ERDC TN-DOER-D17
August 2014

Field Feasibility Study on the Use of Existing Commercially Available Instrumentation to Detect Fine-Scale (≤1mm) Bottom Elevation Changes: Currituck Sound, North Carolina

by David W. Perkey and Heidi M. Wadman

PURPOSE: This is the second in a series of two technical notes that evaluate the capability of the Lindorm Inc. SediMeter™. The SediMeter utilizes infrared optical backscatter (OBS) detectors to determine the location of the sea/river/lake bottom. The previous technical note (ERDC TN-DOER–T11, Perkey and Wadman 2013) presented results of laboratory tests performed to assess the instrument's accuracy. That technical note concluded that the SediMeter was not able to reliably record bed elevation changes on the scale of ≤1mm. However, that technical note further stated that in areas where dredged material may be impacting bottom elevations on larger scales (such as beneficial use of dredged material to build marsh land), the SediMeter might serve as a useful monitoring instrument. This document will present results from field deployment and testing of the SediMeter performed on the USACE Field Research Facility (FRF) property in Currituck Sound, North Carolina. In addition to the SediMeter, the SeaTek Multiple Transducer Array (MTA) and the Nortek Vectrino II Acoustic Doppler Velocimeter (ADV) were also deployed and tested in Currituck Sound. Both of these instruments utilize high-frequency acoustic signals to determine the location of the bottom with an advertised resolution of 1 mm or less. Results of the tests conducted with these instruments will also be presented to assess their feasibility for monitoring fine-scale sedimentation that might occur as a result of particles settling out of dredge plumes.

BACKGROUND: The U.S. Army Corps of Engineers (USACE) is responsible for the operation and maintenance of much of the nation's inland waterways. USACE currently maintains 12,000 miles of commercial and navigation channels, 926 harbors, and owns and operates more than 600 dams. In the process of managing these resources, USACE dredges more than 200 million yd^3 of material annually (USACE Headquarters Services, http://www.usace.army.mil/Services/Pages/Services.aspx). As a result of this dredging, bottom sediments are stirred up and resuspended into plumes. The transport of these plumes via currents can have physical, biological, and chemical impacts on habitats downstream of dredging sites (e.g. Wildish and Thomas 1985; Wilber and Clarke 2001; Hossain et al. 2004; Nayar et al. 2007). In some sensitive habitats, it has been suggested that increased sedimentation on the order of 1 mm or less can result in harmful impacts to the environment. As a result, dredging operations are often regulated and dredging windows are put into place to reduce the effects of this assumed sedimentation. Currently there is no accepted method to quantify sedimentation resulting from dredge-induced suspensions, making it difficult to determine the impacts of this sedimentation on a habitat.

Instrumentation has been developed that may have the ability to quantify sedimentation on the scale of 1 mm or less; however, these instruments require testing to demonstrate their ability to

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
AUG 2014		**00-00-2014 to 00-00-2014**

4. TITLE AND SUBTITLE	
Field Feasibility Study on the Use of Existing Commercially Available Instrumentation to Detect Fine-Scale (≤1mm) Bottom Elevation Changes: Currituck Sound, North Carolina	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Vicksburg,MS, 39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**43**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

accurately measure fine-grained sedimentation at the sub-millimeter scale. As part of the Dredging Operations and Environmental Research (DOER) Program, researchers at the USACE Engineer Research and Development Center-Coastal and Hydraulics Laboratory (ERDC-CHL) are currently testing and evaluating some of these technologies.

SediMeter^{TM}: The SediMeter (Figure 1) is composed of a computer and sensor that utilize infrared OBS detectors to determine the location of the bottom. An array of 36 OBS detectors, spaced 1 cm apart, measures a turbidity profile. A bottom level is then interpolated from the turbidity profile. As illustrated in Figure 2, the instrument is designed to be deployed by first hand-augering a clear plastic tube into the substrate. The SediMeter probe containing the detectors is then slid into the plastic tube and secured in place with a set screw. The sampling protocol is programmed by the user into the attached LogDator^{TM} computer, and the resulting data are stored on the computer (2-MB flash) or on SD/MMC memory cards.

Figure 1. SediMeter (right) with the sampling tube (left) and auger system (middle). OBS detectors are contained within the green section on the instrument.

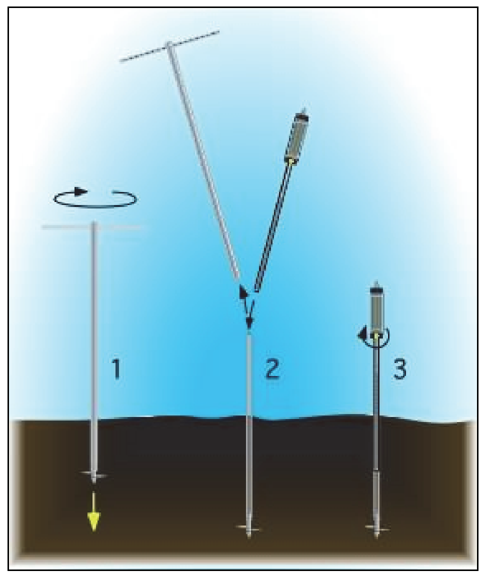

Figure 2. SediMeter being deployed. 1) Plastic sampling tube is screwed into bottom. 2) Auger handle removed and SediMeter is inserted into tube. 3) Set screw is tightened down to hold SediMeter in tube.

MTA: The SeaTek MTA ranging system (Figure 3) is composed of eight-element stainless steel arrays (up to four in number). Transducer spacing and operating frequencies can be built to specification; however, the system tested in this study was composed of two arrays (eight elements each). This particular system was designed for laboratory flume testing, but similar SeaTek ranging systems are utilized in field environments. Transducers are spaced 1 in. apart, with an operating frequency of 5 MHz. Two-way travel time of the acoustic signal is utilized to calculate distance to sea bottom. This configuration of the arrays requires that they be placed within 1 m of the bottom to prevent footprint overlap of adjacent transducers. The system is capable of sampling all 16 transducers at a rate of 5 Hz. RS232 communication with a PC allows for the sampling protocol to be programmed by the user through the use of CrossTalk software. The resulting data are then sent to and stored on a computer or data logger through the same RS232 communication port.

Figure 3. SeaTek MTA Ranging System.

VECTRINO II: The Nortek Vectrino II (Figure 4) is a high-resolution profiling ADV. In addition to providing a 3-cm velocity profile at resolutions as high as 1 mm, the Vectrino II also measures distance to a boundary at an advertised accuracy of 0.5 mm over a variety of bottom surfaces. The instrument has an acoustic frequency of 10 MHz and can detect bottom distance at a range up to 2 m with a sampling rate that ranges from 1-10 Hz. Like the SeaTek MTA, this ADV was designed to be used primarily in laboratory flume studies, but the instrument has been utilized in shallow, swash zone field studies. Data are not stored internally on the instrument but are instead streamed to a data logger or PC through a communication cable. The communication cable also allows for programming and sampling protocol adjustments to be made with the Nortek Vectrino II software installed on an external computer.

Figure 4. Nortek Vectrino II ADV.

METHODS

Laboratory testing. At the time of this study, a Vectrino II ADV was not available for use by ERDC-CHL; therefore, CHL leased an ADV from Nortek. Due to complications in executing that leasing contract and additional issues with required delivery times, laboratory testing could not be performed on the Vectrino II ADV prior to its field deployment. Laboratory testing was previously conducted on the SediMeter to assess its level of accuracy by repositioning the instrument in a column of sand through the use of a linear actuator (Perkey and Wadman 2013). The accuracy of the MTA's bed level measurements was evaluated with the Sensor Insertion Device (SID). Figure 5 illustrates the experimental setup that was utilized.

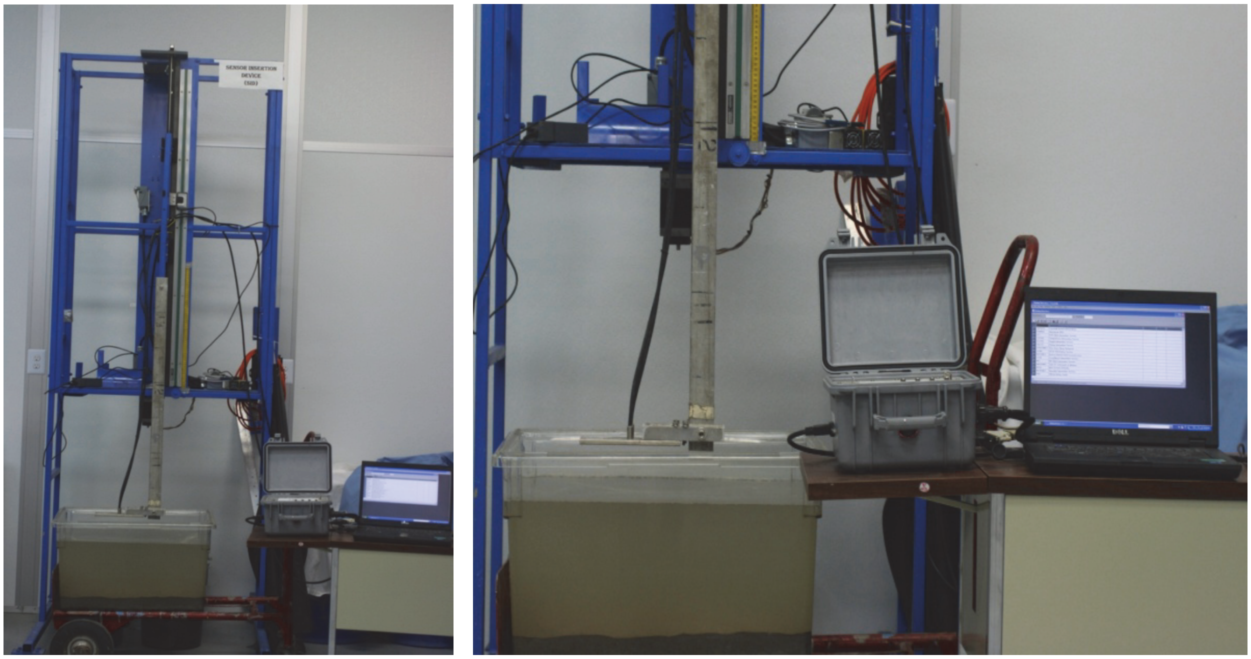

Figure 5. MTA system attached to the SID. The picture on the left shows the entire SID system positioned over the plastic basin and test bed. Closeup on the right shows one of the MTA arrays attached to the SID motion arm.

The SID is composed of an Applied Motion Products two-phase, Model 18 step motor equipped with an ST5-Q-NE microstep drive, which is coupled with a Specialty Motions Inc. XLA9 linear actuator. The XLA9 actuator is capable of straight line steps that are accurate to less than 0.01 mm. The ST5-Q-NE microstep drive allows for PC automated control of the actuator motion through RS-232 communication. The SID motion arm is attached to the XLA9 actuator and moves up or down as programmed by the user. To confirm motion steps performed by the actuator, a ProScale model 150 linear digital measuring system is also incorporated into the SID to provide an independent measurement of movement. The digital measuring system utilizes an encoder that passes over an Absolute (ABS) scale to determine position. The encoder, which is attached to the SID motion arm, transmits and receives signals to and from the scale, which is mounted on the SID frame. Unlike an incremental scale, an ABS scale consists of a unique zigzag pattern on a green laminate strip. The encoder reads the returned signal pattern from the scale, which is unique to a given point on the segment length, and calculates its position to within 10 µm. The ProScale 150 has a reported accuracy of ±(0.025+0.064 x L/430) mm, where L is the length of measurement in millimeters. An LCD display screen on the encoder displays the resulting calculated motion to verify the motion that the user programmed into the linear actuator.

The MTA transducer arrays were mounted to an aluminum plate and attached to the SID motion arm in a downward-facing orientation. The arrays were then submerged into a 75-L plastic basin of fresh water with an approximately 5-cm-thick bed of sand covering the bottom. The MTA arrays were programmed to sample at a frequency of 1 Hz for a period of 10 seconds. After each sampling interval, the arrays were repositioned with the SID motion arm and a new series of distance-to-bottom measurements was collected. Three different magnitudes of motion steps were evaluated in this manner (1.0 cm, 0.1 cm, and 0.05 cm), with 10 motion steps occurring at each interval.

For each motion event, average distance-to-bottom measurements were calculated for each transducer. These averages were then utilized to calculate the motion the instrument measured over the 10-second sampling period and compared to the motion reported by the SID. A difference between the two was calculated and compiled for each transducer over the 10-second sampling interval. These values were averaged and a standard error (SE) was determined at a 95% confidence interval for each test.

Field testing. In March of 2012, the above-described instruments were deployed at the USACE-FRF property in Currituck Sound (located in northeastern North Carolina between the mainland and the Outer Banks (Figure 6)). Located in the northernmost region of the North Carolina Albemarle-Pamlico Estuary System (APES), Currituck Sound is a 300-km-long by 6.8-km-wide, brackish, shallow-water estuary (maximum depth ~3 m). Tidal forcing is insignificant in Currituck Sound (averaging less than 0.1 m), and the system is thus primarily wind-driven. In addition to wind forcing, seiching (both within Currituck Sound and within the greater APES) has been observed to impact estuarine hydrodynamics. However, the scale at which this seiching is important to day-to-day hydrodynamics has yet to be properly quantified (Luettich et al. 2002; McNinch et al. 2012; Wadman et al. 2012; Mulligan et al., in preparation).

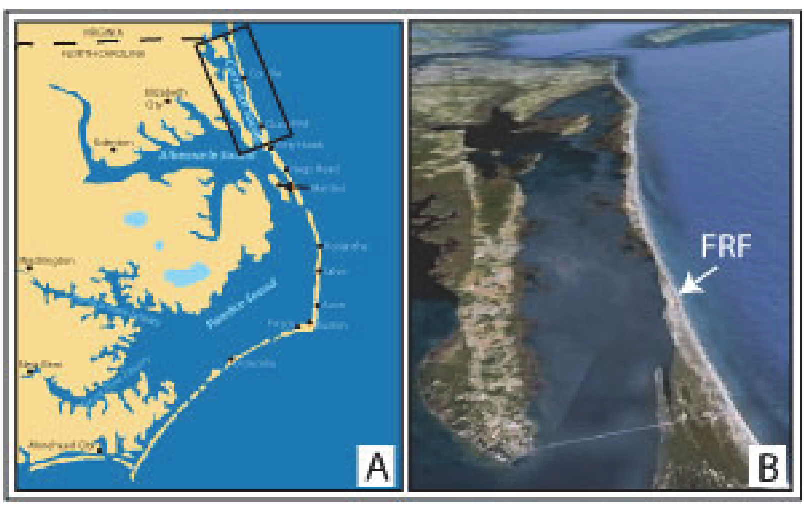

Figure 6. (A) Location of the Albemarle-Pamlico Estuarine System along the coast of North Carolina. Black box shows the location of (B) Currituck Sound and the FRF.

An instrument platform was constructed approximately 200 m off the western shore of the FRF property in 1 m of water (Figures 7 and 8). To ensure stability, the legs of the platform were jetted into the sound bottom to a minimum depth of 10 ft. The MTA, Vectrino II, and YSI 600 OSM for measuring salinity, temperature, and turbidity were then mounted to the platform at an approximate depth of 0.5 m. The SediMeters that were deployed were not secured directly to the platform, but were augered into place and deployed within 4-15 m from the platform. Internal clocks of all instruments were synchronized with an external computer and data were collected hourly. Temperature, salinity, and turbidity data were stored internally on the 600 OSM and downloaded at the conclusion of the experiment. Likewise, all SediMeter bed elevation data were recorded internally on the instrument and recovered at the end of the deployment. Distance data from the SeaTek MTA were transmitted via radio to the instrument control trailer located on the eastern shore of Currituck Sound and stored on a data logger. Data from the Vectrino II were streamed back to the instrument control trailer on a 250-m armored cable.

Figure 7. Map showing the location (in yellow) of the instrument platform and control station on the FRF property on the western shore of the island. Location of the FRF pier is indicated with the red marker on the eastern shore of the island.

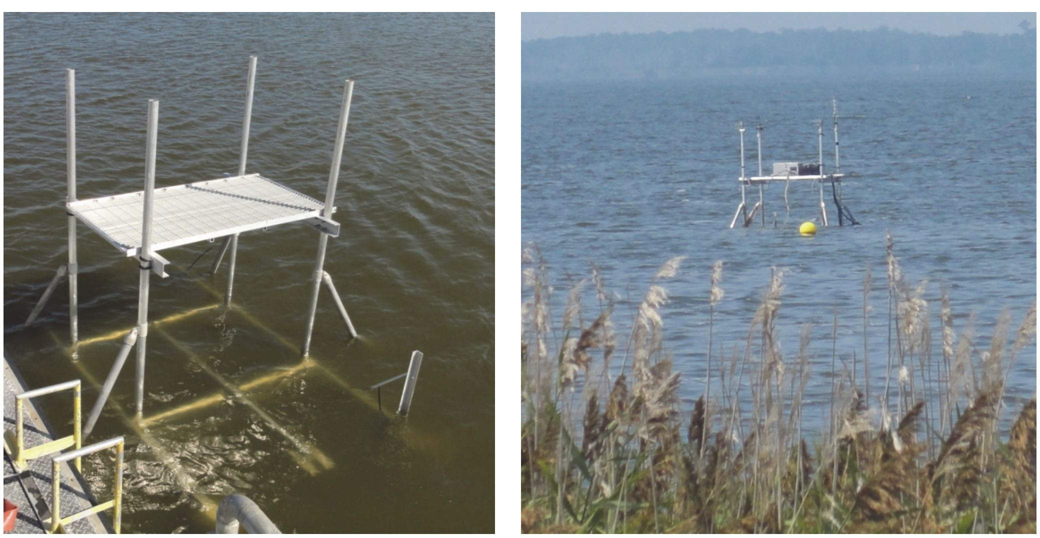

Figure 8. Instrument platform in Currituck Sound. Close-up of the platform during construction is shown on the left. A view of the platform from the shore is shown on the right after instrumentation was mounted to the platform.

Initial field testing and instrument deployment started on 16 March 2012 with the intent of recording any natural variation in bed elevation in this region of Currituck Sound. In June of 2012 an anthropogenic resuspension event was generated in the area surrounding the instrument platform with the FRF's Lighter Amphibious Resupply Cargo (LARC) vehicle. The LARC was stationed ~3 m west of the platform and the engine was run at high RPMs while in neutral for several minutes to stir up bottom sediment. The procedure was repeated at the same location after 1 hr had lapsed. The LARC was then moved ~25 m northwest of the platform and the procedure was repeated two more times to ensure sufficient sediment had been resuspended in the vicinity of the platform. The distance and direction of the LARC relative to the platform were determined in the field based on the local wind pattern on the day of the resuspension event.

