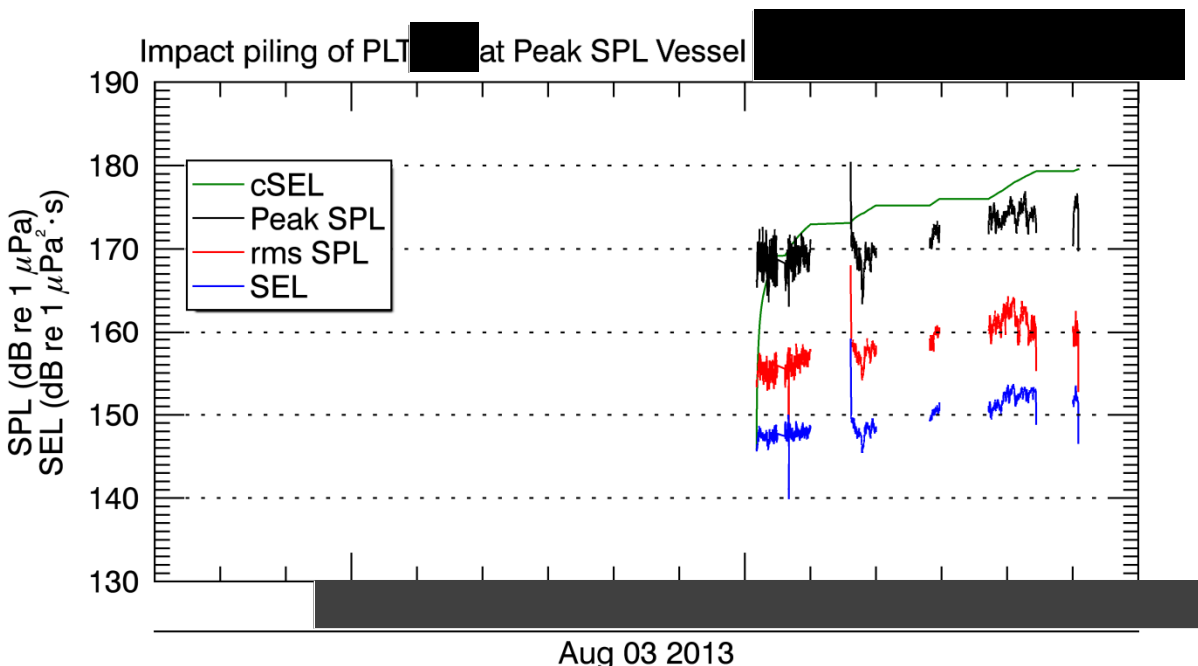


Figure 7. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (EDT) measured at location Peak SPL – Vessel during pile driving at PLT- [REDACTED] (170 ft from pile PLT- [REDACTED])

Table 10. Sound levels for the measurements at Peak SPL - Vessel during pile driving of PLT- [REDACTED] (170 ft from pile PLT- [REDACTED])

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{max}	180.3	167.9	159
L_5	175.4	163	153
L_{25}	173.6	160.5	151.5
L_{50}	170.4	157.9	148.7
L_{75}	168.5	156.2	147.7
L_{95}	166.4	154.4	146.7
L_{mean}	169.1	156.7	148

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

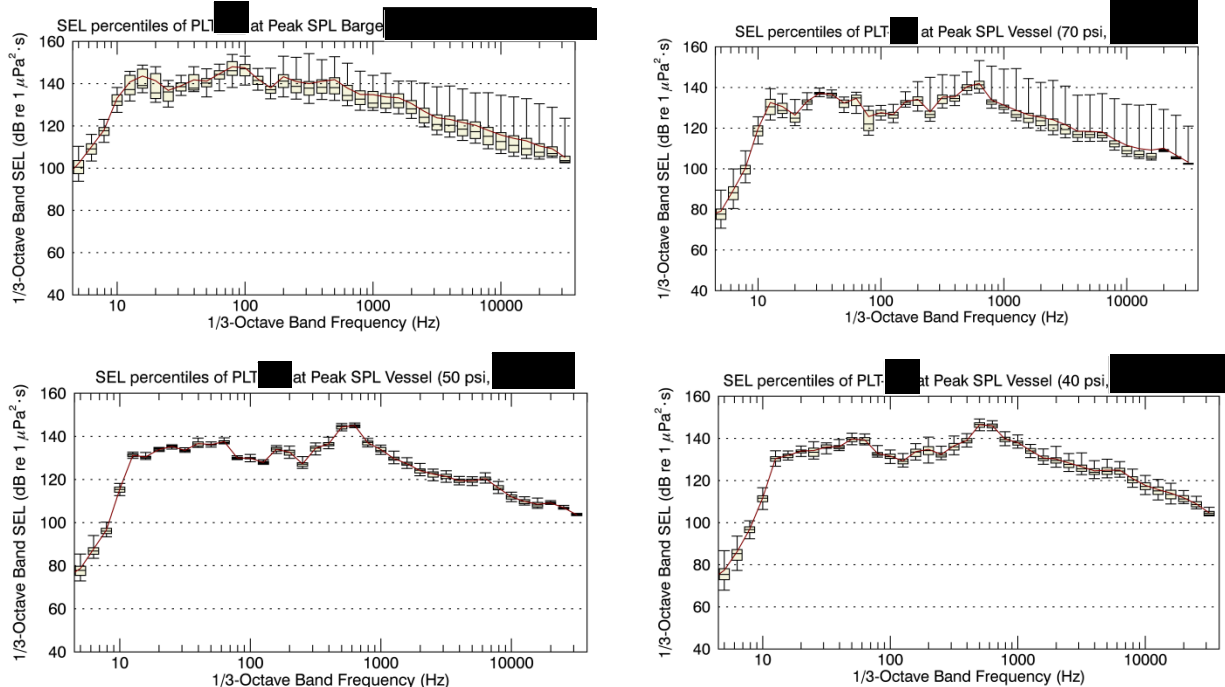


Figure 8. Distribution of one-second 1/3-octave-band single-strike SELs measured at location Peak SPL Vessel, 170 ft from Test Pile PLT-[REDACTED] on [REDACTED] ([REDACTED] strikes).). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 70 psi, [REDACTED] kip·ft [REDACTED] strikes). Bottom left: 50 psi, [REDACTED] kip·ft [REDACTED] strikes). Bottom right: 40 psi, [REDACTED] 0 kip·ft [REDACTED] strikes)

A.2. Impact Pile-Driving Sound Levels From Barge

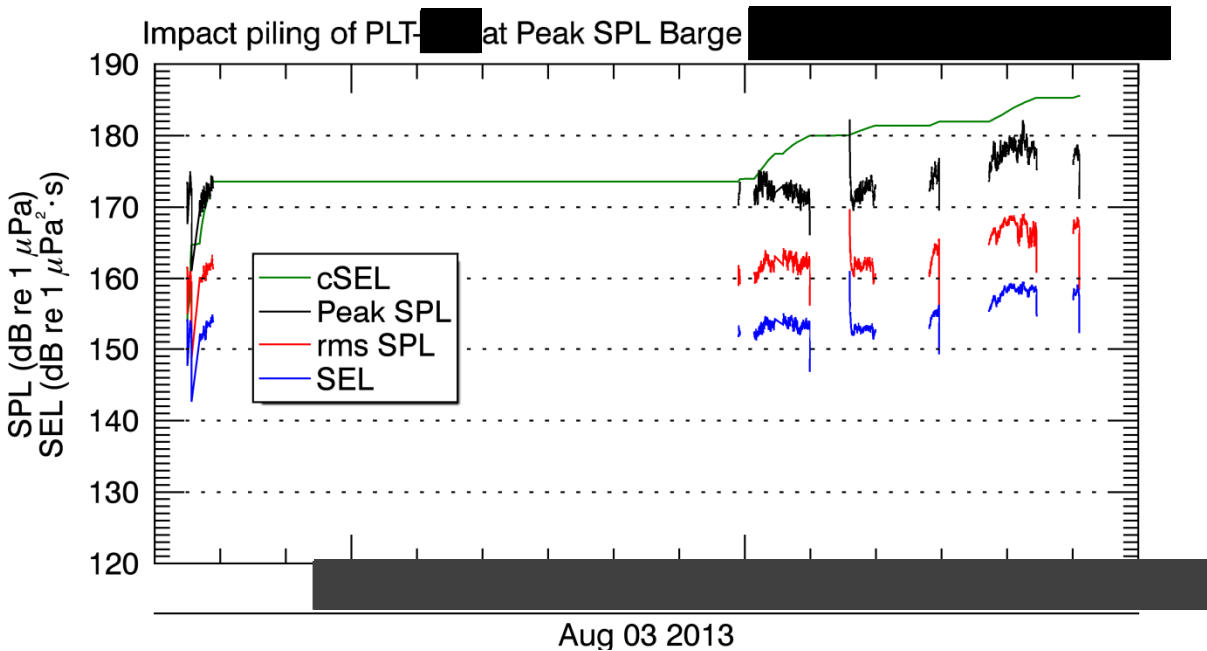


Figure 9. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (EDT) measured at location Peak SPL – Barge during pile driving at PLT- [REDACTED] (100 ft from pile PLT- [REDACTED])

Table 11. Sound levels for the measurements at Peak SPL - Barge during pile driving of PLT- [REDACTED] (100 ft from pile PLT- [REDACTED])

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{\max}	182.1	169.6	160.9
L_5	179.1	168.3	158.9
L_{25}	177	166.3	157.7
L_{50}	173.2	162.8	153.9
L_{75}	171.9	161.8	152.9
L_{95}	170.7	160.5	152.1
L_{mean}	172.4	161.9	153.2

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

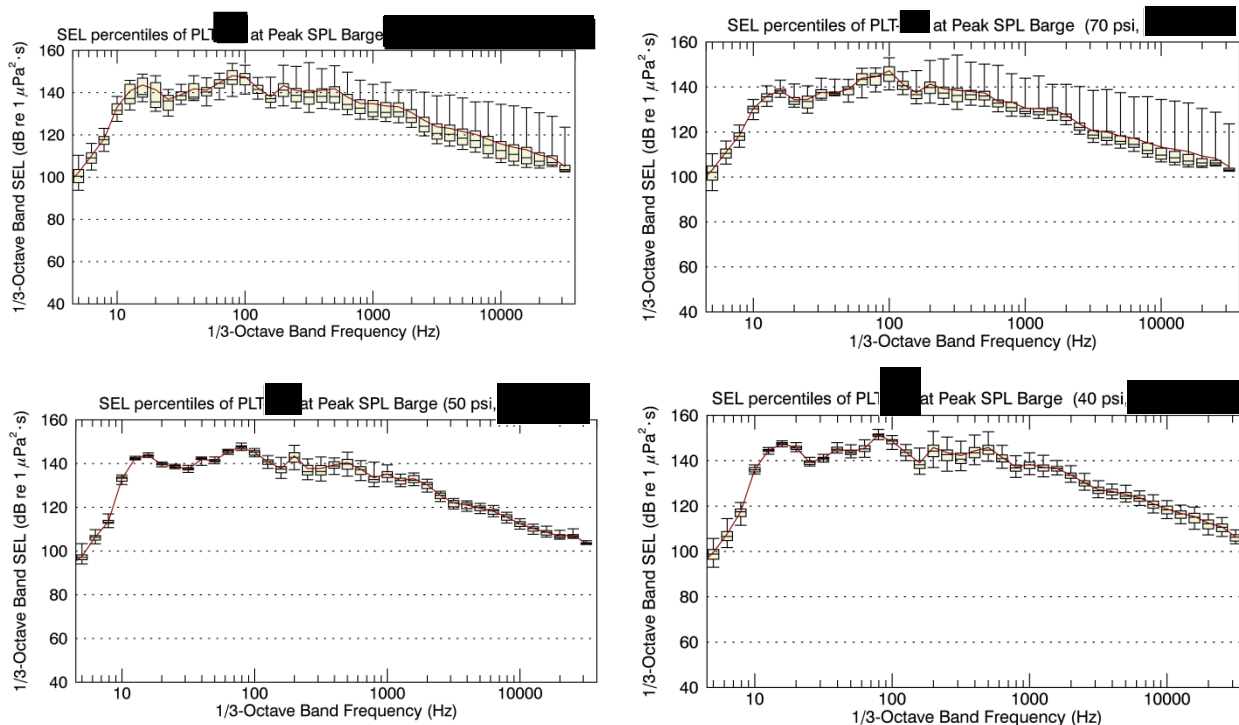


Figure 10. Distribution of one-second 1/3-octave-band single-strike SELs measured at location Peak SPL-Barge, 100 ft from Test Pile PLT- [REDACTED] on [REDACTED] strikes).). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 70 psi, [REDACTED] kip·ft [REDACTED] strikes). Bottom left: 50 psi [REDACTED] kip·ft [REDACTED] strikes). Bottom right: 40 psi, [REDACTED] 0 kip·ft [REDACTED] strikes)

A.3. Impact Pile-Driving Sound Levels cSEL East

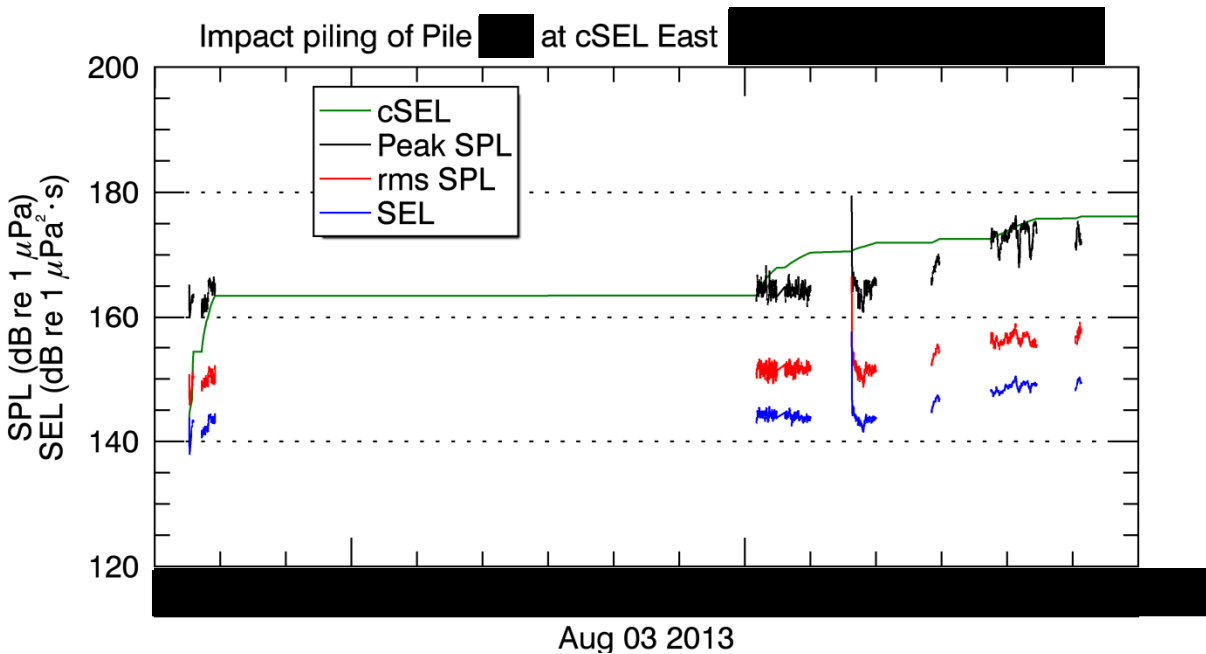


Figure 11. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (EDT) measured at location cSEL East during pile driving at PLT-[REDACTED] (282 ft from pile PLT-[REDACTED]).

Table 12. Sound levels for the measurements at cSEL East during pile driving of PLT-[REDACTED] (282 ft from pile PLT-[REDACTED]).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{\max}	179.3	166.3	157.4
L_5	174.7	157.4	149.5
L_{25}	172.4	155.7	148.3
L_{50}	165.6	152.4	144.5
L_{75}	164.1	151.4	143.7
L_{95}	162.9	150.2	142.9
L_{mean}	164.7	151.6	143.9

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

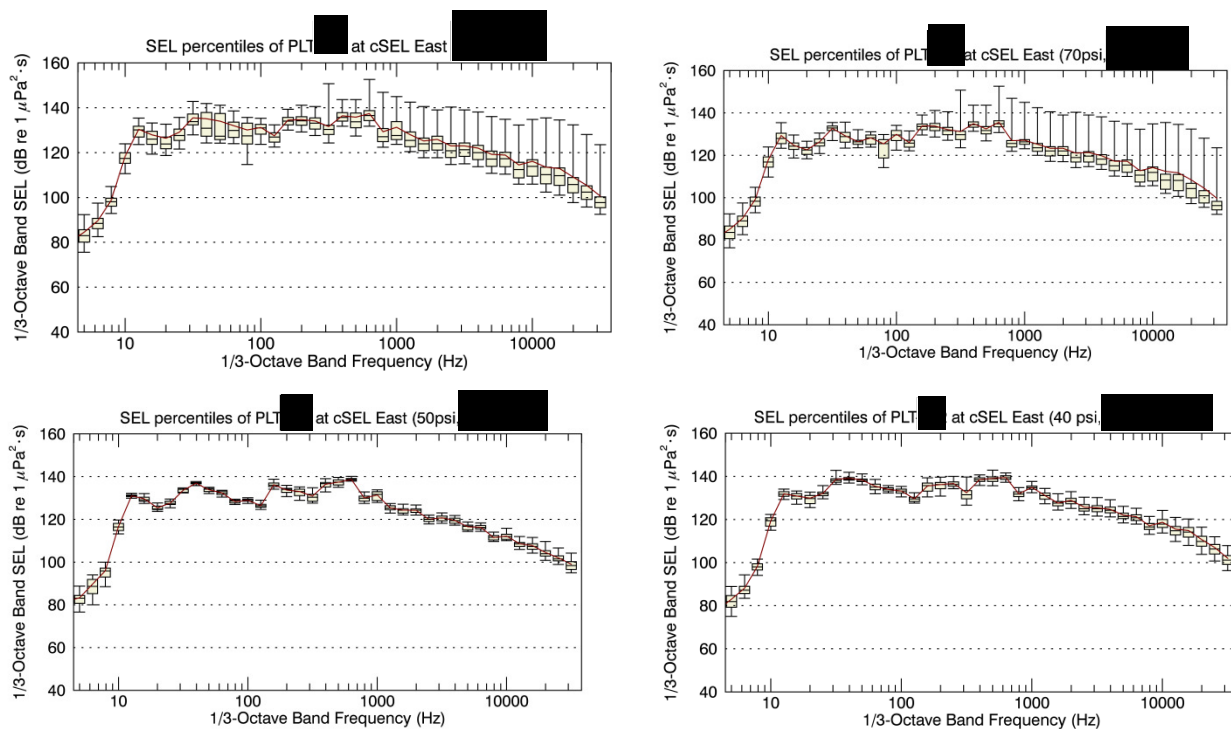


Figure 12. Distribution of one-second 1/3-octave-band single-strike SELs measured at location cSEL East, 282 ft from Test Pile PLT- on strikes).). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 70 psi, strikes). Bottom left: 50 psi, strikes). Bottom right: 40 psi, strikes)

A.4. Impact Pile-Driving Sound Levels cSEL North

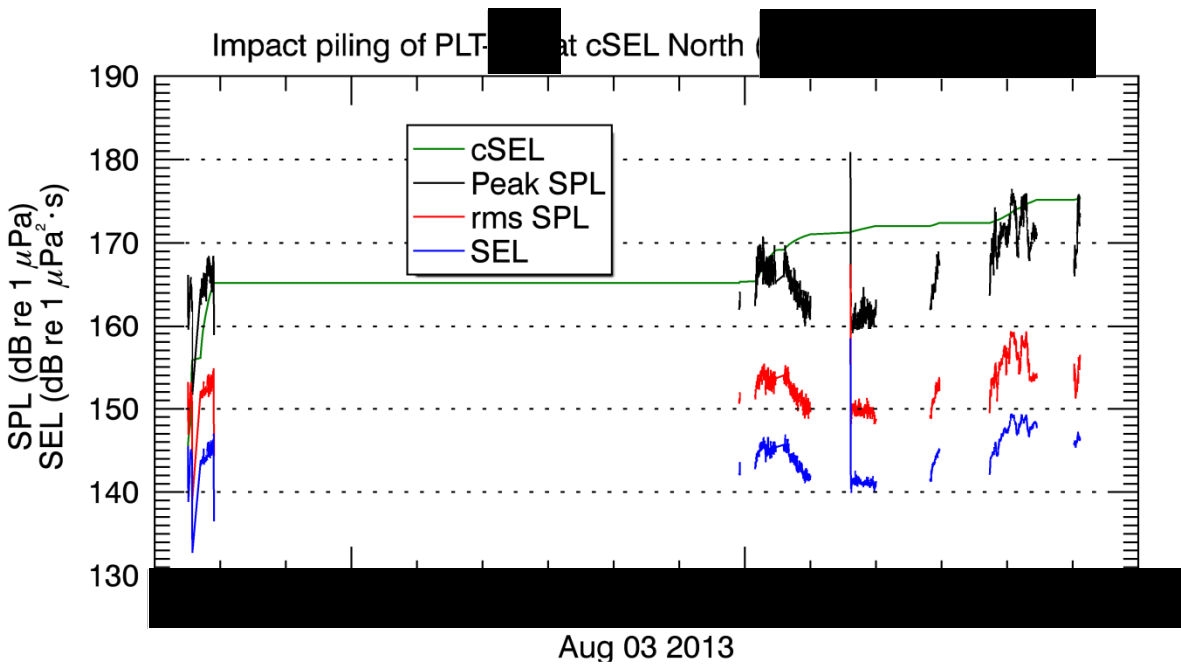


Figure 13. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (EDT) measured at location cSEL North during pile driving at PLT- [REDACTED] (365 ft from pile PLT- [REDACTED]).

