Description of Underwater Noise Attenuation System
Design Unit 2
for the
New NY Bridge Project

Revision 1
May 9, 2014

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Table of Contents

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 on fishes in the Hudson River. This program is being conducted pursuant to the following the New NY Bridge 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 with 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 report compared the NASs that were considered for possible adoption based upon the 2012 Pile Installation Demonstration Program (PIDP). The report also 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 10 dB single strike sound exposure level (SELss) reduction 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 that were established by the NMFS BO Term and Condition 9 and by NYSDEC Permit Condition 14; and
3. System Operation and Compatibility – System can be safely deployed and retrieved repeatedly during production pile driving without impact to pile driving requirements and project schedule.

The *PLT-NAS Description* 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 pile driving. As such, the multi-tier bubble curtain was selected for further testing during test pile installation. The report 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 NAS monitoring, as well as the monitoring locations for production pile driving. The purpose of the present Report is to provide the results of the underwater noise monitoring during installation of test piles for the Design Unit 2 (see Attachment 1) and based on those results, provide the design plans and anticipated operational specifications for the NAS for Design Unit 2 in accordance with the following NYSDEC Permit Conditions 8 and 9:

> 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 [redacted] 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 [redacted] 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 [redacted] 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 Test Piles

The Pile Load Test Program uses test piles in each of the 10 design units plus the Main Span (11 total design units), with the primary purpose to confirm pile load capacities. Design Unit 2 consists of [redacted] in Piers 2 to 4 and [redacted] in Pier 5. Test piles were installed with an IHC S-280 impact hammer. A summary of the impact pile driving for [redacted] test piles at Design Unit 2 is provided in Table 1.

Table 1. Summary of Impact Pile Driving for Test Piles at Design Unit 2

Test Pile	Pile Diameter	Impact Hammering Date
PLT-103P	[redacted]	9/3/2013
PLT-103	[redacted]	9/4/2013

3.0 Unconfined Multi-tier 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 for engineering details on the system.

3.1 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 the template using ½"-diameter wire rope. See Attachment 2 for bubbler ring dimensions and hole diameter, spacing, and orientation.

The aluminum ring is connected to a dedicated compressor (Figure 1). This compressor is connected to a reservoir tank to allow a continuous supply of air throughout pile driving (Figure 1). During the installation of test piles, a flow meter and air pressure gauge are used to measure air flow and pressure (Figure 2). The air compressor is capable of supplying an air pressure of up to 100 pounds per square inch (psi) at an air flow of 1600 cubic feet per meter (cfm) to each bubbler ring (Attachment 3). The reservoir tank allows the system to supply an air flow of up to 2000 cfm, to each bubbler ring, as was demonstrated during testing.

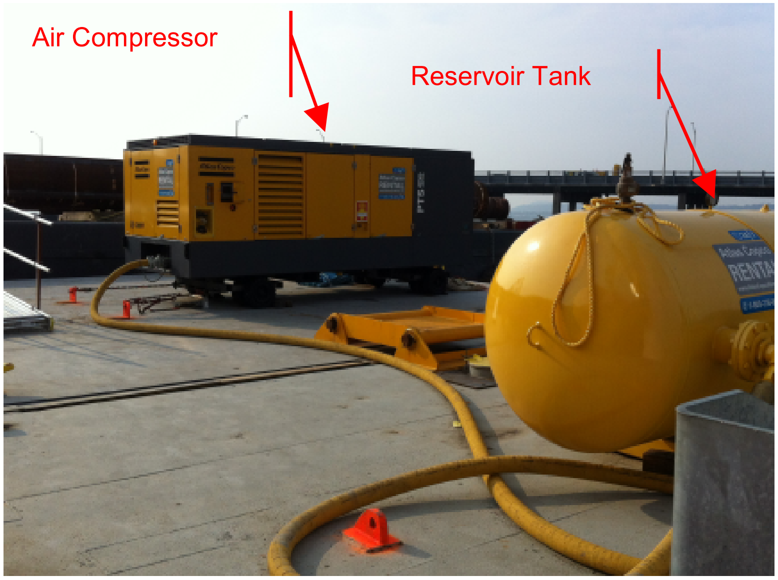

Figure 1. Air Compressor and Reservoir Tank

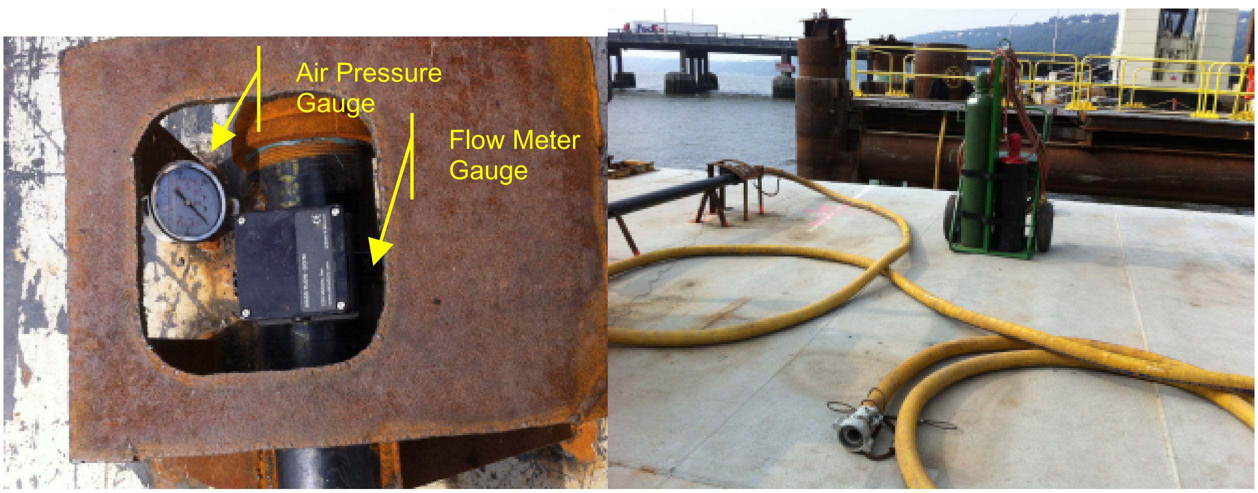

Figure 2. Flow Meter and Pressure Gauge on Outlets from the Reservoir Tank to the Bubbler Ring

3.2 NAS Deployment and Operation

The NAS deployment and operation proceeded as expected. After the piles were initially driven with the vibratory hammer, the bubble curtain ring was deployed with a crane and hung from the secondary template using wire rope slings and shackles (Figure 3). The air compressor/reservoir tank pumped air into the ring (Figure 4), 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 3. Deployment of the Unconfined Multi-tier Bubble Curtain

Figure 4. Operation of the Multi-tier Bubble Curtain

4.0 Underwater Noise Monitoring During Test Pile Installation

4.1 Methods

Details of the equipment, the calibration of the equipment, the data collected, and the signal processing for underwater noise monitoring are included in the Underwater Noise Monitoring Plan. Details on the underwater noise monitoring during the installation of PLT 103P and PLT 103 are provided in the Daily Memoranda for each day of pile driving (Attachment 1).

Figure 5 illustrates a typical barge and hydrophone arrangement [redacted] As seen in Figure 5, a real time Autonomous Multichannel Acoustic Recorder (AMAR-RT) and two Autonomous Multichannel Acoustic Recorders (AMARs) 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). The AMAR-RT was continuously monitored throughout the pile driving process while data collected from the AMARs was downloaded following pile driving. The noise level thresholds predicted in the NMFS BO (April 2013) are as follows:

- peak SPL (sound pressure level) – located on the barge or survey vessel, approximately 33 feet from the pile, based on the distance that can be safely recorded (the distance to the 206 re 1 μPa peak SPL isopleth for [redacted] piles is 20 feet)
- cSEL (cumulative Sound Exposure Level) – located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 μPa^2-s cSEL isopleth for [redacted] piles
- rms SPL (root mean square SPL) – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1μPa rms SPL for [redacted] piles

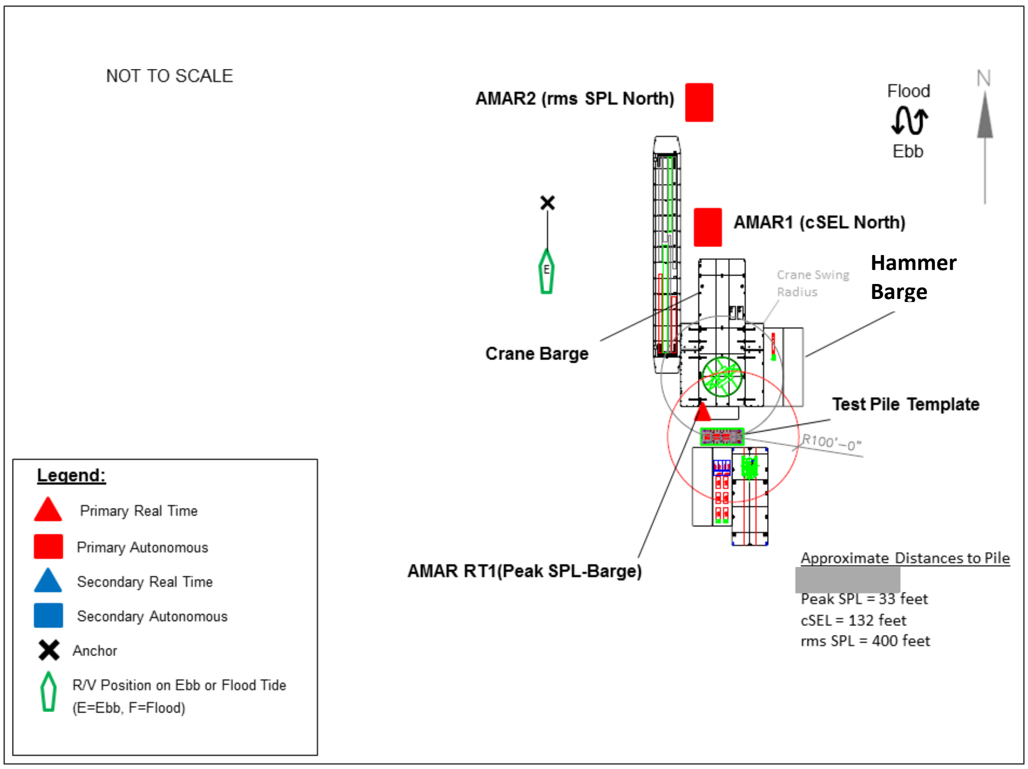

Figure 5. Plan View of a Typical Test Pile Barge Arrangement and Hydrophone Locations for [redacted] piles

Test pile installation for Design Unit 2 occurred during flood and ebb currents. Hydrophones (AMARs) were strategically placed to capture data to analyze variation in the performance of the NAS correlated with variation in the river current and barge placement. During the installation of PLT 103P the NAS was tested down-current and cross-current in a 0.8-0.0 knot flood to slack current. During the installation of PLT 103 NAS was tested down-current and cross-current in a 0.3 – 0.8 knot ebb current. Table 2 provides a summary of the underwater noise monitoring equipment deployment and position relative to the current for the driving of the two test piles.

Table 2. Equipment Deployment and Position Relative to Current for PLT 103P and PLT 103

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)
9/3/2013 PLT 103P	AMAR-RT 11	Peak SPL- Barge	Down-current	Flood to slack (0.8 – 0.0 knots)	27	8
	AMAR-221	cSEL East	Cross-Current		199	9
	AMAR-228	rms SPL East	Cross-current		361	9
9/4/2013 PLT 103	AMAR-RT 11	Peak SPL-Barge	Up-Current	Ebb (0.3 – 0.8 knots)	30	8
	AMAR-228	cSEL East	Cross-Current		125	8
	AMAR-221	rms SPL East	Cross Current		290	9

*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 40 feet from the pile, based on the distance from the pile to the 206 re 1 μPa peak SPL isopleth for piles
- cSEL- located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 μPa^2-s cSEL isopleth for piles
- rms SPL – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1μPa rms SPL for piles

The tests for this design unit were informed by the tests for the previous NAS tests where air flow was varied throughout pile driving but never independently of other variables, such as impact hammer energies or tidal conditions. All tests were performed at a range of tidal conditions and hammer energies which could be expected during production pile driving. Table 3 provides the number of rings deployed and the NAS settings during the installation of the two test piles.

Table 3. Description of NAS During Installation of Test Piles for Design Unit 2

Date Test Pile No.	Water Depth (ft)	Number of Rings	Air Flow (cfm) per Bubbler Ring	Air Pressure (psi)
9/3/2013 PLT 103P	8	1	1100-2000	35-80
9/4/2013 PLT 103	8	1	900-2150	34-80

4.2 Results

4.2.1 NMFS Physiological and Behavioral Thresholds

In accordance with the NMFS BO Term and Condition Number 6, the monitoring program estimated (i) the peak sound pressure level (peak SPL in dB re 1 μPa) at each recorder and the distance from the pile at which the peak SPL exceeds the 206 dB re 1 μPa peak, (ii) the cSEL at each recorder and the distance from the pile at which the cSEL exceeds 187 dB re 1 $\mu Pa^2 \cdot s$ at the end of pile driving[1], and (iii) the rms SPL at each recorder and the distance from the pile at which rms SPL exceeds 150 dB re 1 μPa.

Table 4 provides a summary of the underwater noise levels measured at each recorder during the test pile installation. Table 5 provides the diameter of the sound level isopleths that serve as the NMFS

[1] cSEL increases as the number of strikes increases therefore; the diameter of the 187 dB isopleth also reaches a maximum at the end of piling.

physiological and behavioral thresholds. **These results show that when the NAS was operational, the diameter of the 206 dB re 1 µPa peak SPL did not exceed NMFS requirement of 40 feet for [redacted] piles at Design Unit 2.** The largest diameter of the 206 dB re 1 µPa peak SPL isopleth was 8 ft, which is less than the 206 dB re 1 µPa peak SPL for the NASs tested during the 2012 PIDP. Specifically, during the 2012 PIDP the diameters of the 206 dB re 1 µPa peak SPL isopleth were 15 – 40 feet for [redacted] piles (JASCO 2012)[2]. Furthermore, the estimated diameter of the isopleth at the end of installation of test piles that corresponded to 187 dB re 1 µPa^2-s cSEL never exceeded 204 ft. The river width is approximately 15,000 ft; therefore a fish movement corridor of more than one mile [5,280 ft], which was continuous for more than 1,500 ft, was maintained throughout pile driving, in accordance with NYSDEC Permit Condition 14.