RESULTS

MTA laboratory results. When evaluating the MTA in the laboratory, the first parameter that was investigated was the stability of the distance measurements that each transducer was recording. It was found that transducers #5 and #14 would frequently not report a distance or would report distances that did not correspond with values reported by the other transducers. For those reasons, data collected by these two transducers were not incorporated into the analysis. Figure 9 is a diagram depicting the array orientation used in the laboratory experiments, which shows the location of each transducer.

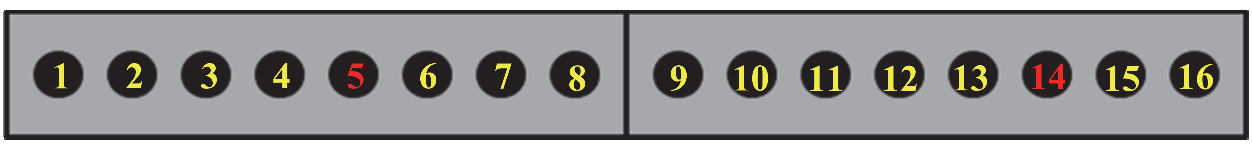

Figure 9. Orientation and position of the MTA arrays and transducers during laboratory testing with the SID system.

It was found that during the 10-second intervals at which the SID motion arm and MTA were stationary, the reported distance to bottom for each transducer showed little variation with time. However, when the motion arm was repositioned, the distance-to-bottom reported by the transducers shifted in a direction and magnitude that corresponded to the motion of the actuator. This pattern can be seen in Figure 10, which shows the results of the 0.1-cm motion steps that were recorded by transducer #1. Because the SID motion arm is accurate to within 26 µm for the motion steps being performed in these tests, the motion reported by the SID was considered true and the results of the MTA were compared against that motion. It was found that over the 10-second sampling period, the array of transducers reported an average motion that ranged from 0.089-0.109 cm (n=140 for each 10-second test) for the nine tests performed with a motion step of 0.1 cm. The tests conducted with 1.0-cm and 0.05-cm motion steps reported average motions that ranged from 0.965-1.017 cm and 0.032-0.054 cm, respectively. This resulted in average differences between the MTA recorded motion and the SID motion of 0.007 cm, 0.000 cm, and 0.003 cm for the 1-cm, 0.1-cm, and 0.05-cm tests, respectively. Results of all motion tests for each transducer can be found in Appendix A.

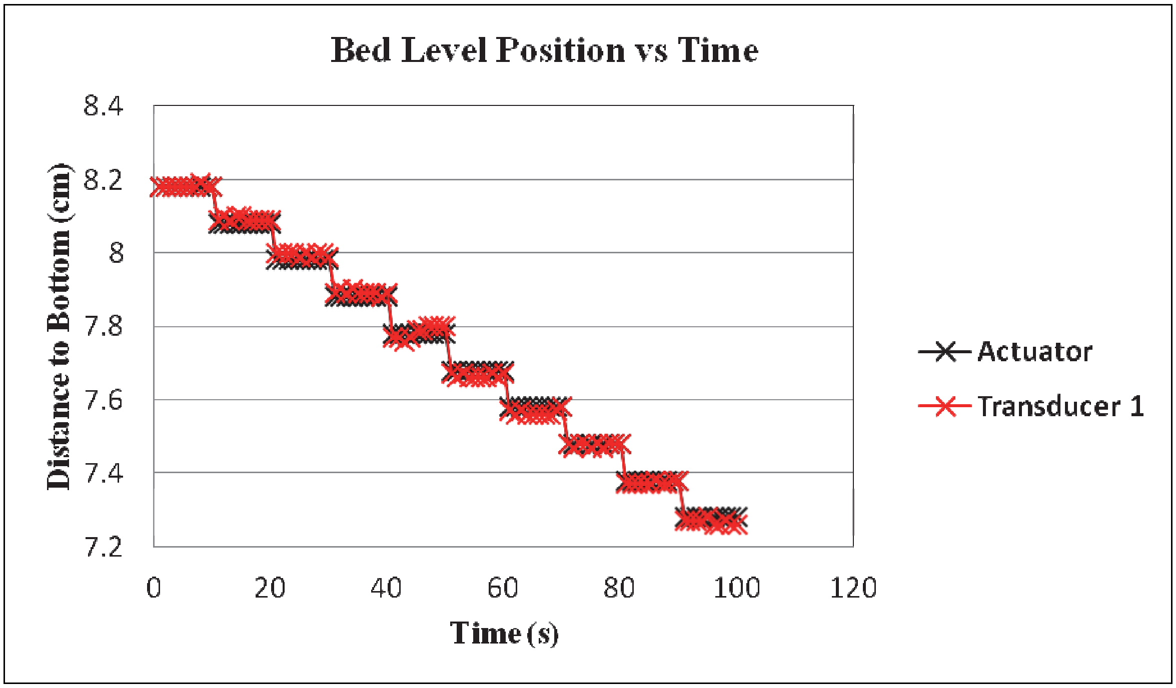

Figure 10. Distance-to-bottom measurements made by the MTA while mounted to the SID. Results from transducer #1 are shown in red, while positions of the SID arm are shown in black.

To evaluate the overall uncertainty and accuracy of the distance-to-bottom measurements made by the instrument, the standard error at 95% confidence was calculated for each 10-second motion test. Standard error (SE) is defined in Equation 1, where S is the standard deviation of the sample and n is the sample size. SE at 95% confidence is defined in Equation 2 (Rao 1998).

$$SE = \frac{s}{\sqrt{n}} \quad (1)$$

$$SE\ 95\% = 1.96 \times SE \quad (2)$$

The nine tests conducted with a 0.1-cm motion step produced an average SE 95% of 0.003 cm. The average SE 95% values for the 1.0-cm and 0.05-cm tests were calculated to be 0.011 cm and 0.002 cm, respectively. T-tests were conducted on the means of the three types of motion step tests and they were found to be statistically equal (α=0.05). Because no significant difference was found between them, the means from all three step tests were averaged and a final mean difference was calculated between the MTA reported elevation change and the SID motion. The average difference in motion between the two devices was found to be -0.001 cm with an average SE 95% value of ±0.005 cm.

While the laboratory tests conducted with the MTA showed the instrument to be capable of detecting elevation changes less than 1 mm in magnitude, it is important to point out that SE of that measurement is dependent upon the sample size (n). As seen in Equation 1, increasing the sample size will lower the standard error and therefore increase accuracy. In each test performed in the laboratory study discussed above, 14 transducers collected data at 1 Hz for a period of 10 seconds (n=140). However, if only one transducer were to be utilized, or if the sampling period were changed to 1 second, the sample size would change significantly. These changes in sample size were applied to the average standard deviation of the 0.1-cm test data, and showed an approximate threefold to tenfold increase in the SE 95% (Table 1).

Table 1. Impacts of sample size on SE 95%. The average standard deviation (S) of the 0.1-cm motion tests was utilized to calculate SE 95% for the various test conditions.

Test Conditions	n	S	SE 95%
14 transducers, 10 seconds	140	0.017	0.003
14 transducers, 1 second	14	0.017	0.009
1 transducer, 10 seconds	10	0.017	0.011
1 transducer, 1 second	1	0.017	0.034

Field deployment results

SediMeter results. During field deployment of the SediMeters in Currituck Sound, the sensor wiper system designed to prevent or reduce biofouling was found to be inadequate. As was noted in the laboratory evaluation of the SediMeter (Perkey and Wadman 2013), these wiper systems had a previous history of malfunctioning that the manufacturer had hoped to address with a correction to the firmware. The three SediMeters were returned to Lindorm Inc. prior to field deployment for these repairs to be completed; however, once deployed, it was discovered that only one of the three wiper systems was functioning properly.

In addition to the wiper system malfunctioning, it was also discovered that after an overnight deployment test in the sound, two of the SediMeters leaked and water started to collect inside the battery and data logger compartment. The remaining SediMeter was found to be leaking the following week. These instruments were shipped back to the manufacturer for repair, where it was discovered that the motor that operates the wiper system was the cause of the leak. There was a design flaw in the watertight seal between the wiper motor and the data logger electronics compartment, which resulted in leaking around the seal. Therefore, once submerged, the instruments began to leak. Once enough water entered the electronics compartment to cause a short, the instrument stopped working completely. As a result, no reliable Sedimeter data were collected during the deployment in Currituck Sound.

This design flaw, and other known instrument problems, resulted in failure of both the auger deployment system and the instrument to write data to the SD/MMC cards reliably. Therefore, Lindorm Inc. no longer supports or sells the version of the SediMeter that was tested in this study (SM2). Instead, the manufacturer is developing an updated version of the SediMeter (SM3) that is being designed to address the failures of the SM2. At the time of this report, the SM3 was still undergoing manufacturer testing.

Vectrino II results: Reliable communication with the Vectrino II was found to be an ongoing problem during field testing at Currituck Sound. The initial experiment design recommended transmitting the data collected by the ADV to a data logger housed in the instrument control trailer via radio communication. To accomplish this, an RS-232 data connection between the Vectrino II and radio modem was required. The Vectrino II is capable of communicating via RS-232, but to transmit the high-resolution data that are collected, the baud rate must be higher than the rate supported by RS-232. Therefore, RS-485 is required. At the time of experiment setup and design, it was not known that RS-232 communication was only sufficient to turn on and initiate communication with the instrument, while data streaming required RS-485 communication.

As a solution, a 250-m armored cable was run from the on-shore control trailer to the platform in Currituck Sound. This cable provided power and RS-485 communication to the Vectrino II. Although the armored cable did initially communicate with and stream data from the Vectrino II, loss of signal from the instrument and unexpected computer shutdowns continued to be a problem. As stated earlier, Nortek designed the Vectrino II instrument primarily for lab and flume use. During the course of experimental design, consultation with Nortek representatives revealed that the testing conducted in Currituck Sound would be the first of its kind with the Vectrino II. Long-term, completely submerged deployment involving a 250-m communications and power cable were conditions that Nortek had not engineered or designed for with the Vectrino II. After several weeks of deployment with unreliable communication, the Vectrino II was recovered and brought back to shore. Communications with the instrument were never reestablished after recovery.

Post-deployment conversations with Nortek technicians have provided some insight into why the communications issues may have occurred. At the time of the experiment, Windows 7 was the preferred operating system for the Vectrino software. While the software was installed successfully on a Windows XP machine, software and operating system compatibility may have contributed to the issues that occurred. Additionally, while the armored cable appeared to provide sufficient power over the 250-m length, it is possible that power surges and voltage drop over such a distance could also have been contributing factors. Lastly, the Vectrino II head is composed of a mix of dissimilar metals that lend themselves to corrosion issues. While there was no clear evidence of excessive corrosion or damage to the instrument after recovery, it is possible that the instrument's submergence in a brackish water environment could have been enough to cause communication failure. As a result of these communication issues, no reliable distance-to-bottom data were collected and analyzed during the instrument's deployment in Currituck Sound.

MTA results. Initial deployment and testing of the MTA system was conducted on 16 March 2012. The arrays were mounted to the middle instrument arm (Figure 8) of the platform in a downward-facing orientation that resulted in the transducer pattern shown in Figure 11. Similar to results observed in the laboratory, some of the transducers had reoccurring issues of not reporting a distance, or reporting distances that did not correspond to the values reported by the other transducers. For that reason, data recorded by transducers 2, 5, 9, and 14 were disregarded and are not analyzed in this report.

Because the MTA system cannot be programmed to power down between sampling intervals, the instrument was left on throughout the duration of the deployment. Although the instrument was continuously collecting and transmitting data, the data logger receiving that data was programmed to collect only one data ensemble from the MTA at the top of every hour. The original experimental design called for the MTA to be powered by a 70-Ah battery that would be charged by a solar panel. After a preliminary 2-day test deployment, it was discovered that the MTA's rate of power consumption was too high for a 70-Ah battery coupled to a solar panel. To address the power requirement of the MTA, a second 250-m armored cable was run from the instrument control trailer out to the platform in Currituck Sound. Power from this cable was then brought to a battery charger that was connected to the 70-Ah battery. This solved the power requirement issues with the MTA. However, due to the complications that occurred with the other instruments described above, continued field testing of the MTA was delayed until June of 2012. The field results presented in this report are based on data that were collected from 22 June to 3 July 2012.

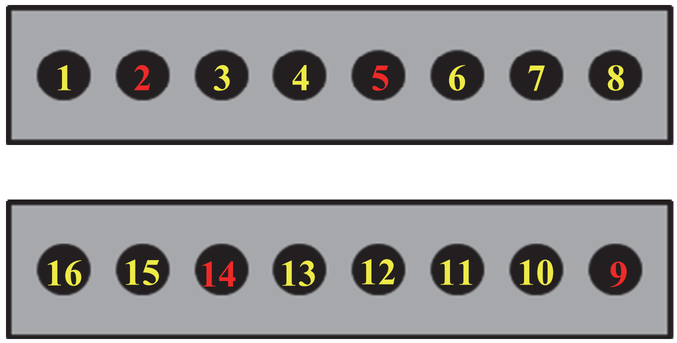

Figure 11. Orientation of the MTA arrays when mounted to the instrument platform.

The distance-to-bottom measurements recorded by each transducer are shown in Figure 12. The results from transducers 2, 5, 9, and 14 were disregarded, which is indicated by the solid blue bars. The remaining 12 transducers recorded similar distance measurements that typically ranged from 52-55 cm throughout the duration of the testing period. Despite being programmed to record data starting at 0:00 on June 22, no data were recorded during the first 18 hr of the day. Sediment resuspension activities conducted by the LARC were initiated at ~09:00 and concluded at ~13:00. Since no MTA data were recorded prior to 18:00, no distance-to-bottom measurements were made during the course of the resuspension event. No obvious change in bed elevation was observed by the transducers in the hours following the event. Furthermore, turbidity data obtained from the YSI 600 OMS did not show evidence of a plume impacting the water column at the instrument platform (Figure 13).

While no clear line of evidence was observed to indicate that the resuspension plume generated by the LARC impacted bottom elevation at the platform, an apparent bed elevation change took place on 29 June 2012. The graphs in Figure 12 demonstrate this by the predominance of the cooler blue and green colors seen prior to 29 June. These colors represent distances of 52-53 cm. However, after 29 June, the color plot shifts to warmer shades of yellow, orange, and red, which signifies measurements of 53.5-54.5 cm. To determine if this visual trend was significant, the 12 distance-to-bottom measurements made by each transducer were averaged together every hour. When these values were plotted against time (Figure 14), a shift in bed elevation was again apparent on 29 June. It was found that with 95% confidence the average distance-to-bed increased from 52.89 cm ±0.26 (n=149) for the time period 22-29 June to 53.49 cm ±0.31 for the time period 29 June–4 July (n=117). While the t-test (α=0.05) conducted on these two means showed that they are statistically different, it is worthwhile to point out that an average elevation change of 0.58 cm was required for the two bed elevations to be considered statistically different. This can be attributed to the fact that the average bed elevation reported by the MTA system routinely fluctuated between sampling events on a range of 0.0-3.8 mm (Figure 14). This statistically significant change in bed elevation exceeds the desired resolution of $\leq$1 mm for this study.

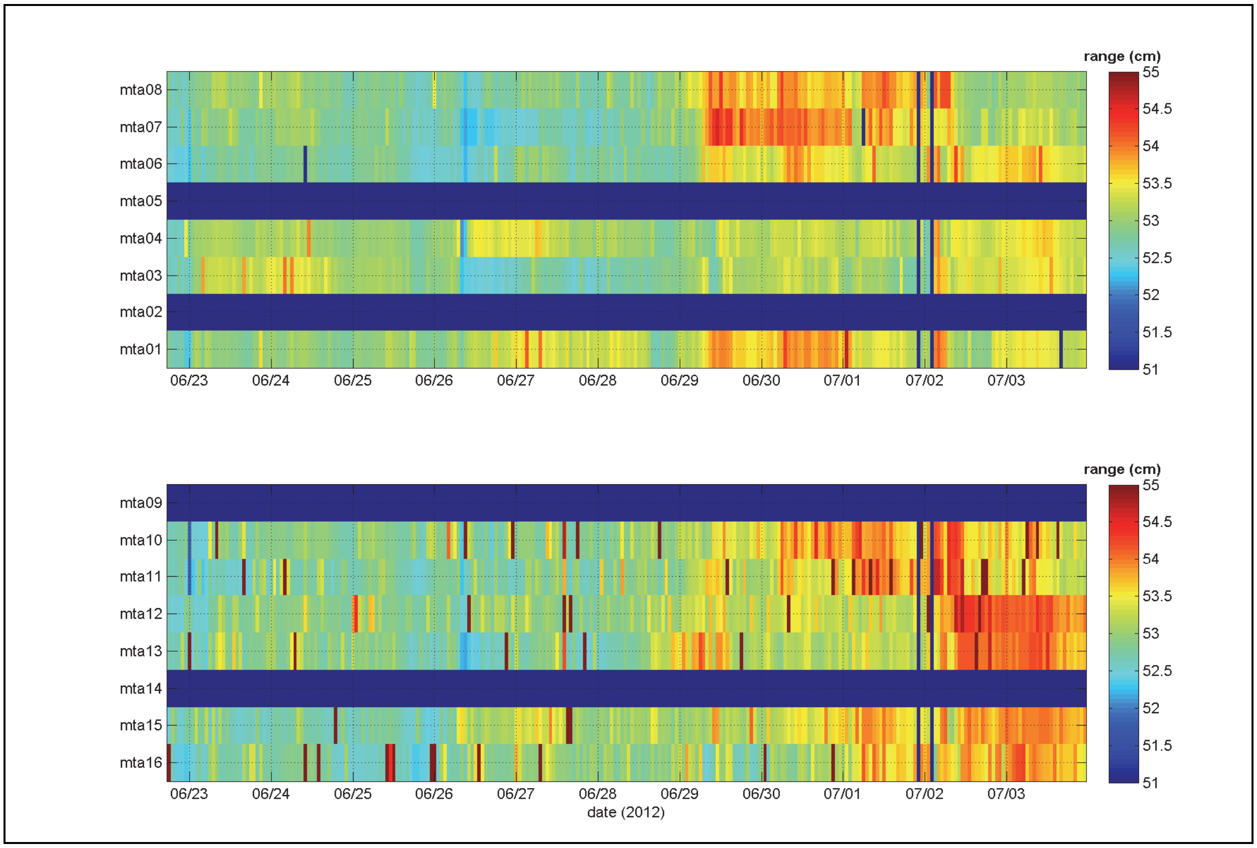

Figure 12. Distance-to-bottom measurements made by each transducer throughout the duration of the experiment. Solid blue lines at transducers 2, 5, 9, and 14 represent data that were not utilized. A change in distance to bottom can be seen in the shift from the cooler colors to warmer yellows and reds after 29 June.