Table 13. Sound levels for the measurements at cSEL North during pile driving of PLT- [REDACTED] (365 ft from pile PLT- [REDACTED]).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{\max}	180.8	167.4	158.3
L_5	174.5	157.9	148.7
L_{25}	169.8	154.3	146.4
L_{50}	166.4	152.8	144.6
L_{75}	162.5	150.5	142
L_{95}	160.3	149.2	140.9
L_{mean}	165.2	152.2	143.9

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

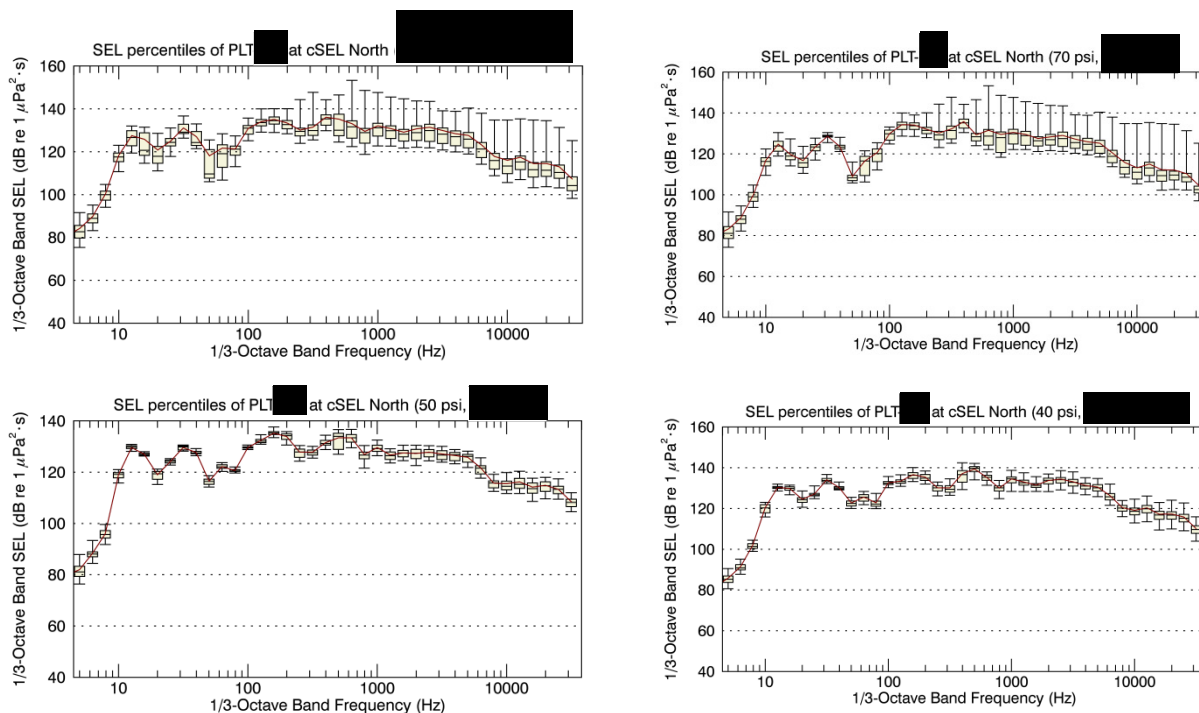


Figure 14. Distribution of one-second 1/3-octave-band single-strike SELs measured at location cSEL North, 365 ft from Test Pile PLT- on (strikes). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 70 psi, (strikes). Bottom left: 50 psi, (strikes). Bottom right: 40 psi, (strikes)

A.5. Impact Pile-Driving Sound Levels cSEL South

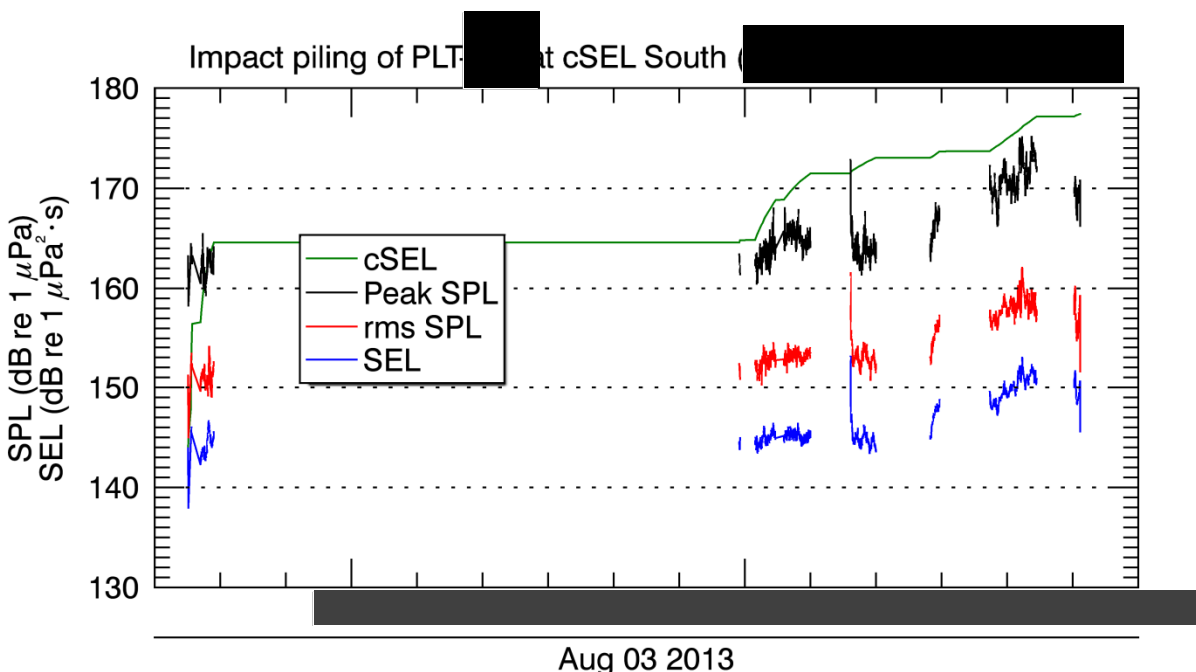


Figure 15. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (EDT) measured at location cSEL South during pile driving at PLT- [REDACTED] (238 ft from pile PLT- [REDACTED] 8).

Table 14. Sound levels for the measurements at cSEL South during pile driving of PLT- [REDACTED] (238 ft from pile PLT- [REDACTED] 8).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² s)
L_{\max}	175.2	162.1	153.2
L_5	172.9	159.3	151.5
L_{25}	169.9	157.2	149
L_{50}	165.4	153.6	145.5
L_{75}	163.9	152.7	144.9
L_{95}	162.3	151.8	144.1
L_{mean}	164.1	152.8	145

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

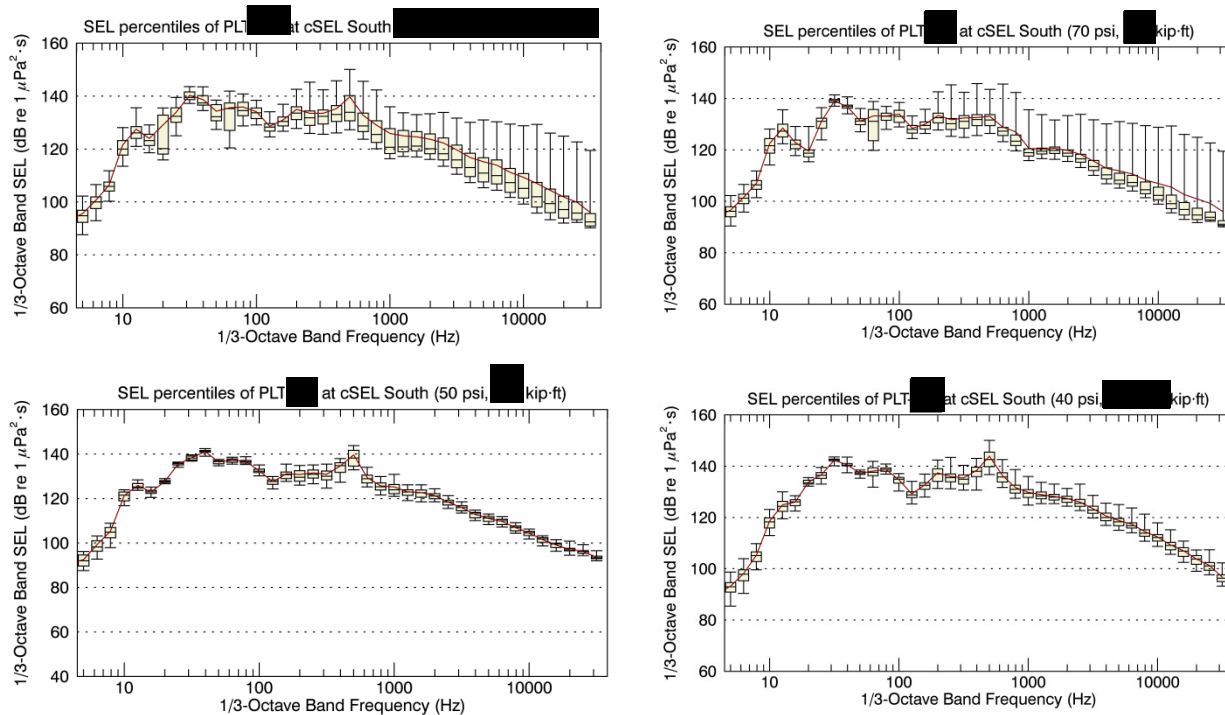


Figure 16. Distribution of one-second 1/3-Octave single-strike SELs measured at location cSEL South, 238 ft from Test Pile PLT- [redacted] on [redacted] strikes). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{\max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 70 psi, [redacted] kip-ft [redacted] strikes). Bottom left: 50 psi, [redacted] kip-ft [redacted] strikes). Bottom right: 40 psi, [redacted] kip-ft [redacted] strikes)



Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile Installation

Daily Memorandum for 19 August 2013

[REDACTED]
HDR

Authors:
[REDACTED]

20 August 2013
[REDACTED]

JASCO Applied Sciences
Suite 202, 32 Troop Ave.
Dartmouth, NS, B3B 1Z1, Canada
[REDACTED]
[REDACTED]
[REDACTED]



1. Summary

1.1. Pile Location and Monitoring Summary

PLT [REDACTED] is a [REDACTED] diameter pile driven at the site of the New NY Bridge on the west side of the navigation channel on 19 Aug 2013 (Table 1). Two real-time acoustic monitoring systems and 3 autonomous acoustic monitoring systems deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) to measure sound levels at ranges of 141 – 502 ft from the pile (Table 2, Figure 1). Piling driving occurred between [REDACTED] EDT. Full flood tide occurred at 08:32 EDT, slowing to slack tide at 11:45 UTC.

Table 1. Summary of PLT-[REDACTED] activities, 19 August 2013

Date:	19 August 2013
Pile-Driving Activity	
Test pile identifier:	PLT-[REDACTED]
Pile diameter:	[REDACTED]
Water depth	[REDACTED]
Hammer type:	[REDACTED]
Total hammer strikes	[REDACTED]
Total penetration (ft)	[REDACTED]
Net duration of pile driving (hh:mm:ss)	[REDACTED]
Maximum single strike energy	[REDACTED] kip-ft [REDACTED] kiloJoules [kJ])
Total energy transferred	[REDACTED] 8 kip-ft ([REDACTED] kJ)
Noise Attenuation System	
Five-tier unconfined bubble curtain airflow rate	800 - 2200 cubic feet per meter (cfm), 40 - 100 psi
River conditions during piling	Flood tide to slack tide, 0 - 1.6 knots (0 – 0.8 m/s depth dependent, Figure 6)



Location	AMAR ID	Distance to Pile (ft)	Water depth (ft)	Max. peak SPL (dB re 1 μPa)	SEL _{cum} (dB re 1 μPa ² s)*
Peak SPL- Barge (up-current)	██████████	125	125	191.9	188.2
Peak SPL- Vessel (cross-current)	██████████T	141		190.6	191.6
cSEL South (up-current)	██████████	396		183.9	184.0
cSEL West (cross-current)	██████████	268		186.1	182.7
cSEL North (down-current)	██████████8	502		180.8	181.0

3

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3 octave single-strike sound exposure levels (SELs), and sound level statistics for the distribution of the measured data are presented in Appendix A.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure levels (SPL), root mean square (rms) SPL, and single strike SELs from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 μ Pa peak SPL isopleth was approximately 6 ft and did not exceed NMFS criteria of a radius of 100 ft for [REDACTED] piles. The diameter of the 187 dB re 1 μ Pa²-s cumulative Sound Exposure Level (cSEL) isopleth was estimated to be approximately 400 ft at the end of pile driving. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore a fish movement corridor more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth radii for the NMFS physiological and behavioral thresholds.

Criteria	Estimated Radius (ft)
206 dB re 1 μ Pa peak SPL	3
187 dB re 1 μ Pa ² -s cSEL	198*
150 dB re 1 μ Pa rms SPL (one second integration time)	3498

*At the end of pile driving.

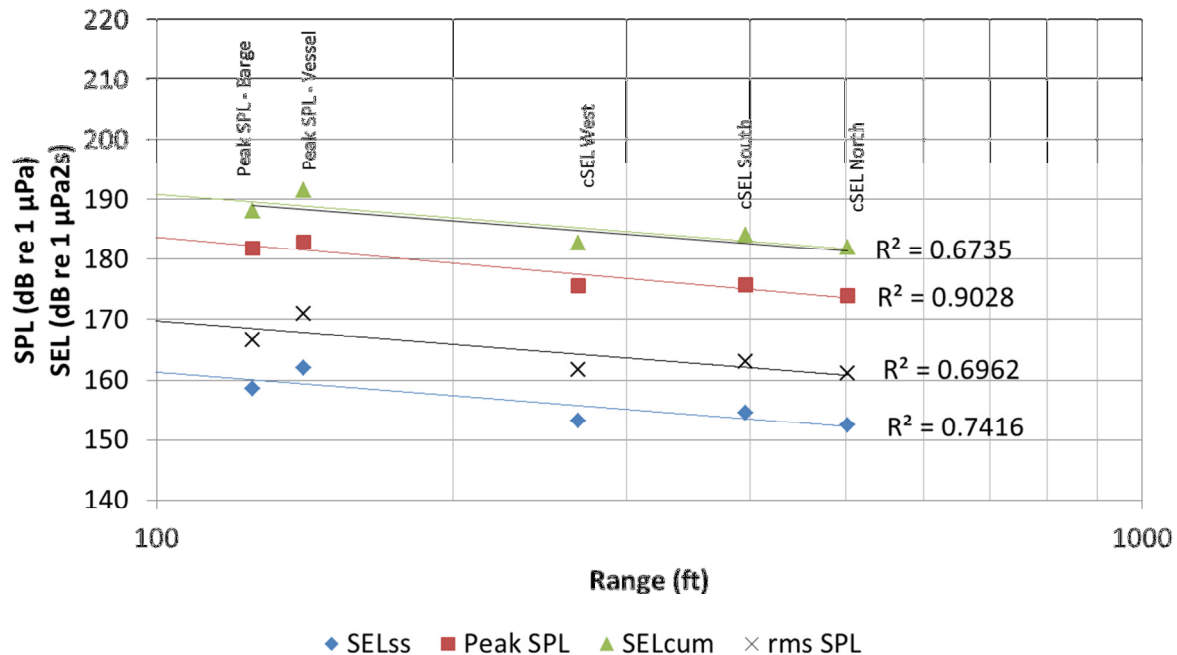


Figure 2. Regression based on mean values of the peak SPL, rms SPL, and single strike SELs from each recorder from pile driving of PLT-█ 19 August 2013. Single Strike SEL, Peak SPL, and rms SPL are instantaneous values. cSEL represents the cumulative Sound Exposure Level at the end of pile driving.

1.3. Observations

1.3.1. Noise Attenuation System (NAS) Airflow Settings, River Currents, and Hammer Energy Effects

The impact hammer was operated at █ kip-ft for most of the pile driving at PLT-█ rising to a maximum of █ kip-ft (█ kJ) at refusal (Figure 3). The NAS air flow rate was increased from ~1000 cfm to ~2000 cfm when the hammer energy was increased (Figure 3) PLT-█ was driven just after full flood-tide, and piling continued during slack tide (Figure 3).

There was a significant decrease in the median measured sound levels during the pile driving. Peak SPL, rms SPL and single strike SEL all appear to have dropped by 10 – 15 dB (Figure 3).

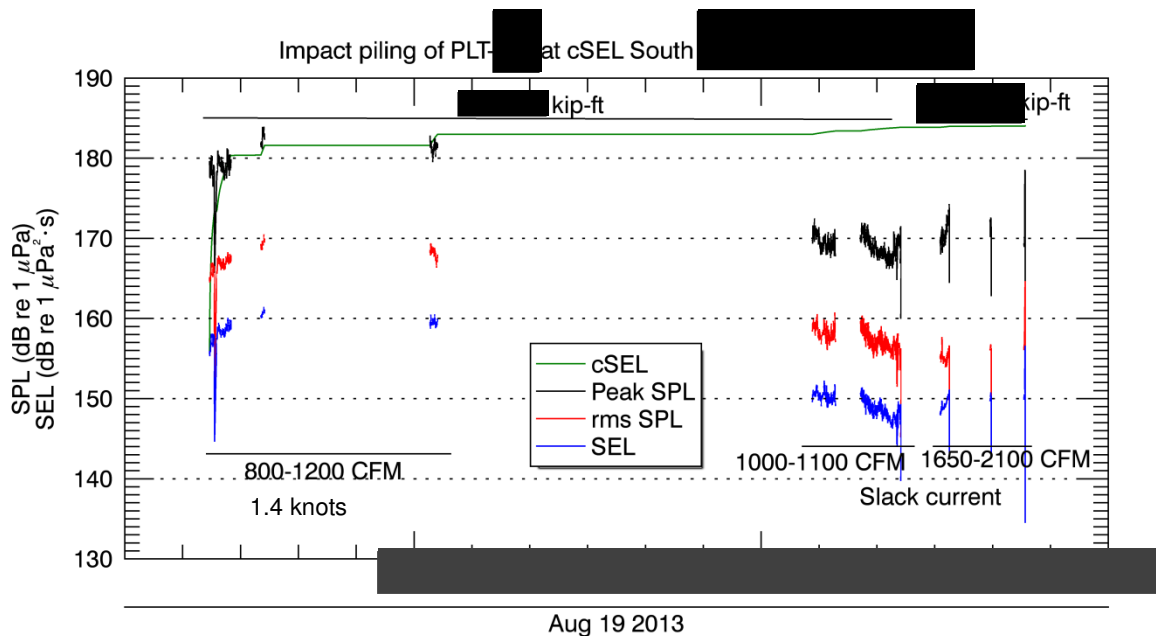


Figure 3. Annotated plot of measured sound levels, hammer energy (kip·ft), noise-attenuation system air flow setting (cfm), and river current (in knots). The measurements were made at location cSEL South, 396 ft up-current from the pile.

The effects of river current conditions on the measured sound levels can be examined by comparing the measurements at 1.4 knots to slack current while the hammer energy and NAS settings were unchanged (Figure 3, Table 4). Sound levels were 15 dB lower on average at cSEL West (cross-current) and cSEL North (down-current), but 10 – 12 dB lower for the other locations. This suggests that the NAS system was more effective at slack current than while the current was running. It is unclear why the levels at cSEL West and cSEL North were more affected than the others. In both current conditions the distances to sound levels were well below the required NMFS and NYSDEC thresholds (**Error! Reference source not found.**).

Table 4. Mean sound levels measured at 1.4 knots current and at slack tide during piling of PLT-█ 19 August 2013. Peak SPL and rms SPL units are dB re 1 μ Pa. Single Strike (SS) SEL units are dB re 1 μ Pa²-s. Effects of current are found by subtracting the sound level at slack current from the level on the same recorder at 1.4 knots current. For example, peak SPL at cSEL North was 177.9 dB at 1.4 knots, and 161.7 dB at slack current, for a difference of 16.2 dB.

Location	Distance to Pile (ft)	1.4 knots current (█ strikes)			Slack current (█ strikes)		
		Peak SPL	rms SPL	SS SEL	Peak SPL	rms SPL	SS SEL
Peak SPL- Barge (up-current)	125	186.6	171.7	163.3	173.2	157.2	151.3
Peak SPL- Vessel (cross-current)	141	187.6	175.3	166.4	175.7	165.3	156.4
cSEL South (up-current)	396	180.3	167.5	158.9	169.2	157.6	149.3
cSEL West (cross-current)	268	180.5	166.4	157.7	164.7	151.3	144
cSEL North (down-current)	502	177.9	165.1	156.5	161.7	150.8	142.8

Table 5. Estimated isopleth radii for the NMFS physiological and behavioral thresholds comparing estimates using the full data set, the results for 1.4 knots and the results for slack current (**Error! Reference source not found.**).

Criteria	Estimated Radius (ft) using full data set	Estimated Radius (ft) 1.4 knots current	Estimated Radius (ft) slack current
206 dB re 1 μ Pa peak SPL	2.9	7.5	2.4
187 dB re 1 μ Pa ² -s cSEL	198	418	70
150 dB re 1 μ Pa rms SPL (one second integration time)	3498	6089	701

It is also possible to compare the median sound levels at each recorder as a function of NAS setting and hammer energy at slack current (Table 6). Since all of these measurements were made at slack current, and all recorders were at very similar depths, we expect that differences in measured sound levels are due to either the increase in hammer energy or changed operation of the NAS system at the higher flow rates. The differences can be highlighted by setting one recorder's values as a reference baseline (in Table 7 the Peak SPL Barge is used as the reference). There are no consistent patterns in the levels compared to the reference, which indicates that neither the increase in hammer energy nor the increase in air flow are having a predictable effect on the measured sound levels (Table 7). The inconsistency of the air flow, the rapidly changing hammer energies, and the low number of strikes mean the effect of changes in air flow at █ can not be conclusively determined.

Table 6. Median sound levels measured during slack current to compare the effects NAS setting and hammer energy during piling of PLT-████ 19 August 2013. Peak SPL and rms SPL units are dB re 1 μ Pa. Single Strike (SS) SEL units are dB re 1 μ Pa²-s. Effects of changing settings are found by subtracting the sound levels from the 1650-2100 cfm measurements from the levels on the same recorder at 800-1200 cfm. For example, peak SPL at cSEL North was 163.6 dB at 1650-2100 cfm, and 161.7 dB at 800-1200 cfm, for a difference of 1.9 dB.

