Appendix 7-C: Suspended Sediment Monitoring during Pre-Installation Trials for the Champlain Hudson Power Express Project – Lake Champlain Report

Suspended Sediment Monitoring during Pre-Installation Trials for the Champlain Hudson Power Express Project

Lake Champlain Report

NYSPSC Certificate Case 10-T-0139

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Acronyms and Abbreviations

ABS	Acoustic backscatter
ADCP	Acoustic Doppler current profiler
Alpha	Alpha Analytical, Inc.
APHA	American Public Health Association
BDL	Below the method detection limit
Certificate	Certificate of Environmental Compatibility and Public Need
CHPE	Champlain Hudson Power Express
CMI	Caldwell Marine, Inc.
COC	Chain of custody
CTD	Conductivity-temperature-depth sensors
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HVDC	High voltage direct current
The Monitoring Plan	Suspended Sediment / Water Quality Monitoring Plan for CHPE (2020 revision)
Normandeau	Normandeau Associates, Inc.
NYSDEC	New York State Department of Environmental Conservation
NYSDPS	New York State Department of Public Service
NYSPSC	New York State Public Service Commission
OBS	Optical backscatter
QAPP	Quality Assurance Project Plan
QC	Quality control
SM	Standard Method
SOP	Standard operating procedure
TRDI	Teledyne RD Instruments
TSS	Total suspended solids
USGS	United States Geological Survey
VMT	Velocity Mapping Toolbox
WQC	Water Quality Certification pursuant to Section 401 of the Federal Water Pollution Control Act, 33 U.S.C § 1341, and Article VII of the New Yor Public Service Law

Executive Summary

CHPE LLC contracted Normandeau Associates, Inc. ("Normandeau") to conduct suspended sediment monitoring to assess the levels of sediment resuspension from the jet and shear plow operations during the pre-installation trials in Lake Champlain and the Hudson River. Additionally, a secondary objective of the pre-installation trial monitoring was to describe quantitative relationships (if any) among the acoustic and optical backscatter data with the laboratory-derived total suspended solids ("TSS") data in attempt to calibrate remote sensing methods for near real-time TSS monitoring during the submarine cable installation activities anticipated to occur from 2024 through 2025. The intent of the TSS sampling during the trials was to monitor sediment plumes from the jet and shear plow operations for potential exceedance of TSS standards set forth in CHPE, LLC's Section 401 Water Quality Certificate ("WQC"). This report documents the activities and results from TSS monitoring during the pre-installation trials in Lake Champlain.

The pre-installation jet plow trial occurred along a 1,000-foot route in Upper Lake Champlain on August 31, 2022. All TSS levels from samples collected at the Upper Lake site before, during, and after the trial (N = 39 samples) had TSS values below the detection limit ("BDL") of the laboratory analysis. The pre-installation shear plow trial occurred along a 1,000-foot route in Lower Lake Champlain on September 1, 2022. TSS measurements collected during the shear plow trial showed slightly higher levels of TSS, but none approached exceeding ambient concentrations by 100 mg/L as per the condition described in the WQC (N = 8 out of 39 samples were BDL). An increase of 4 mg/L was the maximum observed value above background for TSS levels during the shear plow trial in the Lower Lake. The TSS levels for both trials were generally indistinguishable from ambient TSS levels (where detectable) which, based on these data, suggest that TSS monitoring requirements could potentially be relaxed for Lake Champlain (e.g., less frequent sampling). Particularly at the Upper Lake trial site, it appears likely that any sediments that are resuspended due to the plow operations either do not remain in suspension very long and/or do not form a "plume" because of the weak currents observed at the Upper Lake trial location.

Calibration curves for both optical backscatter ("OBS") and acoustic backscatter ("ABS") to estimate TSS were established based on the TSS sample data collected concurrently with OBS and ABS during the TSS monitoring. While statistically significant calibration curves were established for TSS to both OBS and ABS, the R^2 of the regressions and model diagnostic parameters for the OBS-TSS regression clearly indicate OBS was the better predictor of TSS values between the two methods for the conditions encountered and that were sampled during the trials. Different hydrological or background sediment characteristics could change these calibration equations and future regression models. For conditions encountered in these regions of Lake Champlain and based on the data collected and analyzed during the pre-installation trials, the OBS sensor may be more appropriate for guiding compliance decisions during active construction in the lake.