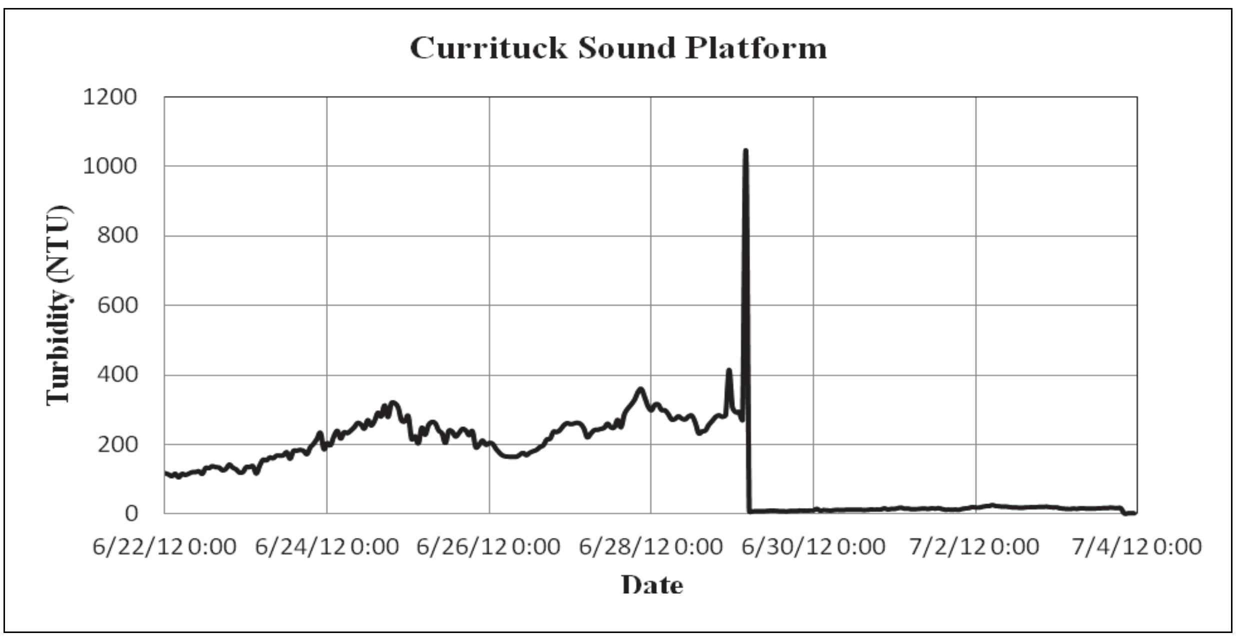

Figure 13. Measured turbidity throughout the duration of the experiment. The spike and rapid decline in turbidity levels after 29 June suggest error in the measurements after that date.

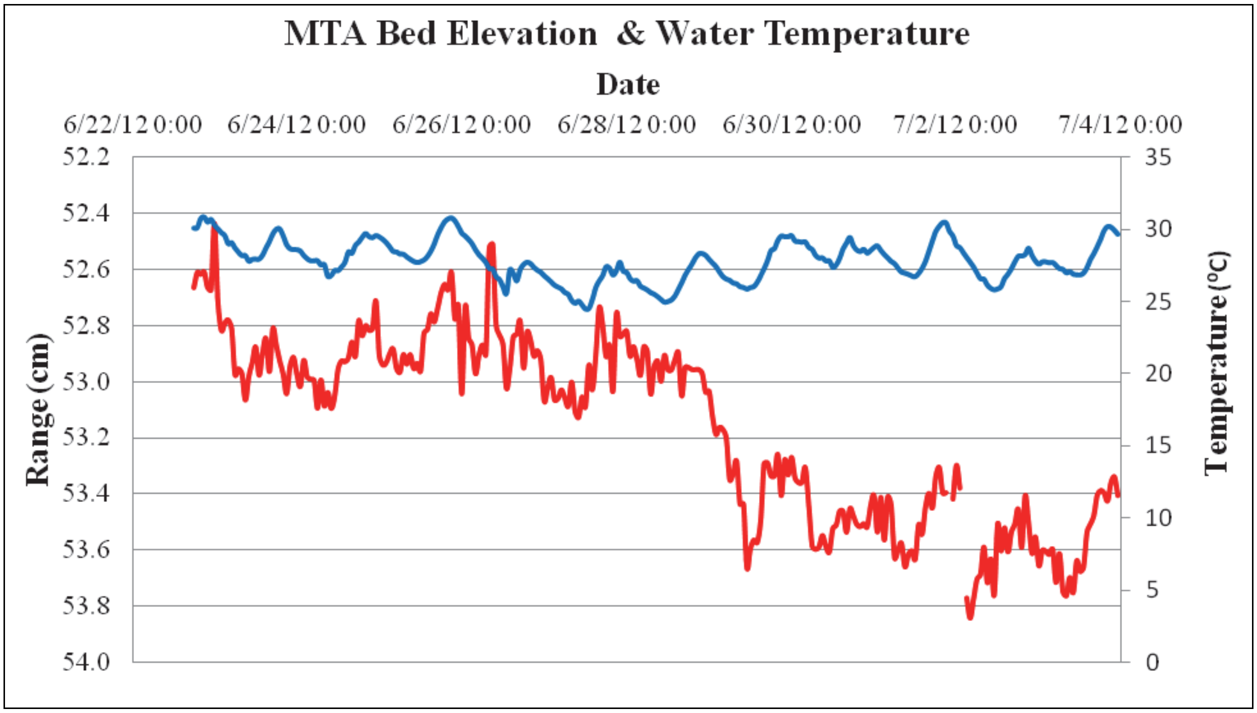

Figure 14. Average distance to bottom measured by the MTA (red line) and the recorded water temperature (blue line) at the platform in Currituck Sound. An increase of average distance can be seen to occur on 29 June, when average distance changed from 52.89 cm to 53.49 cm. In addition, impacts of daily water temperature variation on speed of sound can be seen in the MTA data. Daily highs in temperature correspond with daily reduction in range.

In addition to the change in bed elevation that occurred on 29 June, daily oscillations in bed elevation were also observed in the data set. Because the speed of sound in water is directly proportional to temperature and salinity (Wong and Zhu 1995), daily fluctuations in these parameters could result in the oscillations seen in the data. The salinity data collected by the 600 OMS showed that salinity was fairly stable throughout the experiment, with reported salinities ranging between ~3 and 4 ppt (Appendix C). Conversely, the temperature data collected on the instrument showed variations in temperature that correspond to daily heating events and nightly cooling (Figure 14). The coupling of these peaks and depressions between the temperature and bed elevation data shown in Figure 14 shows how these daily oscillations are actually an artifact of water temperature change. This is due to the fact that the MTA software is not equipped with an algorithm to correct for temperature change when a distance to bottom is calculated. Therefore, as the water warmed up, the MTA reported a shallower distance and as the water cooled down, that distance to bottom deepened.

Over the duration of this experiment, water temperature at the platform ranged from approximately 25-30 °C (Figure 14). Based on the updated UNESCO equations in Wong and Zhu (1995), such a temperature range in water with a salinity of 3.5 ppt would result in the speed of sound varying between 1500.57 and 1512.89 m/s (Table 2). At a distance of 50 cm from the bottom, such a range in sound velocities would result in an approximate 4-mm change in reported bed elevation based on two-way travel times (Table 3). Furthermore, the calculations in Table 2 show that a change in temperature of 1 °C would result in a reported MTA elevation change of approximately 0.8 mm. While changes in temperature between sampling events did not account for the total variation in bed elevation reported by the MTA, it is important to note that accounting for speed of sound corrections is critical if acoustic methods are to be used to evaluate bed elevations at a resolution ≤1 mm.

Table 2. Speed of sound and two-way travel time at 50-cm range calculated with UNESCO equations for water at 1 ATM pressure and 3.5 ppt salinity.

Temp (°C)	Velocity (m/s)	50-cm 2-way travel time (s)
25	1500.74	6.66E-04
26	1503.35	6.65E-04
27	1505.89	6.64E-04
28	1508.35	6.63E-04
29	1510.74	6.62E-04
30	1513.06	6.61E-04

Table 3. Differences in resulting range that would occur at a distance of 50 cm in water at 1 ATM and 3.5 ppt if speed-of-sound changes due to temperature were not accounted for. UNESCO equations were used for calculations, with blue temperatures indicating the actual water temperature and red temperatures indicating the assumed water temperature.

	Difference in Reported Range (mm)					
T (°C)	25	26	27	28	29	30
25	0.00	-0.87	-1.71	-2.52	-3.31	-4.07
26	0.87	0.00	-0.84	-1.66	-2.45	-3.21
27	1.72	0.84	0.00	-0.82	-1.61	-2.37
28	2.54	1.66	0.82	0.00	-0.79	-1.56
29	3.33	2.46	1.61	0.79	0.00	-0.77
30	4.10	3.23	2.38	1.56	0.77	0.00

Figures 13 and 14 demonstrate that the large spike and then sudden drop in turbidity readings that occurred on 29 June coincided with the recorded distance-to-bed increase. A review of wind and wave data from the FRF did not show a weather event that corresponded with this time frame. In addition, the temperature and salinity data recorded by the OMS showed no substantial change in water temperature or salinity that would correspond to this event. Upon recovery, there did not appear to be any physical damage to either instrument or any indication that the platform or instruments had shifted in orientation or position. Therefore, while the malfunction of the YSI 600 OMS turbidity measurement does coincide with the change in bottom elevation, there is no line of evidence to indicate why that change occurred.

CONCLUSIONS: Field testing of the SediMeter (SM2) revealed a fatal flaw in the instrument design involving the anti-biofouling wiper system. An insufficient water-tight seal between the wiper motor and the battery/data logger compartment resulted in water leaking into the electronic control area of the instrument once it was submerged. This leak caused the electronics in the instrument to short and the instrument to fail. The manufacturer, Lindorm Inc., was made aware of the leaking and is no longer producing or supporting the SM2. Lindorm Inc. has begun development of a new SediMeter model (SM3) that will attempt to address and alleviate the issues associated with the SM2. The SM3 was not available for testing at the time of this report.

The high-resolution Vectrino II ADV could not be properly field tested due to continued communication issues with the instrument. Prolonged exposure in a submerged brackish water environment required the use of a 250-m cable for communication. This resulted in deployment conditions that go beyond the intended use of the instrument. The Vectrino II was primarily designed to be a laboratory instrument and was not intended to be used for long-term field deployments.

Based on laboratory testing performed on the SeaTek MTA acoustic ranging system, it was determined that the instrument is capable of accurately measuring elevation changes that are ≤ 1 mm. The accuracy of the bed elevation is dependent upon the number of sounding measurements taken by the instrument. For example, 0.1-cm step testing showed that 10 soundings collected by 14 transducers (n=140) resulted in an SE 95% of ±0.003 cm. However, if only one transducer from the array was utilized for one sounding measurement (n=1), an SE 95% of ±0.034 cm could be expected.

When the MTA ranging system was deployed in Currituck Sound, North Carolina, the resolution at which statistically significant bed elevation changes could be reported decreased significantly. Average bed elevations were observed to fluctuate on scales of 0.0-3.8 mm every hour. The MTA is not equipped with sensors and software to make speed-of-sound adjustments with changes in water temperature and salinity. Based on the updated UNESCO equations in Wong and Zhu (1995), it was calculated that at a range of 50 cm, a change in temperature of 1°C would result in an MTA reported elevation change of approximately 0.8 mm. Any stratification or changes in water temperature and salinity between the MTA and the sea floor would impact distance to bottom measurements. Therefore, recording statistically significant bed elevation changes on the order of 1 mm or less may not be practical in many real world environments. During the deployment in Currituck Sound a significant change in bottom elevation was observed to occur on 29 June; however, it required a minimum change of 0.58 cm to be statistically significant at 95% confidence.

Rapid bed elevation fluctuations on the scale of millimeters are not uncommon in many coastal, estuarine, and riverine environments. This has been shown in several laboratory experiments. In 1992, Williams and Williams were able to induce apparent changes in observable bed elevation of several centimeters in a flume simply by inducing or limiting fluidization of muddy sediment via artificially created waves (Williams and Williams 1992). Marion et al. (2003) observed sub-millimeter to millimeter scale changes in bed elevation by varying the amount of sediment armoring in heterogeneous sediments. Micro-changes in bed elevation unrelated to sediment accumulation or erosion have also been observed in the field. For example, rapid (seconds – hours) millimeter- to centimeter-scale changes in bed elevation have been observed in the nearshore due to: (1) changes in overlying water column pressure from incoming/outgoing swash waves (e.g. McDermott and Sherman 2009); and (2) low-frequency waves (e.g. Nordstrom and Jackson 1990). Although few studies of this nature have been conducted in estuaries, it is plausible that estuarine bed elevations would also fluctuate by millimeters to centimeters in response to, for example, variations in wave-induced pressure. Occasional daily fluctuations in bed elevation on the scale of sub-centimeters were noted by Childers et al. (1993) during their study of the influence of tidal inundation on estuarine accretion relative to local sea level rise, though Childers et al. did not speculate as to the cause of the observed daily fluctuations.

The results of the field testing at Currituck Sound, along with all of the above studies, suggest that observed changes in bed elevation at sub-millimeter to centimeter scales alone cannot definitively indicate whether a region is being impacted by accreting suspended sediment, especially if observed elevation changes are highly variable. However, in research and monitoring applications where bed level changes are on the order of several centimeters, the technologies investigated in this report could be of use. An example of one such application in the dredging industry would be to utilize multiple instruments to monitor land building activities with dredged material placement. These instruments could track bed elevation changes as dredged material is pumped into areas such as wetlands. They could also be used to evaluate the geomorphic stability of marshes and islands after they were constructed. In dredging-related studies such as these, large-scale elevation changes that are on the order of several centimeters would be of importance and therefore would be more appropriate. The direct measurement of small-scale (sub-millimeter to centimeter) deposition of sediments that may be linked to settling of far field dredge plumes does not appear to be feasible with current technologies. Even if an instrument does consistently measure increasing bed elevation with few or no fluctuations, suggesting local accretion, these instruments cannot discern whether the accreting sediments are dredge-sourced or natural, greatly limiting their ability to quantify the effects of dredging on the local environment.

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Appendix A: MTA Lab Data

Table A-1: MTA Measured Motion (cm)
1 cm Motion Steps

Test	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 1	1	1.05	0.97	0.99	0.92	0.98	0.99	1.00	1.00	0.86	0.97	0.99	0.97	0.97	1.01
	2	1.04	0.97	0.99	0.91	0.98	0.99	1.00	1.00	0.86	0.97	0.99	0.98	0.98	1.02
	3	1.05	0.97	0.99	0.91	0.98	0.98	1.00	0.99	0.86	0.97	0.99	0.97	0.97	1.02
	4	1.05	0.97	0.99	0.92	0.98	0.99	1.00	1.00	0.86	0.98	0.99	0.97	0.97	1.02
	5	1.04	0.97	0.99	0.92	0.98	0.99	1.00	1.00	0.86	0.97	0.99	0.98	0.97	1.01
	6	1.04	0.97	0.99	0.92	0.98	0.99	1.00	1.00	0.86	0.97	0.99	0.98	0.97	1.02
	7	1.04	0.97	1.00	0.91	0.98	0.99	1.00	1.01	0.86	0.98	0.99	0.98	0.97	1.01
	8	1.05	0.98	0.99	0.92	0.98	0.99	1.01	1.00	0.86	0.99	0.99	0.98	0.98	1.01
	9	1.05	0.98	0.99	0.91	0.97	0.98	1.00	1.00	0.86	0.97	0.99	0.98	0.98	1.01
	10	1.05	0.98	0.99	0.91	0.98	0.99	1.00	1.00	0.86	0.98	0.99	0.98	0.98	1.02
Test 2	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	1.07	1.02	1.04	0.98	1.03	0.98	1.01	0.99	1.00	1.02	1.01	1.02	1.00	1.05
	2	1.07	1.02	1.04	0.97	1.03	0.99	1.01	0.99	1.01	1.02	1.01	1.01	1.00	1.05
	3	1.08	1.02	1.04	0.98	1.04	0.99	1.01	0.99	1.03	1.02	1.01	1.01	1.00	1.05
	4	1.07	1.02	1.04	0.98	1.04	0.98	1.01	1.00	1.01	1.02	1.01	1.01	1.00	1.05
	5	1.06	1.02	1.04	0.98	1.03	0.99	1.01	0.99	1.01	1.03	1.01	1.01	1.00	1.05
	6	1.07	1.02	1.04	0.98	1.04	0.98	1.01	0.99	1.02	1.03	1.01	1.01	1.00	1.05
	7	1.06	1.03	1.04	0.98	1.04	0.99	1.01	0.99	1.01	1.03	1.01	1.02	1.01	1.05
	8	1.06	1.02	1.04	0.98	1.04	0.99	1.01	0.99	1.01	1.03	1.01	1.01	1.00	1.06
	9	1.07	1.02	1.04	0.99	1.04	0.99	1.01	0.99	1.02	1.03	1.01	1.01	1.01	1.05
	10	1.07	1.03	1.04	0.98	1.04	0.99	1.01	1.00	1.01	1.03	1.01	1.01	1.01	1.05
Test 3	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	1.00	0.98	1.02	1.01	1.00	1.01	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.92
	2	1.00	0.99	1.02	1.01	1.00	1.01	1.02	0.94	1.02	0.98	0.98	1.00	0.99	0.94
	3	1.00	0.99	1.02	1.01	1.00	1.01	1.02	0.95	1.02	0.98	0.98	1.01	0.99	0.78
	4	1.00	0.99	1.02	1.02	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.92
	5	1.00	0.99	1.03	1.02	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.92
	6	1.00	0.99	1.02	1.01	1.00	1.01	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.35
	7	1.00	0.98	1.03	1.01	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.44
	8	1.01	0.99	1.02	1.01	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.01	0.99	0.43
	9	1.01	0.99	1.02	1.02	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.01	0.99	0.52
	10	1.01	0.99	1.02	1.02	1.00	1.02	1.02	0.95	1.02	0.98	0.98	1.00	0.99	0.50
Test 4	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	0.99	0.94	1.01	1.03	0.99	0.99	1.01	0.99	1.03	1.01	1.00	0.99	0.84	0.66
	2	1.00	0.94	1.01	1.04	0.99	0.99	1.01	0.99	1.03	1.02	1.00	0.99	0.83	0.66
	3	1.00	0.94	1.01	1.04	0.99	1.00	1.01	0.99	1.02	1.02	0.99	0.99	0.84	0.65
	4	1.00	0.94	1.01	1.04	0.99	1.00	1.01	0.99	1.03	1.02	1.00	0.99	0.85	0.66
	5	1.00	0.94	1.03	1.04	0.99	1.00	1.02	0.99	1.03	1.02	0.99	0.99	0.85	0.66
	6	1.00	0.94	1.02	1.04	0.99	1.00	1.01	0.99	1.03	1.02	1.00	0.99	0.86	0.66
	7	1.00	0.94	1.01	1.04	0.99	1.01	1.02	0.99	1.03	1.02	0.99	0.99	0.85	0.66
	8	1.00	0.94	1.02	1.04	0.99	0.99	1.02	0.98	1.03	1.02	0.99	0.99	0.85	0.66
	9	1.00	0.94	1.02	1.04	0.99	1.00	1.01	0.99	1.04	1.02	1.00	0.99	0.85	0.66
	10	1.00	0.94	1.02	1.04	0.99	0.99	1.01	0.99	1.03	1.02	1.00	0.99	0.85	0.66