Location	Distance to Pile (ft)	1650-2100 cfm (80-100 psi), slack current, █████ kip-ft (████ strikes)			800-1200 cfm (40-60 psi), slack current, █████ kip-ft (████ strikes)		
		Peak SPL	rms SPL	SS SEL	Peak SPL	rms SPL	SS SEL
Peak SPL-Barge (up-current)	125	174.6	158.4	153.8	173.2	157.2	151.3
Peak SPL-Vessel (cross-current)	141	177.6	162.1	155.6	175.7	165.3	156.4
cSEL South (up-current)	396	170.5	155.1	149.2	169.2	157.6	149.3
cSEL West (cross-current)	268	170.8	159.3	152.6	164.7	151.3	144
cSEL North (down-current)	502	163.6	148.8	142.7	161.7	150.8	142.8

Table 7. dB difference between each station's median sound level and the median sound level measured at the Peak SPL - Barge station during slack current to compare the effects NAS setting and hammer energy for █████

Pile	Distance to Pile (ft)	1650 2100 cfm (80-100 psi), slack current, █████ kip-ft (████ strikes)			800-1200 cfm (40-60 psi), slack current, █████ kip-ft (████ strikes)		
		Peak SPL	rms SPL	SS SEL	Peak SPL	rms SPL	SS SEL
Peak SPL-Barge (up-current)	125	0	0	0	0	0	0
Peak SPL-Vessel (cross-current)	141	3	3.7	1.8	2.5	8.1	5.1
cSEL South (up-current)	396	-4.1	-3.3	-4.6	-4	0.4	-2
cSEL West (cross-current)	268	-3.8	0.9	-1.2	-8.5	-5.9	-7.3
cSEL North (down-current)	502	-11	-9.6	-11.1	-11.5	-6.4	-8.5

1.3.2. Growth of the cSEL Isopleth

The cSEL presented in the figures and tables of this section represent the total energy at the end of pile driving measured at each recorder and the estimated radius of the area which received 187 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ cSEL. Figure 4 depicts how the radius of the 187 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ cSEL area increases over the pile driving period of PLT- [REDACTED]

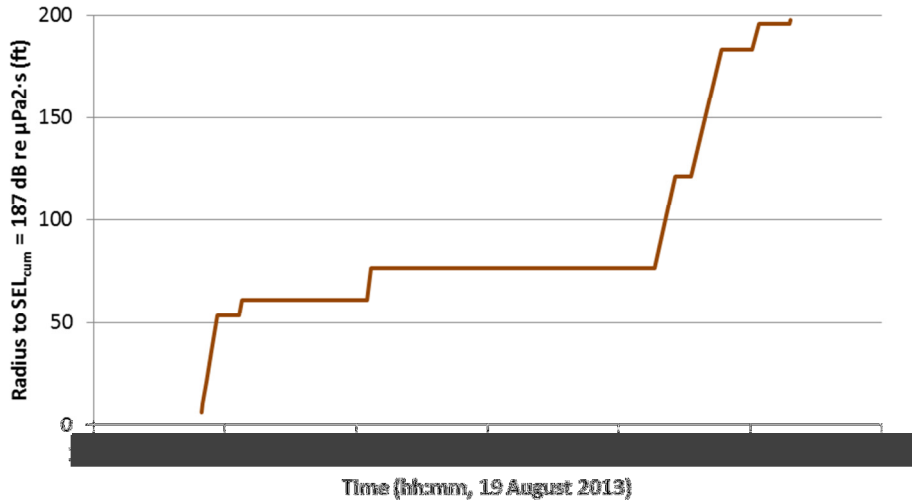


Figure 4. Estimated radius of the area around PLT- [REDACTED] where SEL_{cum} exceeded 187 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ as a function of time. Flat sections are time periods without pile driving (Figure 3).

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Time (EDT)	Activity
06:30	Safety meeting on shore.
07:30	Set out from Cornetta's to deploy 3 AMARs
08:15	3 AMARs deployed
[REDACTED]	
12:10	Begin retrieval of AMARs (ADCP shut down)

Time (EDT)	Activity
12:50	AMARs retrieved
14:15	Back at Cornetta's, data downloaded and gear secured for the day.

2.2. Pile Driving Logs

2.2.1. Noise Attenuation System

Noise Attenuation System (NAS) Used: 5-tier unconfined bubble curtain.

NAS Settings: 800 – 2100 cfm, 40-100 psi

Table 8. NAS Setting recorded by HDR during piling at PLT- 19 August 2013

Time (EDT)	Volume/min (cfm)	Pressure (psi)
	800 – 1200	40 – 60
	900 – 1100	40 – 50
	1000 – 1100	40 – 60
	1000 – 1100	40 – 50
	1000 – 1200	40 – 60
	1650 – 2100	80 – 100
	No readings	No readings
	1650 – 2100	80 – 100

2.2.2. Impact Hammering Log

Total Energy: kip·ft MJ)

Total number of strikes:

Maximum per-strike energy: kip·ft kJ)

Net piling duration (hh:mm:ss):

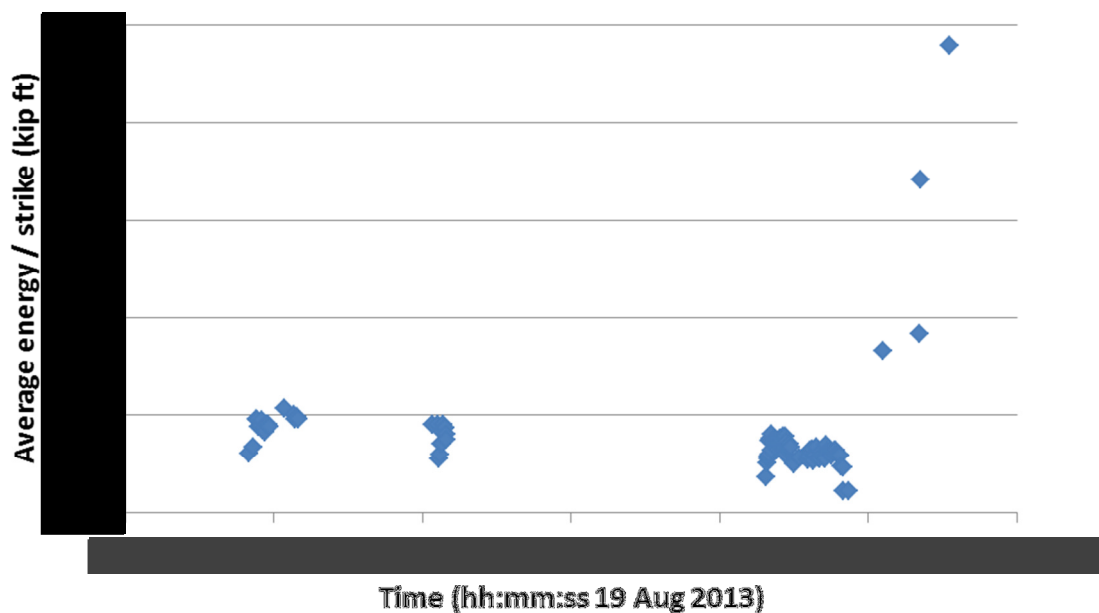


Figure 5. Pile-driving record for PLT-[redacted] as provided by the piling contractor (times in EDT).

3. Weather and River Conditions

Table 9 provides the predicted currents at the project site on 19 August 2013. Figure 4 provides the ADCP-measured currents. Figure 7 provides the speed of sound in water, based on salinity and temperature measured using the CTD.

Table 9. Weather conditions, predicted local tide times, and water depth.

Weather conditions:	Mainly sunny, Sea State 1-2, wind 3-5 knots from south.
Full flood current:	08:32 EDT
Slack current:	11:45 EDT
Full ebb current:	14:57 EDT

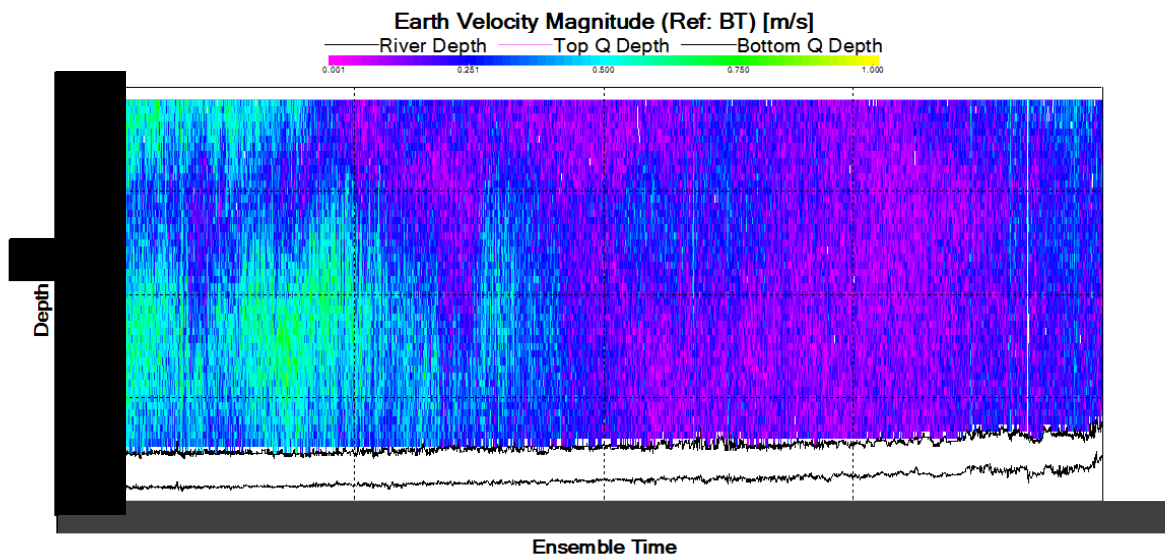


Figure 6. ADCP data from 2013 08 19 at the Peak SPL – Vessel location, times are in EDT.

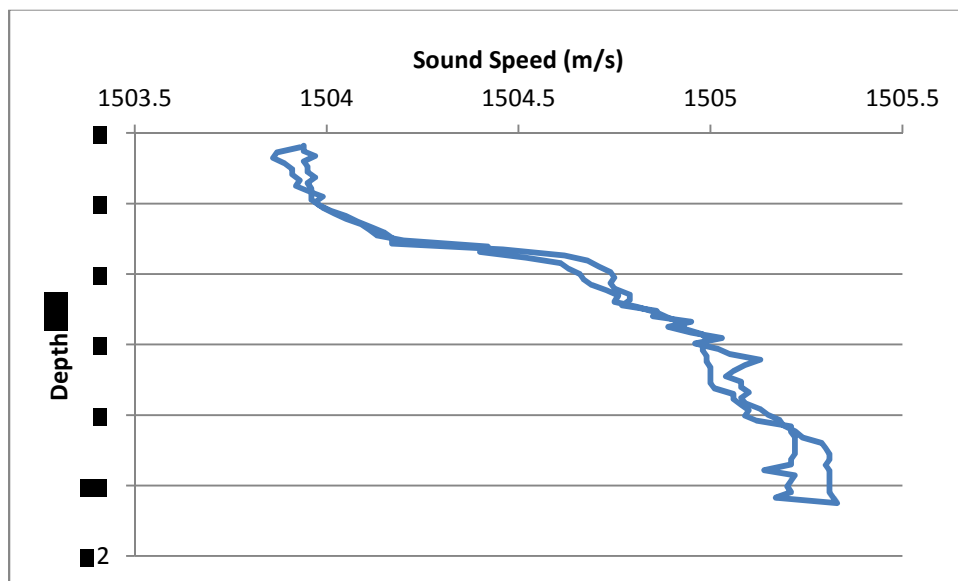


Figure 7. CTD Cast performed at 10:45 (EDT) at the Peak SPL – Barge location.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

The following provides information on the real-time monitoring equipment used on 19 August 2013. Table 10 provides location information on the real-time recorders.

Acoustic Data Logger			Units Deployed
Model:	AMAR RT (JASCO Applied Sciences)		2
<i>SpectroPlotter</i> version:	6.0.1		2
Hydrophone			
Model:	M8KC (GTI)		2
	Sensitivity:	-210.9 dB re 1 V/ μ Pa	1
	Sensitivity:	-210.8 dB re 1 V/ μ Pa	1
Other			
Hydrophone calibrator:	Pistonphone Type 42AC (G.R.A.S. Sound and Vibration)		1
CTD profiler:	Minos X (AML Oceanographic)		1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz		1

Table 10. Locations () and deployment times (EDT) of the AMAR-RT monitoring stations, 19 Aug 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time	Water Depth (ft)	Distance to Pile (ft)
Peak SPL, Barge				08:20		125
Peak SPL, Vessel				09:18		141

4.2. Autonomous Monitoring Equipment

The following provides information on the autonomous monitoring equipment used on 19 August 2013. Table 11 provides the locations of the autonomous recorders.

Acoustic Data Logger			Units Deployed
Model:	AMAR G3 (JASCO Applied Sciences)		3
<i>SpectroPlotter</i> version:	6.0.1		3
Hydrophone			

Model:	M8E-51-0dB (GTI)	3
Sensitivity:	-199.8 dB re 1 V/ μ Pa	1
Sensitivity:	-199.7 dB re 1 V/ μ Pa	1
Sensitivity:	-199.7 dB re 1 V/ μ Pa	1

Table 11. Locations () and deployment times (EDT) of the long-range monitoring AMAR stations 19 Aug 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time	Water Depth	Distance to Pile (ft)
cSEL South (up-current)				07:41		396
cSEL West (cross-current)				08:12		268
cSEL North (down-current)				08:02		502

5. Daily Monitoring Close-out

Raw data archived to disk:	<u>2013-08-19 17:00</u>
Raw data transferred to data-warehouse:	<u>not yet completed</u>
Logs, CTD data & ADCP data transferred to project server:	<u>archived locally</u>
CSV and XLSX analysis files and scripts transferred to project server:	<u>archived locally</u>
Photos transferred to project server:	<u>archived locally</u>

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels From Barge

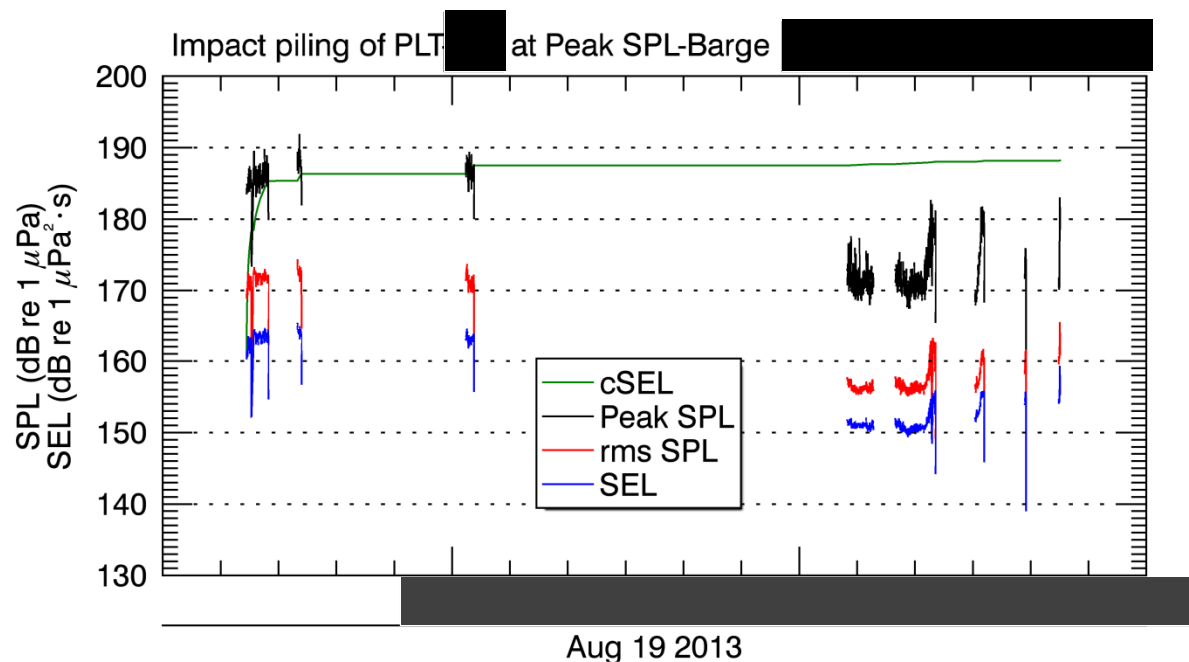


Figure 8. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location Peak SPL – Barge (Up-Current) during pile driving at PLT- [REDACTED] (125 ft from pile PLT- [REDACTED])

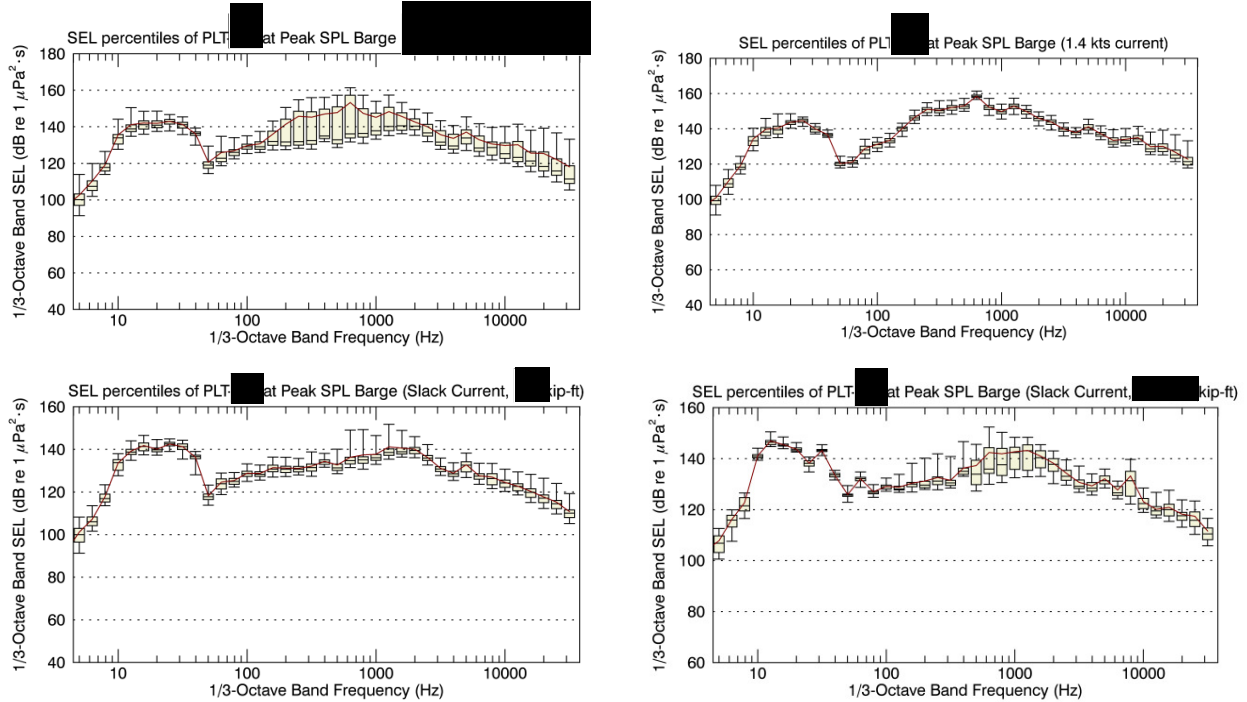


Figure 9. Distribution of one-second 1/3-Octave single-strike SELs measured at location Peak SPL-Barge 125 ft from Test Pile PLT-125 on 125 kip-ft strikes). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 1.4-knot river current, 125 kip-ft strikes). Bottom left: slack current, 125 kip-ft strikes). Bottom right: slack current, 125 kip-ft strikes).

Table 12. Sound levels for the measurements at Peak SPL - Barge (Up-Current) during pile driving of PLT-125 (125 ft from pile PLT-125).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² -s)
L_{max}	191.9	174.3	165.5
L_5	187.8	172.5	164.1
L_{25}	184.8	170.7	162.5
L_{50}	173	157.1	151.6
L_{75}	170.8	156.2	150.8
L_{95}	169.2	155.5	150.1
L_{mean}	181.8	166.7	158.6

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

A.2. Impact Pile-Driving Sound Levels From Vessel

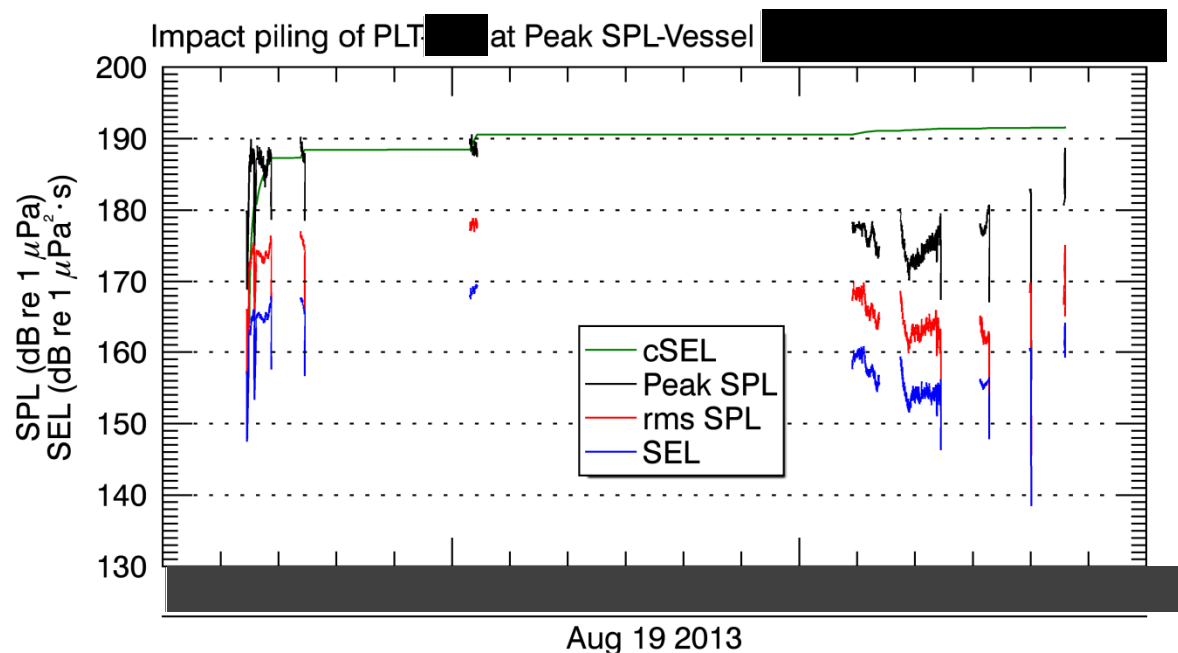


Figure 10. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location Peak SPL – Vessel (cross-current) during pile driving at PLT-████ (141 ft from pile PLT-████ AMAR-RT-12).