Table 4. Summary of the Measured Sound Levels at Each Recorder During the PLT 103P and PLT 103

Date Test Pile No.	Location*	Max. peak SPL (dB re 1 µPa)	cSEL (dB re 1 µPa^{2}-s)**
9/3/2013 PLT 103P	Peak SPL Barge	195	198
	cSEL East	179	184
	rms SPL East	168	173
9/4/2013 PLT 103	Peak SPL Barge	193	194
	cSEL East	170	177
	rms SPL East	166	172

*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 33 feet from the pile, based on the distance from the pile to the 206 re 1 µPa peak SPL isopleth for [redacted] piles
- cSEL- located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 µPa^2-s cSEL isopleth for [redacted] piles
- rms SPL – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1µPa rms SPL for [redacted] piles

**At the completion of pile driving.

Table 5. Diameters of Sound Level Isopleths that Represent NMFS Physiological and Behavioral Impact Threshold

Threshold		PLT 103P	PLT 103
Pile Installation Duration (hh:mm)*		00:45	~00:35**
Approximate Diameter (ft) of Isopleth	206 dB re 1 µPa peak SPL	8	6
	187 dB re 1 µPa^2-s cSEL	204	110
	150 dB re 1 µPa rms SPL	616	378

* Net pile driving times are rounded to the nearest minute.
** Pile Installation Duration is an approximation based on the GZA field log because the IHC read-out malfunctioned.

4.2.2 NAS Performance

The NAS was tested in flood, ebb, and slack currents with hydrophones located in down-current and cross current positions (Table 2). Current speed ranged from 0 to 0.8 knots. Air flow settings ranged from air pressures of 34 to 80 psi and air flows of 900 to 2150 cfm. Although some variation in sound propagation was noted, the NMFS and NYSDEC required thresholds were not exceeded.

Air pressure and air flow were 50–80 psi and 1700–2000 cfm, respectively, throughout the first phase of installation of PLT 103P and 35–45 psi and 1100–1600 cfm, respectively, during the second phase. The NAS was tested in flood to slack current with speed ranging from 0 to 0.8 knots. Hammer energy averaged 120 kip-ft throughout both phases. There was no observable effect on the measured sound levels from the

[2] JASCO. 2012. Underwater Acoustic Monitoring of the Tappan Zee Bridge Pile Installation Demonstration Project.

change in air pressure or the change in current. The thresholds required by the NMFS BO and NYSDEC permit were not exceeded at any point during the installation of this test pile.

Air pressure and flow were 70–80 psi and 1300–2150 cfm, respectively during most of the pile installation, except a 2.5 min period from 16:03–16:05:30 when pressure fell to 34 psi when the valve from a compressor was not open. Hammer energy averaged 122 kip-ft in the first phase of pile driving and 118 kip-ft in the second phase. For PLT 103 the NAS was tested in an ebb current with speed ranging from 0.3 to 0.8 knots. The measured sound levels at the closest measurement location increased by 3–7 dB during this period, but sound levels at the other two locations did not show an increase. The thresholds required by the NMFS BO and NYSDEC permit were not exceeded at any point during the installation of this test pile.

PLTs 104P and 104 are [redacted] piles driven at Design Unit 3, under conditions similar to the conditions at Design Unit 2. The water depth for each of these piles was 9 feet and one bubble ring was used.

Air pressure and flow dropped from 135-0 psi and 1500-0 cfm respectively during the first four minutes of PLT 104P because the valve from the air compressor to the air-tank was closed. Pile driving stopped and resumed with proper NAS operation at 11:12. Air pressure ranged between 55 and 70 psi (1400-1600 cfm) for the remainder of the pile driving. Once the compressor valve was opened and with resumption of air pressure sound levels at all three recorders decreased approximately 10 dB at every measurement location. For additional information regarding the PLT-104P refer to *Description of Underwater Noise Attenuation System (NAS) – Design Unit 3*.

Air pressure and flow were 55-57 psi and 1300-1425 cfm respectively. For PLT 104 hammer energy remained constant throughout pile driving but the currents dropped from 0.6 knots to slack current. However, there was no observable effect on the measured sound levels from the change in current. For additional information regarding the PLT-104 refer to *Description of Underwater Noise Attenuation System (NAS) – Design Unit 3*.

4.3 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] 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 pile driving without affecting pile driving requirements and project schedule.

Results of test pile installation indicate that the unconfined multi-tier bubble curtain with bubble rings spaced a maximum of ten feet vertically, is effective in minimizing noise in order to meet the NMFS and NYSDEC requirements. Not only did the NAS meet the requirements in full ebb and flood currents and for various NAS settings, underwater noise from pile driving isopleths were smaller than anticipated by the NMFS BO. Results indicate that the largest estimated width of the 206 dB re 1μPa peak SPL isopleth was measured at 8 ft, as compared to the 40 ft anticipated by the NMFS BO. These results indicate that the size of the 206 dB re 1 μPa isopleth measured for the [redacted] piles in less than 10 ft of water was smaller than the 206 dB re 1 μPa isopleths measured during the 2012 PIDP. Furthermore, the diameter of the 187 dB re 1 μPa^2-s cSEL isopleth at the end of installation of each pile was never estimated to be more than 204 ft. Therefore, the noise levels across the majority of the river at the construction site would be less than 187 dB cSEL, and would thus provide the required corridor for sturgeon migration through the site.

5.0 NAS Design Plan and Operational Specifications

The installation of the two test piles also demonstrated that the unconfined multi-tier bubble curtain is 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 pile driving for Design Unit 2, the unconfined multi-tier bubble curtain will be deployed and retrieved in a similar manner to the PLT 103P and PLT 103 pile installations. The air pressure gauge will be used to monitor NAS operation during production pile driving. Based on dredging and armoring, the river bottom at Design Unit 2 will be approximately -11 feet at mean lower low water (MLLW). Bubbler rings and compressors will be deployed for each pile in pier 5, so that vertical spacing in the water column is a maximum of 10 feet or less at mean higher high water (MHHW). The NAS will be deployed according the Construction Work Plan. Table 6 provides the expected range of water depths at Pier 5 in Design Unit 2 and the number of bubble curtain rings to be deployed for pile driving at that pier.

Table 6. Range of Water Depths at Each Design Unit 2 Pier and the Number of Bubble Curtain Rings to be Deployed

Pier	Water Depth (feet)	Number of Bubble Curtain Rings*
5	10-12	2

*The number of bubbler rings at specific piles within a pier is subject to change, based on field measurements of water depth during pile installation

The NAS system contains three valves at the:

1. air compressor outlet to the reservoir tank (Figure 6),
2. reservoir tank inlet (Figure 7),
3. reservoir tank outlet (Figure 8) 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 individually to visually confirm sufficient air to each ring. All valves will be opened during the operation of the bubble curtain. The bubble curtain will remain on during periods of active pile driving. The air pressure gauge will be used to monitor NAS operation during production 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 9).

The following will be checked for each of the piles at each pier within Design Unit 2 (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 compressor.
- Air pressure at each reservoir tank outlet approximately 5 minutes after pile driving begins.
- Visual inspection of the water surface for sufficient air bubbles.

Figure 6. Valve at the Air Compressor Outlet to the Reservoir Tank

Figure 7. Valve at the Reservoir Tank Inlet

Figure 8. Valve at the Outlet from the Reservoir Tank to the Bubble Curtain

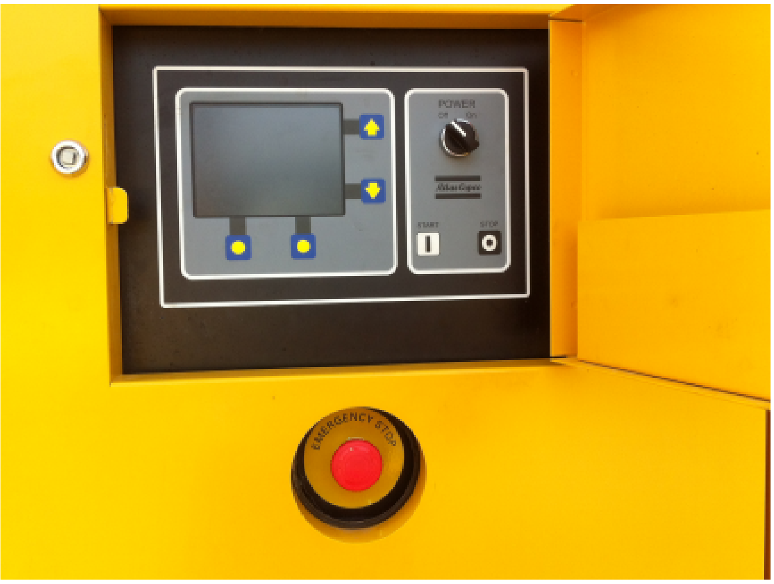

Figure 9. Air Compressor Controls

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 PLT-103P Installation

Daily Memorandum for 03 September 2013

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03 January 2014

P001206-001

1. Summary

1.1. Pile Location and Monitoring Summary

PLT-103P is a [redacted] pile driven at the construction site of the New NY Bridge on the west side of the navigation channel on 03 September 2013 (Table 1). One real-time acoustic monitoring system and two autonomous acoustic monitoring systems were deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) to monitor sound levels during test pile installation (Figure 1, and Table 2). Pile driving occurred between 09:19–10:58 EDT; full flood tide was predicted at 09:17 EDT. Pile driving occurred over two periods, 09:20–09:40 and 10:35–10:55. Breaks often occurred during test pile installation and vary between test piles. The breaks were generally due to transfer of pile equipment and marking test piles during installation.

Table 1. Summary of PLT-103P activities, 03 September 2013.

Date:	03 September 2013
Pile-Driving Activity	
Test pile identifier:	PLT-103P
Pile diameter:	[redacted]
Water depth:	8 ft
Hammer type:	Impact (IHC S-280)
Total hammer strikes:	[redacted]
Total penetration:	
Net duration of pile driving (hh:mm:ss):	00:45:08
Maximum single strike energy:	127 thousand foot-pounds (kip-ft), (172 kJ)
Total energy transferred:	296,511 kip-ft (402 MJ)
Noise Attenuation System (NAS)	
Single-tier unconfined bubble curtain airflow rate:	1100–2000 cubic feet per minute (cfm), 35–80 psi
River conditions during pile driving:	Flood to slack tide, Predicted: 0–1.1 knots (0–0.6 meters per second [m/s], depth dependent; Table 6 and Figure 5) Measured: 0–0.8 knots (0–0.4 m/s, Figure 5)

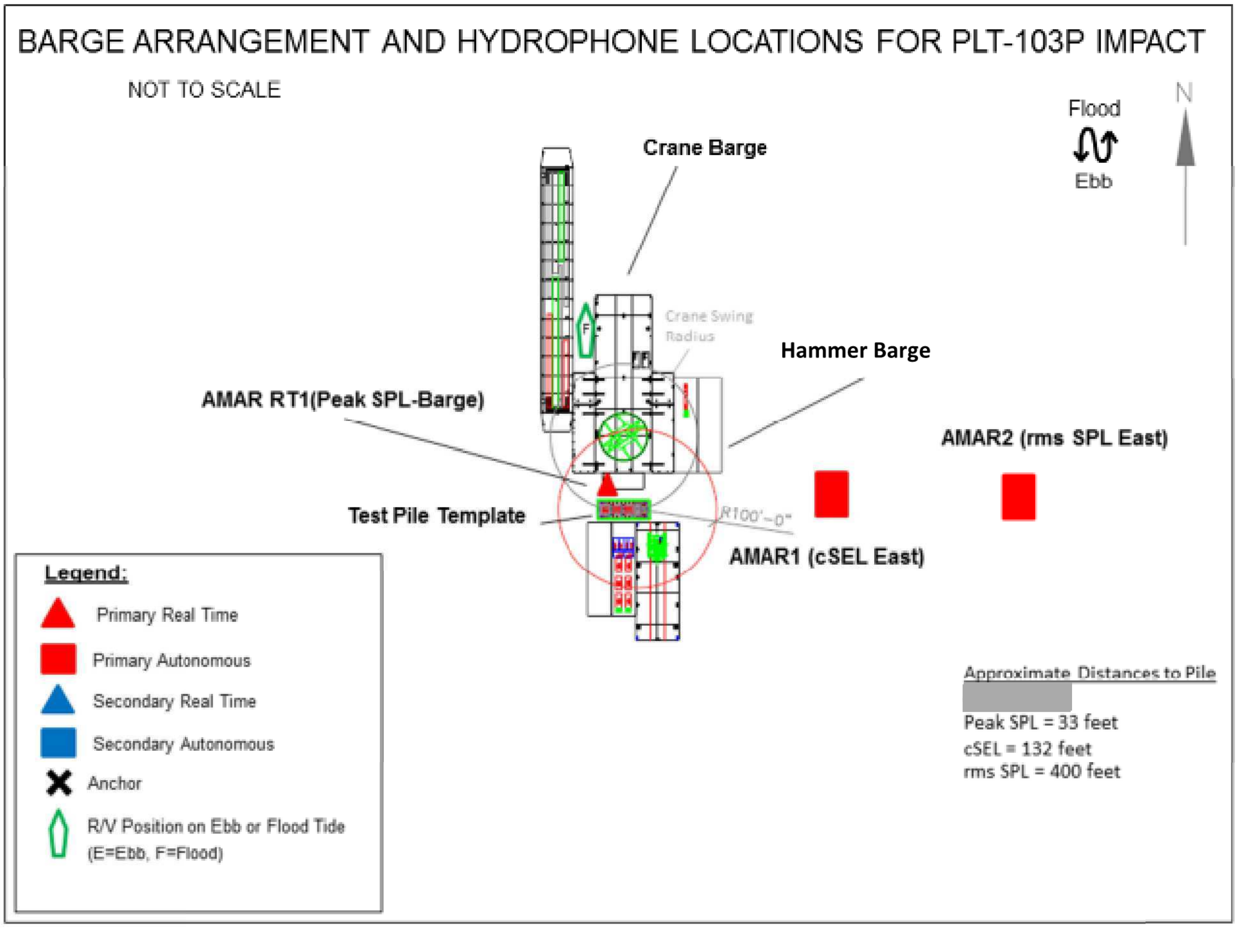

Figure 1. Plan view of pile and barge layout, 03 September 2013, PLT-103P.

Table 2 provides the sound levels measured at each recorder. The maximum sound levels were measured at the Peak SPL Barge location, which was closest to the pile driving. Plots of the measured values, frequency distributions of 1/3 octave single-strike sound exposure level (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 2. Summary of AMAR locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	Recorder ID	Distance to pile (ft)	Water depth (ft)	Max. peak SPL (dB re1 µPa)	cSEL (dB re 1 µPa^2·s)*
Peak SPL Barge (down-current)	AMAR-RT-11	27	8	195	198
cSEL East (cross current)	AMAR-221	199	9	179	184
rms SPL East (cross current)	AMAR-228	361	9	168	173

*Calculated by multiplying the average SELss by the number of strikes reported by the pile driving contractor, representing the total energy at the end of pile driving.

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 SELss from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was approximately 8 ft, and did not exceed NMFS criteria of a diameter of 40 ft for [redacted] piles. The diameter of the 187 dB re 1 µPa^2·s cumulative sound exposure level (cSEL) isopleth was estimated to be 204 ft at the end of pile driving. Since cSEL increases as the number of strikes increases, the diameter of the 187 dB isopleth was smaller than 204 ft for most of the pile driving operation. 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 (NYSDEC) Permit Condition 14.