Table A-1: MTA Measured Motion (cm)
1 cm Motion Steps (continued)

Test	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 5	1	0.97	1.03	0.98	0.99	0.86	0.98	0.98	0.90	0.96	0.98	0.98	0.96	0.95	1.47
	2	0.97	1.02	0.98	0.99	0.86	0.98	0.98	0.90	0.96	0.98	0.98	0.96	0.95	1.47
	3	0.97	1.03	0.99	0.99	0.86	0.97	0.99	0.90	0.96	0.97	0.98	0.96	0.95	1.47
	4	0.97	1.04	0.99	0.99	0.86	0.98	0.98	0.90	0.96	0.98	0.98	0.96	0.95	1.48
	5	0.97	1.03	0.99	0.99	0.87	0.97	1.00	0.90	0.96	0.98	0.98	0.97	0.95	1.48
	6	0.98	1.03	0.98	1.00	0.86	0.98	0.99	0.90	0.96	0.97	0.97	0.96	0.95	1.48
	7	0.98	1.04	0.98	1.00	0.86	0.98	0.99	0.90	0.97	0.97	0.98	0.97	0.95	1.48
	8	0.98	1.04	0.98	0.99	0.86	0.98	0.99	0.90	0.97	0.98	0.98	0.97	0.95	1.48
	9	0.98	1.05	0.98	1.00	0.86	0.98	0.99	0.90	0.96	0.98	0.98	0.96	0.95	1.48
	10	0.98	1.04	0.99	0.99	0.87	0.98	0.99	0.90	0.96	0.98	0.98	0.97	0.95	1.48

Test	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 6	1	1.00	1.03	1.03	1.00	0.95	0.96	0.95	1.01	1.01	0.98	0.99	0.97	1.05	1.04
	2	1.01	1.03	1.03	1.00	0.96	0.96	0.95	1.01	1.01	0.98	0.99	0.97	1.07	1.04
	3	1.00	1.03	1.03	1.00	0.95	0.96	0.95	1.01	1.01	0.98	1.00	0.97	1.06	1.04
	4	1.00	1.03	1.03	1.00	0.96	0.96	0.95	1.01	1.01	0.99	1.00	0.97	1.07	1.04
	5	1.00	1.04	1.03	1.00	0.96	0.96	0.96	1.01	1.00	0.98	1.00	0.97	1.08	1.04
	6	1.00	1.03	1.03	1.00	0.96	0.96	0.95	1.01	1.02	0.98	1.00	0.97	1.08	1.04
	7	1.01	1.04	1.03	1.01	0.96	0.96	0.95	1.01	1.01	0.99	1.00	0.97	1.08	1.04
	8	1.01	1.03	1.03	1.01	0.96	0.96	0.95	1.01	1.01	0.99	1.00	0.97	1.08	1.04
	9	1.00	1.03	1.03	1.01	0.96	0.96	0.95	1.01	1.01	0.98	1.00	0.97	1.08	1.04
	10	1.00	1.04	1.03	1.00	0.96	0.97	0.95	1.01	1.02	0.98	1.00	0.98	1.08	1.04

Test	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 7	1	1.00	1.00	1.00	1.01	1.15	0.99	0.99	1.01	1.00	0.99	0.99	1.00	1.02	0.99
	2	1.01	1.00	1.00	1.01	1.15	1.00	1.00	1.01	0.99	0.98	0.99	1.00	1.01	0.99
	3	1.02	1.00	1.00	1.01	1.15	0.99	1.00	1.00	1.00	0.98	0.99	1.01	1.02	1.00
	4	1.01	1.00	1.00	1.01	1.15	1.00	1.00	1.01	0.99	0.99	0.99	1.01	1.01	0.99
	5	1.01	1.00	1.00	1.01	1.15	1.00	0.99	1.00	0.99	0.99	0.99	1.01	1.02	1.00
	6	1.01	1.00	1.00	1.01	1.15	1.00	1.00	1.01	1.00	0.98	0.99	1.01	1.01	0.99
	7	1.01	1.00	1.00	1.01	1.15	1.00	1.00	1.01	0.99	1.00	1.00	1.01	1.02	0.99
	8	1.01	1.00	1.00	1.01	1.15	1.00	1.00	1.01	1.00	0.99	0.99	1.01	1.02	0.99
	9	1.02	1.00	1.00	1.01	1.15	1.00	1.00	1.01	1.00	0.99	0.99	1.01	1.01	1.00
	10	1.02	1.00	1.00	1.01	1.15	1.00	1.00	1.01	1.00	0.99	0.99	1.01	1.01	1.00

Test	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 8	1	1.00	1.00	0.96	0.99	0.86	0.98	0.98	1.04	0.84	0.97	0.99	0.98	0.98	1.04
	2	1.00	1.00	0.96	0.99	0.86	0.98	0.98	1.05	0.84	0.97	0.99	0.98	0.98	1.04
	3	1.00	0.99	0.96	0.99	0.85	0.98	0.98	1.06	0.85	0.97	0.99	0.99	0.98	1.04
	4	1.00	1.00	0.96	0.99	0.86	0.97	0.98	1.04	0.81	0.97	0.99	0.98	0.98	1.04
	5	1.00	1.00	0.96	0.99	0.85	0.98	0.98	1.05	0.85	0.97	0.99	0.98	0.98	1.04
	6	1.00	1.00	0.96	0.99	0.85	0.98	0.98	1.05	0.85	0.97	0.99	1.00	1.00	1.04
	7	1.00	1.00	0.96	0.99	0.88	0.98	0.98	1.05	0.86	0.97	0.99	0.99	0.98	1.05
	8	1.00	1.00	0.96	0.99	0.83	0.98	0.98	1.04	0.86	0.97	0.99	0.99	0.98	1.05
	9	1.00	1.00	0.96	0.99	0.83	0.98	0.98	1.04	0.87	0.97	0.99	0.99	1.00	1.05
	10	0.99	1.00	0.96	0.99	0.83	0.98	0.98	1.05	0.87	0.97	0.99	0.99	0.98	1.04

	Table A-1: MTA Measured Motion (cm) 1 cm Motion Steps (continued)														
	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 9	1	1.00	0.99	1.01	0.98	1.13	0.98	0.99	0.92	1.09	1.00	0.99	0.99	0.98	1.03
	2	1.01	0.99	1.01	0.98	1.12	0.98	0.99	0.95	1.10	1.00	0.99	1.00	0.97	1.03
	3	1.01	1.00	1.00	0.98	1.13	0.99	0.99	0.94	1.10	1.00	0.99	0.99	0.97	1.03
	4	1.01	0.99	1.02	0.98	1.13	0.99	0.99	0.93	1.10	1.00	0.99	1.00	0.98	1.03
	5	1.01	0.99	1.02	0.98	1.13	0.98	0.99	0.95	1.10	1.00	0.99	1.00	0.97	1.03
	6	1.01	0.99	0.98	0.99	1.13	0.99	0.99	0.93	1.10	1.00	0.99	1.00	0.98	1.03
	7	1.01	1.00	0.98	0.99	1.13	0.99	0.99	0.93	1.10	1.00	0.99	1.00	0.98	1.03
	8	1.01	1.00	0.98	0.99	1.13	0.99	0.99	0.94	1.10	1.00	0.99	1.00	0.98	1.03
	9	1.01	1.00	0.98	0.99	1.13	0.99	0.99	0.93	1.10	1.00	0.99	1.00	0.99	1.03
	10	1.01	1.00	0.98	0.99	1.13	0.99	1.00	0.95	1.10	1.00	1.00	1.00	0.98	1.03

Table A-2: MTA Measured Motion (cm)
0.1 cm Motion Steps

	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 1	1	0.09	0.12	0.07	0.11	-0.07	0.10	0.11	0.10	0.14	0.12	0.08	0.09	0.08	0.11
	2	0.08	0.12	0.06	0.11	-0.07	0.10	0.12	0.09	0.15	0.12	0.08	0.09	0.08	0.11
	3	0.09	0.12	0.05	0.11	-0.07	0.09	0.11	0.10	0.14	0.12	0.08	0.09	0.09	0.11
	4	0.08	0.12	0.06	0.11	-0.07	0.10	0.11	0.10	0.14	0.11	0.08	0.09	0.09	0.11
	5	0.08	0.12	0.07	0.11	-0.07	0.09	0.10	0.10	0.15	0.12	0.08	0.09	0.08	0.10
	6	0.09	0.12	0.06	0.11	-0.07	0.11	0.11	0.09	0.14	0.11	0.08	0.09	0.08	0.10
	7	0.09	0.12	0.06	0.11	-0.07	0.09	0.12	0.10	0.14	0.12	0.08	0.09	0.08	0.10
	8	0.09	0.12	0.07	0.11	-0.07	0.10	0.11	0.10	0.14	0.12	0.08	0.09	0.08	0.10
	9	0.09	0.11	0.07	0.11	-0.07	0.10	0.12	0.10	0.14	0.12	0.08	0.09	0.08	0.10
	10	0.09	0.12	0.07	0.11	-0.07	0.10	0.11	0.09	0.14	0.12	0.08	0.09	0.08	0.09
Test 2	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.09	0.10	0.09	0.11	0.10	0.10	0.14
	2	0.09	0.10	0.11	0.10	0.12	0.11	0.11	0.09	0.10	0.09	0.11	0.10	0.10	0.14
	3	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.10	0.10	0.09	0.11	0.10	0.10	0.13
	4	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.10	0.10	0.09	0.11	0.10	0.09	0.13
	5	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.09	0.10	0.09	0.11	0.10	0.10	0.14
	6	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.10	0.11	0.09	0.11	0.10	0.09	0.14
	7	0.10	0.10	0.10	0.10	0.12	0.11	0.10	0.10	0.10	0.09	0.11	0.10	0.10	0.14
	8	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.09	0.10	0.09	0.11	0.10	0.10	0.13
	9	0.09	0.10	0.10	0.10	0.12	0.11	0.11	0.10	0.11	0.09	0.11	0.10	0.10	0.13
	10	0.10	0.10	0.10	0.10	0.12	0.11	0.10	0.10	0.10	0.09	0.11	0.10	0.09	0.14
Test 3	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	0.11	0.10	0.14	0.10	0.12	0.10	0.09	0.10	0.10	0.10	0.11	0.10	0.10	0.08
	2	0.10	0.10	0.15	0.10	0.11	0.10	0.09	0.10	0.10	0.10	0.11	0.10	0.10	0.07
	3	0.11	0.10	0.15	0.10	0.11	0.10	0.09	0.10	0.10	0.10	0.11	0.11	0.10	0.07
	4	0.10	0.10	0.15	0.10	0.12	0.10	0.09	0.10	0.10	0.10	0.11	0.11	0.10	0.08
	5	0.11	0.10	0.15	0.10	0.11	0.10	0.09	0.09	0.10	0.10	0.11	0.11	0.10	0.11
	6	0.11	0.10	0.15	0.10	0.13	0.10	0.09	0.10	0.10	0.10	0.11	0.10	0.11	0.11
	7	0.11	0.11	0.14	0.10	0.14	0.10	0.09	0.10	0.09	0.11	0.11	0.10	0.10	0.11
	8	0.11	0.10	0.13	0.10	0.11	0.10	0.09	0.10	0.10	0.11	0.11	0.10	0.10	0.11
	9	0.12	0.10	0.14	0.10	0.12	0.10	0.09	0.10	0.10	0.10	0.11	0.10	0.10	0.11
	10	0.11	0.10	0.14	0.10	0.12	0.10	0.09	0.09	0.09	0.10	0.11	0.10	0.11	0.11
Test 4	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
	1	0.12	0.10	0.09	0.10	0.11	0.09	0.09	0.09	0.10	0.11	0.09	0.10	0.10	0.10
	2	0.12	0.09	0.09	0.10	0.10	0.10	0.09	0.09	0.10	0.11	0.08	0.10	0.10	0.10
	3	0.13	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	0.11	0.09	0.10	0.10	0.09
	4	0.12	0.10	0.09	0.10	0.11	0.10	0.09	0.09	0.10	0.11	0.09	0.10	0.09	0.09
	5	0.10	0.09	0.09	0.10	0.10	0.09	0.10	0.09	0.09	0.11	0.09	0.10	0.10	0.10
	6	0.10	0.09	0.09	0.11	0.10	0.10	0.10	0.09	0.10	0.11	0.08	0.10	0.10	0.10
	7	0.09	0.10	0.09	0.09	0.10	0.10	0.10	0.09	0.10	0.11	0.09	0.10	0.10	0.10
	8	0.09	0.10	0.09	0.10	0.11	0.10	0.10	0.09	0.10	0.11	0.09	0.10	0.10	0.09
	9	0.09	0.09	0.08	0.09	0.10	0.09	0.10	0.09	0.10	0.11	0.08	0.10	0.10	0.09
	10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.08	0.10	0.10	0.09

	Table A-2: MTA Measured Motion (cm) 0.1 cm Motion Steps (continued)														
Test 5	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.11	0.10	0.08	0.09	0.23	0.09	0.10	0.10	0.11	0.09	0.09	0.10	0.09	0.12
	2	0.12	0.10	0.07	0.10	0.22	0.09	0.10	0.10	0.11	0.09	0.09	0.10	0.10	0.11
	3	0.11	0.10	0.08	0.10	0.23	0.09	0.10	0.11	0.11	0.09	0.09	0.10	0.08	0.11
	4	0.12	0.10	0.10	0.09	0.22	0.09	0.10	0.11	0.10	0.10	0.09	0.10	0.08	0.11
	5	0.12	0.10	0.10	0.10	0.21	0.09	0.10	0.10	0.11	0.09	0.10	0.10	0.09	0.11
	6	0.12	0.10	0.10	0.10	0.21	0.09	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.11
	7	0.12	0.10	0.10	0.10	0.22	0.09	0.10	0.10	0.11	0.09	0.09	0.10	0.09	0.11
	8	0.11	0.10	0.11	0.09	0.21	0.09	0.10	0.10	0.10	0.10	0.09	0.10	0.09	0.11
	9	0.12	0.10	0.11	0.10	0.21	0.09	0.10	0.10	0.10	0.08	0.09	0.10	0.09	0.11
	10	0.11	0.10	0.11	0.10	0.20	0.10	0.10	0.10	0.10	0.09	0.09	0.10	0.10	0.11
Test 6	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.09	0.10	0.07	0.10	0.09	0.11	0.10	0.09	0.08	0.10	0.09	0.09	0.10	0.12
	2	0.10	0.10	0.07	0.10	0.10	0.11	0.11	0.08	0.09	0.10	0.10	0.09	0.10	0.12
	3	0.09	0.10	0.08	0.10	0.10	0.11	0.10	0.10	0.09	0.10	0.09	0.09	0.10	0.12
	4	0.10	0.10	0.07	0.09	0.10	0.11	0.10	0.09	0.09	0.11	0.10	0.09	0.10	0.11
	5	0.10	0.10	0.07	0.09	0.11	0.11	0.11	0.09	0.09	0.10	0.10	0.09	0.10	0.12
	6	0.10	0.10	0.07	0.09	0.11	0.11	0.10	0.09	0.10	0.10	0.10	0.08	0.10	0.12
	7	0.10	0.10	0.07	0.09	0.11	0.10	0.10	0.09	0.09	0.10	0.10	0.08	0.10	0.11
	8	0.10	0.10	0.07	0.09	0.11	0.11	0.10	0.09	0.09	0.10	0.10	0.09	0.10	0.12
	9	0.09	0.10	0.07	0.09	0.11	0.11	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.12
	10	0.08	0.10	0.08	0.09	0.11	0.11	0.10	0.10	0.09	0.11	0.09	0.08	0.10	0.12
Test 7	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.09	0.08	0.10	0.10	0.11	0.10	0.09	0.09	0.11	0.10	0.09	0.10	0.09	0.12
	2	0.10	0.08	0.11	0.09	0.11	0.08	0.10	0.09	0.11	0.10	0.09	0.10	0.09	0.12
	3	0.09	0.08	0.11	0.10	0.11	0.10	0.10	0.09	0.11	0.10	0.10	0.10	0.09	0.12
	4	0.09	0.09	0.11	0.09	0.11	0.09	0.10	0.09	0.12	0.10	0.09	0.10	0.10	0.12
	5	0.10	0.08	0.11	0.10	0.11	0.09	0.10	0.09	0.12	0.10	0.10	0.10	0.10	0.12
	6	0.09	0.09	0.10	0.10	0.11	0.09	0.10	0.09	0.12	0.10	0.09	0.10	0.09	0.12
	7	0.10	0.08	0.10	0.10	0.11	0.09	0.10	0.09	0.12	0.10	0.10	0.10	0.09	0.12
	8	0.09	0.08	0.11	0.10	0.11	0.09	0.11	0.09	0.12	0.10	0.10	0.10	0.09	0.11
	9	0.09	0.08	0.10	0.10	0.11	0.09	0.10	0.09	0.12	0.10	0.09	0.10	0.09	0.11
	10	0.09	0.08	0.09	0.10	0.11	0.09	0.10	0.09	0.12	0.10	0.09	0.10	0.10	0.12
Test 8	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.11	0.11	0.14	0.09	0.09	0.10	0.10	0.09	0.10	0.10	0.11	0.10	0.10	0.08
	2	0.11	0.11	0.13	0.10	0.08	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09
	3	0.11	0.11	0.13	0.10	0.08	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.09	0.09
	4	0.11	0.11	0.14	0.10	0.09	0.10	0.08	0.10	0.10	0.11	0.10	0.10	0.10	0.09
	5	0.11	0.11	0.13	0.10	0.09	0.10	0.08	0.10	0.10	0.11	0.10	0.10	0.09	0.09
	6	0.10	0.11	0.13	0.09	0.09	0.10	0.08	0.11	0.10	0.09	0.10	0.10	0.10	0.09
	7	0.11	0.11	0.13	0.10	0.09	0.10	0.08	0.11	0.09	0.10	0.10	0.10	0.09	0.09
	8	0.11	0.11	0.13	0.09	0.08	0.10	0.08	0.11	0.10	0.10	0.11	0.10	0.10	0.09
	9	0.10	0.11	0.13	0.09	0.08	0.10	0.08	0.11	0.11	0.11	0.10	0.10	0.10	0.09
	10	0.10	0.11	0.12	0.10	0.09	0.10	0.07	0.11	0.09	0.10	0.11	0.10	0.10	0.09