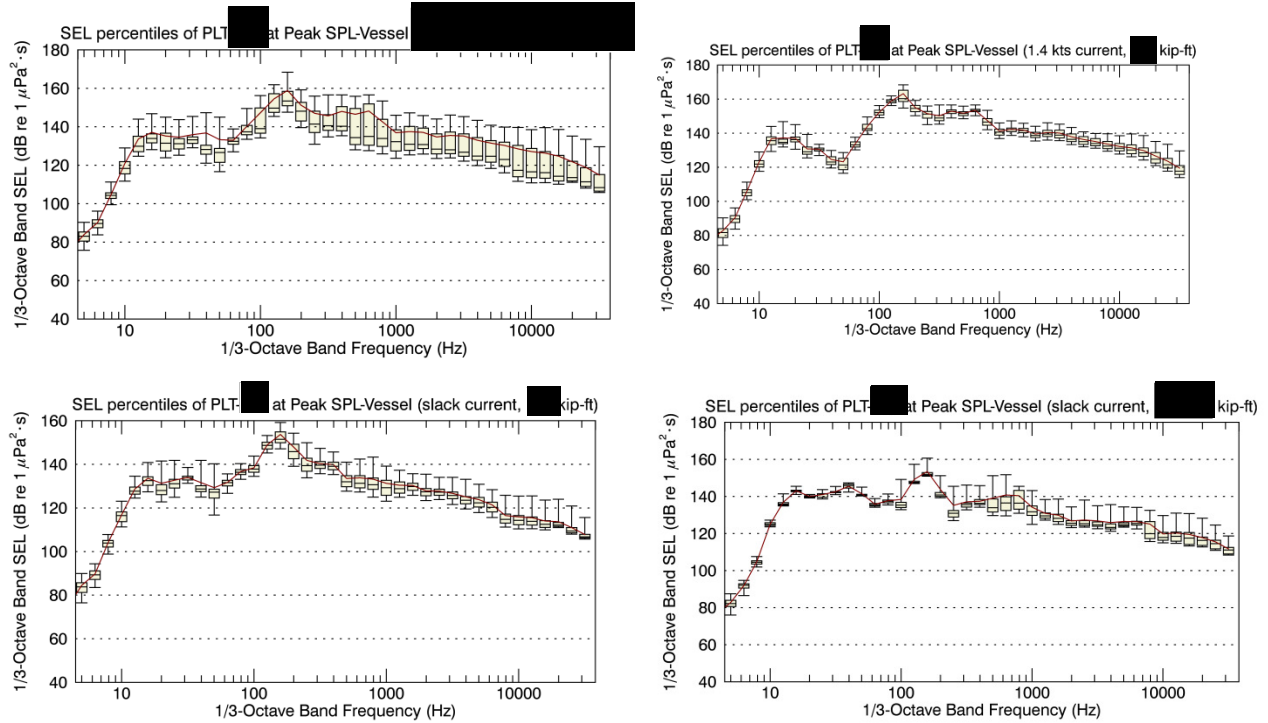


Figure 11. Distribution of one-second 1/3-octave-band single-strike SELs measured at location Peak SPL-Vessel 141 ft from Test Pile PLT- (on strikes). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 1.4-knot river current, kip-ft strikes). Bottom left: slack current kip-ft strikes). Bottom right: slack current, kip-ft strikes).

Table 13. Sound levels for the measurements at Peak SPL - Vessel (cross-current) during pile driving of PLT- (141 ft from pile PLT-).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² -s)
L_{max}	190.6	178.9	169.6
L_5	188.6	177.7	168.3
L_{25}	186	173.1	164.4
L_{50}	177.2	165.5	156.9
L_{75}	174.8	163.1	154.4
L_{95}	166.4	154.4	146.7
L_{mean}	183	170.9	162

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

A.3. Impact Pile-Driving Sound Levels cSEL South

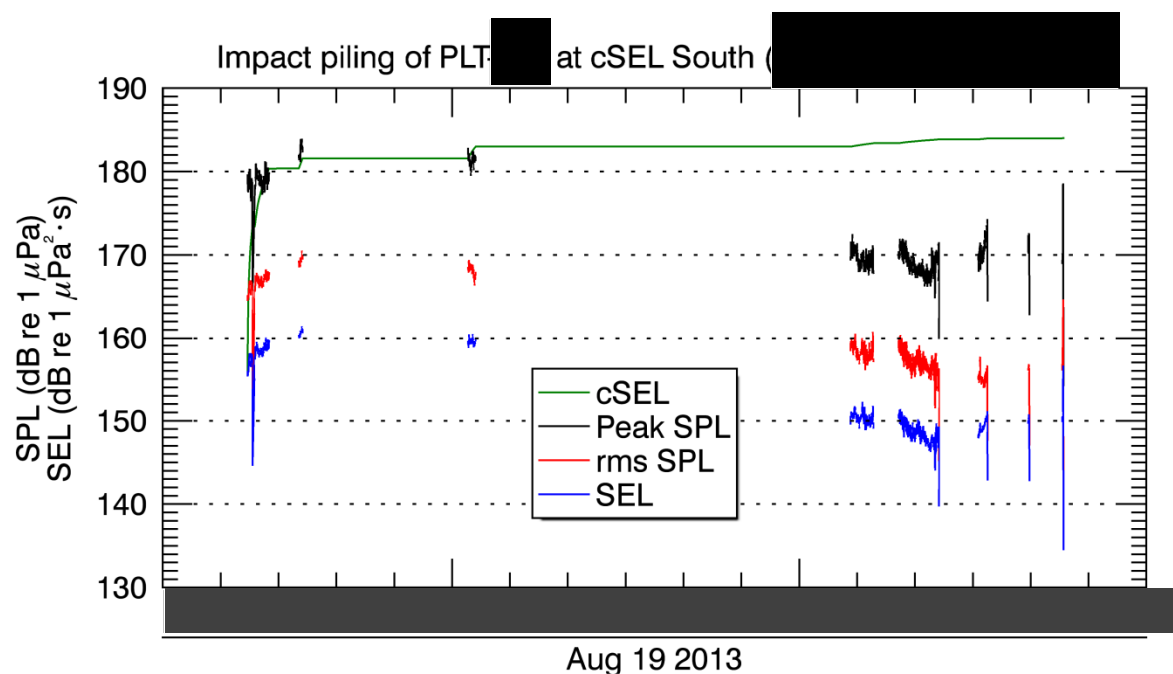


Figure 12. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location cSEL South (up-current) during pile driving at PLT- [REDACTED] (396 ft from pile PLT- [REDACTED] AMAR-221).

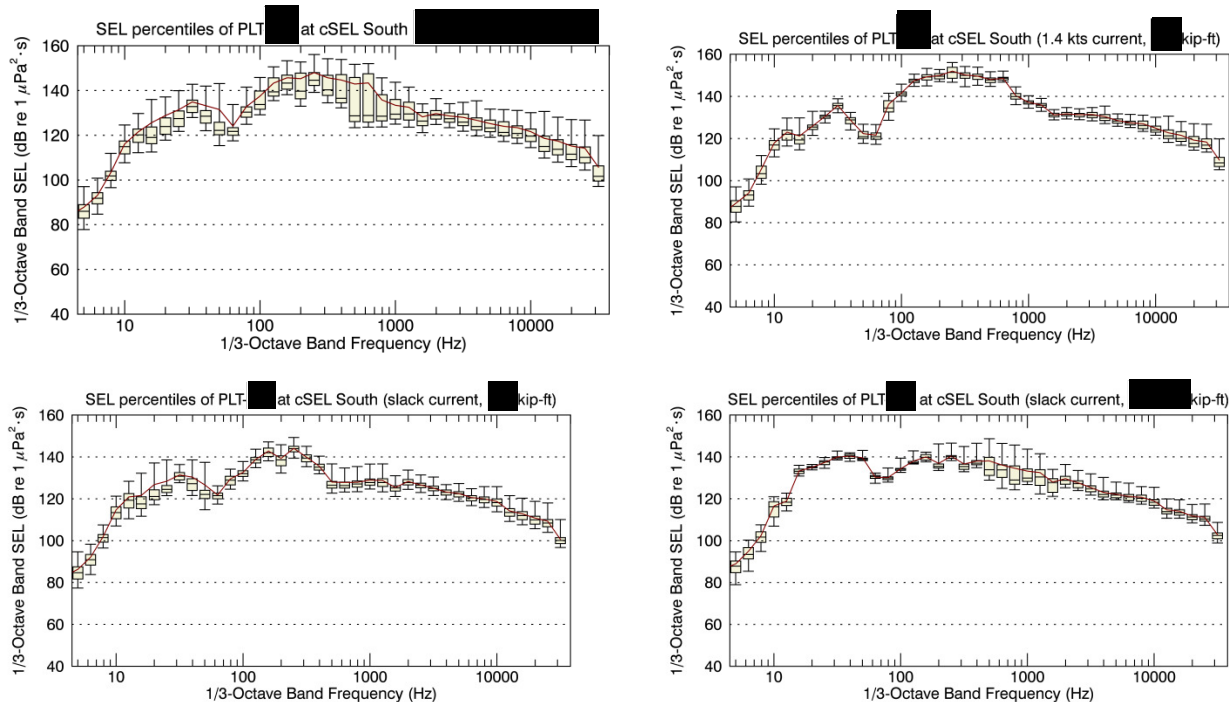


Figure 13. Distribution of one-second 1/3-Octave single-strike SELs measured at location cSEL South 396 ft from Test Pile PLT- [REDACTED] on [REDACTED] strikes). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 1.4-knot river current, [REDACTED] kip-ft [REDACTED] strikes). Bottom left: slack current, [REDACTED] kip-ft [REDACTED] strikes). Bottom right: slack current, [REDACTED] kip-ft [REDACTED] strikes).

Table 14. Sound levels for the measurements at cSEL South (up-current) during pile driving of PLT- [REDACTED] (396 ft from pile PLT- [REDACTED]).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² -s)
L_{max}	183.9	170.5	161.4
L_5	181.7	168.5	159.9
L_{25}	178.2	166.2	157.8
L_{50}	170.1	158	150.1
L_{75}	168.6	156.6	148.7
L_{95}	167.5	154.9	147.2
L_{mean}	175.8	163.1	154.6

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

A.4. Impact Pile-Driving Sound Levels cSEL West

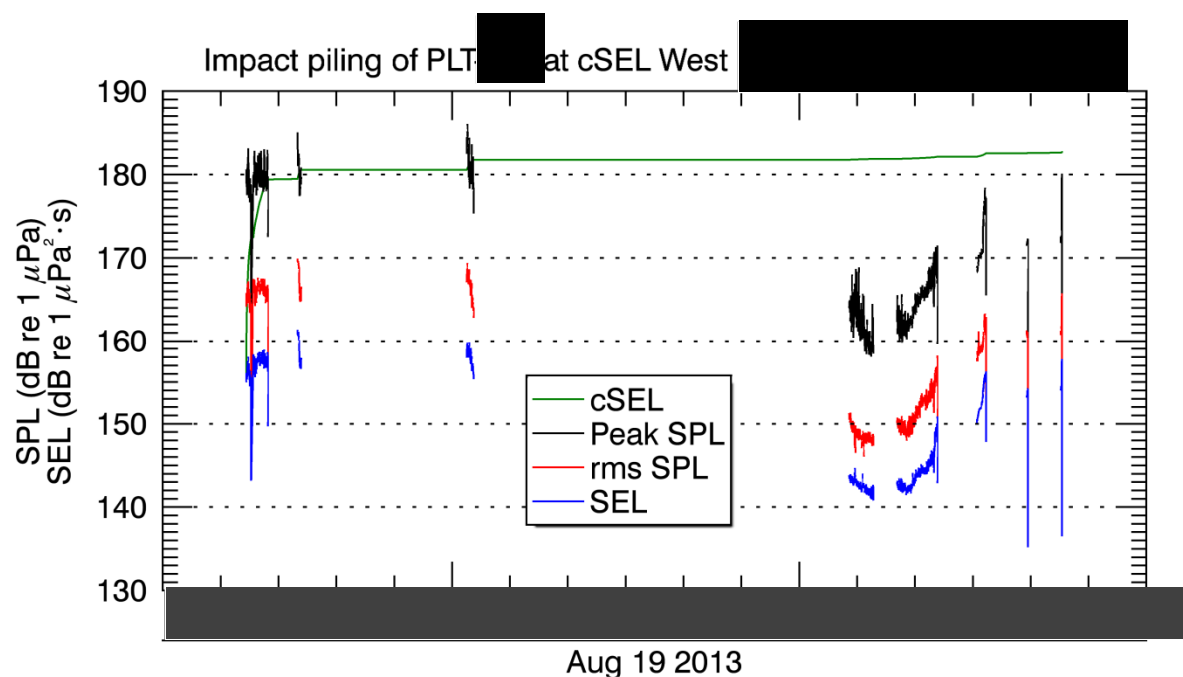


Figure 14. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location cSEL West (cross-current) during pile driving at PLT- [REDACTED] (268 ft from pile PLT- [REDACTED]).

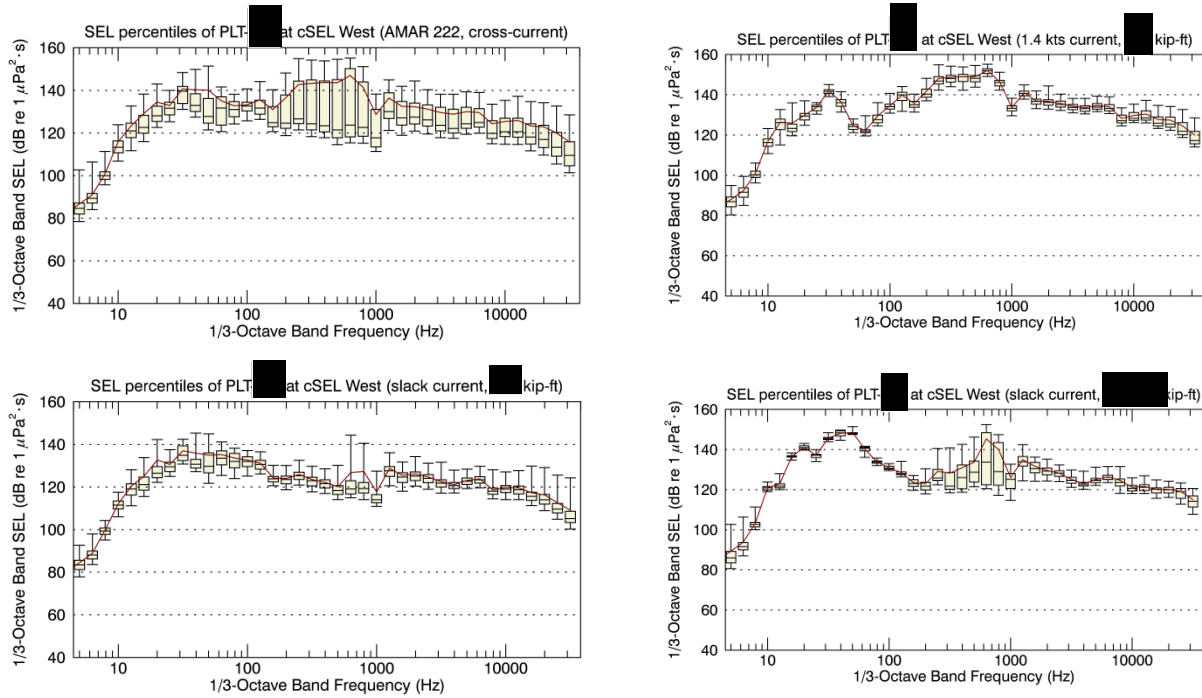


Figure 15. Distribution of one-second 1/3-Octave single-strike SELs measured at location cSEL West 268 ft from Test Pile PLT- [REDACTED] on [REDACTED]. Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{\max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 1.4-knot river current, [REDACTED] kip-ft [REDACTED] strikes). Bottom left: slack current, [REDACTED] kip-ft [REDACTED] strikes). Bottom right: slack current, [REDACTED] kip-ft [REDACTED] strikes).

Table 15. Sound levels for the measurements at cSEL West (cross-current) during pile driving of PLT- [REDACTED] (268 ft from pile PLT- [REDACTED]).

Sound Level Statistic*	peak SPL (dB re 1 μPa)	rms SPL (dB re 1 μPa)	Single Strike SEL (dB re 1 $\mu\text{Pa}^2\text{-s}$)
L_{\max}	186.1	169.9	161.4
L_5	181.6	167.4	158.5
L_{25}	178.4	164.7	156.1
L_{50}	166.3	153	144.8
L_{75}	162.7	149.5	142.7
L_{95}	159.8	148	141.7
L_{mean}	175.6	161.7	153.2

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

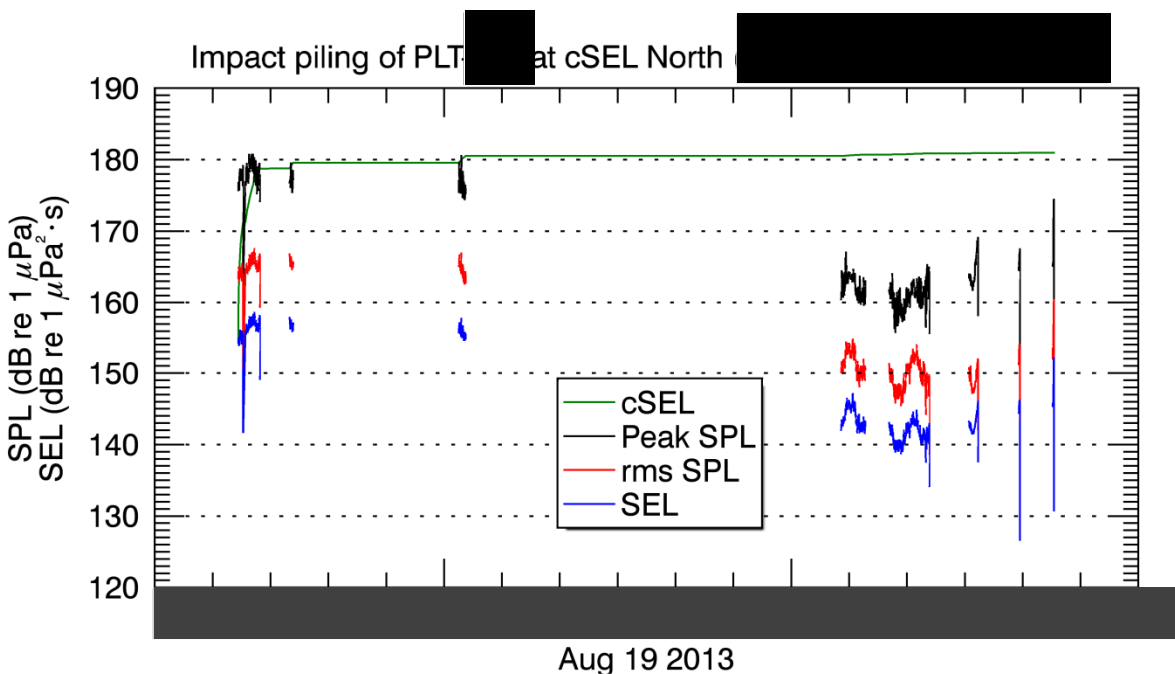
A.5. Impact Pile-Driving Sound Levels cSEL North

Figure 16. *Impact Pile Driving*: Peak and rms sound pressure level (SPL) and cumulative sound exposure level (cSEL) versus time (UTC, subtract 4 hours for EDT) measured at location cSEL North (down-current) during pile driving at PLT- [REDACTED] (502 ft from pile PLT- [REDACTED])

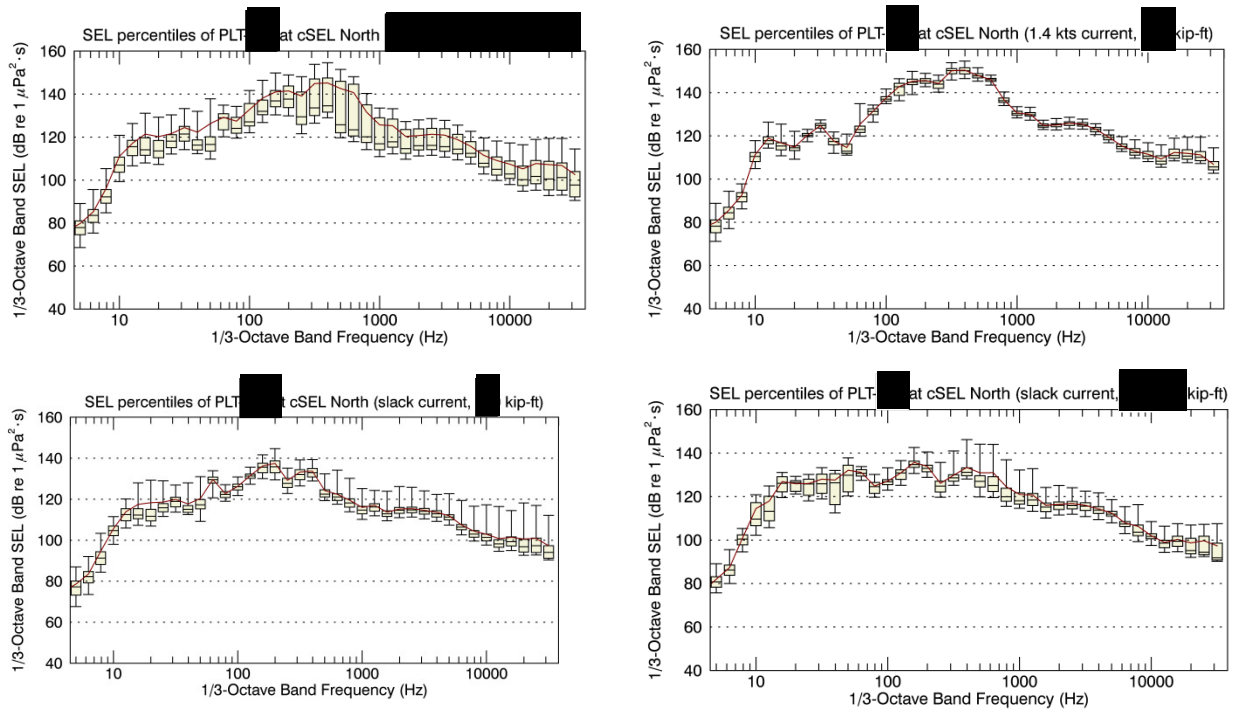


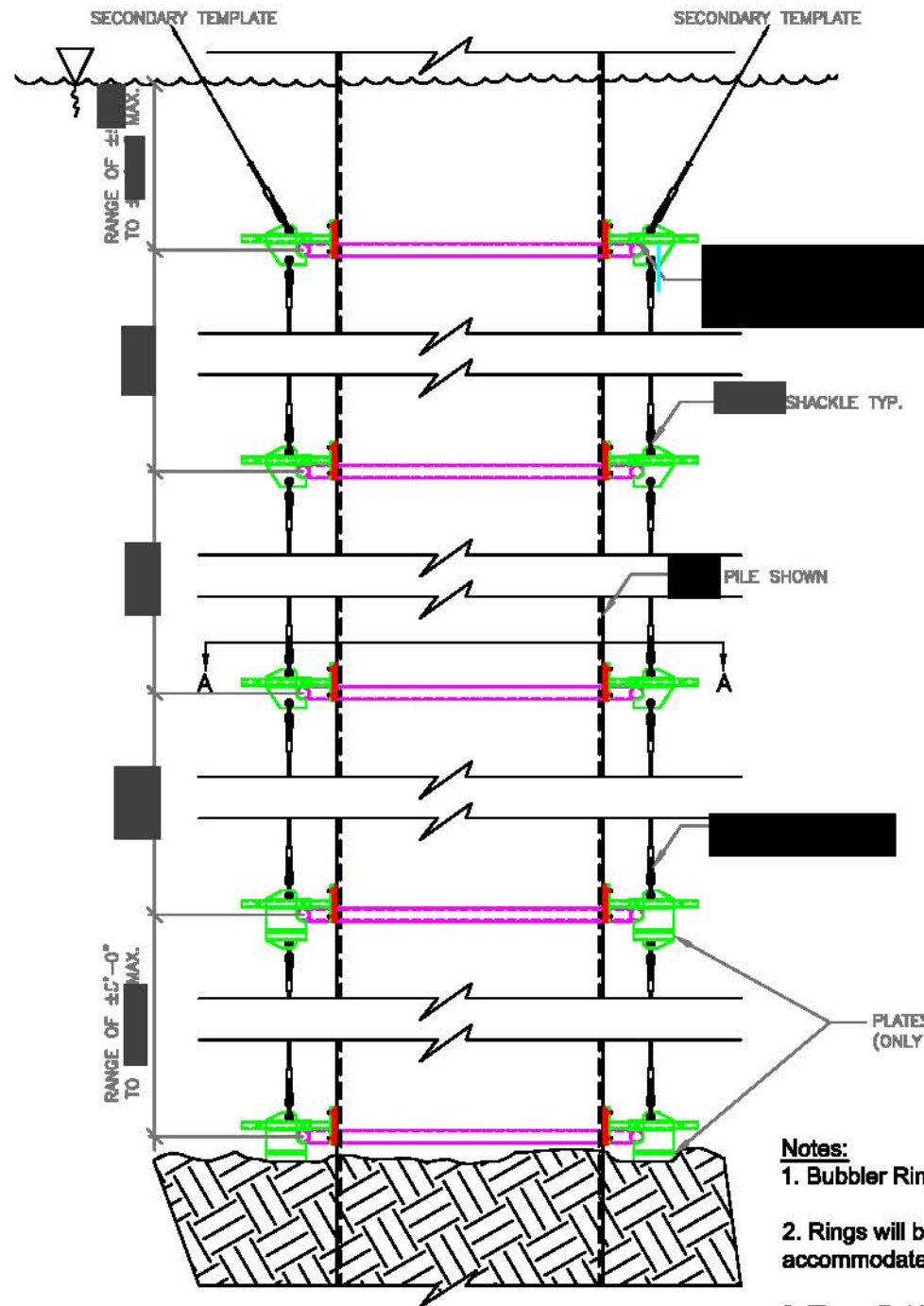
Figure 17. Distribution of one-second 1/3-Octave single-strike SELs measured at location cSEL North 502 ft from Test Pile PLT-[redacted] on [redacted]). Beige bars indicate the first, second, and third quartiles (L_{25} , L_{50} , and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}). Top left: all NAS settings. Top right: 1.4-knot river current, [redacted] strikes). Bottom left: slack current, [redacted] kip-ft strikes). Bottom right: slack current, [redacted] kip-ft strikes).