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

Criteria	Estimated Mean Diameter (ft)
206 dB re 1 µPa peak SPL	8
187 dB re 1 µPa^2·s cSEL	204*
150 dB re 1 µPa rms SPL (1 s integration time)	616

* At the end of pile driving

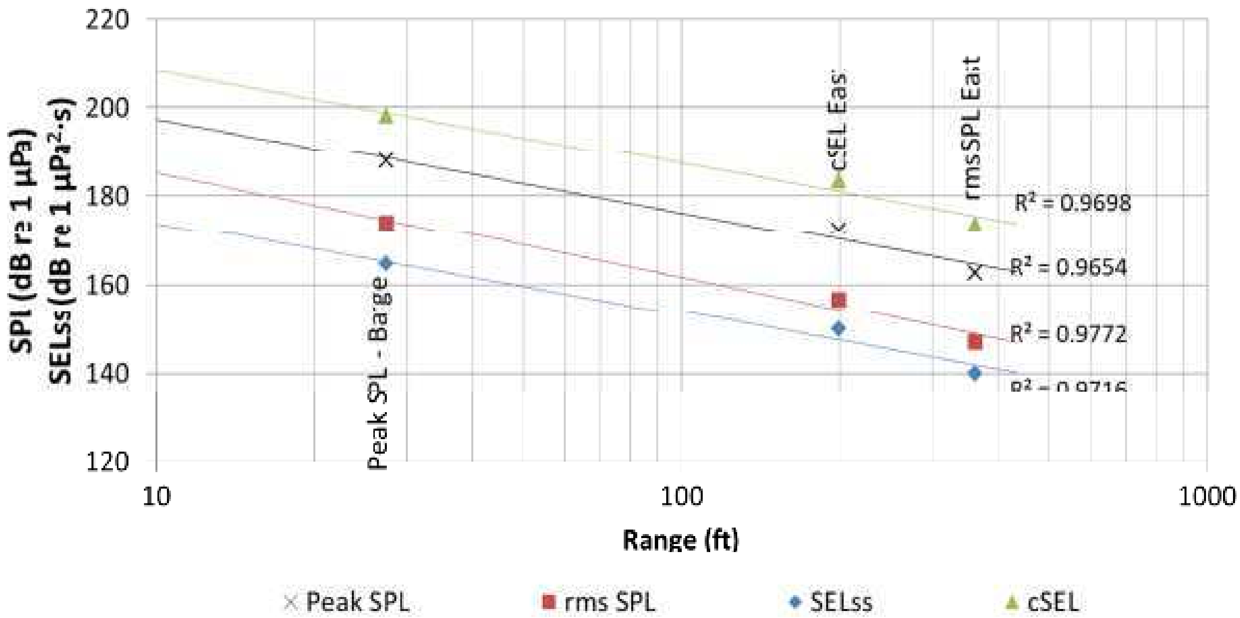

Figure 2. Regression based on mean values of the SELss, peak SPL, cSEL, and rms SPL from each recorder from pile driving of Test Pile PLT-103P, 03 September 2013. SELss, peak SPL, and rms SPL are instantaneous values. The cSEL represents the total sound energy measured, and reflects the cumulative exposure at the end of the pile driving.

1.3. Observations

The hammer energy was nearly constant at 120±8 kip-ft (Figure 4) throughout the pile driving at PLT-103P. Pile driving occurred over two periods, 09:20–09:40 and 10:35–10:55. The current was an average of 0.5 knots during the first period and slack during the second period (Figure 5). Both autonomous recorders were cross-current (Figure 1). The NAS air pressure was 50–80 psi (1700–2000 cfm) during the first period and 35–45 psi (1100–1600 cfm) during the second period (Table 5). There was no observable effect on the measured sound levels from the change in air pressure or the change in current (Figure 3).

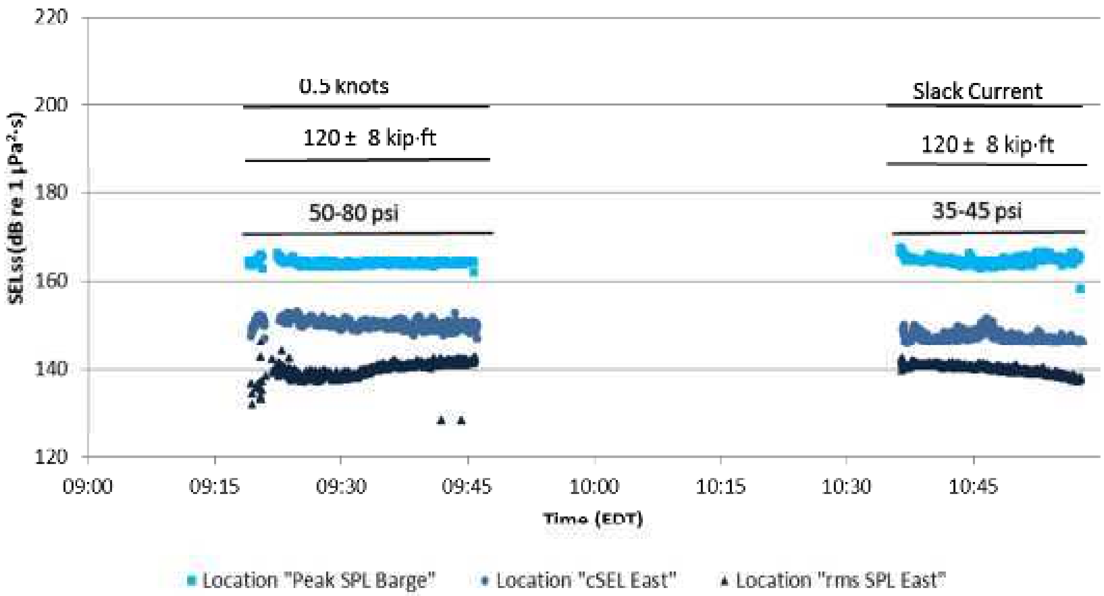

Figure 3. Comparison of SELss at each location annotated with hammer energy (kip-ft), NAS air pressure (psi), and river current (knots).

2. Activity Logs

Table 4 provides activities for 03 September 2013.

2.1. Log of JASCO and Construction Activities

Table 4. JASCO and construction activities for Test Pile PLT-103P, 03 September 2013.

Time (EDT)	Activity
07:45	Arrive at dock and leave for Hudson Harbor
08:20	Arrive Hudson Harbor and transit to barge
08:30	Arrive at barge and prepare recorders
08:55	AMAR-RT-11 deployed and recording.
09:05	Begin deploying AMAR-221
09:15	Begin deploying AMAR-228
09:19	Start pile driving
10:58	Pile driving complete
11:38	Begin retrieving all recorders
13:00	All work complete.

2.2. Pile Driving Logs

2.2.1. NAS

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

NAS Settings: 1100–2000 cfm, 35–80 psi

Table 5. NAS setting pile driving at PLT-103P, 03 September 2013.

Time (EDT)	Volume/min (cfm)	Pressure (psi)
09:19–09:46	1700–2000	50–80
10:47–10:58	1100–1600	35–45

2.2.2. Impact Hammering Log

Total energy: 296,511 kip-ft (402 MJ)

Total number of strikes:

Maximum per-strike energy: 127 kip-ft (172 kJ)

Net pile driving duration (hh:mm:ss): 00:45:08

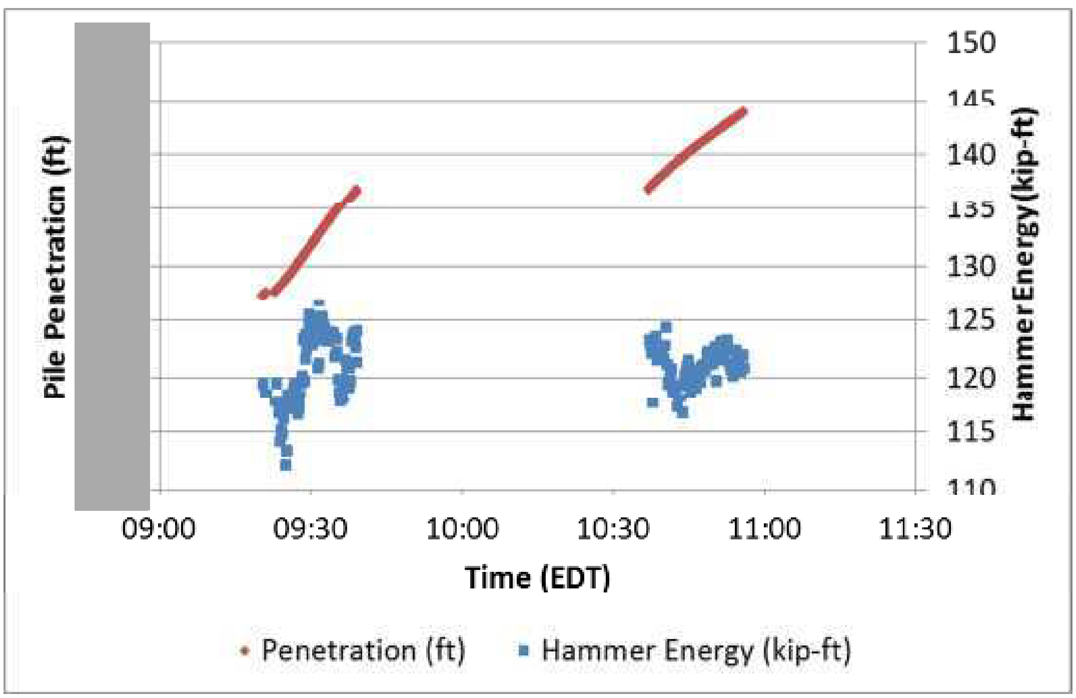

Figure 4. Hammer energy (kip-ft) and pile penetration (ft) during pile driving of PLT-103P, 03 September 2013.

3. Weather and River Conditions

Table 6 provides the predicted currents at the project site on 03 September 2013. Figure 5 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 CTD.

Table 6. Weather conditions, current, and predicted local tide times.

Weather conditions:	Cloudy, calm, wind ~3 kts from south.
Full ebb current:	15:23 (1.5 kts max)
Slack current:	11:45, EDT
Full flood current:	09:17 (1.1 kts max)

Reference: http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2013&stn=0611+George Washington Bridge&secstn=Tappan+Zee+Bridge&sbfh=%2B1&sbfm=12&fldh=%2B0&fldm=55&sbeh=%2B0&sbem=52&ebbh=%2B1&ebbm=06&fldr=0.6&ebbr=0.8&fldavgd=356&ebbavgd=175&footnote=

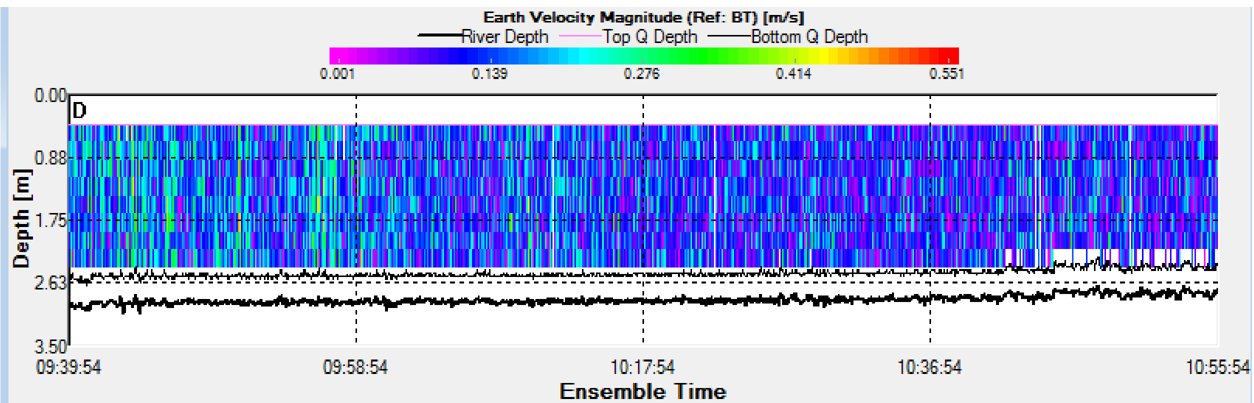

Figure 5. ADCP data from 03 September 2013 at location Peak SPL Barge, times are in EDT

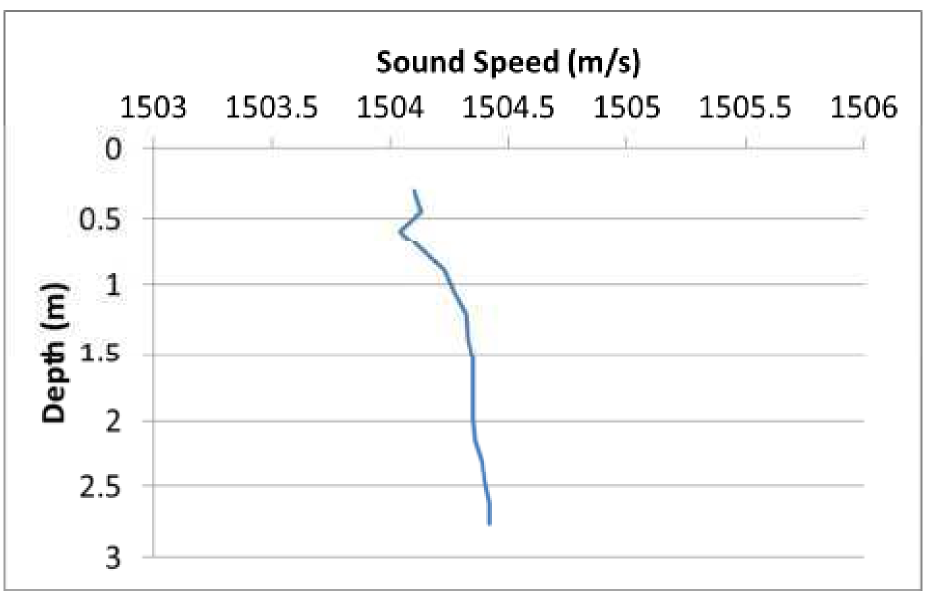

Figure 6. CTD cast performed on the Alpine Vessel at 41.071466° N, 73.914640° W.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 7 provides information on the real-time monitoring equipment used on 03 September 2013. Table 8 provides location information on the real-time recorders

Table 7. Real-time monitoring equipment for Test Pile PLT-103P, 03 September 2013.

Acoustic Data Logger		**Units deployed**
Model:	AMAR RT (JASCO Applied Sciences)	1
SpectroPlotter version:	6.0.1	1
Hydrophone		
Model:	M8KC (GTI)	1
AMAR-RT-11 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 8. Locations (WGS84) and deployment times (EDT) of the AMAR-RT monitoring stations, 03 Sep 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time	Water Depth (ft)	Distance to Pile (ft)
Peak SPL Barge	AMAR-RT-11	41.071870	73.915200	08:55	8	27

4.2. Autonomous Monitoring Equipment

Table 9 provides information on the autonomous monitoring equipment used on 03 September 2013. Table 10 provides the locations of the autonomous recorders.

Table 9. Autonomous monitoring equipment Test Pile PLT-103P, 03 September 2013.