**Table A-2: MTA Measured Motion (cm)
0.1 cm Motion Steps (continued)**

	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 9	1	0.10	0.11	0.08	0.09	0.10	0.09	0.11	0.09	0.11	0.10	0.10	0.09	0.07	0.12
	2	0.10	0.11	0.09	0.10	0.10	0.09	0.11	0.09	0.11	0.10	0.10	0.09	0.08	0.11
	3	0.10	0.11	0.08	0.09	0.10	0.09	0.11	0.08	0.11	0.10	0.10	0.10	0.07	0.12
	4	0.10	0.11	0.09	0.09	0.09	0.09	0.11	0.10	0.11	0.11	0.10	0.09	0.08	0.12
	5	0.09	0.11	0.09	0.10	0.10	0.09	0.11	0.09	0.11	0.10	0.10	0.10	0.08	0.12
	6	0.11	0.11	0.09	0.09	0.09	0.09	0.09	0.08	0.11	0.10	0.10	0.10	0.08	0.12
	7	0.11	0.11	0.10	0.09	0.10	0.09	0.11	0.09	0.11	0.10	0.10	0.09	0.08	0.12
	8	0.10	0.11	0.09	0.09	0.10	0.09	0.11	0.09	0.11	0.10	0.10	0.09	0.08	0.12
	9	0.11	0.11	0.09	0.09	0.09	0.09	0.11	0.09	0.11	0.10	0.10	0.10	0.08	0.12
	10	0.11	0.11	0.09	0.09	0.09	0.09	0.11	0.10	0.11	0.11	0.10	0.10	0.08	0.11

Table A-3: MTA Measured Motion (cm)
0.05 cm Motion Steps

	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 1	1	0.04	0.05	0.06	0.05	0.06	0.05	0.06	0.06	0.04	0.06	0.06	0.05	0.06	0.08
	2	0.05	0.06	0.06	0.05	0.05	0.05	0.06	0.05	0.04	0.06	0.07	0.05	0.06	0.07
	3	0.04	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.04	0.07	0.06	0.05	0.06	0.07
	4	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.04	0.06	0.06	0.05	0.06	0.07
	5	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.04	0.07	0.06	0.05	0.06	0.08
	6	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.04	0.04	0.05	0.06	0.05	0.06	0.07
	7	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.04	0.07	0.06	0.05	0.06	0.08
	8	0.05	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.04	0.06	0.06	0.05	0.06	0.08
	9	0.04	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.04	0.06	0.06	0.05	0.06	0.08
	10	0.05	0.05	0.06	0.05	0.06	0.05	0.06	0.04	0.04	0.05	0.06	0.05	0.06	0.07
	Time (s)	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
Test 2	1	0.04	0.05	0.04	0.07	0.05	0.05	0.06	0.04	0.06	0.05	0.04	0.05	0.04	0.06
	2	0.04	0.06	0.04	0.06	0.05	0.06	0.06	0.04	0.06	0.04	0.04	0.06	0.05	0.05
	3	0.04	0.05	0.05	0.07	0.05	0.05	0.06	0.04	0.06	0.05	0.04	0.05	0.04	0.05
	4	0.04	0.05	0.05	0.07	0.05	0.05	0.06	0.04	0.06	0.04	0.04	0.06	0.04	0.05
	5	0.04	0.05	0.05	0.06	0.04	0.05	0.05	0.03	0.06	0.04	0.04	0.06	0.05	0.05
	6	0.04	0.06	0.05	0.06	0.05	0.05	0.05	0.04	0.06	0.05	0.04	0.05	0.03	0.05
	7	0.04	0.05	0.04	0.07	0.05	0.05	0.06	0.03	0.06	0.05	0.04	0.06	0.04	0.05
	8	0.04	0.05	0.05	0.06	0.05	0.05	0.06	0.04	0.06	0.04	0.04	0.06	0.04	0.05
	9	0.04	0.05	0.05	0.07	0.05	0.06	0.06	0.04	0.06	0.05	0.04	0.06	0.05	0.05
	10	0.04	0.06	0.04	0.07	0.05	0.05	0.07	0.03	0.06	0.05	0.04	0.05	0.05	0.05
	Time (s)	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
Test 3	1	0.04	0.07	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.03	0.07	0.05	0.05	0.04
	2	0.05	0.07	0.05	0.04	0.05	0.05	0.06	0.05	0.04	0.04	0.07	0.04	0.05	0.03
	3	0.05	0.07	0.05	0.03	0.05	0.05	0.04	0.05	0.04	0.04	0.07	0.04	0.05	0.04
	4	0.05	0.07	0.05	0.03	0.05	0.05	0.04	0.05	0.04	0.04	0.08	0.04	0.05	0.03
	5	0.05	0.07	0.05	0.03	0.05	0.05	0.04	0.05	0.04	0.04	0.07	0.05	0.05	0.04
	6	0.05	0.07	0.05	0.04	0.04	0.06	0.05	0.06	0.04	0.04	0.07	0.04	0.05	0.04
	7	0.05	0.07	0.05	0.03	0.04	0.05	0.04	0.05	0.04	0.04	0.07	0.04	0.05	0.04
	8	0.04	0.07	0.05	0.03	0.05	0.05	0.05	0.05	0.04	0.03	0.07	0.04	0.05	0.04
	9	0.05	0.07	0.05	0.04	0.04	0.06	0.05	0.05	0.04	0.03	0.07	0.05	0.04	0.04
	10	0.05	0.07	0.05	0.04	0.04	0.05	0.04	0.05	0.04	0.04	0.07	0.04	0.05	0.04
	Time (s)	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
Test 4	1	0.00	0.04	0.04	0.05	0.03	0.06	0.04	0.05	0.03	0.05	0.03	0.05	0.06	0.04
	2	0.01	0.04	0.04	0.05	0.03	0.05	0.03	0.06	0.01	0.05	0.04	0.05	0.06	0.04
	3	0.01	0.04	0.04	0.05	0.03	0.04	0.03	0.05	0.02	0.05	0.04	0.05	0.06	0.04
	4	0.01	0.05	0.05	0.05	0.03	0.04	0.04	0.05	0.03	0.05	0.04	0.05	0.06	0.04
	5	0.01	0.05	0.04	0.05	0.03	0.05	0.03	0.05	0.03	0.05	0.04	0.05	0.06	0.04
	6	0.00	0.04	0.04	0.05	0.03	0.05	0.04	0.05	0.03	0.05	0.05	0.06	0.06	0.04
	7	0.01	0.04	0.05	0.05	0.03	0.04	0.03	0.05	0.02	0.05	0.03	0.06	0.06	0.04
	8	0.01	0.05	0.04	0.05	0.03	0.05	0.04	0.06	0.04	0.05	0.03	0.05	0.06	0.04
	9	0.01	0.04	0.06	0.05	0.03	0.04	0.04	0.05	0.03	0.05	0.04	0.06	0.06	0.04
	10	0.01	0.05	0.05	0.05	0.03	0.04	0.03	0.06	0.02	0.05	0.04	0.06	0.06	0.04

**Table A-3: MTA Measured Motion (cm)
0.05 cm Motion Steps (continued)**

	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 5	1	0.04	0.04	0.04	0.04	0.04	0.02	0.04	0.04	0.05	0.04	0.03	0.06	0.04	0.01
	2	0.04	0.04	0.06	0.04	0.04	0.02	0.04	0.03	0.04	0.04	0.03	0.06	0.04	0.01
	3	0.03	0.05	0.05	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.01
	4	0.04	0.04	0.04	0.04	0.04	0.02	0.04	0.03	0.04	0.04	0.04	0.06	0.04	0.00
	5	0.04	0.05	0.05	0.04	0.04	0.02	0.04	0.03	0.05	0.04	0.04	0.06	0.04	0.01
	6	0.04	0.04	0.05	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.03	0.06	0.04	0.01
	7	0.04	0.04	0.04	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.00
	8	0.04	0.04	0.05	0.04	0.04	0.02	0.04	0.04	0.05	0.04	0.04	0.06	0.04	0.01
	9	0.04	0.05	0.04	0.04	0.04	0.02	0.04	0.04	0.05	0.03	0.04	0.06	0.04	0.03
	10	0.04	0.05	0.05	0.03	0.05	0.02	0.04	0.03	0.04	0.03	0.03	0.06	0.04	0.03
Test 6	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.04	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.04	0.04	0.05	0.04	0.05	0.05
	2	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.05
	3	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.04	0.05	0.05
	4	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.04	0.04	0.05	0.04	0.05	0.05
	5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.04
	6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.04
	7	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.03	0.04	0.04
	8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.04
	9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.04
	10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.04
Test 7	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.04	0.06	0.05
	2	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06
	3	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06
	4	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.06	0.06
	5	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06
	6	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05
	7	0.07	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.04	0.07	0.05
	8	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.04	0.06	0.06
	9	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.04	0.06	0.05
	10	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.04	0.06	0.06
Test 8	**Time (s)**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 6**	**Trans 7**	**Trans 8**	**Trans 9**	**Trans 10**	**Trans 11**	**Trans 12**	**Trans 13**	**Trans 15**	**Trans 16**
	1	0.05	0.06	0.05	0.05	0.05	0.06	0.07	0.05	0.06	0.04	0.05	0.06	0.03	0.04
	2	0.05	0.06	0.05	0.05	0.06	0.06	0.07	0.05	0.05	0.03	0.05	0.06	0.03	0.03
	3	0.04	0.06	0.05	0.05	0.05	0.06	0.06	0.04	0.06	0.03	0.05	0.06	0.05	0.02
	4	0.04	0.06	0.05	0.05	0.06	0.06	0.07	0.05	0.06	0.04	0.05	0.06	0.05	0.03
	5	0.04	0.06	0.05	0.05	0.06	0.06	0.07	0.04	0.06	0.04	0.05	0.06	0.04	0.03
	6	0.04	0.06	0.05	0.05	0.06	0.06	0.06	0.05	0.06	0.05	0.05	0.06	0.04	0.03
	7	0.04	0.06	0.05	0.05	0.05	0.06	0.07	0.04	0.05	0.04	0.04	0.06	0.04	0.03
	8	0.05	0.06	0.05	0.05	0.06	0.06	0.07	0.04	0.06	0.04	0.05	0.06	0.04	0.02
	9	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.04	0.06	0.05	0.05	0.06	0.05	0.03
	10	0.05	0.06	0.05	0.05	0.06	0.06	0.07	0.04	0.06	0.03	0.05	0.06	0.04	0.03

Table A-3: MTA Measured Motion (cm)
0.05 cm Motion Steps (continued)

	Time (s)	Trans 1	Trans 2	Trans 3	Trans 4	Trans 6	Trans 7	Trans 8	Trans 9	Trans 10	Trans 11	Trans 12	Trans 13	Trans 15	Trans 16
Test 9	1	0.06	0.06	0.05	0.05	0.04	0.06	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.04
	2	0.05	0.06	0.04	0.06	0.04	0.06	0.03	0.04	0.05	0.04	0.04	0.05	0.05	0.03
	3	0.05	0.06	0.05	0.06	0.05	0.06	0.04	0.04	0.05	0.03	0.04	0.05	0.05	0.03
	4	0.05	0.06	0.04	0.05	0.04	0.06	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.03
	5	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04
	6	0.06	0.06	0.04	0.06	0.04	0.06	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.04
	7	0.05	0.06	0.04	0.05	0.04	0.06	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.03
	8	0.06	0.06	0.04	0.05	0.04	0.06	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.03
	9	0.05	0.06	0.04	0.05	0.04	0.06	0.03	0.04	0.04	0.05	0.04	0.05	0.04	0.03
	10	0.06	0.06	0.04	0.05	0.04	0.06	0.04	0.04	0.04	0.03	0.04	0.05	0.05	0.03

Appendix B: MTA Field Data at Currituck Sound

Table B-1: Measured Distance-to-Bottom (cm)

Date & Time	Transducer #											
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
6/22/12 18:00	52.85	52.63	52.61	52.55	52.65	52.87	52.65	52.72	52.59	52.73	52.47	68.01	52.67
6/22/12 19:00	52.64	52.6	52.57	52.47	52.51	52.61	52.63	52.61	52.45	52.57	53.01	52.66	52.61
6/22/12 20:00	52.68	52.56	52.68	52.4	52.6	52.67	52.67	52.67	52.5	52.74	52.84	52.4	52.62
6/22/12 21:00	52.65	52.84	52.57	52.43	52.56	52.69	52.75	52.74	52.51	52.64	52.53	52.4	52.61
6/22/12 22:00	52.72	52.56	52.57	52.4	52.91	52.6	52.72	52.85	52.49	53.24	52.5	52.41	52.66
6/22/12 23:00	52.36	52.72	53.45	52.44	52.55	52.61	52.84	52.44	52.89	52.65	52.76	52.37	52.67
6/23/12 0:00	52.35	52.55	52.79	52.31	52.37	52.75	51.86	51.82	52.86	55.57	52.71	52.43	52.44
6/23/12 1:00	52.98	52.89	52.97	52.8	52.89	52.8	52.54	52.35	52.58	52.46	52.86	52.44	52.71
6/23/12 2:00	53.14	53.01	53.09	52.63	52.76	52.92	52.51	52.45	52.47	52.93	53.3	52.59	52.82
6/23/12 3:00	53.12	52.95	53.02	52.78	52.7	52.9	52.49	52.94	52.5	52.52	52.8	52.78	52.79
6/23/12 4:00	52.75	53.84	53.07	52.41	53.08	52.89	52.47	52.35	52.51	52.67	52.78	52.54	52.78
6/23/12 5:00	53.15	53.2	53.08	52.72	53	52.96	52.46	52.44	52.46	52.43	53.24	52.6	52.81
6/23/12 6:00	53.11	53.26	53.11	52.7	52.83	52.89	53.51	52.77	52.8	53.1	52.61	53.02	52.98
6/23/12 7:00	52.9	53.26	53.16	52.74	52.88	53.19	52.8	52.53	52.76	52.78	53.24	53.21	52.95
6/23/12 8:00	52.89	53.29	53.24	52.8	52.87	53.17	66.24	52.78	52.87	53.25	52.59	52.95	52.97
6/23/12 9:00	52.94	53.34	53.13	52.88	52.95	53.24	53.05	52.57	53.27	53.56	53.15	52.7	53.07
6/23/12 10:00	52.93	53.3	53.13	52.84	52.92	53.21	52.92	52.69	53.07	53.35	52.73	52.68	52.98
6/23/12 11:00	52.94	53.26	53.15	52.8	52.96	53.1	53.06	52.56	52.78	52.89	52.93	52.75	52.93
6/23/12 12:00	52.93	53.22	53.13	52.73	53.31	52.93	52.77	52.54	52.75	52.82	52.67	52.71	52.88
6/23/12 13:00	52.93	53.36	53.08	52.93	53.07	53.02	52.68	52.54	53.14	53.65	52.63	52.69	52.98
6/23/12 14:00	52.89	53.24	53.07	52.82	53.01	52.96	52.73	52.59	53.14	52.94	52.55	52.83	52.90
6/23/12 15:00	52.87	53.13	53.05	52.7	52.8	53	53	52.45	52.77	53.26	52.54	52.58	52.85
6/23/12 16:00	52.8	53.84	52.96	52.74	52.73	52.95	53.41	74.54	52.77	52.63	52.6	53.17	52.96
6/23/12 17:00	53.6	53.18	53.11	52.85	52.81	53.44	52.8	53.07	52.88	52.87	52.66	53.24	53.04
6/23/12 18:00	52.93	53.25	53.14	52.88	52.99	53.02	52.87	53.21	52.91	52.88	52.5	52.76	52.95

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-2: Measured Distance-to-Bottom (cm)