Table 16. Sound levels for the measurements at cSEL North (down-current) during pile driving of PLT-[redacted] (502 ft from pile PLT-[redacted]).

Sound Level Statistic*	peak SPL (dB re 1 μ Pa)	rms SPL (dB re 1 μ Pa)	Single Strike SEL (dB re 1 μ Pa ² -s)
L_{max}	180.8	167.6	158.7
L_5	179.4	166.4	157.6
L_{25}	177	164.5	155.9
L_{50}	163.1	152.5	144.1
L_{75}	160.8	150.1	142.4
L_{95}	158.4	147.3	139.9
L_{mean}	172.8	160.1	151.5

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

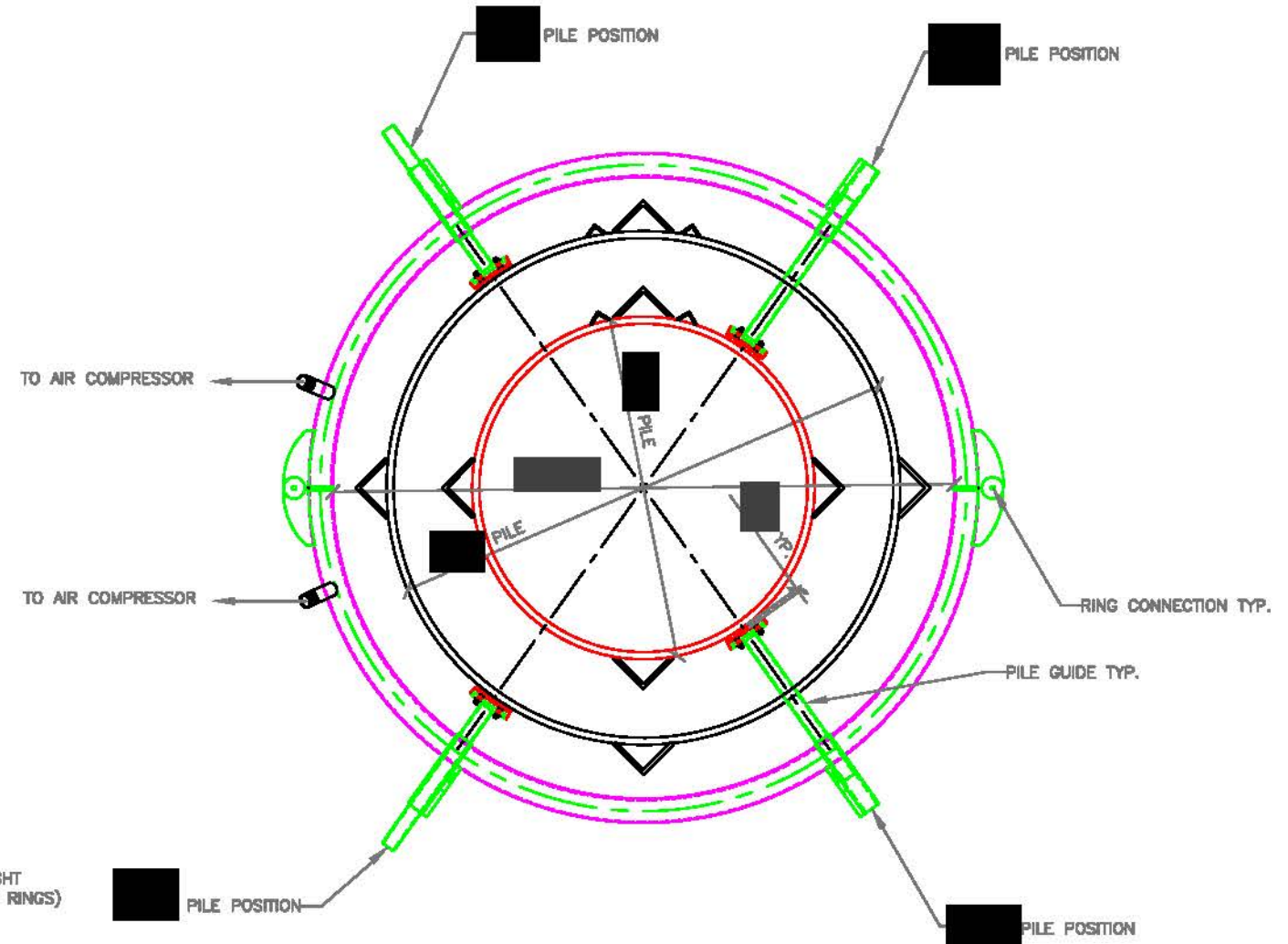
Attachment 2 – Design Plans for the Multi-Tier Bubble Curtain (Drawings)



ELEVATION - BUBBLER RINGS
SCALE: NTS

Notes:

1. Bubbler Rings will be spaced at 10'-0" centers maximum
2. Rings will be removed and added as needed to accommodate varying depths
3. These Bubbler Rings can be used on [REDACTED] diameter piles



PLAN - BUBBLER RINGS
SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: -
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/20/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN RINGS FOR [REDACTED] PILES	DRAWING NUMBER: [REDACTED]

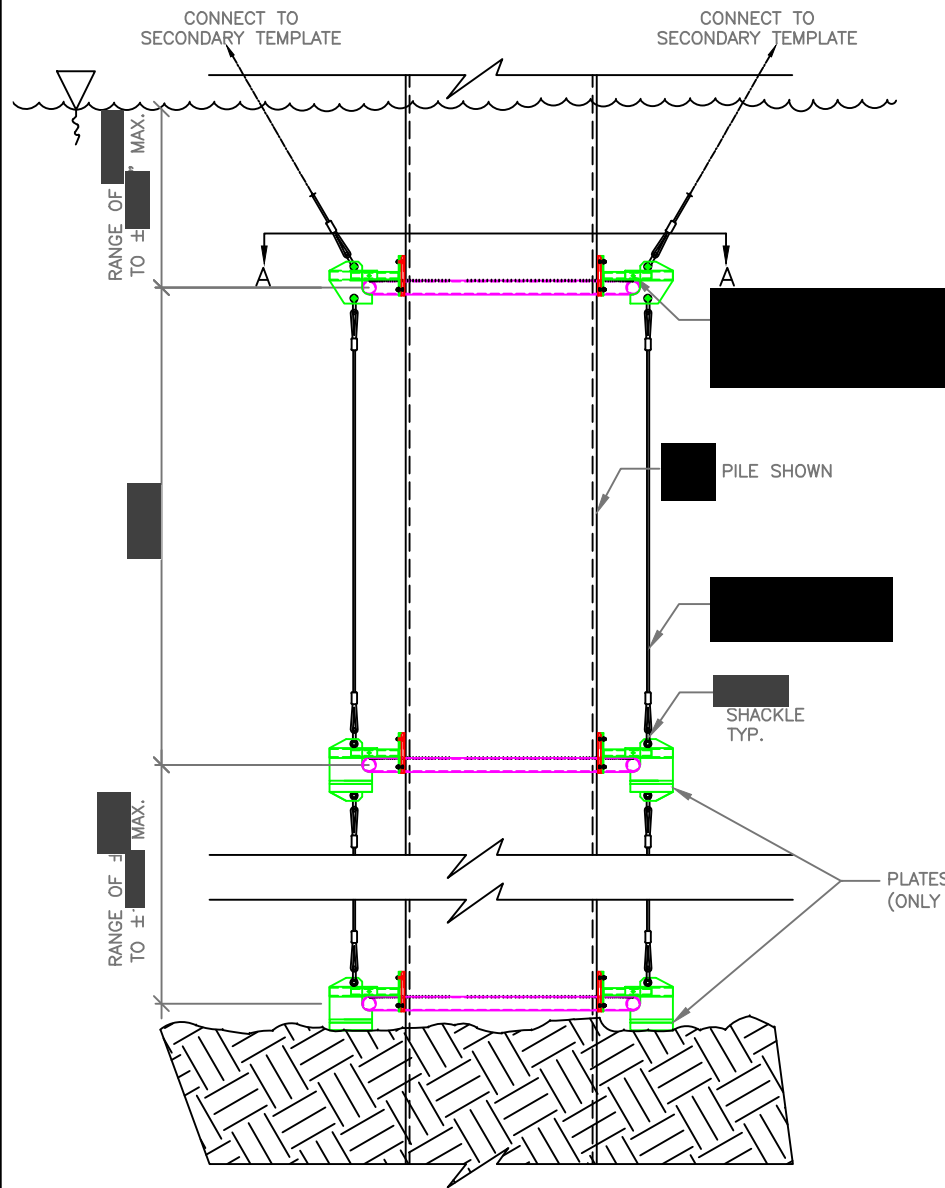
CHECKED BY:

DRAFTED BY: MARTIR_ORTEZ

CHECKED BY:

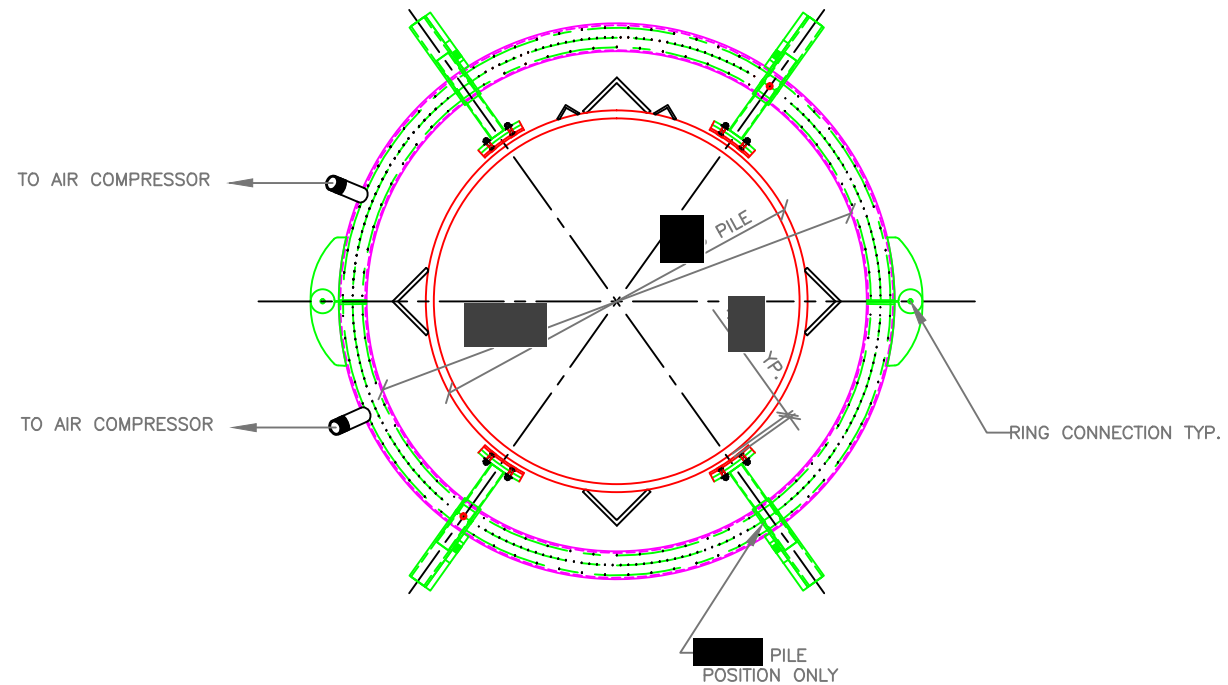
DESIGNED BY:

DESIGN SUPERVISOR:



ELEVATION - BUBBLER RINGS [REDACTED] PILES
SCALE: NTS

- Notes:
1. Bubbler Rings will be spaced at 10'-0" centers maximum
 2. Rings will be removed and added as needed to accommodate varying depths
 3. These Bubbler Rings can be used on [REDACTED] diameter piles only



A PLAN - BUBBLER RINGS
SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: -
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR [REDACTED] PILES	DRAWING NUMBER: [REDACTED]

DOCUMENT TRACKING CODE: -

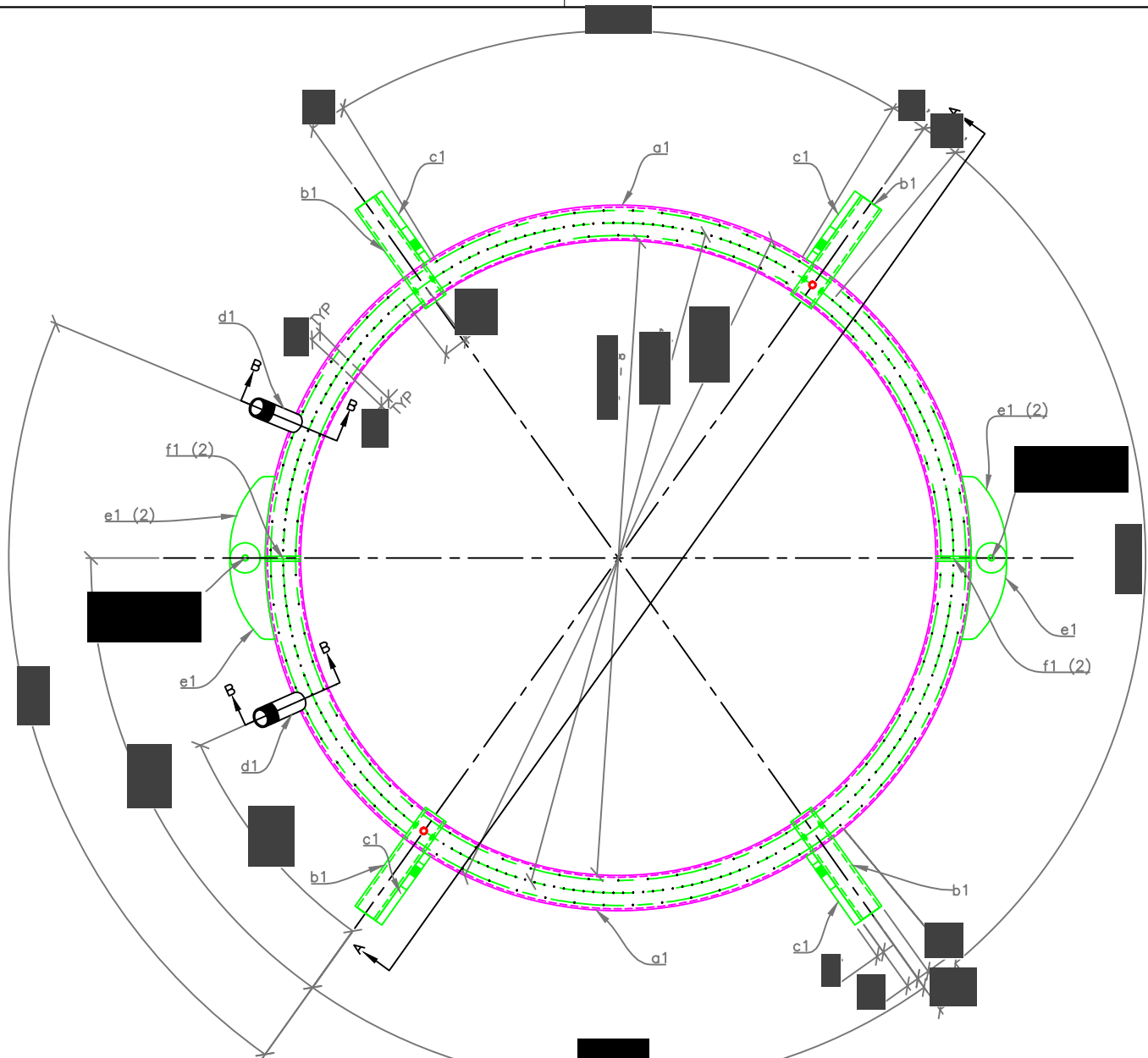
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DRAFTED BY: MARTIR_ORTIZ

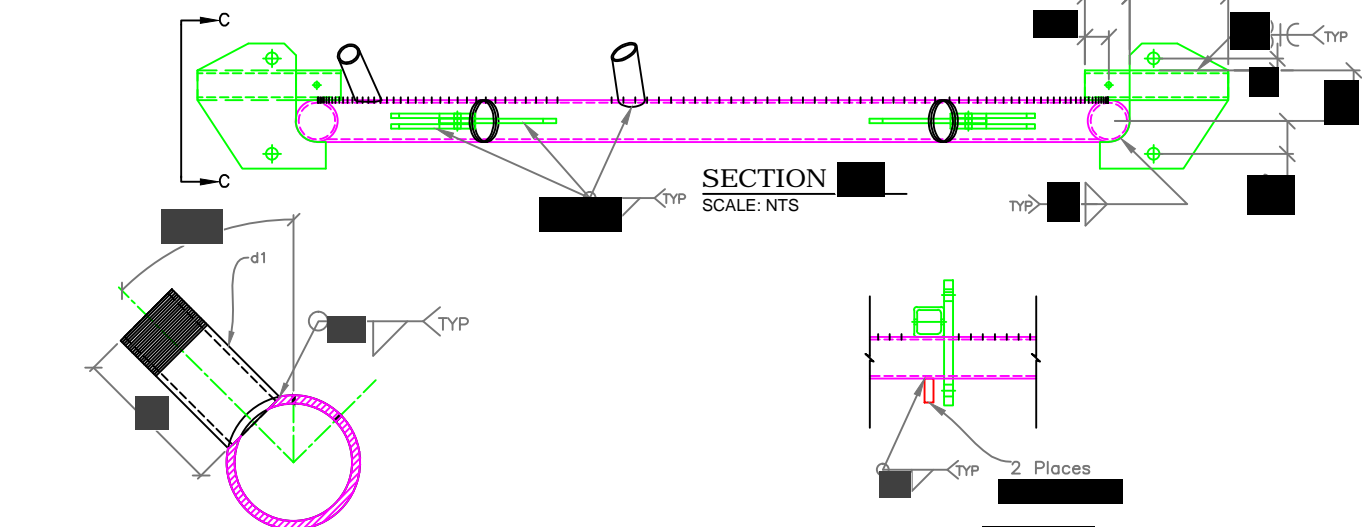
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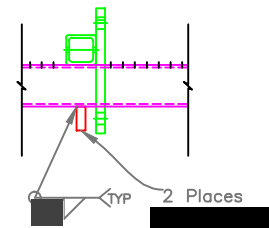
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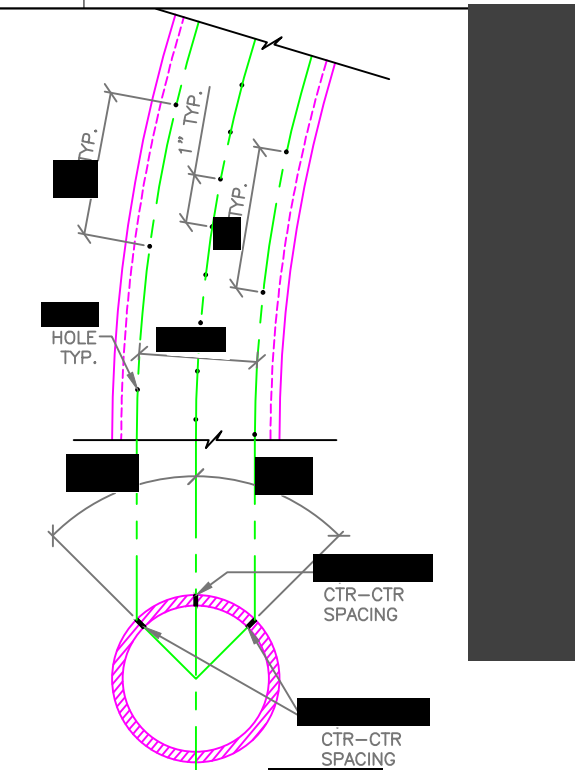
OP BUBBLER RING FOR PILES