Acoustic Data Logger		**Units deployed**
Model:	AMAR G3 (JASCO Applied Sciences)	2
SpectroPlotter version:	6.0.1	2
Hydrophone		
Model:	M8E-51-0dB (GTI)	2
AMAR-221 sensitivity:	-199.8 dB re 1 V/µPa	1
AMAR-228 sensitivity:	-199.7 dB re 1 V/µPa	1

Table 10. Locations (WGS84) and deployment times (EDT) of the long-range monitoring AMAR stations 03 September 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
cSEL East (cross current)	AMAR-221	41.071466	73.914640	09:05	9	199
rms SPL East (cross current)	AMAR-228	41.071424	73.913986	09:15	9	361

Appendix A. Pile Driving Plots

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

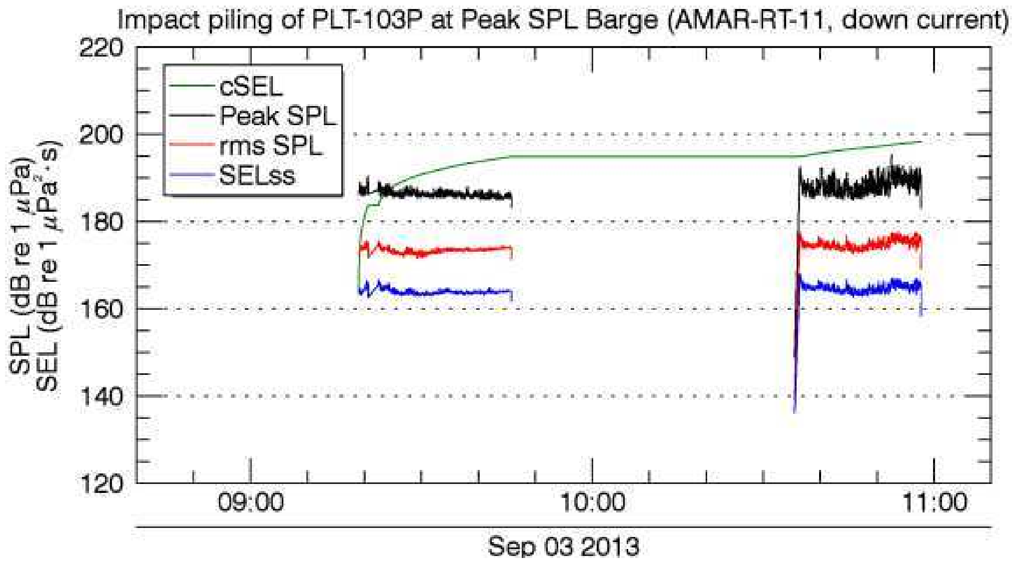

Figure 7.*Impact Pile Driving*: Peak SPL, rms SPL, SELss, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103P measured 27 ft from the pile at location Peak SPL Barge using AMAR-RT-11. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

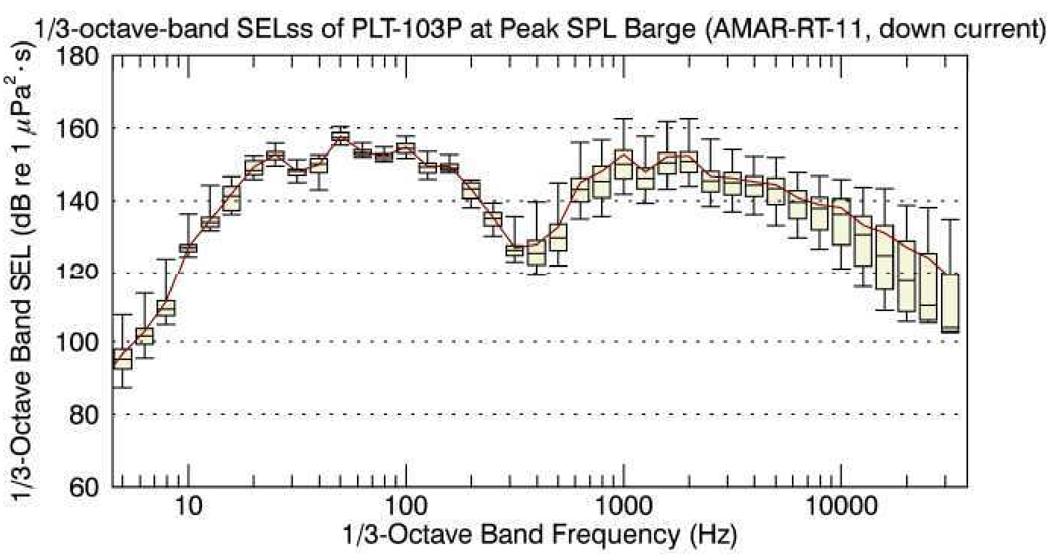

Figure 8. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-103P measured 27 ft from the pile at location Peak SPL Barge using AMAR-RT-11. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 11. Sound Levels for the pile driving of Test Pile PLT-103P measured 27 ft from the pile at location Peak SPL Barge using AMAR-RT-11

Sound level statistics*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	195.4	177.8	168.2
L_5	190.8	176.3	165.9
L_{25}	188.1	174.7	164.8
L_{50}	186.7	173.8	164.1
L_{75}	186.0	173.3	163.6
L_{95}	185.4	172.5	163.2
L_{mean}	187.6	174.2	164.4

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

A.2. Impact Pile-Driving Sound Levels cSEL East

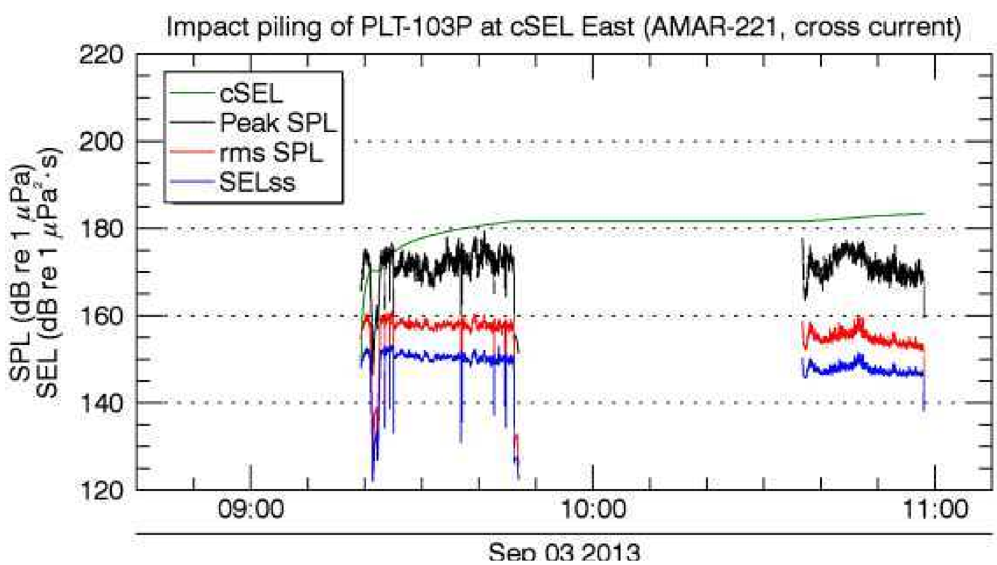

Figure 9. *Impact Pile Driving*: Peak SPL, rms SPL, SELss, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103P measured 199 ft from the pile at location cSEL East using AMAR-221. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

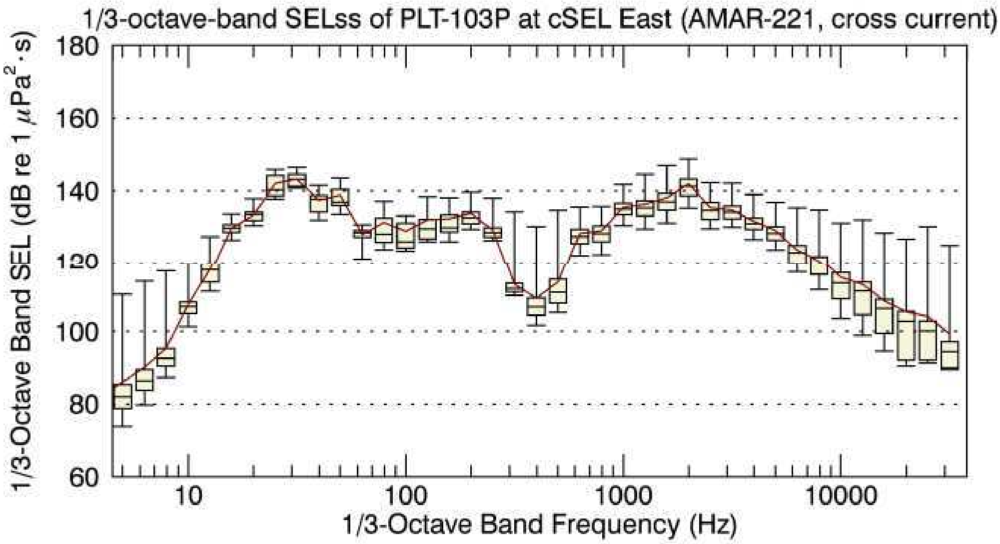

Figure 10.Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-103P measured 199 ft from the pile at location cSEL East using AMAR-221. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 12. Sound Levels for the pile driving of Test Pile PLT-103P measured 199 ft from the pile at location cSEL East using AMAR-221

Sound level statistics*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa²·s)
L_{max}	179.4	161.2	153.3
L_5	175.8	159.3	151.8
L_{25}	173.6	158.0	150.6
L_{50}	171.8	156.8	149.4
L_{75}	169.9	154.5	147.3
L_{95}	167.6	152.9	146.4
L_{mean}	172.5	156.8	149.4

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

A.3. Impact Pile-Driving Sound Levels rms SPL East

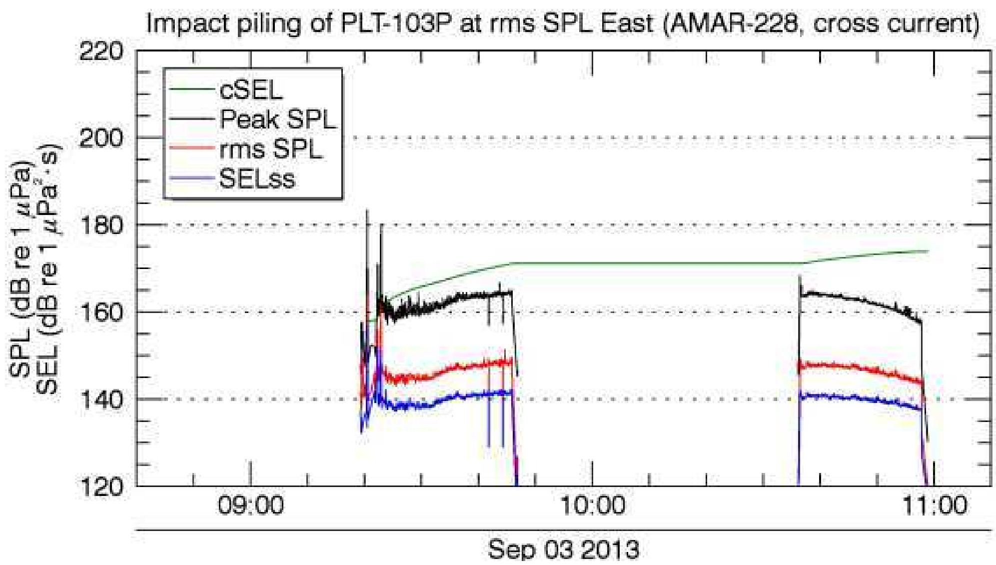

Figure 11. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103P measured 361 ft from the pile at location rms SPL East using AMAR-228. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

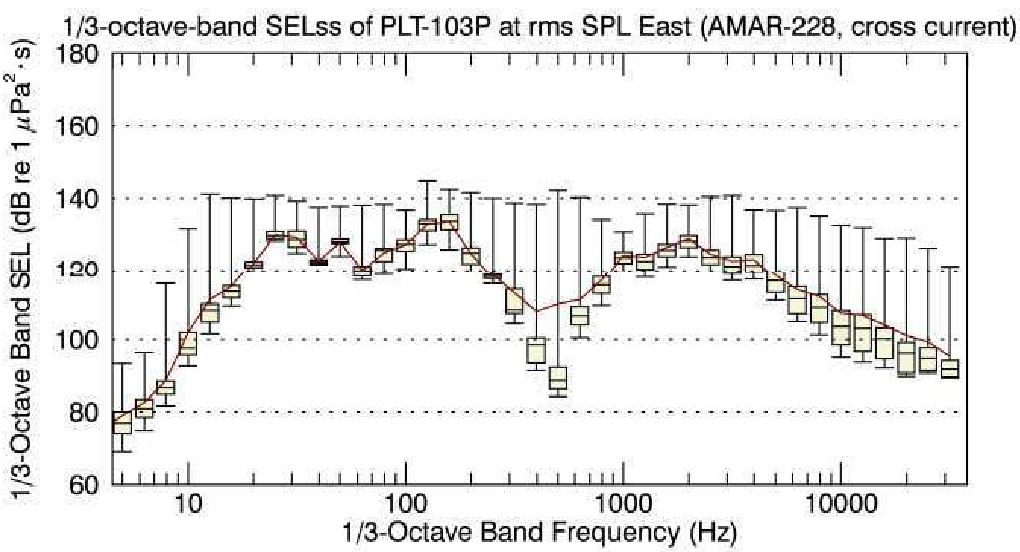

Figure 12. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-103P measured 361 ft from the pile at location rms SPL East using AMAR-228. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 13. Sound Levels for the pile driving of Test Pile PLT-103P measured 361 ft from the pile at location rms SPL East using AMAR-228.

Sound level statistics*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 $\mu Pa^2 \cdot s$)
L_{max}	168.4	151.5	142.5
L_5	164.3	148.3	141.4
L_{25}	163.7	147.6	140.7
L_{50}	162.5	146.8	140.1
L_{75}	160.7	145.2	138.9
L_{95}	158.4	144.1	137.9
L_{mean}	162.4	146.6	140.0

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

Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile PLT-103 Installation

Daily Memorandum for 04 September 2013

Submitted to:
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03 January 2014

P001206-001

1. Summary

1.1. Pile Location and Monitoring Summary

PLT-103 is a [redacted] pile driven at the construction site of the New NY Bridge on the west side of the navigation channel on 04 September 2013 (Table 1). One real-time acoustic monitoring system and two autonomous acoustic monitoring systems were deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) to monitor sound levels during test pile installation (Figure 1, and Table 2). Pile driving occurred between during two periods between 15:05–16:26 EDT. Breaks often occurred during test pile installation. Breaks are approximate and varied between test piles. The breaks were generally due to transfer of pile equipment and marking test piles during installation. Pile driving occurred predominantly during the ebb current. Full ebb current occurred at 16:01 EDT.

Table 1. Summary of PLT-103 activities, 04 September 2013.