Date & Time	Transducer #											
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
6/23/12 19:00	52.98	53.2	52.99	52.71	52.71	52.85	52.81	53.2	52.99	52.79	52.52	53.36	52.93
6/23/12 20:00	52.94	53.2	53.2	52.86	52.99	52.92	53.05	52.69	53.35	52.82	52.95	52.7	52.97
6/23/12 21:00	53.6	53.18	53.11	52.85	52.81	53.44	52.8	53.07	52.88	52.87	52.66	53.24	53.04
6/23/12 22:00	52.93	53.25	53.14	52.88	52.99	53.02	52.87	53.21	52.91	52.88	52.5	52.76	52.95
6/23/12 23:00	52.94	53.42	53.04	52.84	52.87	53.08	52.88	52.55	52.81	53.1	52.63	52.8	52.91
6/24/12 0:00	53.04	53.48	53.11	52.87	52.86	53.1	52.9	52.76	53.1	53.09	52.62	52.75	52.97
6/24/12 1:00	53.05	53.44	53.07	52.78	52.88	53.15	52.86	53.49	52.98	53.07	52.8	52.63	53.02
6/24/12 2:00	52.93	53.32	53.14	52.8	53.07	53.04	52.88	52.64	52.82	52.85	52.79	52.8	52.92
6/24/12 3:00	52.93	53.38	53.27	52.81	53.01	53.01	52.9	53.34	52.87	52.78	52.72	52.77	52.98
6/24/12 4:00	52.93	54.03	53.05	52.8	53.03	52.98	52.88	57.89	52.89	52.76	52.68	52.87	52.99
6/24/12 5:00	53.04	53.33	53.05	52.89	52.98	53.11	52.81	53.32	52.9	52.96	52.73	52.82	53.00
6/24/12 6:00	53.15	53.98	53.14	52.86	53.12	53.18	52.87	52.76	52.9	53.56	52.73	52.88	53.09
6/24/12 7:00	52.99	53.42	53.13	52.88	53.11	53.13	52.97	52.67	52.98	58.54	52.82	52.83	52.99
6/24/12 8:00	53.03	53.42	53.33	52.91	53.07	53.29	52.96	52.67	52.93	53.36	53.21	52.86	53.09
6/24/12 9:00	53.11	53.46	53.12	52.89	53.01	53.03	52.94	52.7	53	53.29	53.01	52.9	53.04
6/24/12 10:00	53.07	53.37	53.15	0	53.02	52.91	53.18	53.06	53.6	52.86	52.73	67.87	53.10
6/24/12 11:00	53.03	53.45	53.95	52.86	53.04	52.99	52.94	52.8	53	52.95	52.7	52.91	53.05
6/24/12 12:00	52.95	53.3	53.07	52.95	53.19	52.97	52.87	52.71	52.93	52.86	52.7	52.95	52.95
6/24/12 13:00	52.97	53.22	53.04	52.87	52.95	52.93	52.96	52.81	52.9	53.05	52.63	52.78	52.93
6/24/12 14:00	52.88	53.25	52.99	52.75	52.96	52.87	52.94	53.2	52.82	52.75	52.81	64.59	52.93
6/24/12 15:00	52.87	53.17	53	52.71	52.76	52.89	52.99	53.36	53.08	52.69	52.66	52.8	52.92
6/24/12 16:00	52.82	53.49	52.95	52.87	52.77	52.95	52.95	52.63	52.91	52.67	52.59	52.71	52.86
6/24/12 17:00	53.01	53.31	53.03	52.67	52.79	52.89	52.9	52.79	52.86	53.1	52.6	52.97	52.91
6/24/12 18:00	52.84	53.07	53	52.66	52.76	52.76	52.85	52.46	52.87	52.89	52.67	52.56	52.78
6/24/12 19:00	52.81	53.16	52.88	52.75	52.81	52.87	52.8	52.8	52.82	52.92	63.85	52.58	52.84

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-3: Measured Distance-to-Bottom (cm)													
Date & Time	Transducer #												
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
6/24/12 20:00	52.89	53.01	52.95	52.68	52.84	52.93	52.75	52.68	52.93	52.75	52.68	52.51	52.80
6/24/12 21:00	52.74	53	52.87	52.68	52.67	52.76	52.67	52.98	52.71	53.26	52.96	52.51	52.82
6/24/12 22:00	52.8	52.94	52.88	52.66	52.78	52.66	52.69	52.88	52.77	52.86	52.74	53.07	52.81
6/24/12 23:00	52.8	52.96	52.89	52.68	52.71	52.67	52.68	52.65	52.73	52.73	52.55	52.5	52.71
6/25/12 0:00	52.87	53.02	52.95	52.81	52.84	52.7	52.74	52.65	53.86	53.31	52.64	52.51	52.91
6/25/12 1:00	52.95	53.05	52.98	52.76	52.87	52.74	52.75	52.67	54.38	52.93	52.67	52.53	52.94
6/25/12 2:00	52.98	53.11	53.03	52.83	52.93	52.93	53.24	52.72	53.26	52.94	52.66	52.56	52.93
6/25/12 3:00	52.93	53.05	53.05	52.87	52.82	52.89	52.92	52.81	53.1	52.9	52.91	52.56	52.90
6/25/12 4:00	52.89	53.11	53.01	52.86	52.9	52.81	53.02	52.87	52.93	53.01	52.59	52.6	52.88
6/25/12 5:00	52.93	53.08	52.99	52.84	52.79	52.82	53.04	52.94	53.73	52.85	52.83	52.59	52.95
6/25/12 6:00	52.97	53.12	53	52.82	52.85	52.89	53.15	52.85	53.68	52.81	52.9	52.56	52.97
6/25/12 7:00	52.95	53.12	52.99	53.03	52.85	52.91	52.99	52.83	52.92	53.02	52.66	52.57	52.90
6/25/12 8:00	52.98	53.18	53.01	52.84	52.81	52.84	52.96	53.11	53.18	52.81	52.89	52.64	52.94
6/25/12 9:00	52.95	53.07	53	52.99	52.81	52.81	52.95	53.16	52.81	52.94	52.72	52.63	52.90
6/25/12 10:00	53.22	53.05	53.01	52.79	53.19	52.86	52.81	52.91	52.87	52.94	52.84	76.18	52.95
6/25/12 11:00	53.22	53.01	53.07	52.9	52.83	52.88	52.9	52.88	52.88	52.88	52.83	54.38	52.93
6/25/12 12:00	53.11	53.17	53.05	52.93	52.84	52.9	52.85	52.88	52.89	53.17	52.79	56.49	52.96
6/25/12 13:00	53.07	53	52.99	52.78	52.76	52.73	52.8	52.71	52.83	52.84	52.77	52.65	52.83
6/25/12 14:00	53.02	53.07	52.94	52.71	52.7	52.99	52.73	52.73	52.75	52.8	52.68	52.65	52.81
6/25/12 15:00	53.03	52.89	52.9	52.71	52.62	52.83	52.75	52.64	52.81	52.8	52.62	52.5	52.76
6/25/12 16:00	52.87	53.08	53.05	52.71	52.85	52.64	52.71	52.65	52.97	52.65	52.55	52.71	52.79
6/25/12 17:00	53.25	52.86	52.8	52.6	52.71	52.64	52.91	52.57	52.96	52.56	52.52	52.45	52.74
6/25/12 18:00	53.2	52.77	52.74	52.53	52.53	52.63	53.07	52.52	52.71	52.61	52.54	52.34	52.68
6/25/12 19:00	52.85	52.74	52.7	52.52	52.54	52.56	52.79	52.46	52.73	52.65	52.96	52.34	52.65
6/25/12 20:00	52.82	52.76	52.74	52.49	52.73	52.59	52.65	52.53	52.77	52.88	52.72	52.39	52.67

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-4: Measured Distance-to-Bottom (cm)													
Date & Time	**Transducer #**												
	1	**3**	**4**	**6**	**7**	**8**	**10**	**11**	**12**	**13**	**15**	**16**	**Ave**
6/25/12 21:00	52.78	52.78	52.82	52.47	52.56	52.61	52.58	52.55	52.79	52.58	52.42	52.39	52.61
6/25/12 22:00	52.85	53	52.89	52.49	52.57	52.67	53.2	52.63	53.27	52.78	52.46	52.51	52.78
6/25/12 23:00	52.75	52.86	52.9	52.56	52.52	52.75	53.28	52.7	52.75	52.54	52.4	59.12	52.73
6/26/12 0:00	52.88	52.88	53.01	52.53	52.57	53.44	53.13	52.81	52.96	52.67	52.44	55.2	53.04
6/26/12 1:00	52.82	52.88	52.97	52.54	52.68	52.76	52.87	52.85	52.75	52.6	52.51	52.56	52.73
6/26/12 2:00	52.81	52.92	53.12	52.53	52.73	52.87	52.9	52.82	52.75	52.75	52.86	53.07	52.84
6/26/12 3:00	52.87	52.98	52.95	52.55	52.92	52.96	52.86	52.85	52.83	52.62	52.5	53.55	52.87
6/26/12 4:00	53.05	52.96	53.04	52.56	52.74	52.83	54.12	52.75	53.22	53.01	52.79	52.59	52.97
6/26/12 5:00	53.11	53.18	52.99	52.67	52.88	52.88	53.2	52.79	52.66	52.92	52.88	52.71	52.91
6/26/12 6:00	53.16	53.04	53.14	52.5	52.54	52.81	53.44	52.83	52.66	52.88	52.66	52.77	52.87
6/26/12 7:00	52.95	52.9	53.47	52.63	52.72	52.71	52.88	52.94	52.79	52.61	53.55	52.68	52.90
6/26/12 8:00	52.73	52.25	52.11	52.42	52.29	52.58	52.37	52.26	52.48	52.24	53.6	52.94	52.52
6/26/12 9:00	53.01	52.39	52.32	52.19	52.17	52.26	55.21	52.61	52.51	52.17	53.32	52.66	52.51
6/26/12 10:00	53.17	52.43	53.21	52.42	52.25	52.64	53.28	52.68	63.46	52.36	53.06	53.29	52.80
6/26/12 11:00	53.23	52.44	53.36	52.5	52.3	52.51	53.11	52.9	53.11	52.44	53.3	52.82	52.84
6/26/12 12:00	53.25	52.38	53.49	52.55	52.3	52.56	52.7	53.26	52.91	52.38	53.04	53.59	52.87
6/26/12 13:00	53.22	52.49	53.51	52.63	52.44	52.53	52.78	52.71	52.94	52.41	52.93	55.69	53.02
6/26/12 14:00	53.18	52.48	53.5	52.67	52.67	52.71	52.64	52.96	53.33	52.72	53.09	53.47	52.95
6/26/12 15:00	53.15	52.55	53.41	52.49	52.34	52.88	52.9	52.66	53.01	52.51	53.21	52.97	52.84
6/26/12 16:00	53.07	52.44	53.48	52.72	52.32	52.98	52.66	52.79	53.03	52.51	53.14	52.83	52.83
6/26/12 17:00	53.3	52.49	53.4	52.6	52.35	52.82	52.4	52.6	52.78	52.72	53.06	52.89	52.78
6/26/12 18:00	53.64	52.4	53.26	53.31	52.43	52.66	52.97	53.06	53.21	52.59	53.06	52.82	52.95
6/26/12 19:00	53.2	52.55	53.37	52.61	52.43	52.71	52.73	52.64	53.16	52.62	53.08	52.78	52.82
6/26/12 20:00	53.23	52.45	53.38	52.58	52.56	52.83	52.67	52.79	53.17	52.58	53.15	52.82	52.85
6/26/12 21:00	53.26	52.64	53.54	52.65	52.58	52.66	53.02	52.76	52.99	57.65	53.14	52.76	52.91

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-5: Measured Distance-to-Bottom (cm)													
Date & Time	Transducer #												
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
6/26/12 22:00	53.28	52.5	53.34	52.67	52.4	52.77	53.5	52.51	52.8	52.94	53.12	52.84	52.89
6/26/12 23:00	53.42	52.53	53.44	52.74	52.61	52.81	62.09	52.57	53.34	52.63	53.11	52.93	52.92
6/27/12 0:00	53.59	52.64	53.4	53.05	52.44	52.8	52.78	52.66	53.04	53.3	53.38	53.75	53.07
6/27/12 1:00	53.47	52.62	53.42	53.08	52.48	52.84	52.94	52.64	53.06	52.83	53.57	53.32	53.02
6/27/12 2:00	53.59	52.73	53.39	53	52.49	53.11	52.94	52.68	53	52.64	53.23	53.02	52.99
6/27/12 3:00	54.17	52.73	53.4	52.76	52.5	52.85	52.95	53.09	53.4	52.68	53.34	52.91	53.07
6/27/12 4:00	53.51	52.81	53.44	53.01	52.52	53.11	52.95	53.08	53.15	52.78	53.41	52.95	53.06
6/27/12 5:00	53.42	53.16	53.43	53.01	52.53	52.93	52.95	52.87	52.91	52.86	53.29	52.99	53.03
6/27/12 6:00	53.42	52.88	53.71	53.03	52.56	52.96	52.7	53.16	52.87	52.84	53.65	52.92	53.06
6/27/12 7:00	54	52.84	53.67	52.81	52.75	52.9	52.77	52.96	52.83	52.99	53.44	73.3	53.09
6/27/12 8:00	53.47	52.73	53.34	53.09	52.84	52.88	52.7	52.75	52.94	52.84	53.28	53.16	53.00
6/27/12 9:00	53.34	52.72	53.42	53.01	52.67	52.89	53.72	52.72	53.12	52.97	53.25	53.45	53.11
6/27/12 10:00	53.4	52.83	53.22	52.93	52.71	53.02	53.49	52.88	52.94	52.9	53.95	53.26	53.13
6/27/12 11:00	53.45	52.71	53.29	52.96	52.75	52.93	53.06	52.96	52.94	53	53.44	53.16	53.05
6/27/12 12:00	53.33	52.8	53.24	52.88	52.7	53.08	53.21	53.18	52.86	53.5	53.31	52.98	53.09
6/27/12 13:00	53.22	52.73	53.17	52.84	52.71	52.9	52.75	52.87	52.76	52.92	53.45	52.97	52.94
6/27/12 14:00	53.28	52.66	53.2	52.84	52.58	52.75	54.7	53.76	55.88	54.21	53.23	52.96	53.03
6/27/12 15:00	53.62	52.58	53.25	52.72	52.58	52.83	52.91	52.68	53.23	52.67	62.06	52.92	52.91
6/27/12 16:00	53.11	52.58	53.02	52.61	52.58	52.8	52.57	52.61	61.16	52.58	59.6	52.91	52.74
6/27/12 17:00	53.27	52.46	52.98	52.51	52.54	52.71	52.72	52.96	52.77	52.88	52.97	52.81	52.80
6/27/12 18:00	53.26	52.52	53.01	52.87	52.69	53.12	55.09	53.05	52.75	52.53	53.15	53.06	52.91
6/27/12 19:00	53.32	52.93	53.09	52.81	52.75	52.67	52.84	52.63	53.1	52.53	53.02	52.76	52.87
6/27/12 20:00	53.15	52.57	53.1	52.78	52.64	52.65	52.84	52.59	52.79	55.37	52.92	53.01	53.03
6/27/12 21:00	53.45	52.49	53.08	52.58	52.4	52.77	52.85	52.61	52.67	52.48	52.94	52.79	52.76
6/27/12 22:00	53.23	52.5	53.09	52.79	52.51	52.7	53.01	52.78	52.95	52.56	52.86	53.08	52.84

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-6: Measured Distance-to-Bottom (cm)													
Date & Time	Transducer #												
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
6/27/12 23:00	53.31	52.54	52.89	52.75	52.61	52.64	52.77	52.68	52.7	53.17	52.88	53.04	52.83
6/28/12 0:00	53.26	52.69	53.28	52.8	52.53	52.7	52.69	52.62	52.85	52.59	52.94	52.89	52.82
6/28/12 1:00	53.26	52.6	53.13	52.88	52.57	52.64	52.97	53.63	52.95	52.53	53	52.75	52.91
6/28/12 2:00	53.22	52.58	52.96	52.83	52.84	52.83	52.78	52.87	52.9	52.62	52.94	53.13	52.88
6/28/12 3:00	53.29	53.05	53.15	52.65	52.57	53.25	52.62	52.77	53.16	52.68	52.82	53.04	52.92
6/28/12 4:00	53.54	52.67	53.15	52.98	52.57	53.11	52.98	52.72	52.9	52.69	53.34	53.08	52.98
6/28/12 5:00	53.32	52.68	53.19	52.53	52.73	52.78	52.76	53.17	52.88	52.68	52.99	52.79	52.88
6/28/12 6:00	53.5	52.7	53.02	52.75	52.64	52.84	52.98	52.73	52.79	52.71	53.24	52.8	52.89
6/28/12 7:00	53.32	52.74	53.08	52.66	52.97	52.7	53.52	53.86	52.98	52.74	52.9	53.06	53.04
6/28/12 8:00	53.28	52.79	52.99	53.08	52.7	52.78	52.9	52.98	52.84	52.91	53.11	52.99	52.95
6/28/12 9:00	53.32	52.85	53.02	52.72	52.74	52.78	52.87	52.84	52.94	52.79	52.88	53.36	52.93
6/28/12 10:00	53.3	52.74	53.05	52.73	52.74	53.23	53.33	52.87	53.2	52.73	53.22	52.84	53.00
6/28/12 11:00	53.39	52.76	53.04	52.82	52.74	52.77	52.99	52.93	52.92	52.77	53.04	52.7	52.91
6/28/12 12:00	53.24	52.77	53.03	52.88	52.74	53.04	52.91	53.07	52.91	52.86	53.07	52.96	52.96
6/28/12 13:00	53.26	52.82	52.95	52.73	52.95	52.81	53.12	53.06	53.07	52.97	53.03	52.73	52.96
6/28/12 14:00	53.23	52.65	52.91	52.8	52.86	52.85	53.07	53.14	52.87	52.91	52.94	52.85	52.92
6/28/12 15:00	53.1	52.74	52.96	52.73	52.68	52.5	52.94	52.82	53.39	52.95	53.1	52.84	52.90
6/28/12 16:00	52.73	52.81	53.15	52.81	53.06	52.69	53.3	52.98	53.11	53.37	53.52	53.07	53.05
6/28/12 17:00	52.66	52.84	52.77	52.68	52.88	52.93	53.03	52.92	53.14	53.39	53.39	52.76	52.95
6/28/12 18:00	52.68	52.81	52.81	52.73	53.08	53.13	57.2	52.68	53.04	53.31	53.01	53.02	52.95
6/28/12 19:00	52.92	52.88	52.81	52.75	52.92	52.96	52.83	52.88	53.4	53.15	53.08	52.9	52.96
6/28/12 20:00	52.7	52.89	52.72	52.64	52.91	52.99	53.04	53.6	52.9	53.13	53.01	52.95	52.96
6/28/12 21:00	52.81	52.91	52.73	52.67	52.87	52.98	52.91	52.85	53.63	53.24	53.06	52.82	52.96
6/28/12 22:00	52.86	52.84	52.81	52.73	53.19	52.88	52.85	52.72	53.01	53.71	52.86	53.19	52.97
6/28/12 23:00	52.95	52.84	52.91	52.82	52.92	53.2	53.04	52.98	52.97	53.61	53.19	53.02	53.04