SECTION TYPICAL PIPE NIPPLE
SCALE: NTS



SECTION TYPICAL PIPE NIPPLE
SCALE: NTS



TYPICAL SECTION
SCALE: NTS

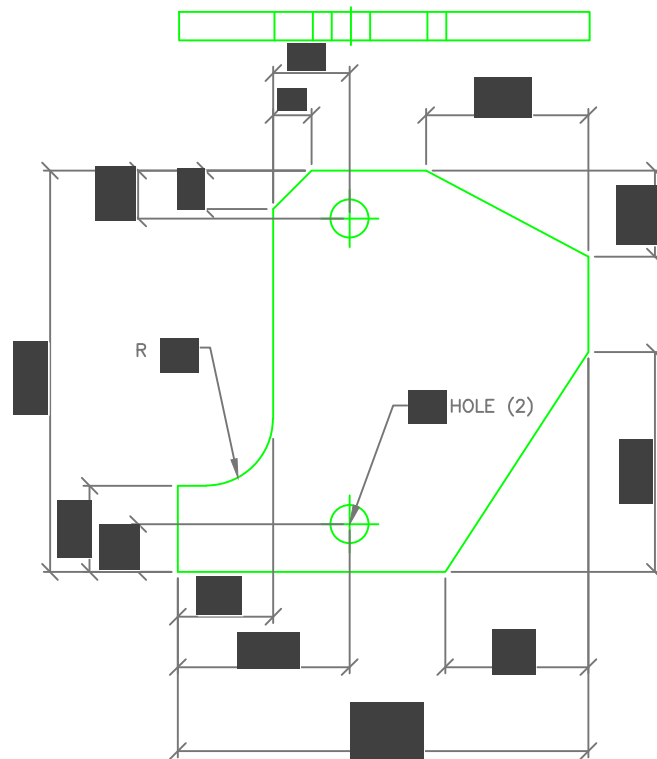


PLATE
SCALE: NTS

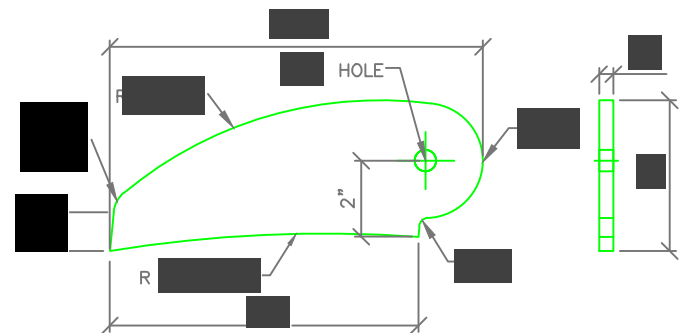
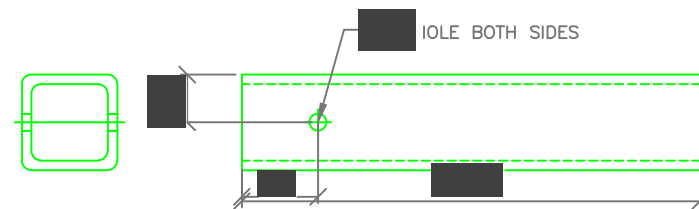


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SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



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LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR_PILES	DRAWING NUMBER: -

DOCUMENT TRACKING CODE: -

CHECKED BY:

DRAFTED BY:

CHECKED BY:

DESIGNED BY:

DESIGN SUPERVISOR:

MATCH DRILL COUNTERSUNK AS SHOWN IN DETAIL

b2

a6

c2

SCALE: NTS

GUIDES FOR PILES

SCALE: NTS

SCALE: NTS

CHAMFER
TYPICAL

REVISIONS

DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: —
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR PILES	DRAWING NUMBER: —

DOCUMENT TRACKING CODE: —

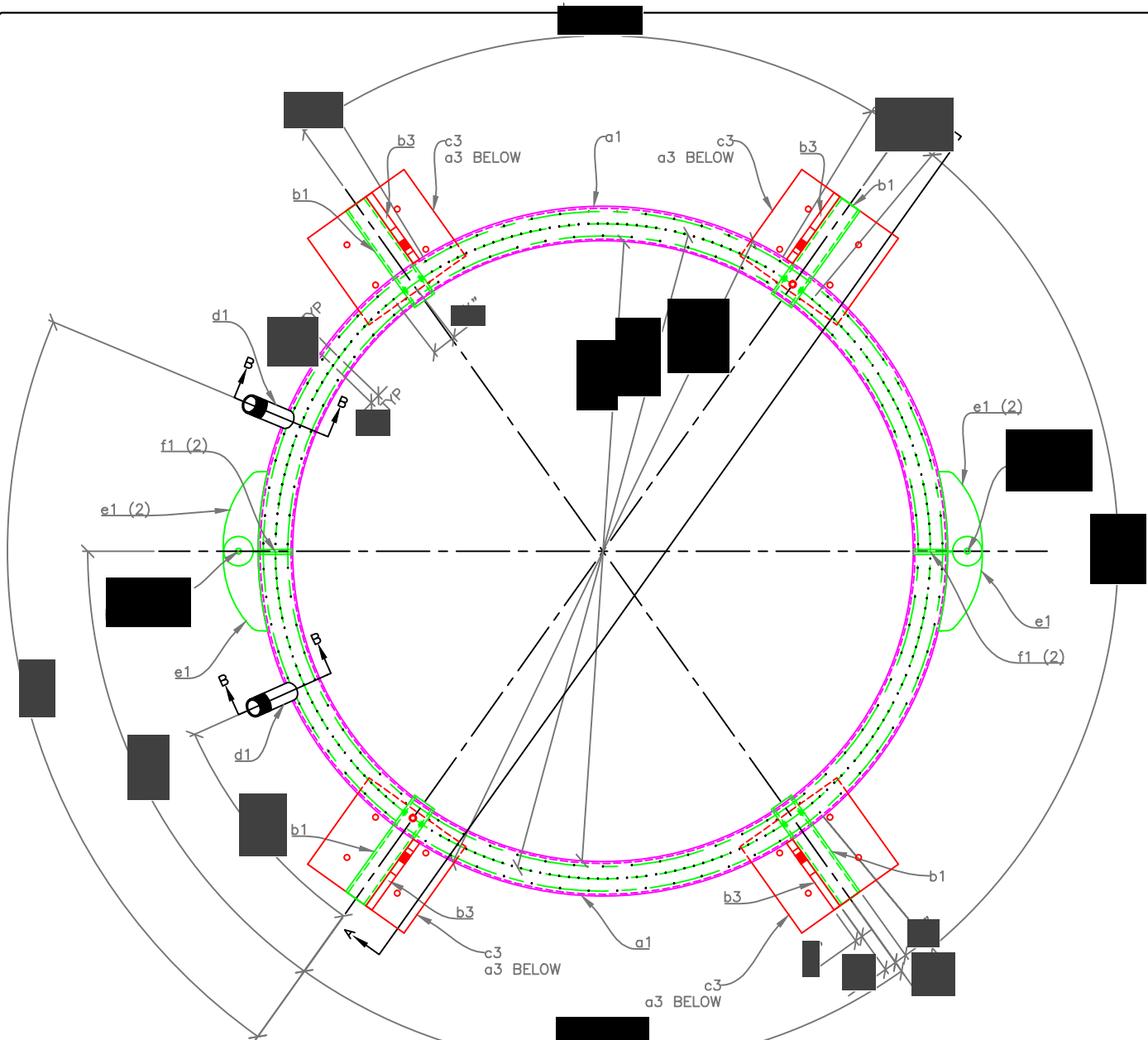
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DRAFTED BY: MARTIR_ORTIZ

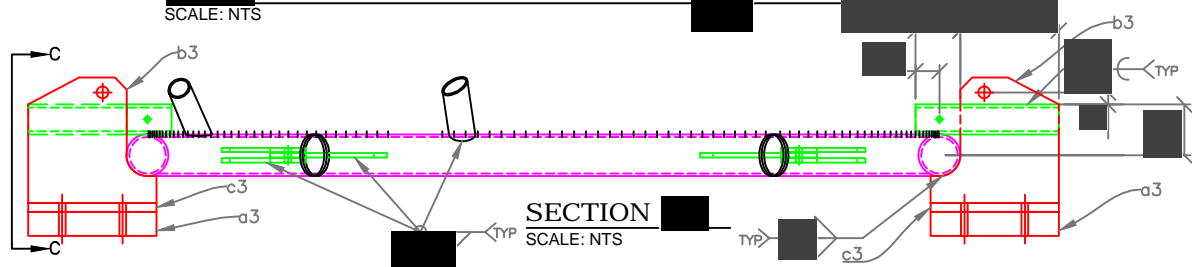
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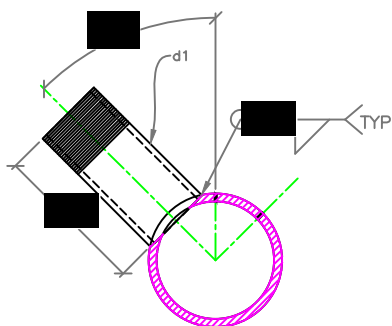
DESIGN SUPERVISOR:



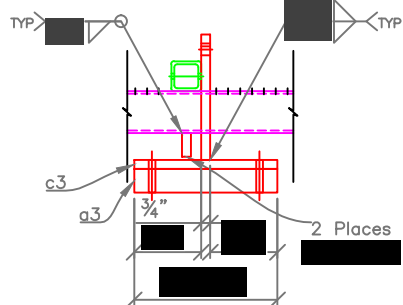
_____ - BOTTOM BUBBLER RING FOR _____ PILES
SCALE: NTS



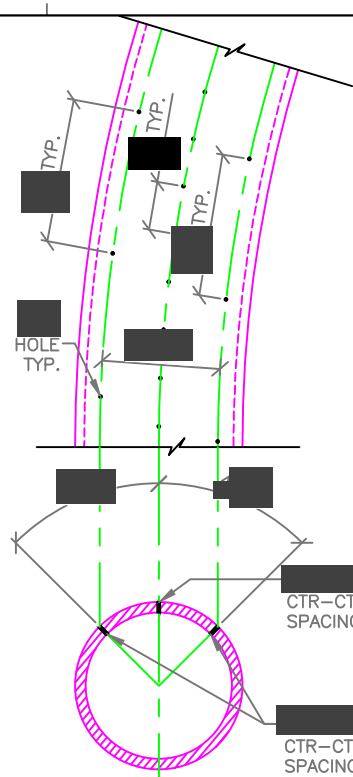
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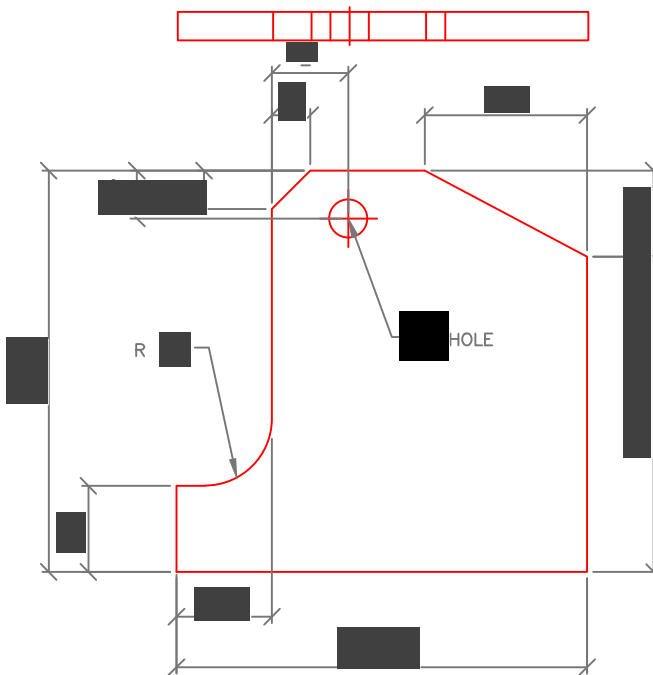
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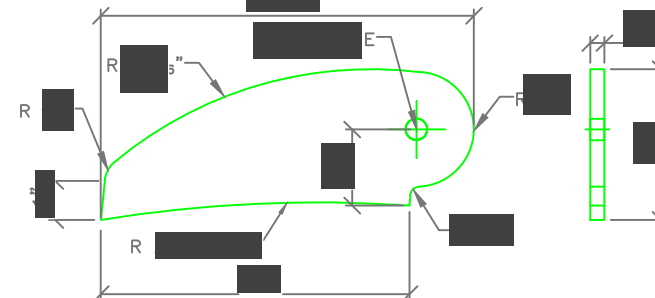
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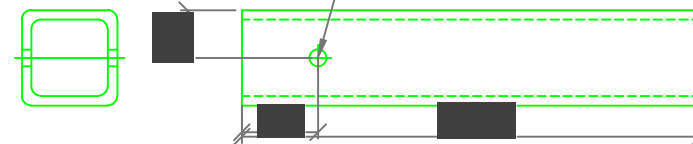
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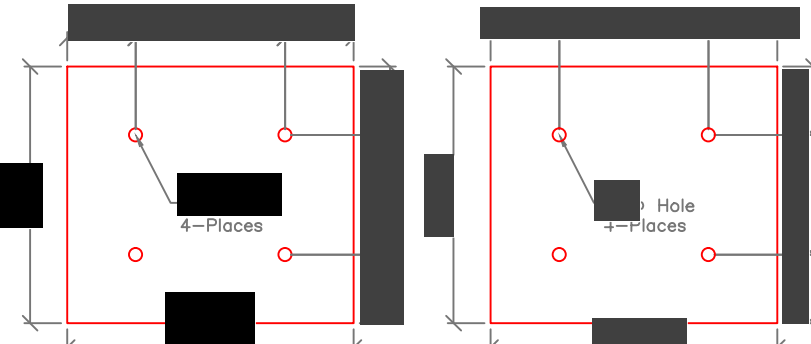
_____ PLATE 1
SCALE: NTS



_____ PLATE 3
SCALE: NTS
Ø HOLE BOTH SIDES



SCALE: NTS



_____ PLATE 4
SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: -
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR _____ PILES	DRAWING NUMBER: _____

DOCUMENT TRACKING CODE: -

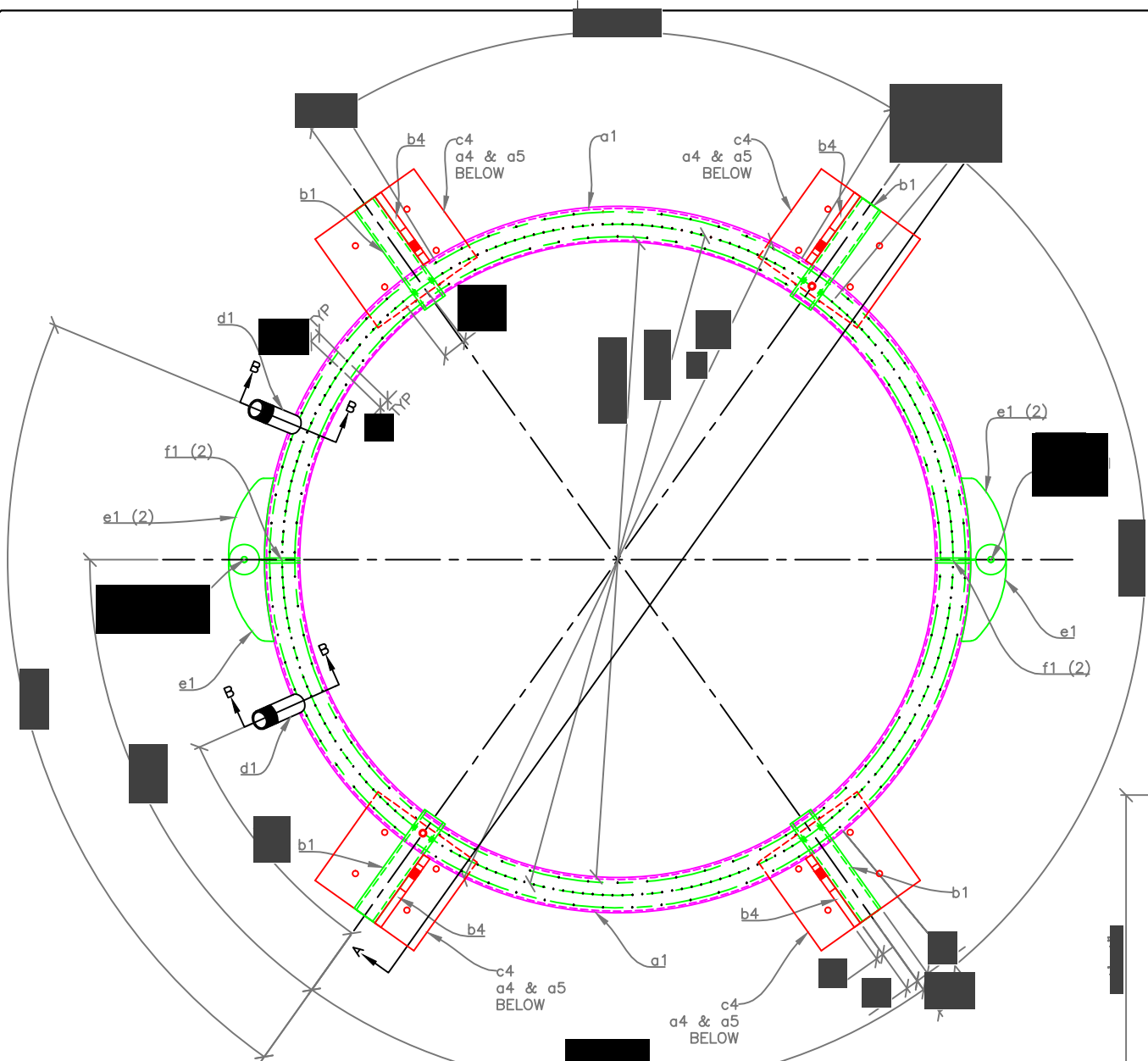
CHECKED BY:

DRAFTED BY:

CHECKED BY:

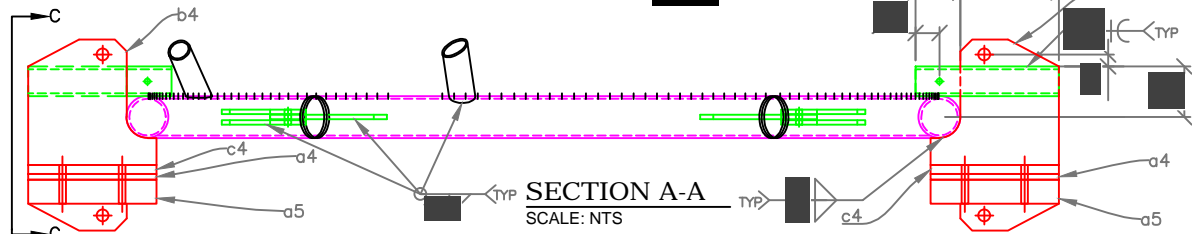
DESIGNED BY:

DESIGN SUPERVISOR:



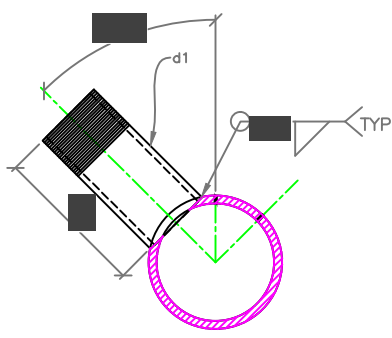
MIDDLE BUBBLER RING FOR PILES

SCALE: NTS



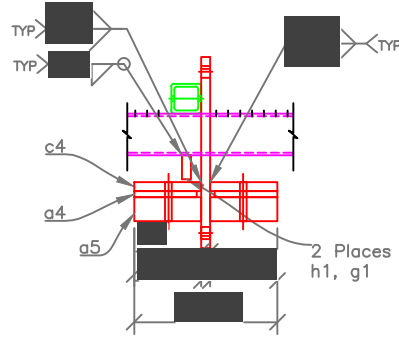
SECTION A-A

SCALE: NTS



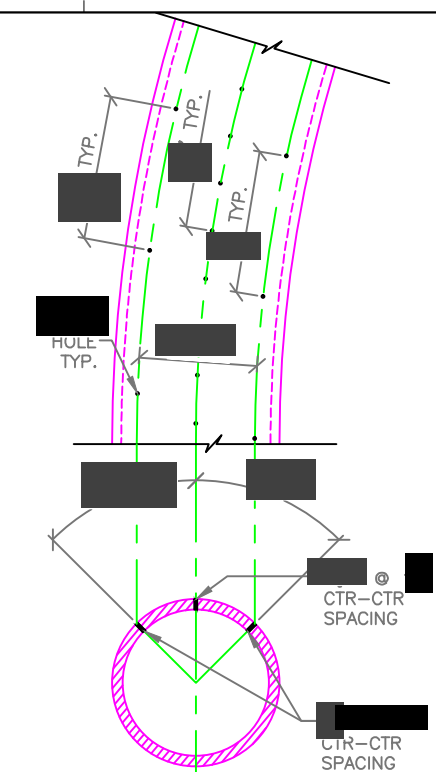
TYPICAL PIPE NIPPLE

SCALE: NTS



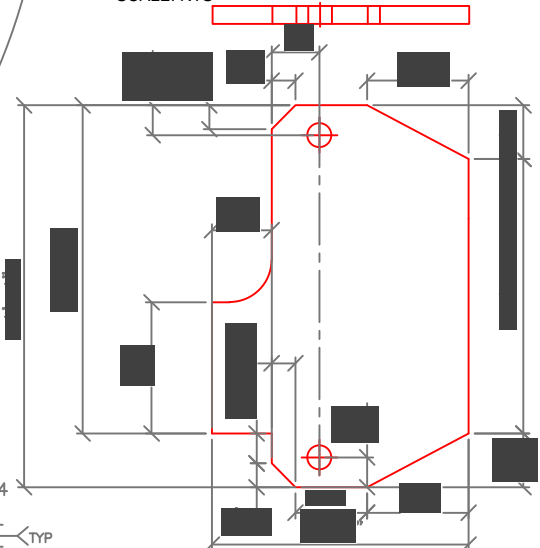
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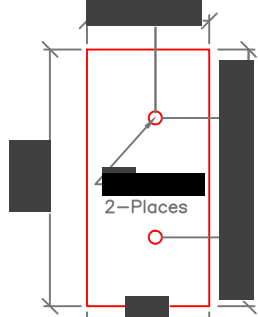
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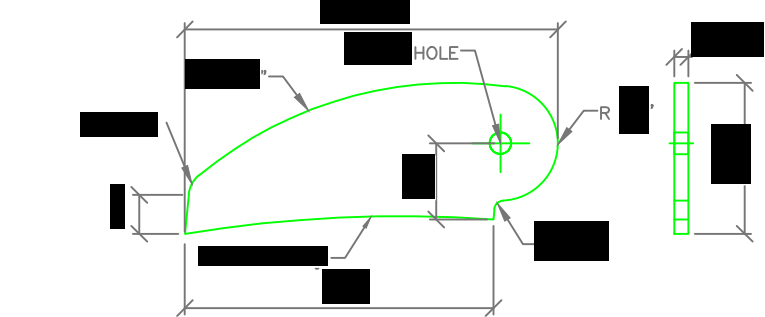
HOLE LAYOUT