Date:	04 September 2013
Pile-Driving Activity	
Test pile identifier:	PLT-103
Pile diameter:	[redacted]
Water depth:	8 ft
Hammer type:	Impact (IHC S-280)
Total hammer strikes:	[redacted]
Total penetration:	[redacted]
Net duration of pile driving (hh:mm:ss):	~00:35:00*
Maximum single strike energy:	127 thousand foot-pounds (kip-ft), (172 kJ)
Total energy transferred:	223,901 kip-ft (303 MJ)
Noise Attenuation System (NAS)	
Single-tier unconfined bubble curtain airflow rate:	900–2150 cubic feet per minute (cfm), 34–80 psi
River conditions during pile driving:	Ebb tide, 0.3–0.8 knots (0.15–0.4 meters per second [m/s], depth dependent; Figure 5)

* Pile installation duration is an approximation based on the number of strikes recorded in the GZA field log and an assumption of 57 strikes per minute, because the hammer read-out malfunctioned.

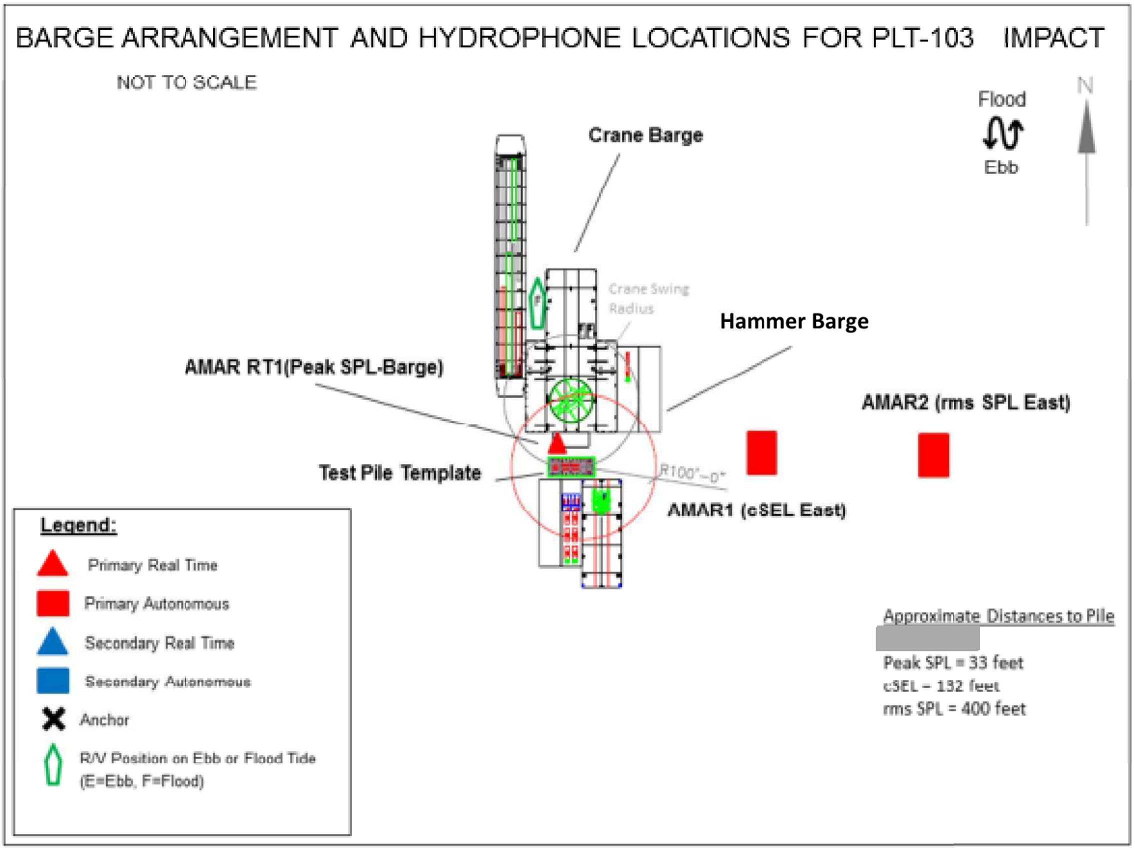


Figure 1. Plan view of pile and barge layout, 04 September 2013, PLT-103.

Table 2 provides the sound levels measured at each recorder. The maximum sound levels were measured at the Peak SPL Barge location, which was closest to the pile driving. Plots of the measured values, frequency distributions of 1/3 octave single-strike sound exposure level (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 2. Summary of AMAR locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	Recorder ID	Distance to pile (ft)	Water depth (ft)	Max. peak SPL (dB re1 μPa)	cSEL (dB re 1 $\mu Pa^2 \cdot s$)*
Peak SPL Barge (up current)	AMAR-RT-11	30	8	193	194
cSEL East (cross current)	AMAR-221	125	8	170	177
rms SPL East (cross current)	AMAR-228	290	9	166	172

*Calculated by multiplying the average SELss by the number of strikes reported by the pile driving contractor..

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 SELss from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was less than 6 ft, and did not exceed NMFS criteria of a diameter of 40 ft for [redacted] The diameter of the 187 dB re 1 µPa²·s cumulative sound exposure level (cSEL) isopleth was estimated to be 110 ft at the end of pile driving. Since cSEL increases as the number of strikes increases, the diameter of the 187 dB isopleth was smaller than 110 ft for most of the pile driving operation 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 (NYSDEC) Permit Condition 14.

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

Criteria	Estimated Mean Diameter (ft)
206 dB re 1 µPa peak SPL	6
187 dB re 1 µPa²·s cSEL	110*
150 dB re 1 µPa rms SPL (1 s integration time)	378

* At the end of pile driving

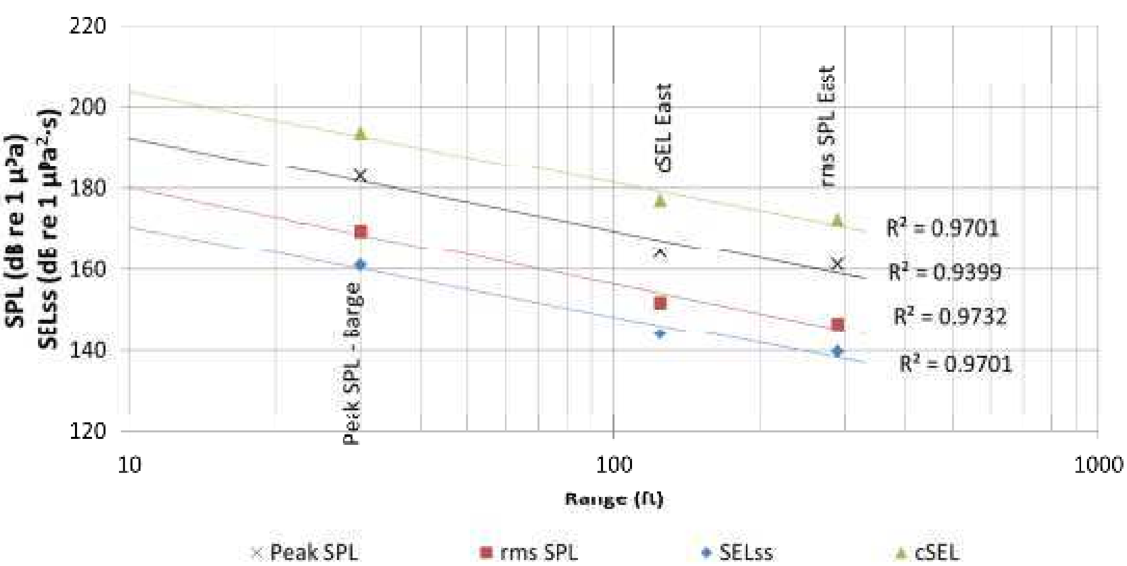


Figure 2. Regression based on mean values of the peak SPL, rms SPL, SELss, and cSEL from each recorder from pile driving of Test Pile PLT-103, 04 September 2013. SELss, peak SPL, and rms SPL are instantaneous values. The cSEL represents the total sound energy measured during the pile driving.

1.3. Observations

Pile driving occurred over two periods, 15:05-15:25 and 16:03-16:28. The hammer energy was nearly constant at 122±3 kip-ft during the first period, and 118±7 kip-ft during the second period (Figure 4). The current was an average of 0.5-0.6 knots during the entire period (Figure 5). Both autonomous recorders were cross-current (Figure 1). The NAS air pressure was 70–80 psi (1300–2150 cfm) during most of the pile driving, except a 2.5 min period from 16:03–16:05:30 when pressure fell to 34 psi due to a failure to open the valves from the compressors (Table 6). The measured sound levels at location Peak SPL Barge increased by 3–7 dB during the period when the NAS compressor valves were closed (Figure 3). Sound levels at locations cSEL East and rms SPL East did not show an increase during this period (Figure 3).

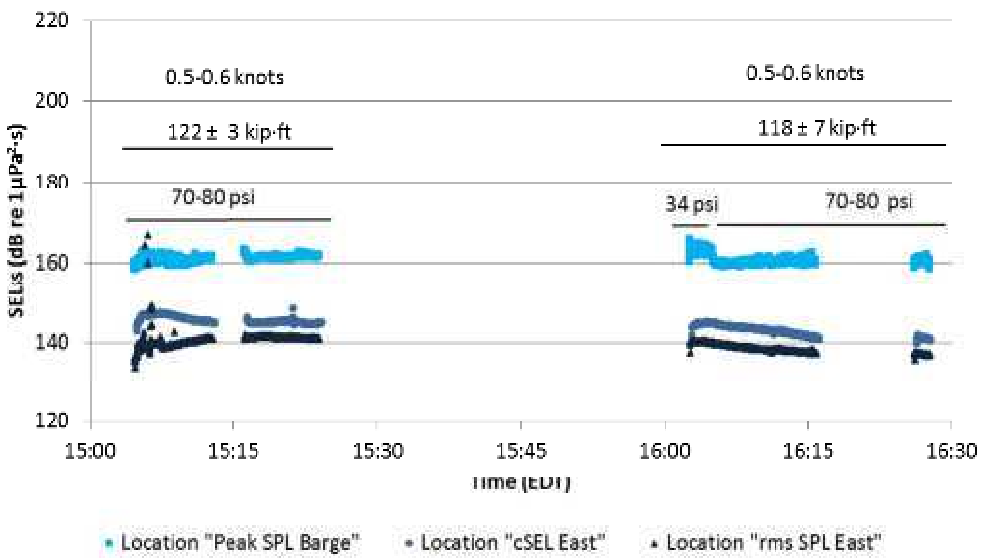


Figure 3. SELss at each location annotated with hammer energy (kip-ft), NAS air pressure (psi), and river current (knots). Air pressure to the rings was reduced from 16:03–16:05; however, sound levels only increased at location Peak SPL Barge.

Based on the regression, the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was 10 ft when the air pressure dropped to 34 psi, and did not exceed NMFS criteria of a diameter of 40 ft for four-foot piles (Table 4). The diameter of the 187 dB re 1 µPa^2·s cSEL isopleth would have been 124 ft at the end of pile driving if 1875 strikes had occurred at these sound levels (Table 4).

Table 4. Estimated isopleth diameters for the NMFS physiological and behavioral thresholds using only the sound levels measured with no NAS, 16:03–16:05:30, 04 September 2013.

Criteria	Estimated Mean Diameter (ft)
206 dB re 1 µPa peak SPL	10
150 dB re 1 µPa rms SPL (1 s integration time)	398

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Table 4 provides activities for 04 September 2013.

Table 5. JASCO and construction activities for Test Pile PLT-103, 04 September 2013.

Time (EDT)	Activity
07:20	Arrive at dock and leave for barges
07:29	Start deploying AMAR recorders
07:53	Complete deploying AMAR recorders
08:00	Transfer to barge and deploy Real Time AMAR system
08:20	Complete Real Time AMAR system deployment, begin monitoring pile driving activity
15:05	Pile driving begins
16:28	Pile driving completed, start to retrieve all recorders
17:10	All AMAR retrieved. Head to dock
17:20	Begin data download at dock, securing equipment.
18:20	All work complete.

2.2. Pile Driving Logs

2.2.1. NAS

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

NAS Settings: 900 – 2150 cfm, 34 – 80 psi

Table 6. NAS settings during pile driving at PLT-103, 04 September, 2013.

Time (EDT)	Volume/min (cfm)	Pressure (psi)
15:05–15:21	1300–1500	70–75
16:03–16:05	900–1000	34*
16:06–1616	1300–2150	70–80f
16:26–16:28	1250–1350	70–75

*After two minutes of pile driving it was discovered that the valve from the compressors to the air tanks was not open. 34 psi was the pressure in the air tanks when the valve was opened at 16:05.

2.2.2. Impact Hammering Log

Total energy: 223,901 kip-ft (303 MJ)

Total number of strikes:

Maximum per-strike energy: 127 kip-ft (172 kJ)

Net pile driving duration (hh:mm:ss): ~00:35:00*

* Pile installation duration is an approximation based on the number of strikes recorded in the GZA field log and an assumption of 57 strikes per minute, because the hammer read-out malfunctioned.

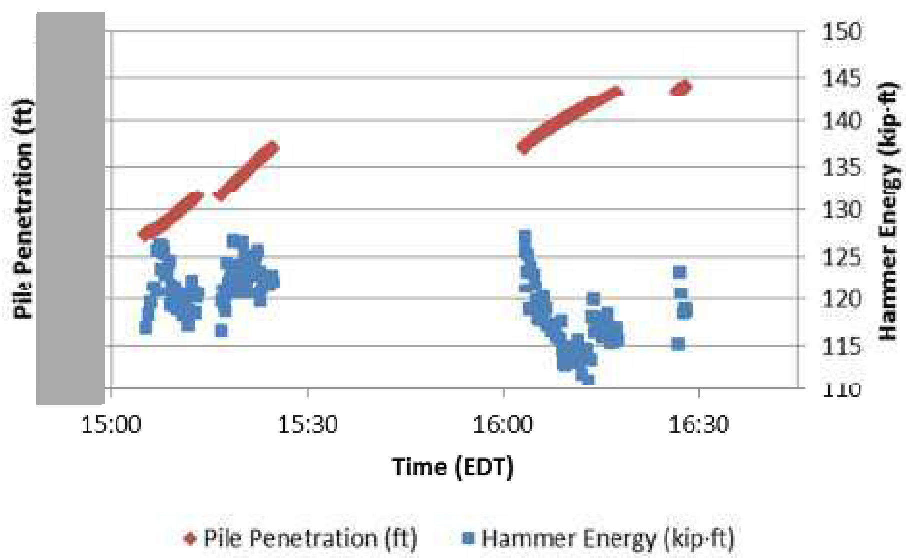


Figure 4. Hammer energy (kip-ft) and pile penetration (ft) during pile driving of PLT-103, 04 September 2013.

3. Weather and River Conditions

Table 7 provides the predicted currents at the project site on 04 September, 2013. Figure 5 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 CTD.