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-7: Measured Distance-to-Bottom (cm)													
Date & Time	**Transducer #**												
	1	**3**	**4**	**6**	**7**	**8**	**10**	**11**	**12**	**13**	**15**	**16**	**Ave**
6/29/12 0:00	53.26	52.93	52.88	52.74	52.86	52.99	53.24	52.81	53.03	53.46	52.91	53.3	53.03
6/29/12 1:00	53.19	52.92	53.07	52.86	52.99	53.16	53.3	52.92	53.27	53.89	52.96	52.97	53.13
6/29/12 2:00	53.11	52.99	53.03	52.8	53.1	53.31	53.08	53	53.24	53.68	53.09	53.82	53.19
6/29/12 3:00	53.13	53.04	53.17	52.89	52.98	53.5	53.3	53.15	53.26	53.27	52.98	53.28	53.16
6/29/12 4:00	53.25	52.99	53.21	52.85	52.88	53.34	53.02	53.21	53.19	53.83	53.09	53.18	53.17
6/29/12 5:00	53.13	53.09	52.87	53.06	53.18	53.32	53.32	53.19	53.41	53.8	53.13	52.9	53.20
6/29/12 6:00	53.34	53.13	53.05	53.15	53.24	53.5	53.16	53.36	53.35	54.19	53.09	53.63	53.35
6/29/12 7:00	53.45	53.47	52.86	53.69	53.63	53.63	52.84	53.27	53.56	54.06	52.93	52.53	53.33
6/29/12 8:00	53.61	53.36	52.9	53.35	53.86	53.71	53.01	53.69	53.03	53.34	53.07	52.47	53.28
6/29/12 9:00	53.8	52.73	52.85	53.67	54.1	54.13	53.03	53.64	53.73	53.79	53.2	52.57	53.44
6/29/12 10:00	53.94	52.68	52.68	53.64	54.36	53.85	53.59	53.62	53.13	53.11	53.88	52.74	53.44
6/29/12 11:00	53.85	52.77	53.22	53.66	54.62	53.87	53.39	53.69	53.59	53.88	53.87	53.53	53.66
6/29/12 12:00	53.94	52.94	53.53	53.57	54.3	54.35	53.45	53.57	53.49	53.89	53.15	52.98	53.60
6/29/12 13:00	53.94	53.43	53.33	53.75	54.08	53.77	53.91	53.2	53.77	53.62	53.03	52.94	53.56
6/29/12 14:00	53.89	53.25	53.39	53.6	54.33	53.79	53.41	56.11	53.19	53.75	53.28	53.42	53.57
6/29/12 15:00	53.85	53.44	53.14	53.59	54.35	53.92	53.4	53.47	53.1	53.25	53.11	53.36	53.50
6/29/12 16:00	53.6	53.06	53.19	53.28	53.92	53.9	53.47	52.98	53.18	53	53.24	52.68	53.29
6/29/12 17:00	53.64	53.07	53.38	53.33	53.81	53.72	53.24	53.25	53.19	53.01	53.14	52.68	53.29
6/29/12 18:00	53.63	53.05	53.17	53.33	54.43	53.48	53.26	53.1	53.16	60.28	53.02	52.58	53.34
6/29/12 19:00	53.65	53.02	53.13	53.55	54.07	53.59	53.24	53.71	53.22	52.99	52.99	52.86	53.34
6/29/12 20:00	53.55	53.11	53.18	53.27	53.82	53.84	53.17	52.95	52.97	53.01	53.19	53.05	53.26
6/29/12 21:00	53.56	53.11	53.19	53.3	53.95	53.76	53.5	53	53.67	53.16	54.11	52.55	53.41
6/29/12 22:00	53.51	53.12	53.17	53.35	53.88	53.53	53.32	53.04	53.23	53.23	53.33	52.62	53.28
6/29/12 23:00	53.64	53.14	53.11	53.44	53.96	53.73	53.75	53.11	53.18	53.12	53.05	52.75	53.33
6/30/12 0:00	53.57	53.11	53.11	53.26	53.79	53.7	53.54	53.02	53.03	53.11	53	52.99	53.27

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-8: Measured Distance-to-Bottom (cm)													
Date & Time	**Transducer #**												
	1	**3**	**4**	**6**	**7**	**8**	**10**	**11**	**12**	**13**	**15**	**16**	**Ave**
6/30/12 1:00	53.62	53.12	53.11	53.53	53.98	53.58	53.36	53.09	53.04	53.29	53.04	54.94	53.34
6/30/12 2:00	53.64	53.17	53.06	53.26	54	53.76	53.14	53	53.63	53.42	53.64	52.59	53.36
6/30/12 3:00	53.71	53.16	53.28	53.18	54.14	53.44	53.3	53.39	53.2	53.16	53.12	53.22	53.36
6/30/12 4:00	53.49	53.14	53.36	53.36	53.91	53.52	53.33	53.05	53.22	53.05	53.16	53.08	53.31
6/30/12 5:00	53.81	53.3	53.31	53.39	54.14	53.96	53.5	53.64	53.22	52.88	53.21	52.89	53.44
6/30/12 6:00	53.81	53.22	53.28	53.54	54.23	54.31	54.07	54.14	53.27	52.89	53.19	53.07	53.59
6/30/12 7:00	54.26	53.42	53.29	53.73	54	53.9	53.83	53.65	53.4	53.27	53.35	53.06	53.60
6/30/12 8:00	53.98	53.38	53.27	53.98	54.08	53.89	53.63	53.8	64.44	53.15	53.47	52.84	53.59
6/30/12 9:00	53.87	53.24	53.3	53.75	54.09	53.92	53.86	53.71	53.45	53.15	53.36	52.87	53.55
6/30/12 10:00	53.98	53.34	53.16	54	54	54.04	54.27	53.28	53.52	53.09	53.56	52.8	53.59
6/30/12 11:00	53.85	53.33	53.49	53.93	54.17	53.8	53.72	53.51	53.53	53.18	53.58	53.18	53.61
6/30/12 12:00	53.76	53.2	53.18	53.82	53.95	53.73	53.92	53.58	53.19	53.22	53.54	53.19	53.52
6/30/12 13:00	53.95	53.03	53.22	53.62	54.2	53.76	53.67	53.33	53.36	53.38	53.52	53.09	53.51
6/30/12 14:00	53.95	53.13	53.31	53.84	53.88	53.56	53.51	53.45	53.45	53.41	53.24	52.8	53.46
6/30/12 15:00	53.81	53.12	53.32	53.56	53.83	53.65	53.84	53.28	53.3	53.06	53.27	53.5	53.46
6/30/12 16:00	53.74	53.3	53.43	53.6	53.86	53.6	54.52	53.25	53.63	53.03	53.42	53.05	53.54
6/30/12 17:00	53.89	53.09	53.33	53.61	53.96	53.6	53.79	53.39	53.22	52.99	53.41	53.14	53.45
6/30/12 18:00	53.92	53.12	53.33	53.59	54.11	53.66	53.72	53.25	53.36	53.02	53.54	53.12	53.48
6/30/12 19:00	53.98	53.06	53.26	53.47	53.91	53.75	53.97	53.39	53.18	53.15	53.98	53	53.51
6/30/12 20:00	53.89	53.2	53.28	53.49	53.86	53.78	54.28	53.42	53.23	53.29	53.33	53.14	53.52
6/30/12 21:00	53.78	53.33	53.27	53.43	53.86	53.74	53.92	58.37	53.2	53.02	53.59	56.03	53.51
6/30/12 22:00	53.9	53.42	53.17	53.44	53.96	53.73	53.72	53.91	53.25	53.11	53.51	53.09	53.52
6/30/12 23:00	53.58	53.02	53.12	53.39	53.89	53.66	53.93	53.19	53.34	53.34	53.64	53.23	53.44
7/1/12 0:00	53.79	53.06	53.13	53.5	53.67	53.9	53.64	53.34	53.16	53.13	53.6	52.95	53.41
7/1/12 1:00	54.73	52.84	53.17	53.51	53.92	53.49	53.69	53.54	52.98	53.3	53.8	53.45	53.54

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-9: Measured Distance-to-Bottom (cm)													
Date & Time	Transducer #												
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
7/1/12 2:00	53.86	52.92	53.2	53.34	54.04	53.54	53.7	53.55	53.66	52.97	53.19	52.97	53.41
7/1/12 3:00	53.42	53.12	53.24	53.2	53.1	53.15	54.11	55.6	53.25	53.59	53.57	53.41	53.56
7/1/12 4:00	53.27	53.13	52.92	53.07	53.13	53.35	54.26	53.91	53.2	53.22	54.04	53.42	53.41
7/1/12 5:00	53.58	53.3	53.2	53.07	53.2	53.42	54.5	53.82	52.96	53.21	53.46	53.56	53.44
7/1/12 6:00	53.27	53.02	53.3	53.36	0	53.98	53.81	54.37	53.2	53.45	53.99	54.15	53.63
7/1/12 7:00	53.31	53.05	53.29	53.53	53.73	53.92	53.85	53.94	53.16	53.64	53.99	53.78	53.60
7/1/12 8:00	53.27	53.08	53.29	53.46	54.12	53.88	53.85	59.27	53.65	53.26	53.99	53.48	53.58
7/1/12 9:00	53.43	53.05	53.36	54.11	53.57	53.87	53.98	54.05	53.26	53.26	53.85	54.12	53.66
7/1/12 10:00	53.45	53.03	53.34	53.29	53.75	53.96	53.9	54.52	53.25	53.27	53.78	53.85	53.62
7/1/12 11:00	53.44	53.13	53.26	53.36	54.13	53.94	53.96	53.89	53.85	53.2	53.65	53.42	53.60
7/1/12 12:00	53.51	53.06	53.41	53.28	53.8	54.21	54.09	54	53.07	53.12	54	54.03	53.63
7/1/12 13:00	53.49	52.99	53.12	53.24	53.84	54.09	53.79	53.92	53.31	53.08	53.77	53.47	53.51
7/1/12 14:00	53.33	52.93	53.35	53.34	54.04	53.93	54.08	57.95	53.31	53.33	53.84	53.49	53.54
7/1/12 15:00	53.39	52.83	52.98	53.28	53.48	53.93	53.74	53.97	53.35	53.14	53.73	53.52	53.45
7/1/12 16:00	53.27	52.8	53.27	53.25	53.48	53.63	53.61	53.85	53.18	53.25	53.48	53.7	53.40
7/1/12 17:00	53.44	53.5	53	53.24	53.49	53.72	53.66	53.63	53.15	53.31	53.6	53.66	53.45
7/1/12 18:00	53.34	52.77	52.99	53.15	53.36	53.57	53.6	53.57	53.15	53.31	53.6	53.63	53.34
7/1/12 19:00	53.21	52.72	53.01	53.14	53.38	53.58	53.61	53.57	53.12	53.32	53.54	53.46	53.31
7/1/12 20:00	53.16	52.76	53.12	53.17	53.9	53.72	53.47	54.19	53.17	53.06	53.56	53.47	53.40
7/1/12 21:00	53.14	52.72	53.18	53.12	53.57	53.84	53.54	53.73	53.53	53.19	53.33	53.85	53.40
7/1/12 23:00	52.93	52.96	53.37	53.37	53.66	53.83	55.45	53.79	53.15	53.05	53.5	53.99	53.42
7/2/12 0:00	53.21	52.79	52.59	53.2	53.53	53.63	53.34	53.69	53.26	53.22	53.4	53.71	53.30
7/2/12 1:00	53.02	52.64	52.78	53.93	53.37	52.92	53.86	53.83	58.95	53.65	53.26	53.91	53.38
7/2/12 3:00	53.99	53.67	53.76	53.81	53.55	54.13	54.24	54.63	53.62	53.49	53.48	52.87	53.77
7/2/12 4:00	54.15	53.91	53.9	54.02	53.4	53.75	54.17	54.68	53.57	53.32	53.44	53.79	53.84

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-10: Measured Distance-to-Bottom (cm)													
Date & Time	Transducer #												
	1	3	4	6	7	8	10	11	12	13	15	16	Ave
7/2/12 5:00	53.93	53.63	53.11	53.12	53.56	54.24	53.88	54.31	53.89	53.95	53.97	53.68	53.77
7/2/12 6:00	53.85	53.67	53.35	53.07	53.41	54.19	53.57	53.61	53.79	54.04	54.09	53.79	53.70
7/2/12 7:00	53.31	53.4	53.09	53.46	53.78	54.19	54.47	54.55	53.81	53.39	53.12	53.66	53.69
7/2/12 8:00	53.19	53.11	53.47	53.67	53.66	53.62	54.31	54.2	53.9	53.49	52.95	53.5	53.59
7/2/12 9:00	52.96	53.31	53.54	54.27	53.41	53.23	54.34	54.21	54.69	53.84	53.37	53.42	53.72
7/2/12 10:00	53.11	53.4	53.5	53.57	53.03	53.12	54.24	54.12	54.35	54.13	53.77	53.23	53.63
7/2/12 11:00	53.02	53.43	53.4	53.83	53.22	53.15	54.01	54.63	54.8	54.18	53.57	53.88	53.76
7/2/12 12:00	52.83	53.4	53.34	53.23	53.01	52.96	53.59	53.41	54.37	54.18	53.88	53.88	53.51
7/2/12 13:00	53.36	53.61	53.47	53.14	53.05	52.97	53.5	53.48	54.32	54.17	54.12	54.04	53.60
7/2/12 14:00	52.87	53.36	53.39	53.41	52.92	52.97	53.56	53.69	54.34	54.17	53.86	53.7	53.52
7/2/12 15:00	52.89	53.31	53.33	53.46	52.92	52.93	53.56	53.36	54.22	55.72	53.9	53.67	53.61
7/2/12 16:00	52.97	53.27	53.32	53.51	52.88	52.9	53.72	53.46	54.96	54.04	53.73	53.67	53.54
7/2/12 17:00	52.88	53.31	53.24	53.56	53.35	52.91	53.35	66.33	54.3	54.02	54.03	53.62	53.51
7/2/12 18:00	52.82	53.35	53.2	53.43	53.33	52.93	53.48	60.93	54.12	54.06	53.83	53.45	53.45
7/2/12 19:00	52.93	53.36	53.2	53.48	52.92	53.04	53.69	53.63	54.54	54.63	53.71	53.95	53.59
7/2/12 20:00	53.33	53.34	53.27	53.45	52.84	52.8	53.6	53.33	54	53.91	53.59	53.41	53.41
7/2/12 21:00	53.5	53.26	53.39	53.56	53.07	52.88	53.29	53.25	54.13	54.02	53.73	53.94	53.50
7/2/12 22:00	53.37	53.77	53.33	53.68	53.03	53.18	53.77	53.25	54.07	53.97	53.9	54.02	53.61
7/2/12 23:00	53.45	53.33	53.51	53.6	53.27	52.96	53.48	53.57	54.21	54.09	53.93	53.23	53.55
7/3/12 0:00	53.4	53.34	53.42	53.72	53.08	52.99	53.96	53.83	54.16	54.03	54.07	53.87	53.66
7/3/12 1:00	53.36	53.34	53.42	53.67	53.33	53.08	53.65	53.47	54.09	53.94	53.96	53.9	53.60
7/3/12 2:00	53.38	53.33	53.43	53.64	53.08	53.1	53.49	53.64	54.08	54.08	53.91	54.08	53.60
7/3/12 3:00	53.51	53.37	53.44	53.66	53.08	53.02	53.53	53.49	54.18	53.91	53.97	54.22	53.62
7/3/12 4:00	53.46	53.42	53.51	53.56	53.41	53.02	53.37	53.25	54.07	54.07	53.78	54.24	53.60
7/3/12 5:00	53.58	53.42	53.58	53.71	53.47	53.04	53.52	56.1	54.13	54.07	54.03	54.31	53.71

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Table B-11: Measured Distance-to-Bottom (cm)													
Date & Time	**Transducer #**												
	1	**3**	**4**	**6**	**7**	**8**	**10**	**11**	**12**	**13**	**15**	**16**	**Ave**
7/3/12 6:00	53.46	53.45	53.51	53.72	53.28	53.13	58.25	53.48	54.01	54.08	53.96	53.65	53.61
7/3/12 7:00	53.48	53.48	53.5	53.75	53.36	53.16	54.08	53.91	54.16	54.22	53.99	53.88	53.75
7/3/12 8:00	53.48	53.5	53.58	53.82	53.27	53.28	53.87	54.02	54.09	54.2	53.99	54.05	53.76
7/3/12 9:00	53.59	53.47	53.64	53.6	53.23	53.18	58	53.46	54.45	54.15	53.97	53.93	53.70
7/3/12 10:00	53.49	53.57	53.61	54.15	53.43	53.18	53.72	53.53	54.19	54.27	54.02	53.85	53.75
7/3/12 11:00	53.48	53.5	53.7	53.61	53.23	53.13	53.56	53.54	54.1	53.95	54.06	53.8	53.64
7/3/12 12:00	53.47	53.45	53.63	53.6	53.24	53.13	53.66	53.44	54.19	54.52	54.02	53.76	53.68
7/3/12 13:00	53.43	53.86	53.63	53.56	53.49	53.13	53.36	53.48	54.3	53.99	53.96	53.74	53.66
7/3/12 14:00	53.41	53.51	53.51	53.48	53.13	53.01	53.3	53.29	53.94	53.98	53.85	54.03	53.54
7/3/12 15:00	53.32	53.47	53.45	53.46	53.22	53	59.64	53.49	53.95	53.81	53.81	53.6	53.51
7/3/12 16:00	0	53.41	53.35	53.42	53.05	53.11	53.41	53.14	53.87	53.67	54.01	53.8	53.48
7/3/12 17:00	53.21	53.35	53.35	53.37	52.97	53.01	53.15	53.12	53.85	53.97	53.82	53.67	53.40
7/3/12 18:00	53.16	53.24	53.25	53.32	53.12	52.98	53.19	53.28	54.02	53.65	53.78	53.66	53.39
7/3/12 19:00	53.2	53.42	53.35	53.36	53.16	52.99	53.15	53.31	53.7	53.7	53.74	53.68	53.40
7/3/12 20:00	53.18	53.24	53.23	53.36	53.19	52.97	53.57	53.3	53.83	53.62	53.69	53.91	53.42
7/3/12 21:00	53.21	53.24	53.26	53.3	53.04	53.07	53.26	53.15	53.8	53.7	53.75	53.52	53.36
7/3/12 22:00	53.29	53.24	53.27	53.3	52.92	52.89	53.24	53.29	53.83	53.65	53.63	53.52	53.34
7/3/12 23:00	53.32	53.42	53.3	53.4	53.01	52.96	53.25	53.16	54	53.73	53.89	53.43	53.41

Red font indicates data not incorporated into average distance due to outlying nature of measurement