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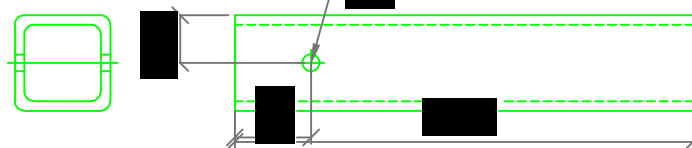
HOLE LAYOUT

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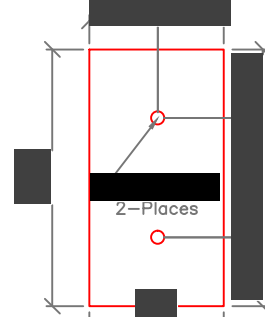
HOLE LAYOUT

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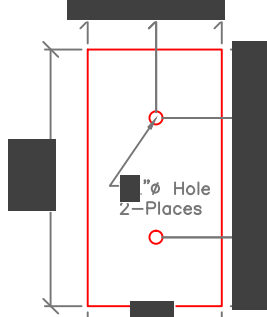
HOLE LAYOUT

SCALE: NTS



HOLE LAYOUT

SCALE: NTS



HOLE LAYOUT

SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER:
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE_CURTAIN_RINGS_FOR_PILES	DRAWING NUMBER:

DOCUMENT TRACKING CODE: -

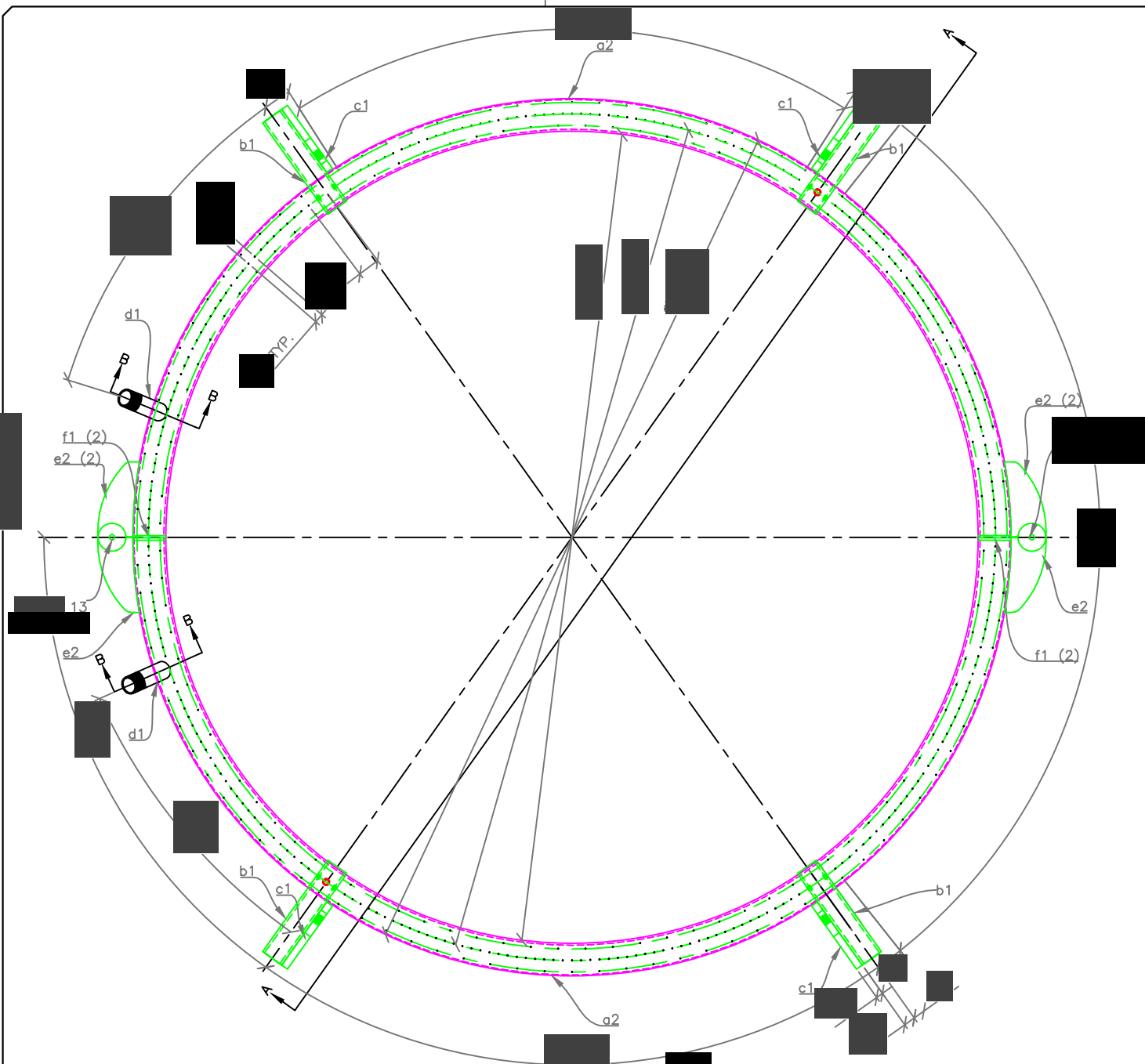
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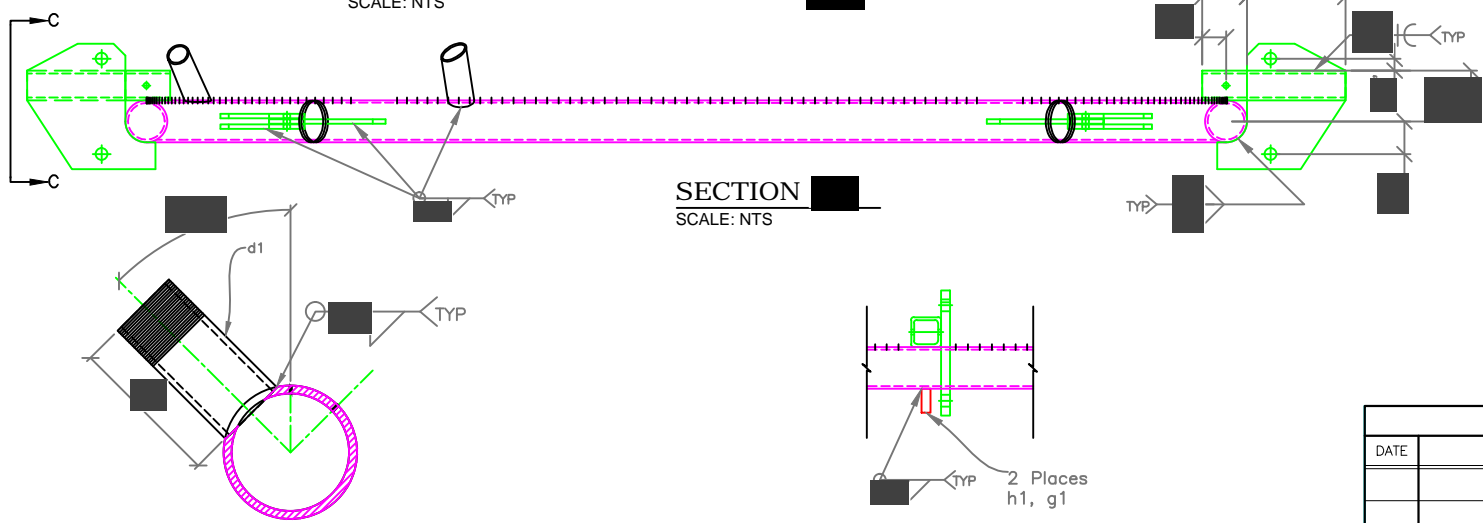
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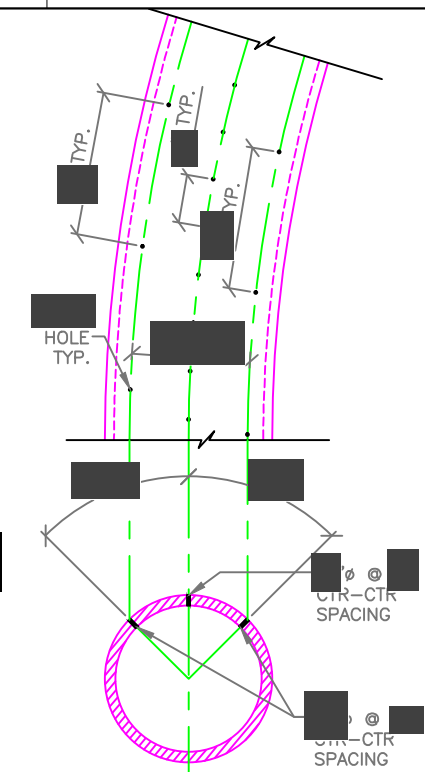
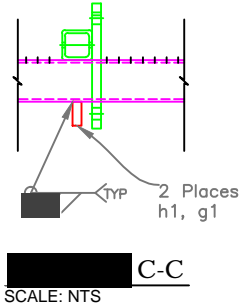
DESIGN SUPERVISOR:



TOP BUBBLER RING FOR PILES
SCALE: NTS



TYPICAL PIPE NIPPLE
SCALE: NTS



TYPICAL SECTION - HOLE LAYOUT
SCALE: NTS

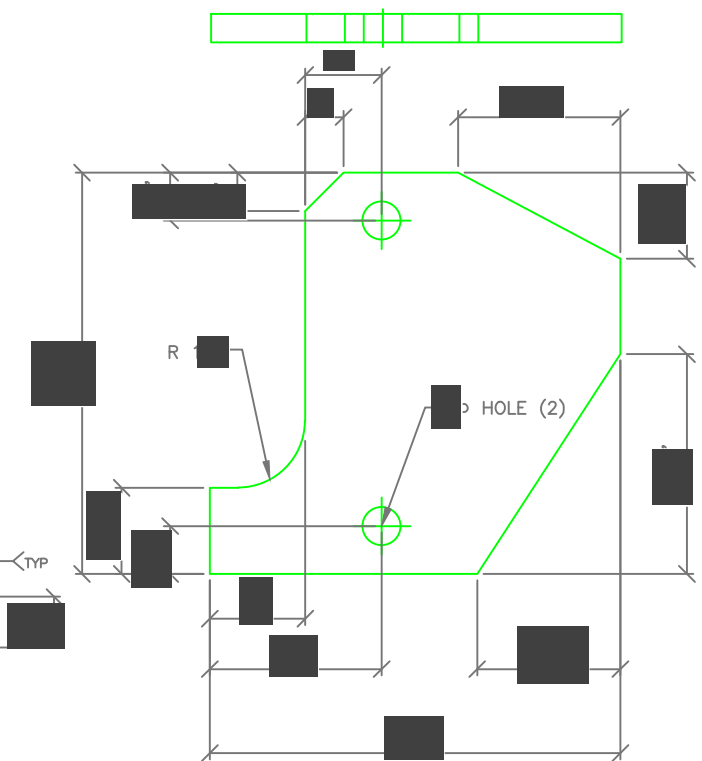


PLATE 1
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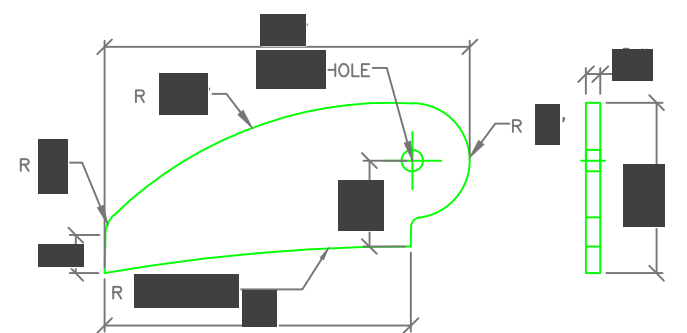
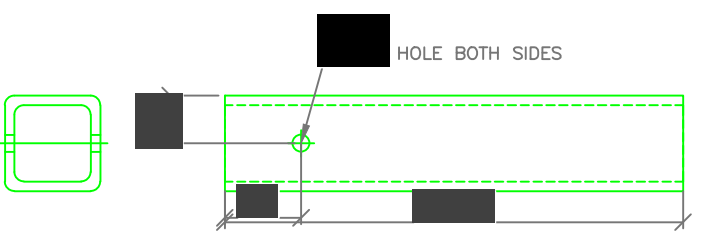


PLATE 3
SCALE: NTS



SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER:
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR_PILES	DRAWING NUMBER:

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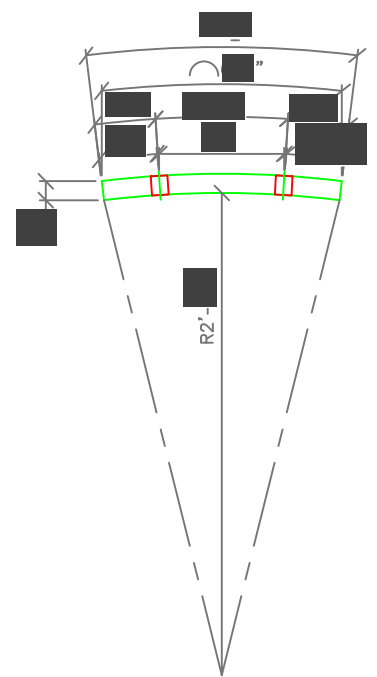
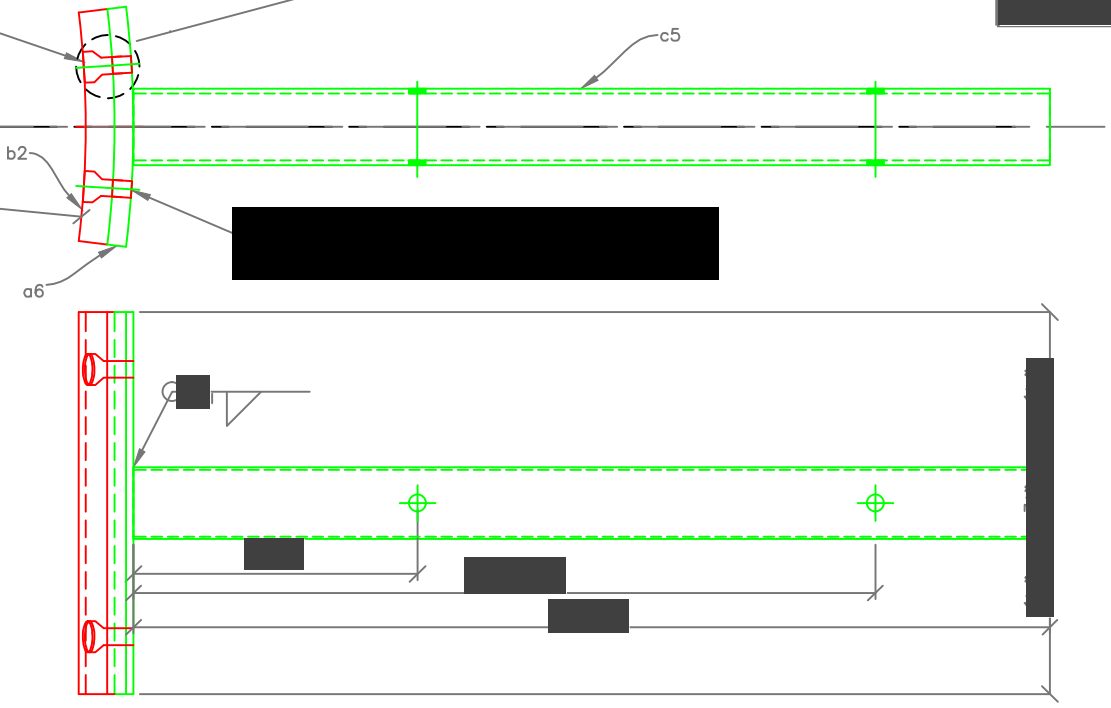
DRAFTED BY:

CHECKED BY:

DESIGNED BY:

DESIGN SUPERVISOR:

MATCH DRILL COUNTERSUNK AS SHOWN IN DETAIL



GUIDES FOR PILES
SCALE: NTS

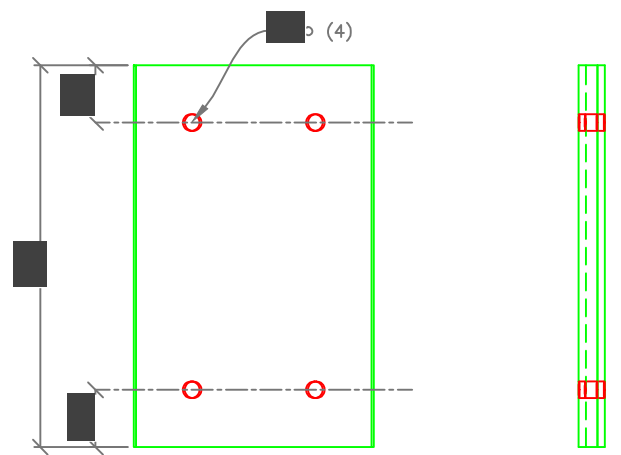
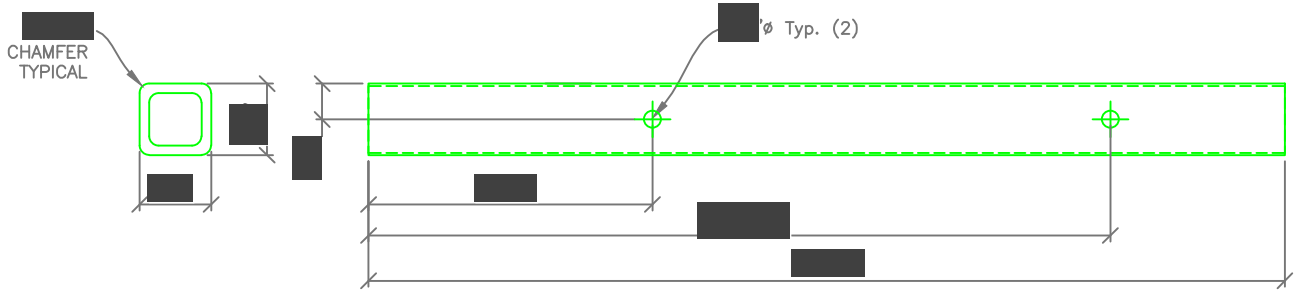
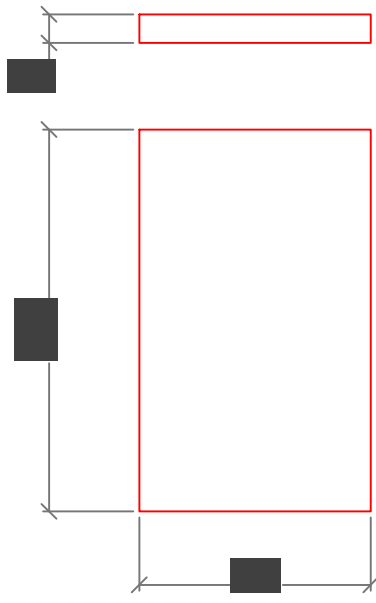




PLATE
SCALE: NTS

SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: —
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR PILES	DRAWING NUMBER: —