Table 7. Weather conditions, current, and predicted local tide times (EDT)

Weather conditions:	Sunny, 3–5 knots Westerly wind.
Full ebb current:	16:01 (-1.9 knots)
Slack current:	12:24, 18:34
Full flood current:	09:49 (1.1 knots)

Reference: http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2013&stn=0611+George Washington Bridge&secstn=Tappan+Zee+Bridge&sbfh=%2B1&sbfm=12&fldh=%2B0&fldm=55&sbeh=%2B0&sbem=52&ebbh=%2B1&ebbm=06&fldr=0.6&ebbr=0.8&fldavgd=356&ebbavgd=175&footnote=

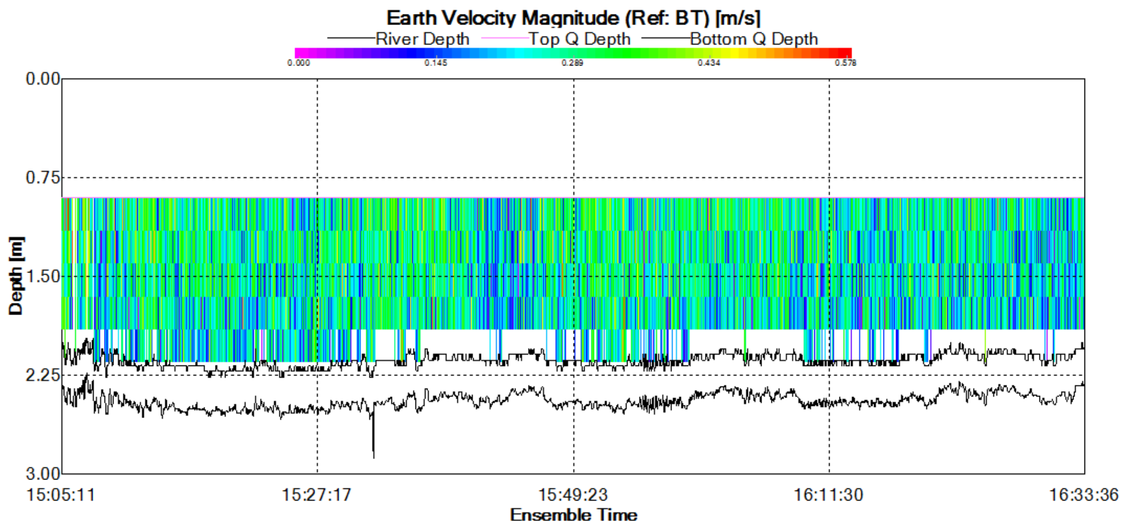


Figure 5. ADCP data from 04 September 2013 at location Peak SPL Vessel location, times are in EDT

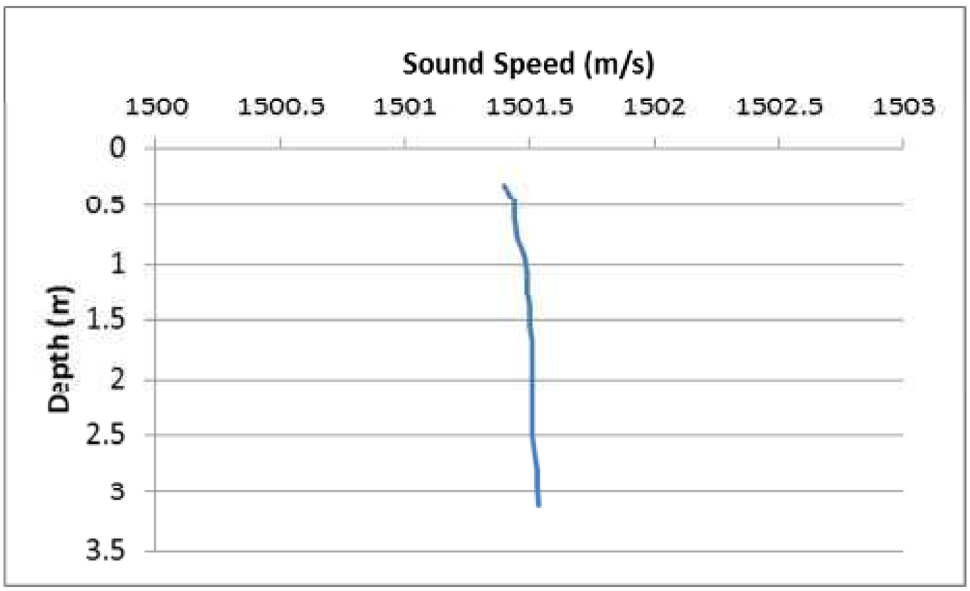


Figure 6. CTD cast performed at 09:09 EDT from location Peak SPL Vessel.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 8 provides information on the real-time monitoring equipment used on 04 September 2013. Table 9 provides location information on the real-time recorders

Table 8. Real-time monitoring equipment for Test Pile PLT-103, 04 September 2013.

Acoustic Data Logger		**Units deployed**
Model:	AMAR RT (JASCO Applied Sciences)	1
SpectroPlotter version:	6.0.1	1
Hydrophone		
Model:	M8KC (GTI)	1
AMAR RT 11 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 9. Locations (WGS84) and deployment times (EDT) of the AMAR-RT monitoring stations, 04 September 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time	Water Depth (ft)	Distance to Pile (ft)
Peak SPL, Barge	AMAR-RT-11	41.071810	73.9151	08:20	8	30

4.2. Autonomous Monitoring Equipment

Table 10 provides information on the autonomous monitoring equipment used on 04 September 2013. Table 11 provides the locations of the autonomous recorders.

Table 10. Autonomous acoustic monitoring equipment deployed 4 September 2013.

Acoustic Data Logger		Units deployed
Model:	AMAR G3 (JASCO Applied Sciences)	2
SpectroPlotter version:	6.0.1	2
Hydrophone		
Model:	M8E-51-0dB (GTI)	2
AMAR-221 sensitivity:	-199.9 dB re 1 V/µPa	1
AMAR-228 sensitivity:	-199.8 dB re 1 V/µPa	1

Table 11. Locations (WGS84) and deployment times (EDT) of the long-range monitoring AMAR stations on 04 September 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time	Water Depth (ft)	Distance to pile (ft)
cSEL East (cross current)	AMAR-221	41.07154	73.91470	7:39	8	125
rms SPL East (cross current)	AMAR-228	41.07134	73.91416	7:53	9	290

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels from Peak SPL Barge

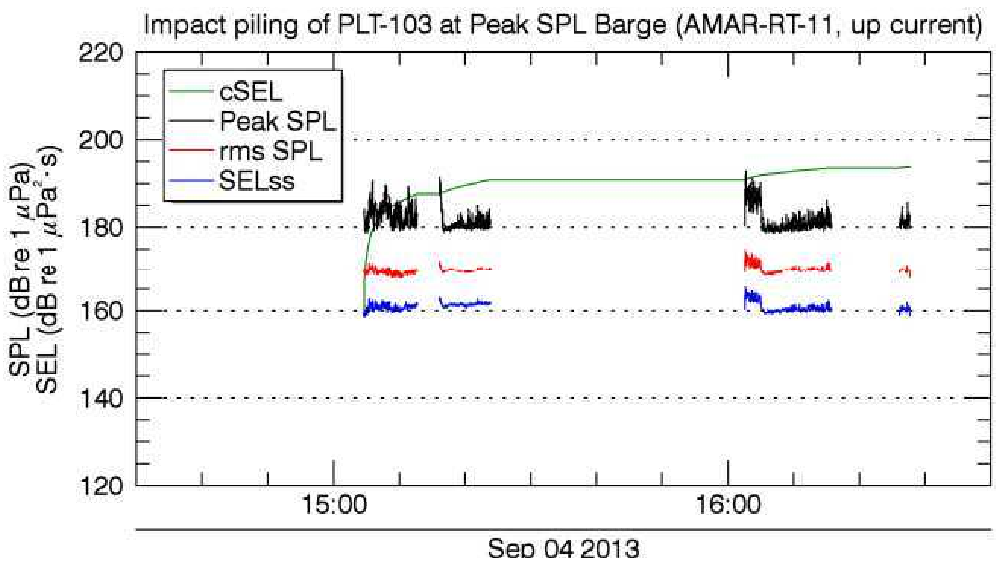


Figure 7. *Impact Pile Driving*: Peak SPL, rms SPL, SELss, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103 measured 30 ft from the pile at location Peak SPL Barge using AMAR-RT-11. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

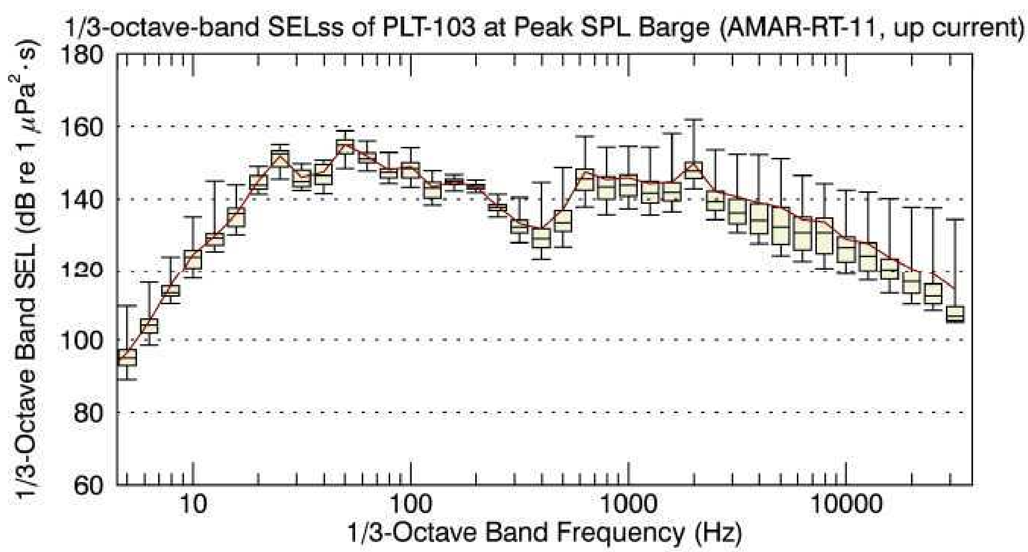


Figure 8.Distribution 1/3-octave-band SELss for the pile driving of Test Pile PLT-103 measured 30 ft from the pile at location Peak SPL Barge using AMAR-RT-11. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 12. Sound levels for the pile driving of Test Pile PLT-103 measured 30 ft from the pile at location Peak SPL Barge using AMAR-RT-11.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	192.9	175.0	165.6
L_5	187.9	171.8	162.8
L_{25}	182.9	170.0	161.4
L_{50}	180.9	169.5	160.8
L_{75}	180	169.0	160.1
L_{95}	179.2	168.3	159.6
L_{mean}	182.9	169.7	161.0

*The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the nth percentile level (Ln) 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 at cSEL East

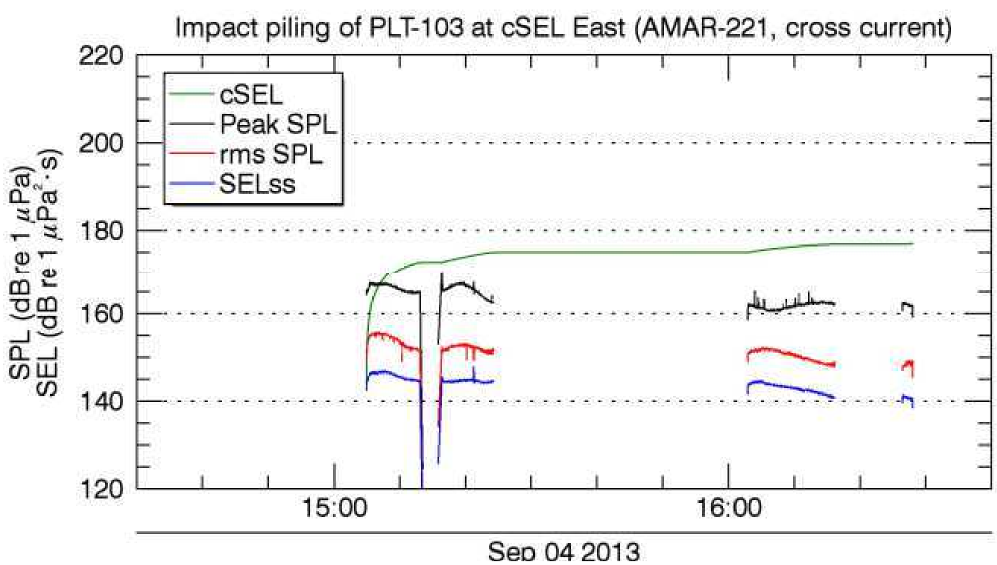


Figure 9. *Pile Driving*: Peak SPL, rms SPL, SELss, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103 measured 125 ft from the pile at location cSEL East using AMAR-221. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

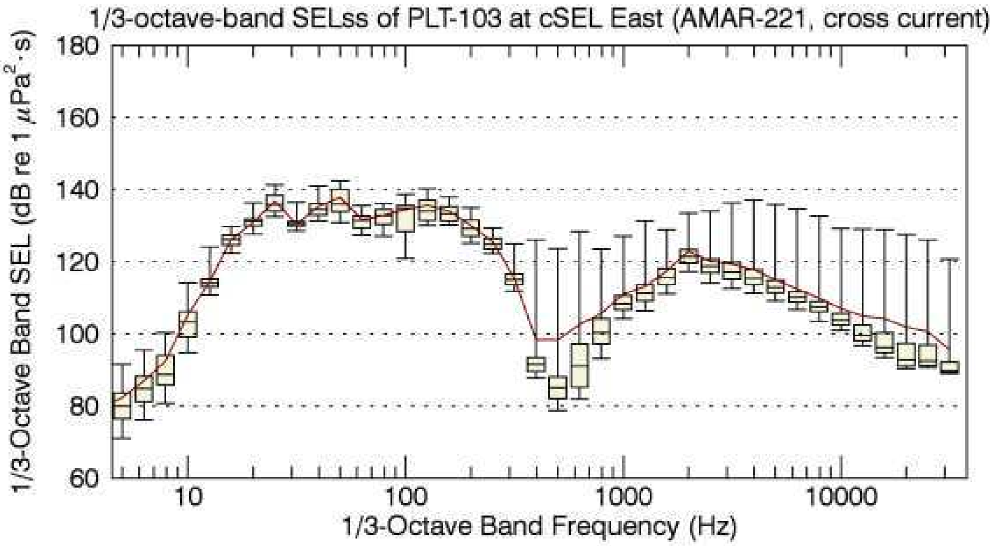


Figure 10. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-103 measured 125 ft from the pile at location cSEL East using AMAR-221. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 13. Sound levels for the pile driving of Test Pile PLT-103 measured 125 ft from the pile at location cSEL East using AMAR-221.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa²·s)
L_{max}	170.2	155.8	147.9
L_5	166.8	155.2	146.5
L_{25}	165.8	152.5	144.8
L_{50}	162.7	151.7	144.3
L_{75}	161.8	150.4	142.9
L_{95}	160.8	148.4	140.9
L_{mean}	164.2	152.0	144.2