Appendix C: YSI 600 OMS Data from Currituck Sound

Table C-1: Temperature, Salinity, Turbidity

Date & Time	Temp. (°C)	Salinity (ppt)	Turbidity (NTU)	Date & Time	Temp. (°F)	Salinity (ppt)	Turbidity (NTU)
6/22/12 0:00	29.75	3.45	120.5	6/24/12 4:00	28.58	3.32	205
6/22/12 1:00	30.14	3.48	118.4	6/24/12 5:00	28.49	3.35	199.2
6/22/12 2:00	29.91	3.46	117.2	6/24/12 6:00	28.17	3.34	224.6
6/22/12 3:00	29.66	3.45	117.6	6/24/12 7:00	27.95	3.31	240.2
6/22/12 4:00	29.63	3.48	118.6	6/24/12 8:00	27.82	3.3	217.9
6/22/12 5:00	29.65	3.56	115.2	6/24/12 9:00	27.82	3.28	236
6/22/12 6:00	29.43	3.6	110.2	6/24/12 10:00	27.82	3.28	233.3
6/22/12 7:00	29.15	3.72	117.1	6/24/12 11:00	27.52	3.25	241
6/22/12 8:00	29.02	3.76	106.6	6/24/12 12:00	27.55	3.32	250.2
6/22/12 9:00	28.81	3.71	116.6	6/24/12 13:00	26.74	3.25	262.6
6/22/12 10:00	28.49	3.77	113.5	6/24/12 14:00	26.8	3.18	258.3
6/22/12 11:00	28.19	3.84	117.3	6/24/12 15:00	27.14	3.18	246.4
6/22/12 12:00	28.05	3.85	121.6	6/24/12 16:00	27.13	3.16	270.8
6/22/12 13:00	27.84	3.9	121.5	6/24/12 17:00	27.39	3.18	255.5
6/22/12 14:00	27.7	3.86	124.2	6/24/12 18:00	27.71	3.2	268
6/22/12 15:00	27.56	3.85	116.6	6/24/12 19:00	28.43	3.2	291.7
6/22/12 16:00	27.57	3.93	133.7	6/24/12 20:00	28.33	3.18	281.5
6/22/12 17:00	27.73	3.9	133	6/24/12 21:00	28.87	3.2	313.3
6/22/12 18:00	28.02	3.96	138.8	6/24/12 22:00	29.11	3.22	279.9
6/22/12 19:00	28.47	3.94	135.7	6/24/12 23:00	29.44	3.31	319.9
6/22/12 20:00	29.01	4.06	134.9	6/25/12 0:00	29.7	3.38	319.8
6/22/12 21:00	29.58	4.15	126.8	6/25/12 1:00	29.49	3.29	307
6/22/12 22:00	30.08	4.01	130.9	6/25/12 2:00	29.42	3.27	270
6/22/12 23:00	30.1	3.53	143.2	6/25/12 3:00	29.56	3.28	266.9
6/23/12 0:00	30.73	3.88	134.7	6/25/12 4:00	29.47	3.31	282.4
6/23/12 1:00	30.85	3.92	129.8	6/25/12 5:00	29.3	3.43	216.4
6/23/12 2:00	30.5	3.7	120.6	6/25/12 6:00	29.08	3.39	224.5
6/23/12 3:00	30.68	4.05	121.7	6/25/12 7:00	28.78	3.35	204.3
6/23/12 4:00	30.29	3.89	135.8	6/25/12 8:00	28.47	3.41	249.1
6/23/12 5:00	30.03	3.97	135.9	6/25/12 9:00	28.43	3.39	229
6/23/12 6:00	29.76	3.93	139	6/25/12 10:00	28.28	3.53	256.5
6/23/12 7:00	29.56	3.64	117.6	6/25/12 11:00	28.27	3.59	265.6
6/23/12 8:00	28.99	3.49	140.4	6/25/12 12:00	28.08	3.7	261.9
6/23/12 9:00	29.07	3.68	157.3	6/25/12 13:00	27.91	3.74	241.3
6/23/12 15:00	27.91	3.52	169.9	6/25/12 14:00	27.77	3.76	232.5
6/23/12 16:00	27.93	3.48	178.7	6/25/12 15:00	27.7	3.75	205.3
6/23/12 17:00	27.93	3.47	160.1	6/25/12 16:00	27.75	3.81	240.2
6/23/12 18:00	28.2	3.43	182.3	6/25/12 17:00	27.87	3.96	238
6/23/12 19:00	28.7	3.38	183.1	6/25/12 18:00	28.11	3.91	223.6
6/23/12 20:00	29.15	3.35	185.4	6/25/12 19:00	28.49	4.04	233.5
6/23/12 21:00	29.68	3.38	182.6	6/25/12 20:00	28.99	4.05	245.4
6/23/12 22:00	30	3.36	173.1	6/25/12 21:00	29.63	4.11	241.7
6/23/12 23:00	30.02	3.38	192.9	6/25/12 22:00	30.11	3.86	227.6
6/24/12 0:00	29.54	3.37	203.1	6/25/12 23:00	30.51	4.14	238.9
6/24/12 1:00	28.93	3.34	217.5	6/26/12 0:00	30.71	4.14	193
6/24/12 2:00	28.65	3.31	234.1	6/26/12 1:00	30.79	4.01	199.9
6/24/12 3:00	28.6	3.32	187.6	6/26/12 2:00	30.58	3.93	212.4

Table C-2: Temperature, Salinity, Turbidity							
Date & Time	**Temp. (°C)**	**Salinity (ppt)**	**Turbidity (NTU)**	**Date & Time**	**Temp. (°F)**	**Salinity (ppt)**	**Turbidity (NTU)**
6/26/12 3:00	30.19	4.04	199.9	6/28/12 2:00	27.71	3.13	336.7
6/26/12 4:00	29.73	3.85	205.4	6/28/12 3:00	27.1	3.08	310.6
6/26/12 5:00	29.53	3.87	202.6	6/28/12 4:00	27.01	3.07	298.8
6/26/12 6:00	29.28	3.87	188	6/28/12 5:00	26.58	3.11	314.9
6/26/12 7:00	28.99	3.85	177.1	6/28/12 6:00	26.4	3.1	315.9
6/26/12 8:00	28.57	3.96	169.1	6/28/12 7:00	26.44	3.21	299.8
6/26/12 9:00	28.23	3.93	166.6	6/28/12 8:00	26.05	3.24	299.3
6/26/12 10:00	27.99	3.94	165.7	6/28/12 9:00	25.93	3.27	288
6/26/12 11:00	27.7	3.9	166	6/28/12 10:00	25.79	3.26	272.7
6/26/12 12:00	27.28	3.94	165.2	6/28/12 11:00	25.61	3.24	274.2
6/26/12 13:00	27.23	3.68	171.3	6/28/12 12:00	25.5	3.27	281.9
6/26/12 14:00	26.71	3.5	177	6/28/12 13:00	25.33	3.26	275.2
6/26/12 15:00	26.5	3.36	170.4	6/28/12 14:00	25.13	3.27	272.7
6/26/12 16:00	26.01	3.35	177.6	6/28/12 15:00	24.94	3.28	281.4
6/26/12 17:00	25.55	3.31	181.5	6/28/12 16:00	24.99	3.17	283.5
6/26/12 18:00	27.19	3.35	185.4	6/28/12 17:00	25.1	3.16	263.6
6/26/12 19:00	26.93	3.33	193.6	6/28/12 18:00	25.36	3.15	232.9
6/26/12 20:00	26.43	3.23	198.6	6/28/12 19:00	25.8	3.18	238.7
6/26/12 21:00	27.2	3.2	215.1	6/28/12 20:00	26.28	3.19	241
6/26/12 22:00	27.56	3.19	217.5	6/28/12 21:00	26.8	3.19	257.6
6/26/12 23:00	27.71	3.18	237.7	6/28/12 22:00	27.21	3.15	268.3
6/27/12 0:00	27.62	3.24	236.6	6/28/12 23:00	27.58	3.22	280.1
6/27/12 1:00	27.35	3.16	243.1	6/29/12 0:00	28.01	3.29	284.7
6/27/12 2:00	27.16	3.15	255.4	6/29/12 1:00	28.3	3.24	280.5
6/27/12 3:00	27.02	3.17	262.2	6/29/12 2:00	28.31	3.26	285.9
6/27/12 4:00	26.77	3.17	259.1	6/29/12 3:00	28.19	3.29	414.8
6/27/12 5:00	26.57	3.14	260.9	6/29/12 4:00	27.91	3.27	307.9
6/27/12 6:00	26.35	3.16	263.4	6/29/12 5:00	27.66	3.3	293.2
6/27/12 7:00	26.12	3.17	259.9	6/29/12 6:00	27.41	3.19	293.6
6/27/12 8:00	25.99	3.19	247.5	6/29/12 7:00	27.04	3.13	272.7
6/27/12 9:00	25.86	3.19	221.4	6/29/12 8:00	26.72	3.14	1042.9
6/27/12 10:00	25.62	3.17	231.4	6/29/12 9:00	26.55	3.11	9.1
6/27/12 11:00	25.49	3.17	241.8	6/29/12 10:00	26.46	3.13	9.2
6/27/12 12:00	25.07	3.16	242.7	6/29/12 11:00	26.27	3.15	9.7
6/27/12 13:00	24.87	3.13	245.6	6/29/12 12:00	26.22	3.24	9.7
6/27/12 14:00	25.02	3.12	248.6	6/29/12 13:00	26.02	3.3	9.5
6/27/12 15:00	24.76	3.14	260.6	6/29/12 14:00	25.97	3.33	10.2
6/27/12 16:00	24.48	3.15	250.2	6/29/12 15:00	25.85	3.37	10.9
6/27/12 17:00	24.51	3.14	249.8	6/29/12 16:00	25.96	3.56	11.1
6/27/12 18:00	25.12	3.13	271.3	6/29/12 17:00	26.02	3.52	10.8
6/27/12 19:00	25.95	3.15	250.4	6/29/12 18:00	26.32	3.53	9.7
6/27/12 20:00	26.42	3.18	287.9	6/29/12 19:00	26.77	3.63	9.7
6/27/12 21:00	26.78	3.16	304	6/29/12 20:00	27.26	3.71	9
6/27/12 22:00	27.39	3.15	315.4	6/29/12 21:00	27.81	3.72	10.1
6/27/12 23:00	27.3	3.13	329.2	6/29/12 22:00	28.51	3.71	10.1
6/28/12 0:00	26.83	3.1	350.6	6/29/12 23:00	28.65	3.29	10
6/28/12 1:00	27.12	3.15	360.4	6/30/12 0:00	29.22	3.37	11.7

Table C-3: Temperature, Salinity, Turbidity							
Date & Time	Temp. (°C)	Salinity (ppt)	Turbidity (NTU)	Date & Time	Temp. (°F)	Salinity (ppt)	Turbidity (NTU)
6/30/12 1:00	29.53	3.38	11.3	7/2/12 0:00	30.46	3.01	16.2
6/30/12 2:00	29.48	3.22	10.7	7/2/12 1:00	30.43	3.05	17.5
6/30/12 3:00	29.48	3.22	11.8	7/2/12 2:00	29.85	3.12	18.5
6/30/12 4:00	29.56	3.24	11.8	7/2/12 3:00	29.52	3.2	21.4
6/30/12 5:00	29.19	3.13	16.1	7/2/12 4:00	28.87	3.43	20.3
6/30/12 6:00	29.14	3.12	10.9	7/2/12 5:00	28.73	3.65	19.8
6/30/12 7:00	29.1	3.16	12.8	7/2/12 6:00	28.38	3.53	22.3
6/30/12 8:00	29.12	3.21	12.3	7/2/12 7:00	28.04	3.53	23.9
6/30/12 9:00	28.75	3.22	11.2	7/2/12 8:00	27.72	3.62	24.2
6/30/12 10:00	28.6	3.33	12.5	7/2/12 9:00	27.38	3.62	27.2
6/30/12 11:00	28.19	3.11	13.4	7/2/12 10:00	26.96	3.22	24.4
6/30/12 12:00	28	3.11	12.7	7/2/12 11:00	26.57	3.26	23.7
6/30/12 13:00	28.02	3.11	12.8	7/2/12 12:00	26.54	3.45	22.6
6/30/12 14:00	27.8	3.11	14	7/2/12 13:00	26.13	3.3	22.9
6/30/12 15:00	27.81	3.1	13.9	7/2/12 14:00	25.9	3.23	21.4
6/30/12 16:00	27.36	3.09	13.7	7/2/12 15:00	25.8	3.26	20.2
6/30/12 17:00	27.53	3.16	13.4	7/2/12 16:00	25.87	3.15	20.2
6/30/12 18:00	27.99	3.14	13.4	7/2/12 17:00	26.02	3.16	19.4
6/30/12 19:00	28.64	3.1	13	7/2/12 18:00	26.58	3.06	19.4
6/30/12 20:00	29.05	3.07	13.4	7/2/12 19:00	26.88	3.03	20.6
6/30/12 21:00	29.43	3.07	14.6	7/2/12 20:00	27.26	2.99	20.7
6/30/12 22:00	28.86	3.07	14.1	7/2/12 21:00	27.74	3	20.6
6/30/12 23:00	28.56	3.05	14.2	7/2/12 22:00	28.12	2.99	21.4
7/1/12 0:00	28.46	3.05	14.5	7/2/12 23:00	28.15	3	21.7
7/1/12 1:00	28.61	3.01	17.7	7/3/12 0:00	28.25	2.99	21.8
7/1/12 2:00	28.35	3.07	14.4	7/3/12 1:00	28.68	3.01	22.7
7/1/12 3:00	28.52	3.1	16.2	7/3/12 2:00	28.18	3.02	21.1
7/1/12 4:00	28.74	3.08	16	7/3/12 3:00	27.8	2.99	20.4
7/1/12 5:00	28.85	3.09	18.4	7/3/12 4:00	27.58	3.03	20.8
7/1/12 6:00	28.53	3.1	19.8	7/3/12 5:00	27.74	3.09	18
7/1/12 7:00	28.25	3.07	16.5	7/3/12 6:00	27.74	3.06	17
7/1/12 8:00	28.02	3.12	17.3	7/3/12 7:00	27.68	3.04	16.2
7/1/12 9:00	27.77	3.12	15	7/3/12 8:00	27.7	3.04	15.8
7/1/12 10:00	27.61	3.09	15.5	7/3/12 9:00	27.49	3.01	17.2
7/1/12 11:00	27.3	3.05	15.9	7/3/12 10:00	27.27	3.06	16.3
7/1/12 12:00	27.03	3.1	17	7/3/12 11:00	27.22	3.02	17.8
7/1/12 13:00	26.96	3.09	17.2	7/3/12 12:00	26.98	2.98	17.6
7/1/12 14:00	26.87	3.13	16.1	7/3/12 13:00	27.06	3.05	17
7/1/12 15:00	26.76	3.05	18	7/3/12 14:00	26.89	2.99	17.2
7/1/12 16:00	26.71	3.08	16.9	7/3/12 15:00	26.85	2.99	16.9
7/1/12 17:00	26.95	3.08	18.3	7/3/12 16:00	26.84	2.99	17.6
7/1/12 18:00	27.29	3.08	15.9	7/3/12 17:00	26.96	3.04	18
7/1/12 19:00	27.78	3.1	13.8	7/3/12 18:00	27.34	3.06	18.8
7/1/12 20:00	28.48	3.09	14.2	7/3/12 19:00	27.9	3.04	18.3
7/1/12 21:00	29.18	3.05	13.4	7/3/12 20:00	28.31	3.03	20
7/1/12 22:00	29.85	3.01	14.4	7/3/12 21:00	28.8	3.05	19.1
7/1/12 23:00	30.2	3.06	13.2	7/3/12 22:00	29.32	3.03	18.6

Table C-4: Temperature, Salinity, Turbidity			
Date & Time	**Temp. (°C)**	**Salinity (ppt)**	**Turbidity (NTU)**
7/3/12 23:00	29.91	3.12	18.2
7/4/12 0:00	30.19	3.13	3.25
7/4/12 1:00	30.14	3.18	3.27
7/4/12 2:00	29.92	3.19	3.32
7/4/12 3:00	29.65	3.2	3.39
7/4/12 4:00	29.42	3.25	3.43

Appendix D: Statistical Test Results

Difference Between MTA Reported motion & SID Motion 1 cm vs 0.1 cm (α=0.05)		
t-Test: Two-Sample Assuming Unequal Variances		
	1 cm Motion Test	*0.1 cm Motion Test*
Mean	**-7.476E-03**	**7.143E-05**
Variance	3.7583E-04	3.5052E-05
Observations	9	9
Hypothesized Mean Difference	0	
Degrees of freedom	16	
t Stat	1.1170	
t Critical two-tail	**2.1009**	
t-stat < t-critical, accept null hypothesis mean1=mean2		

Difference Between MTA Reported motion & SID Motion 0.1 cm vs 0.05 cm (α=0.05)		
t-Test: Two-Sample Assuming Unequal Variances		
	0.1cm Motion Test	*0.05 cm Motion Test*
Mean	**7.143E-05**	**2.952E-03**
Variance	3.5052E-05	4.5390E-05
Observations	9	9
Hypothesized Mean Difference	0	
Degrees of freedom	16	
t Stat	**0.9636**	
t Critical two-tail	**2.1009**	
t-stat < t-critical, accept null hypothesis mean1=mean2		

Difference Between MTA Reported motion & SID Motion 1 cm vs 0.05 cm (α=0.05)		
t-Test: Two-Sample Assuming Unequal Variances		
	1 cm Motion Test	*0.05 cm Motion Test*
Mean	**-7.476E-03**	**2.952E-03**
Variance	3.7583E-04	4.5390E-05
Observations	9	9
Hypothesized Mean Difference	0	
Degrees of freedom	16	
t Stat	**1.5244**	
t Critical two-tail	**2.1009**	
t-stat < t-critical, accept null hypothesis mean1=mean2		

MTA Distance Measurements Before June 29th vs After June 29th (α=0.05)		
t-Test: Two-Sample Assuming Unequal Variances		
	6/22/12-6/29/12	*6/29/12-7/4/12*
Mean	**52.89**	**53.49**
Variance	0.3580	0.3927
Observations	149	117
Hypothesized Mean Difference	0	
Degrees of freedom	264	
t Stat	**7.8614**	
t Critical two-tail	**1.9719**	
t-stat > t-critical, Reject null hypothesis mean1=mean2		