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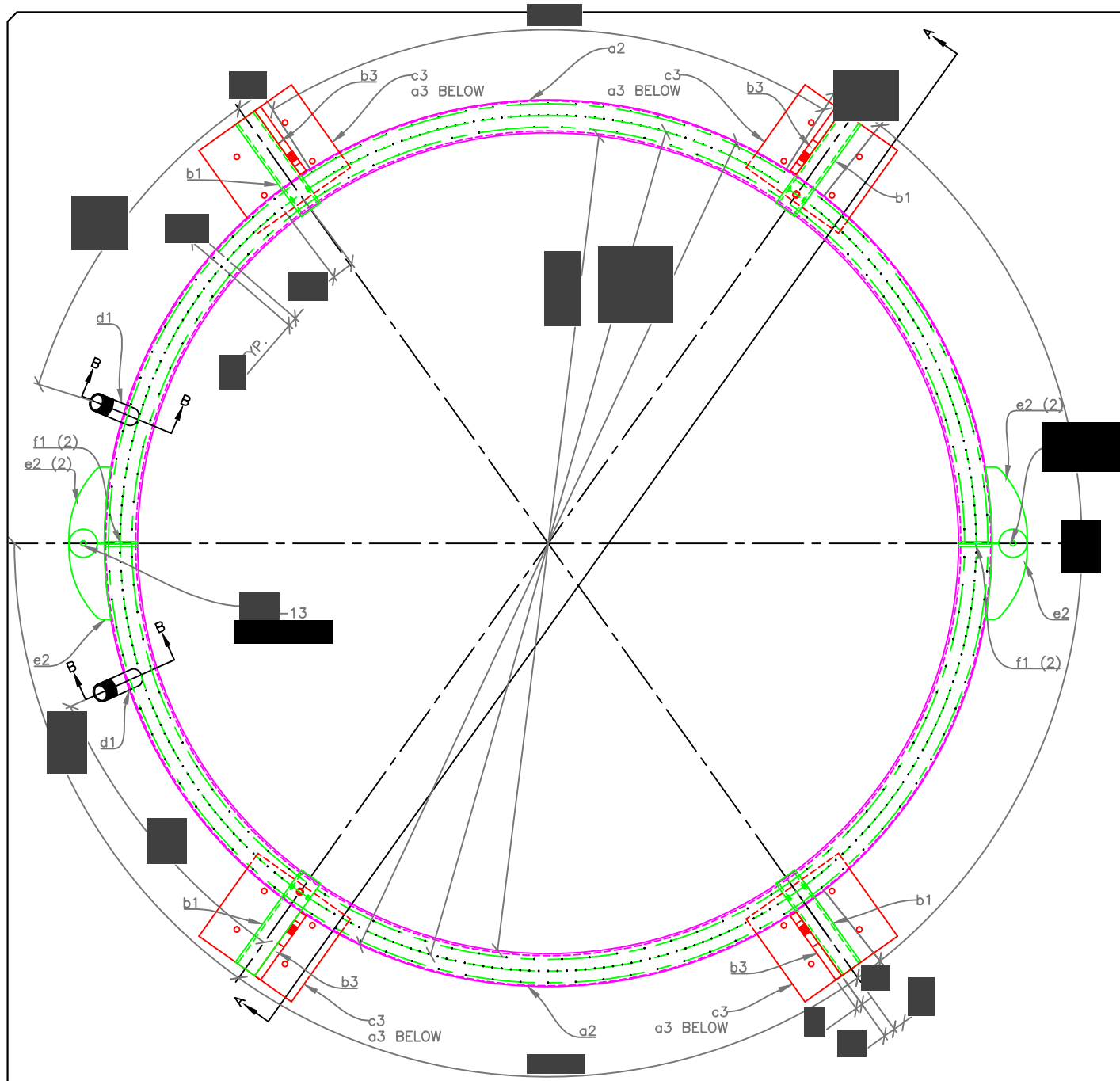
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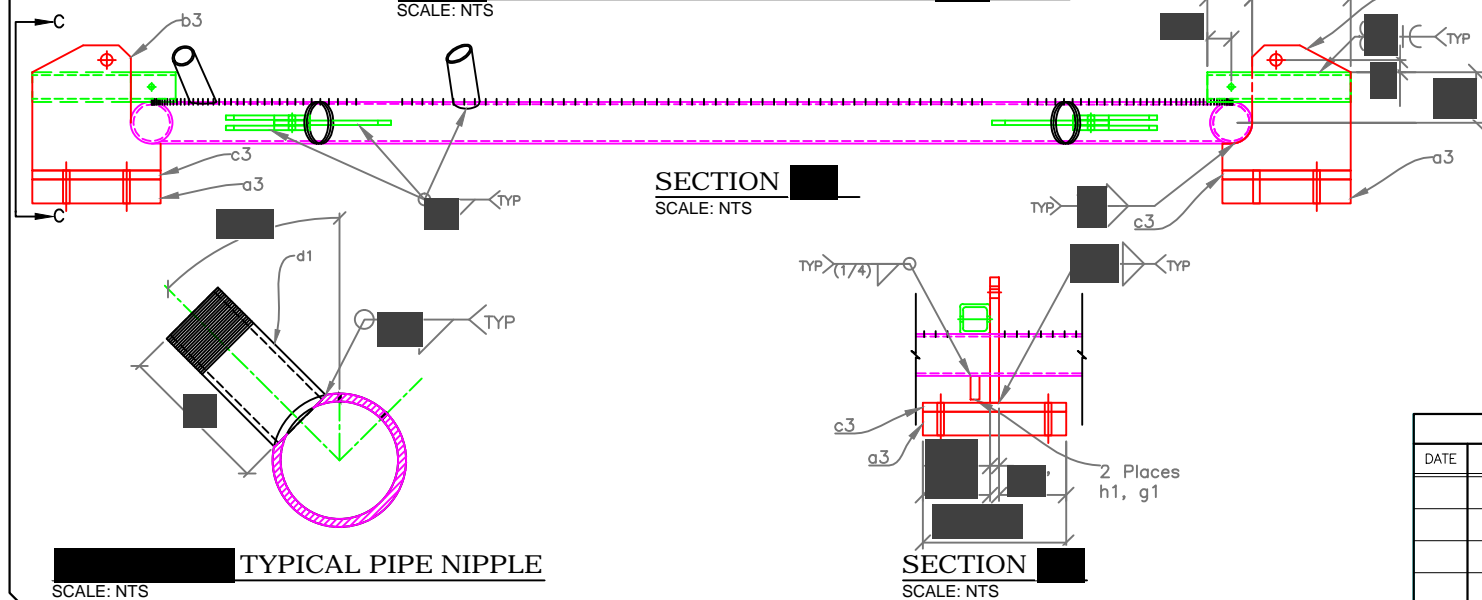
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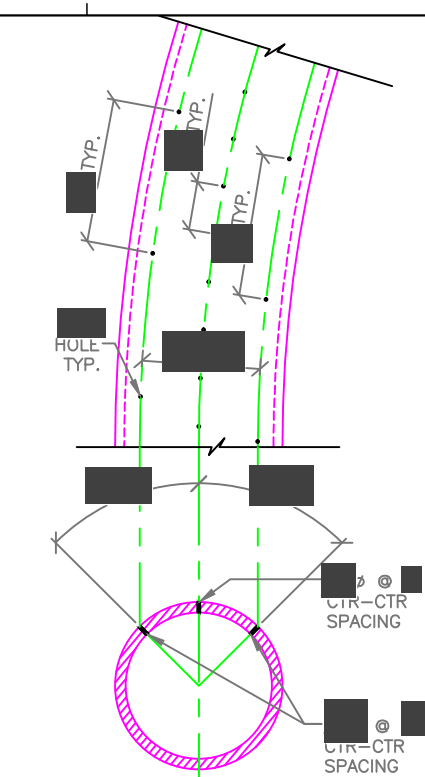
DESIGN SUPERVISOR:



BOTTOM BUBBLER RING FOR PILES
SCALE: NTS



TYPICAL PIPE NIPPLE
SCALE: NTS



TYPICAL SECTION -
SCALE: NTS

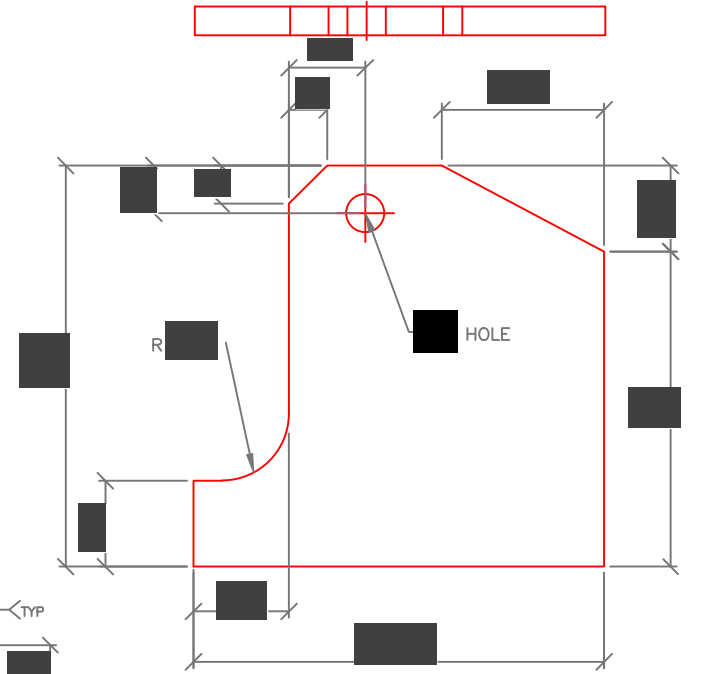
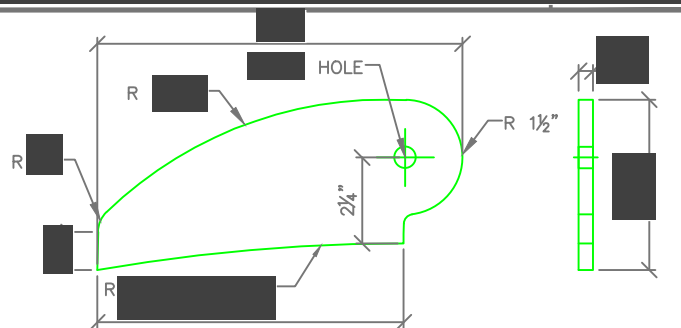
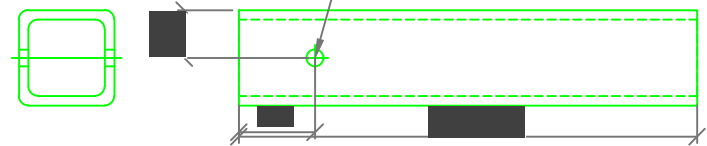


PLATE
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e2-PLATE
SCALE: NTS



SCALE: NTS

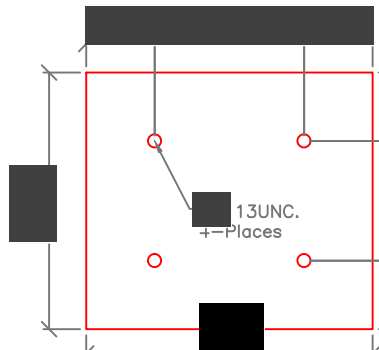


PLATE
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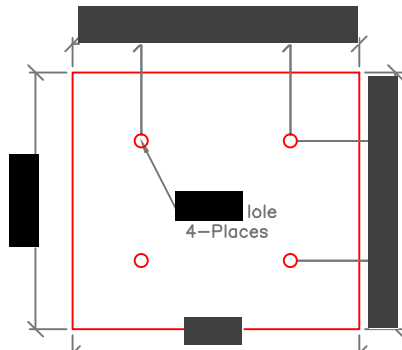


PLATE
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REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER: -
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN_RINGS FOR_PILES	DRAWING NUMBER: -

DOCUMENT TRACKING CODE: -

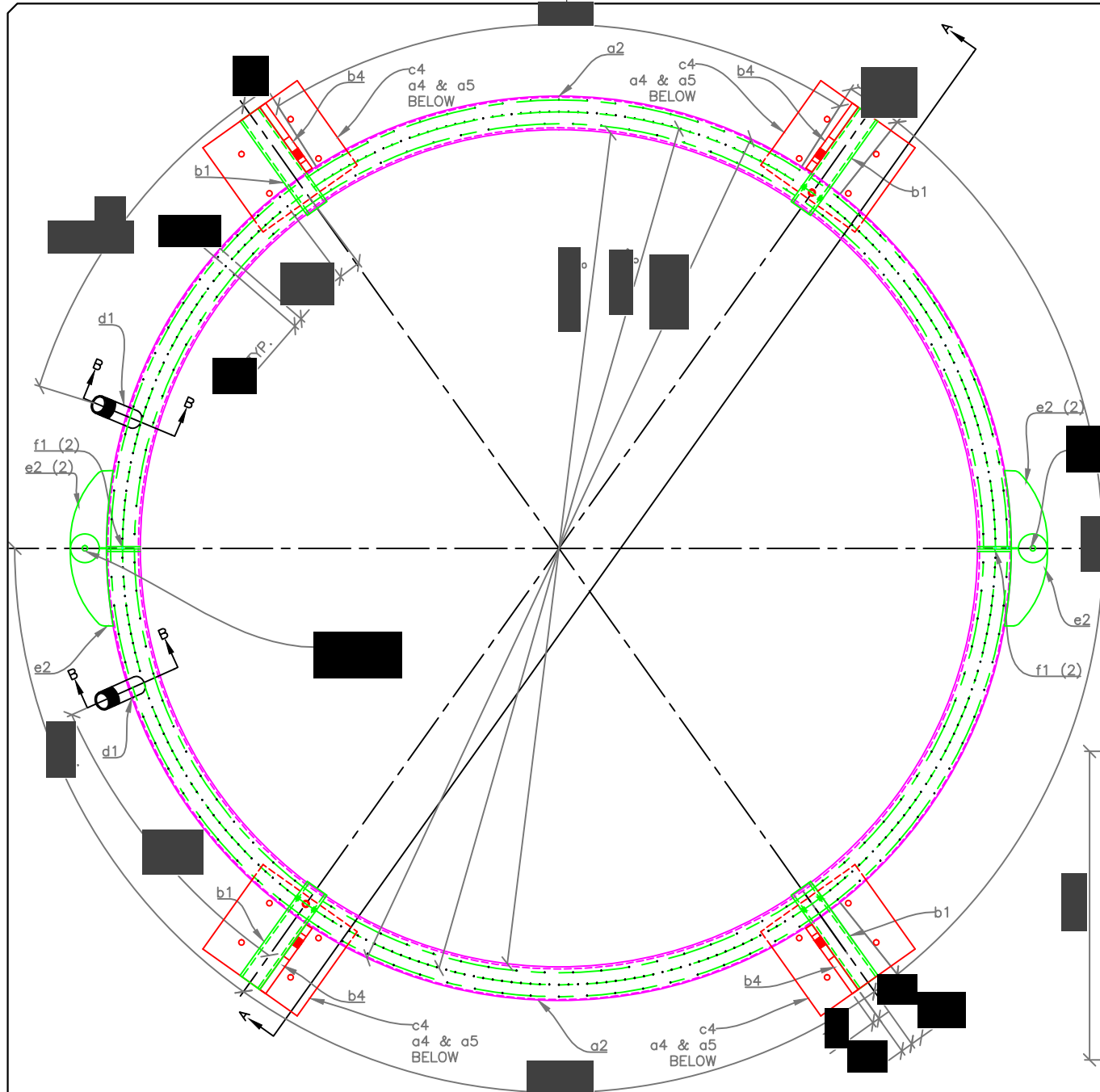
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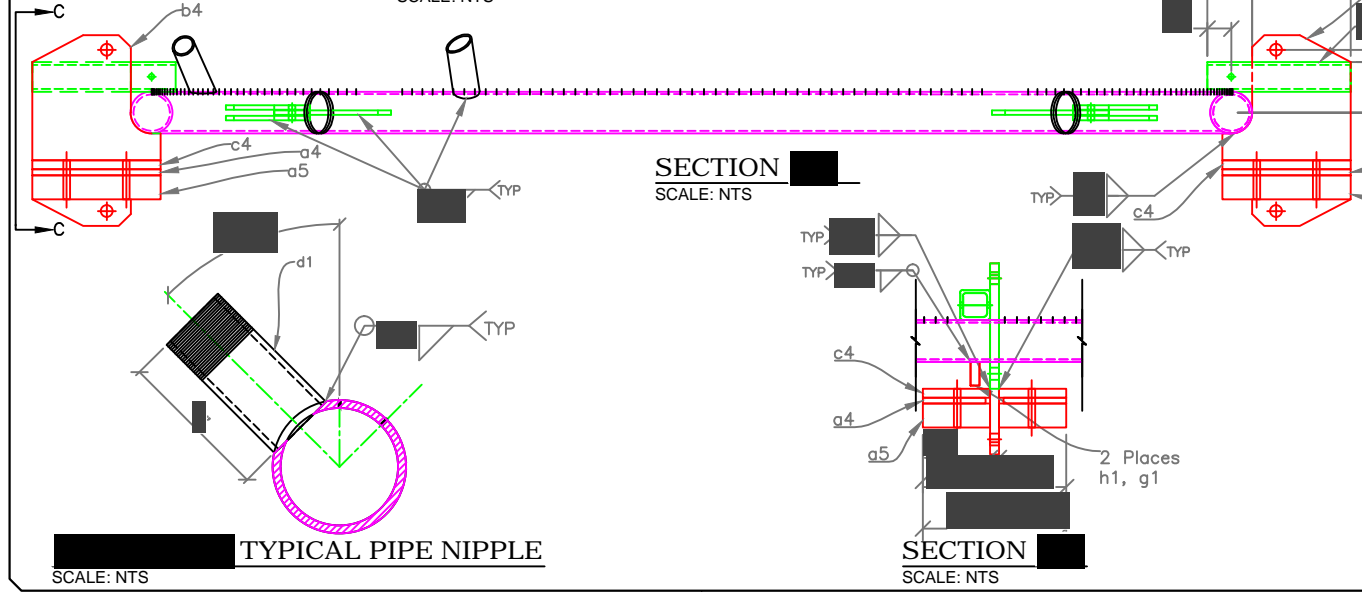
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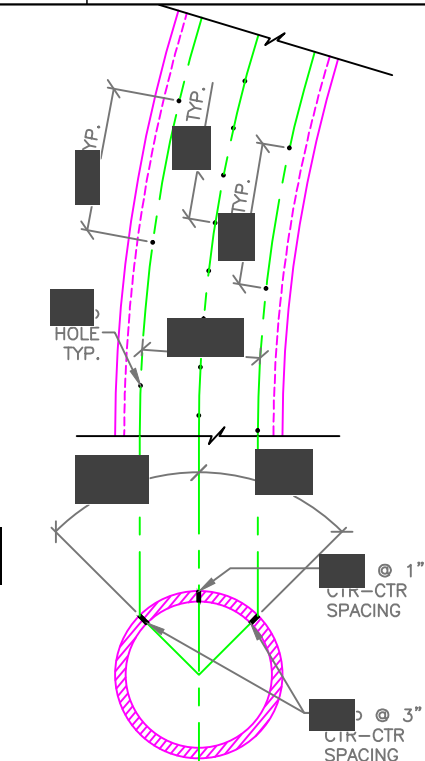


_____ - MIDDLE BUBBLER RING FOR _____ PILES
SCALE: NTS



_____ TYPICAL PIPE NIPPLE
SCALE: NTS

SECTION _____
SCALE: NTS



TYPICAL SECTION - _____
SCALE: NTS

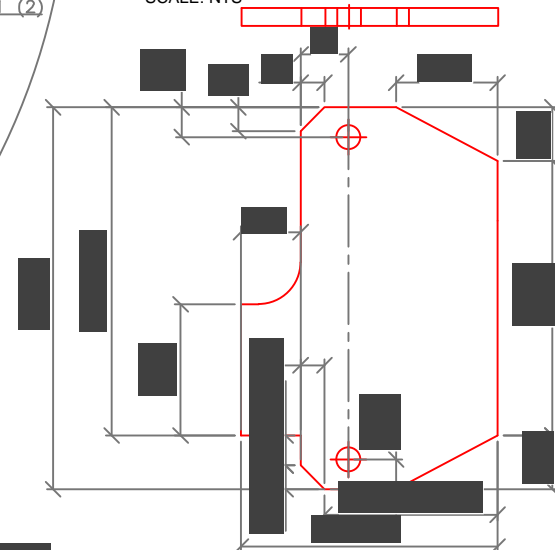


PLATE 1 _____
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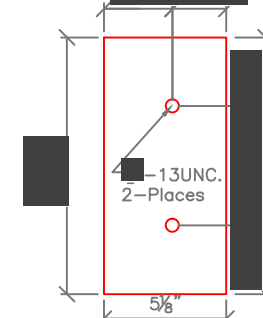


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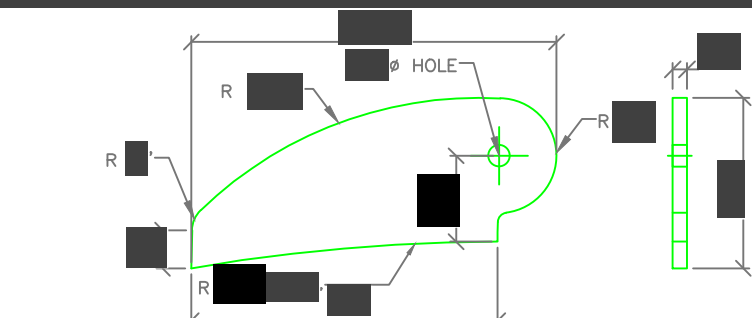


PLATE 3 _____
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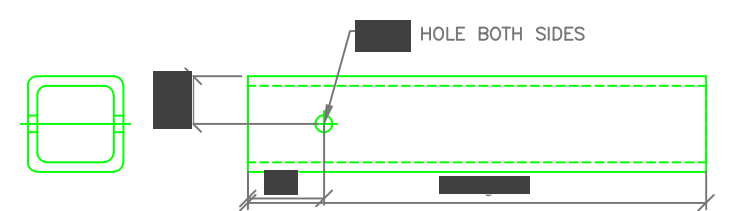


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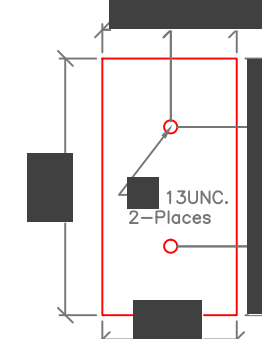


PLATE 5 _____
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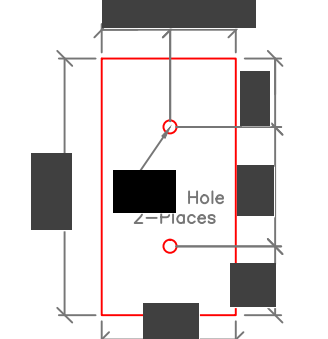
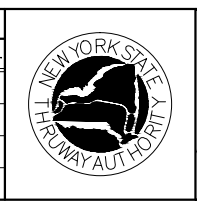


PLATE 6 _____
SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.



TITLE OF PROJECT TAPPAN_ZEE_BRIDGE	CONTRACT NUMBER:
LOCATION OF PROJECT NEW_YORK_STATE	DATE: 5/19/13
TITLE OF DRAWING UNCONFINED_BUBBLE_CURTAIN_RINGS_FOR_____PILES	DRAWING NUMBER:

CONTRACT NUMBER:
DATE: 5/19/13
DRAWING NUMBER:

DOCUMENT TRACKING CODE: _____

Attachment 3 – Air Compressor Specifications

Atlas Copco Rental



PTS 916

100% Oil-free Air Compressor - Diesel driven - TIER III compliant



Atlas Copco Rental is the leader in 100% oil-free air compressor rentals and maintains a strong commitment to customer service and availability, with locations across North America. A highly specialized service team is readily accessible 24/7 when you work with the Atlas Copco Rental team.

Sustainable Productivity

Atlas Copco

PTS 916 100% Oil-free Air Compressor

General

Dimensions LxWxH	17'8" x 7'3" x 7'9"
Shipping weight (wet)	18,600 lbs / 8,437 kg
Fuel tank capacity	237 gal / 900 l
Sound pressure level LPA	74 dB (A)
Sound power level LWA	102 dB (A)

Engine

Engine make	Caterpillar
Type	C18 Acert
Output	575 HP / 429 kW
Fuel consumed (Gal/Hr)	22

Compressor

Number of stages	2
Maximum capacity FAD l/s	762
Maximum capacity FAD m³/min	45.7
Maximum capacity FAD cfm	1,600

Performance

Working Pressure		Free Air Delivery		
bar(e)	psig	m³/min	m³/H	cfm
6.9	10-150	45.7	2,742	1,300-1,600
9.3	135	43.1	2,586	1,522
10.3	150	37.4	2,244	1,321

Other Features

- Integrated aftercooler (15°F + A)
- Spillage free frame
- Weatherproof canopy
- Spark arrestor
- Overspeed shut down system
- Cold weather package
- Auxillary tank hook ups w/ switching valves
- Operator safety devices:
 - Emergency stop buttons
 - Warning light
 - Alarm horn

Additional Rental Product Solutions

- Boosters
- Dryers
- Fuel Tanks (double wall)
- Hoses
- Manifolds
- Nitrogen Generation Equipment
- Particulate Discharge Scrubbers
- Trailers

Atlas Copco



Never use compressed air as breathing air without prior purification in accordance with local legislation and standards.



The TÜV found no traces of oil in the output air stream. Atlas Copco has thereby become the first compressor manufacturer to receive certification for a new industry standard of air purity: **ISO 8573-1 CLASS 0**. More information can be found on: www.classzero.com

All Routine Service Included

We provide routine maintenance at no charge. No hidden costs!

Triple certification, Triple benefit



**24/7 Rental Service all across
USA and Canada
1-800-736-8267
www.AtlasCopcoRental.com**