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

A.3. Impact Pile-Driving Sound Levels at rms SPL East

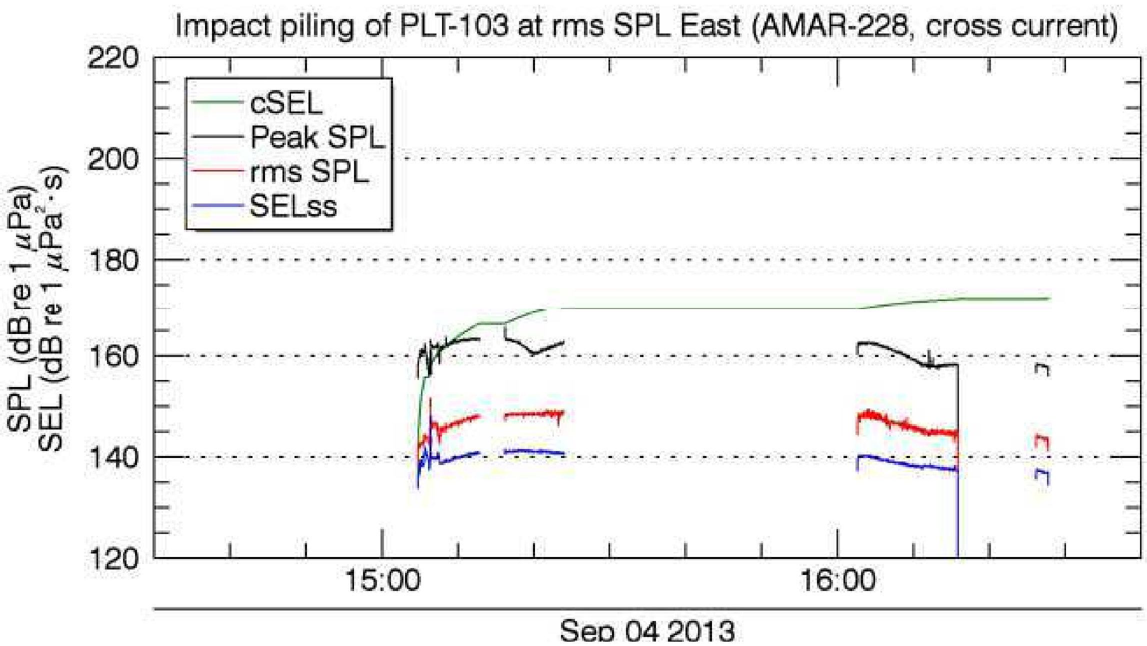


Figure 11. *Impact Pile Driving*: Peak SPL, rms SPL, SELss, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-103 measured 290 ft from the pile at location rms SPL East using AMAR-228.). For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

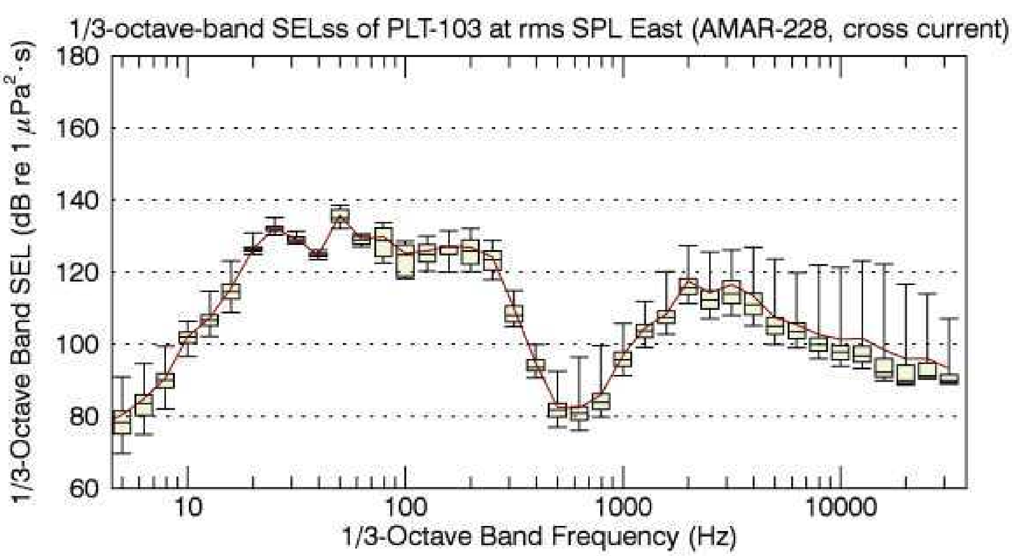


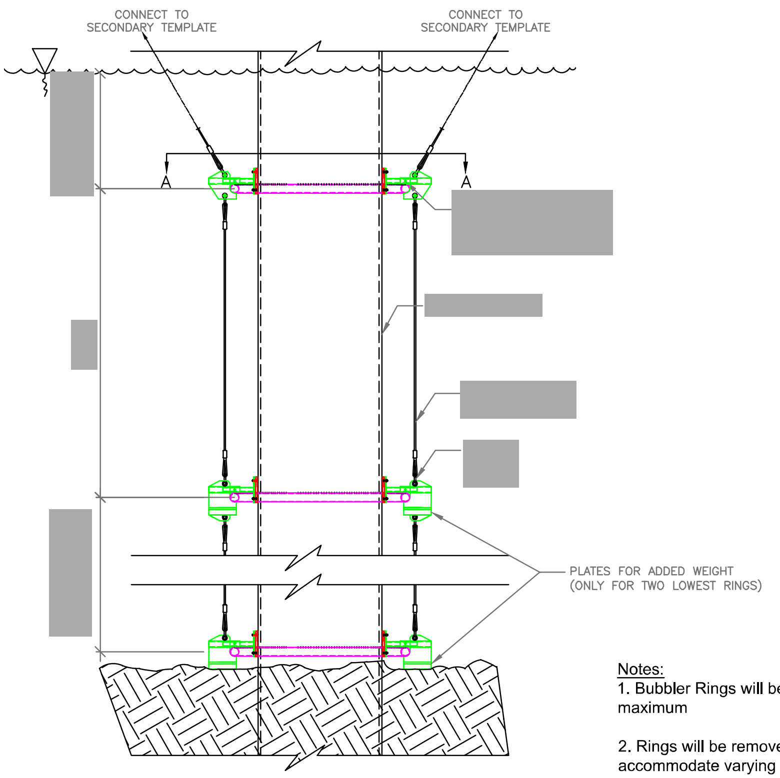
Figure 12. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-103 measured 290 ft from the pile at location rms SPL East using AMAR-228. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 14. Sound levels for the pile driving of Test Pile PLT-103 measured 290 ft from the pile at location rms SPL East using AMAR-228

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	165.5	151.7	148
L_5	163.2	148.7	141.2
L_{25}	162.4	148.3	140.8
L_{50}	161.5	146.9	139.6
L_{75}	159.1	145.3	138.2
L_{95}	157.9	143.7	137.2
L_{mean}	161.2	147	139.7

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

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



ELEVATION - BUBBLER RINGS PILES

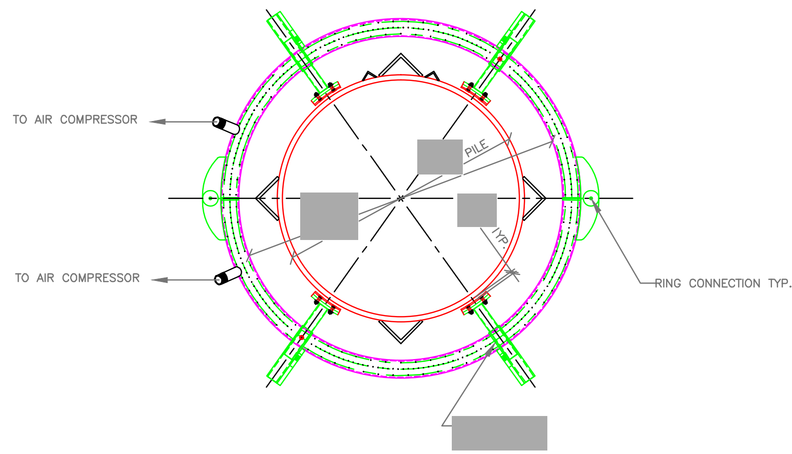
SCALE: NTS

Notes:

1. Bubbler Rings will be spaced at centers maximum

2. Rings will be removed and added as needed to accommodate varying depths

3. These Bubbler Rings can be used on diameter piles only



A/- PLAN - BUBBLER RINGS

SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.

NEW YORK STATE THRUWAY AUTHORITY

TAPPAN ZEE CONSTRUCTORS, LLC

TITLE OF PROJECT: TAPPAN_ZEE_BRIDGE

LOCATION OF PROJECT: NEW_YORK_STATE

TITLE OF DRAWING: UNCONFINED_BUBBLE CURTAIN_RINGS

CONTRACT NUMBER: –

DATE: 5/19/13

DRAWING NUMBER: 2UBCR

DOCUMENT TRACKING CODE: -

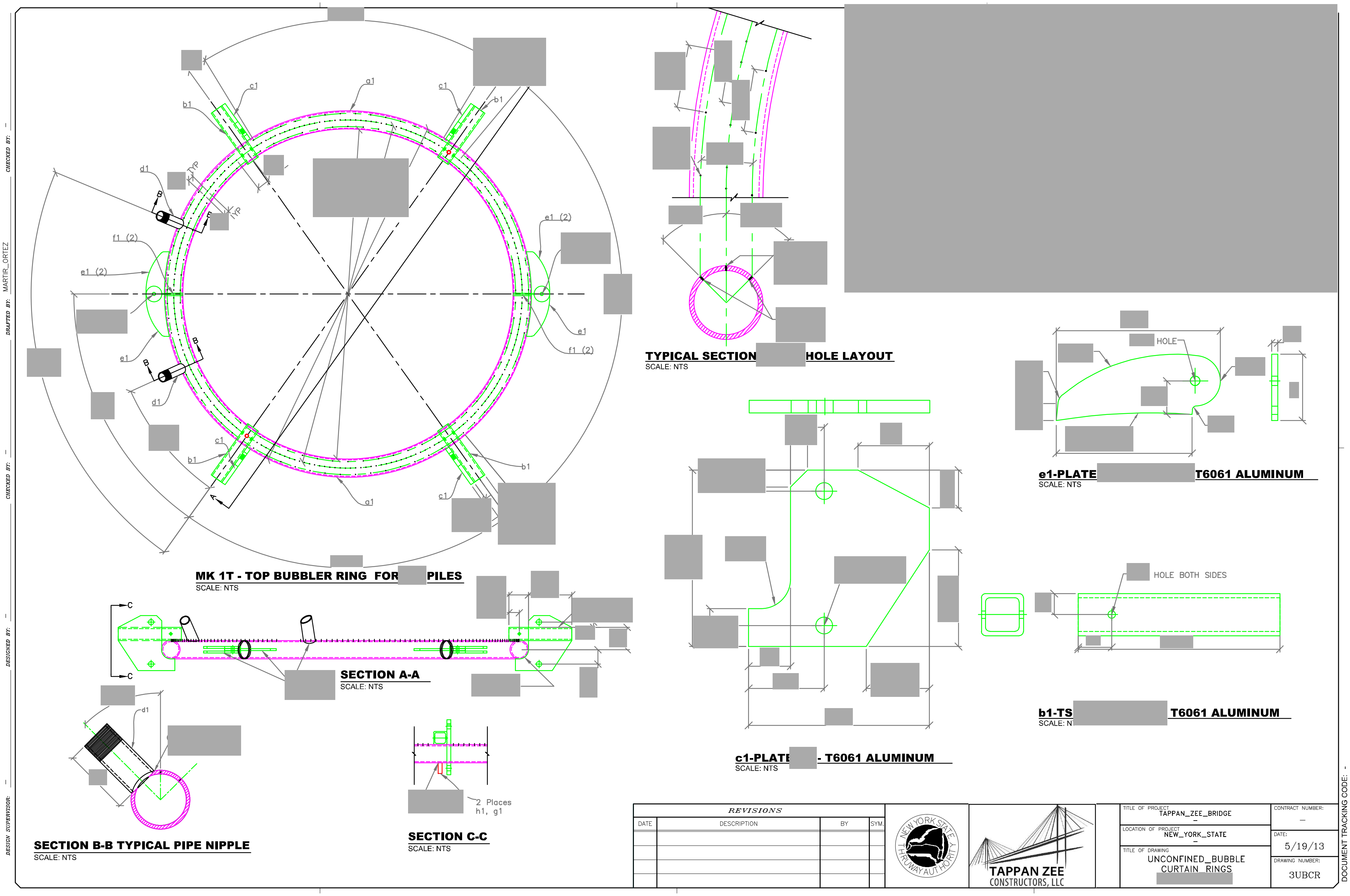
DESIGN SUPERVISOR:

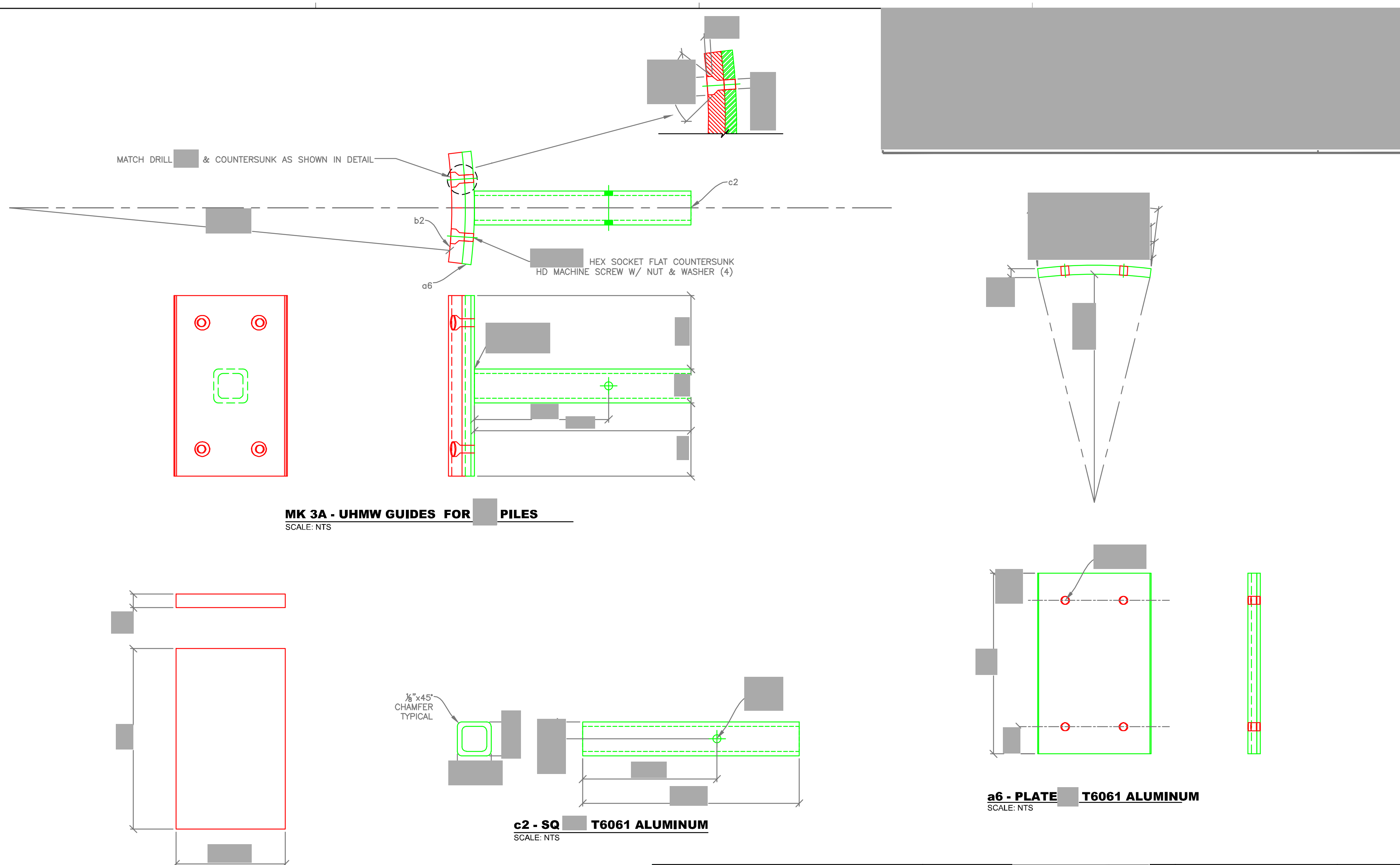
DESIGNED BY:

CHECKED BY:

DRAFTED BY: MARTIR_ORTEZ

CHECKED BY:


MK 1T - TOP BUBBLER RING FOR [redacted] PILES
SCALE: NTS
a1
b1
c1
d1
e1
e1 (2)
f1 (2)
TYP
B
SECTION A-A
SCALE: NTS
C
SECTION B-B TYPICAL PIPE NIPPLE
SCALE: NTS
SECTION C-C
SCALE: NTS
2 Places
h1, g1
TYPICAL SECTION [redacted] HOLE LAYOUT
SCALE: NTS
c1-PLATE [redacted] - T6061 ALUMINUM
SCALE: NTS
e1-PLATE [redacted] T6061 ALUMINUM
SCALE: NTS
HOLE
b1-TS [redacted] T6061 ALUMINUM
SCALE: NTS
HOLE BOTH SIDES
DESIGN SUPERVISOR:
DESIGNED BY:
CHECKED BY:
DRAFTED BY: MARTIR_ORTEZ
CHECKED BY:
DOCUMENT TRACKING CODE: -
REVISIONS
DATE
DESCRIPTION
BY
SYM.
NEW YORK STATE THRUWAY AUTHORITY
TAPPAN ZEE CONSTRUCTORS, LLC
TITLE OF PROJECT TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT NEW_YORK_STATE
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN RINGS
CONTRACT NUMBER: —
DATE: 5/19/13
DRAWING NUMBER: 3UBCR



MK 3A - UHMW GUIDES FOR [redacted] PILES
SCALE: NTS

b2 - UHMW [redacted]
SCALE: NTS

c2 - SQ [redacted] T6061 ALUMINUM
SCALE: NTS

a6 - PLATE [redacted] T6061 ALUMINUM
SCALE: NTS

CHECKED BY:
DRAFTED BY: MARTIR_ORTEZ
CHECKED BY:
DESIGNED BY:
DESIGN SUPERVISOR:

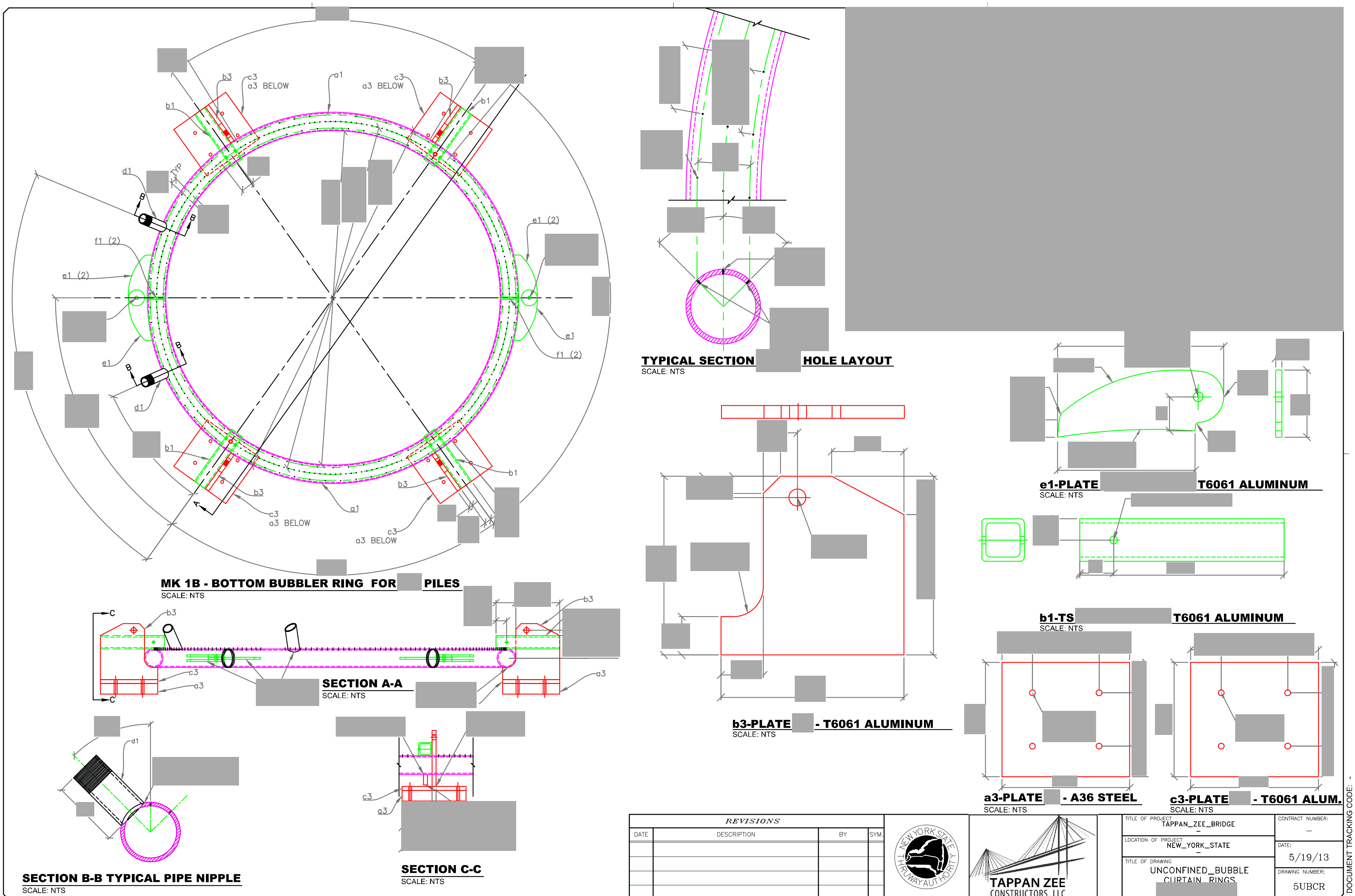
REVISIONS			
DATE	DESCRIPTION	BY	SYM.

NEW YORK STATE THRUWAY AUTHORITY

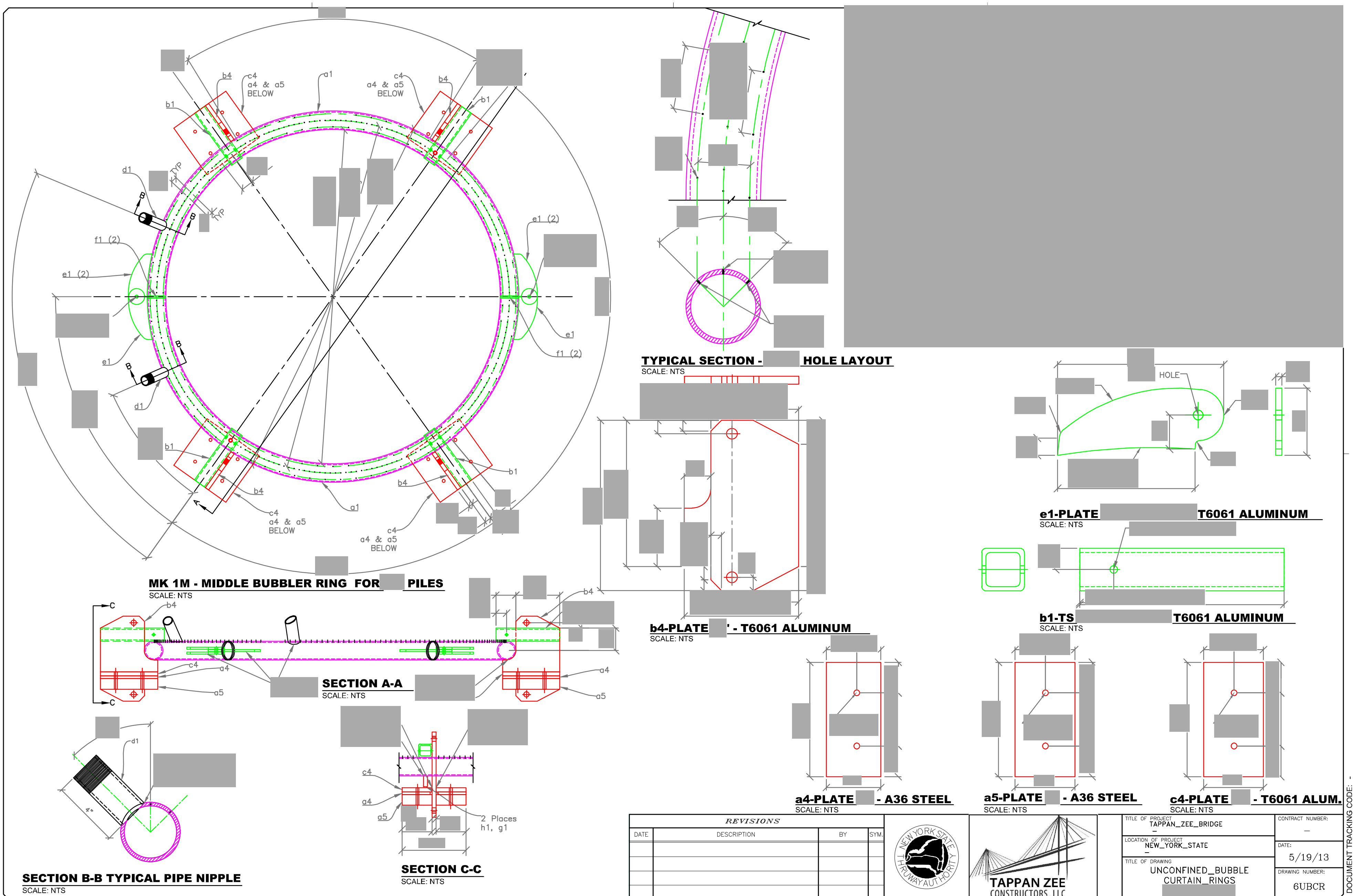
TAPPAN ZEE CONSTRUCTORS, LLC

TITLE OF PROJECT: TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT: NEW_YORK_STATE
TITLE OF DRAWING: UNCONFINED_BUBBLE CURTAIN RINGS [redacted]
CONTRACT NUMBER: –
DATE: 5/19/13
DRAWING NUMBER: 4UBCR

DOCUMENT TRACKING CODE: -



MK 1B - BOTTOM BUBBLER RING FOR PILES
SCALE: NTS
b1
b3
c3
a3 BELOW
a1
d1
TYP
e1 (2)
f1 (2)
e1
B
A
TYPICAL SECTION HOLE LAYOUT
SCALE: NTS
e1-PLATE T6061 ALUMINUM
SCALE: NTS
b1-TS T6061 ALUMINUM
SCALE: NTS
b3-PLATE - T6061 ALUMINUM
SCALE: NTS
SECTION A-A
SCALE: NTS
C
SECTION B-B TYPICAL PIPE NIPPLE
SCALE: NTS
SECTION C-C
SCALE: NTS
a3-PLATE - A36 STEEL
SCALE: NTS
c3-PLATE - T6061 ALUM.
SCALE: NTS
REVISIONS
DATE
DESCRIPTION
BY
SYM.
NEW YORK STATE THRUWAY AUTHORITY
TAPPAN ZEE CONSTRUCTORS, LLC
TITLE OF PROJECT
TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT
NEW_YORK_STATE
TITLE OF DRAWING
UNCONFINED_BUBBLE CURTAIN RINGS
CONTRACT NUMBER:
DATE:
5/19/13
DRAWING NUMBER:
5UBCR
DOCUMENT TRACKING CODE: -
DESIGN SUPERVISOR:
DESIGNED BY:
CHECKED BY:
DRAFTED BY: MARTIR_ORTEZ
CHECKED BY:



MK 1M - MIDDLE BUBBLER RING FOR [redacted] PILES
SCALE: NTS
b4
c4
a4 & a5
BELOW
a1
b1
d1
TYP
e1 (2)
f1 (2)
e1
g1
TYPICAL SECTION - [redacted] HOLE LAYOUT
SCALE: NTS
b4-PLATE [redacted]' - T6061 ALUMINUM
SCALE: NTS
HOLE
e1-PLATE [redacted] T6061 ALUMINUM
SCALE: NTS
b1-TS [redacted] T6061 ALUMINUM
SCALE: NTS
SECTION A-A
SCALE: NTS
C
a4
a5
SECTION B-B TYPICAL PIPE NIPPLE
SCALE: NTS
SECTION C-C
SCALE: NTS
2 Places
h1, g1
a4-PLATE [redacted] - A36 STEEL
SCALE: NTS
a5-PLATE [redacted] - A36 STEEL
SCALE: NTS
c4-PLATE [redacted] - T6061 ALUM.
SCALE: NTS
REVISIONS
DATE
DESCRIPTION
BY
SYM.
NEW YORK STATE THRUWAY AUTHORITY
TAPPAN ZEE
CONSTRUCTORS, LLC
TITLE OF PROJECT
TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT
NEW_YORK_STATE
TITLE OF DRAWING
UNCONFINED_BUBBLE
CURTAIN_RINGS
CONTRACT NUMBER:
DATE:
5/19/13
DRAWING NUMBER:
6UBCR
DOCUMENT TRACKING CODE: -
DESIGN SUPERVISOR:
DESIGNED BY:
CHECKED BY:
DRAFTED BY:
MARTIR_ORTEZ
CHECKED BY:

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.

Atlas Copco

Sustainable Productivity

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

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

CLASS 0 ISO 8573-1

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!

Additional Rental Product Solutions

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

Triple certification, Triple benefit

LLOYD'S REGISTER QUALITY ASSURANCE · ISO9001
LLOYD'S REGISTER QUALITY ASSURANCE · ISO14001
LLOYD'S REGISTER QUALITY ASSURANCE · OHSAS 18001

Atlas Copco

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