In summary, the trials in Lake Champlain demonstrated that (1) jet and shear plow activities produced no observable plume or a narrow range of slightly elevated TSS levels; (2) the ADCP may not be appropriate for estimating TSS levels in real-time during the installation phase in Lake Champlain; and (3) both the remote sensing calibrations to TSS exhibited low (ABS) to moderate (OBS) predictive power and may be subject to modification during the installation phase of the Project to reflect hydrological and sediment conditions encountered that were not observed during the trials.

1 Introduction

1.1 Background

The Champlain Hudson Power Express ("CHPE") transmission project ("Project") in Lake Champlain and the Hudson River will install a high-voltage direct current ("HVDC") electric transmission line capable of delivering up to 1,250 megawatts of clean renewable energy from hydroelectric generation facilities in Canada to New York City. The electric transmission line will consist of two HVDC cables buried underwater or underground. The submarine segment of CHPE transmission route is approximately 192 miles, where 97 miles are in Lake Champlain. Prior to commencing submarine installation activities, pre-installation trials are required to be conducted in Lake Champlain and the Upper Hudson River to test operational conditions of the jet plow and shear plow equipment to be used during the installation process. This report provides the results of the pre-installation trials in Lake Champlain.

1.2 Regulatory Overview

A Certificate of Environmental Compatibility and Public Need ("Certificate") for the Project was issued effective by the New York State Public Service Commission ("NYSPSC") on April 18, 2013. The Certificate contains several conditions for installation of the submarine portion of the CHPE route, including certain studies, which were adopted from the Joint Proposal of Settlement for Case 10-T-0139. One of these requirements was monitoring of suspended sediment and water quality chemical parameters in the water column during pre-installation trials of the jet plow and shear plow equipment to be used during cable installation. On October 18, 2013, CHPE submitted a monitoring plan titled *Suspended Sediment / Water Quality Monitoring Plan* (i.e., "the Monitoring Plan"). The Monitoring Plan was developed in conjunction with the Project's Water Quality Certification pursuant to Section 401 of the Federal Water Pollution Control Act, 33 U.S.C § 1341, and Article VII of the New Yor Public Service Law Section 401 ("the WQC"), as well as comments received from the New York State Department of Environmental Conservation ("NYSDEC") and the New York State Department of Public Service ("NYSDPS").

1.3 Objectives

The Monitoring Plan outlined the requirements for the suspended sediment and water quality monitoring during pre-installation trials of the jet plow and shear plow equipment, specifically the monitoring of total suspended solids ("TSS") in the water column during the pre-installation trials, as detailed in Section 3.2. The objectives of the TSS monitoring program were to assess the amount of sediment resuspension in the water column during operation of the jet plow and shear plow, and to make potential recommendations for modifications to the jet/shear plow operation or monitoring procedures based on the results of the pre-installation trials.

CHPE, LLC contracted Normandeau Associates, Inc. ("Normandeau") to conduct the suspended sediment monitoring during the pre-installation trials which included, but was not limited to, collection of site-specific measurements of TSS from water samples, concurrently with measurements of acoustic and optical backscatter to assess the levels of sediment resuspension from the jet and shear plow operations during the pre-installation trials in Lake Champlain and the Hudson River. Additionally, a secondary objective of the pre-installation trial monitoring was to attempt to describe quantitative relationships (if any) among the acoustic and optical backscatter and laboratory derived TSS data for potential development of remote sensing methods for near real-time TSS monitoring during the submarine cable installation activities anticipated to occur from 2024 through 2025.

The intent of the TSS monitoring during the trials was to assess the potential observable impact from the plow operations, with respect to the standards set forth in the WQC. This report documents the activities associated with the monitoring of TSS during the pre-installation trials in Lake Champlain.

1.4 Project Locations

The pre-installation trials documented in this report occurred in Upper and Lower Lake Champlain, as designated by the permit-defined regions of the lake to the north and south of the Lake Champlain Bridge. Figure 1-1 presents an overview map of the site locations for the jet plow (Upper Lake) and shear plow (Lower Lake) trials, with the coordinates provided by CHPE's marine construction contractor, Caldwell Marine, Inc. ("CMI"). Each trial route was planned to be approximately 1,000 ft in length.

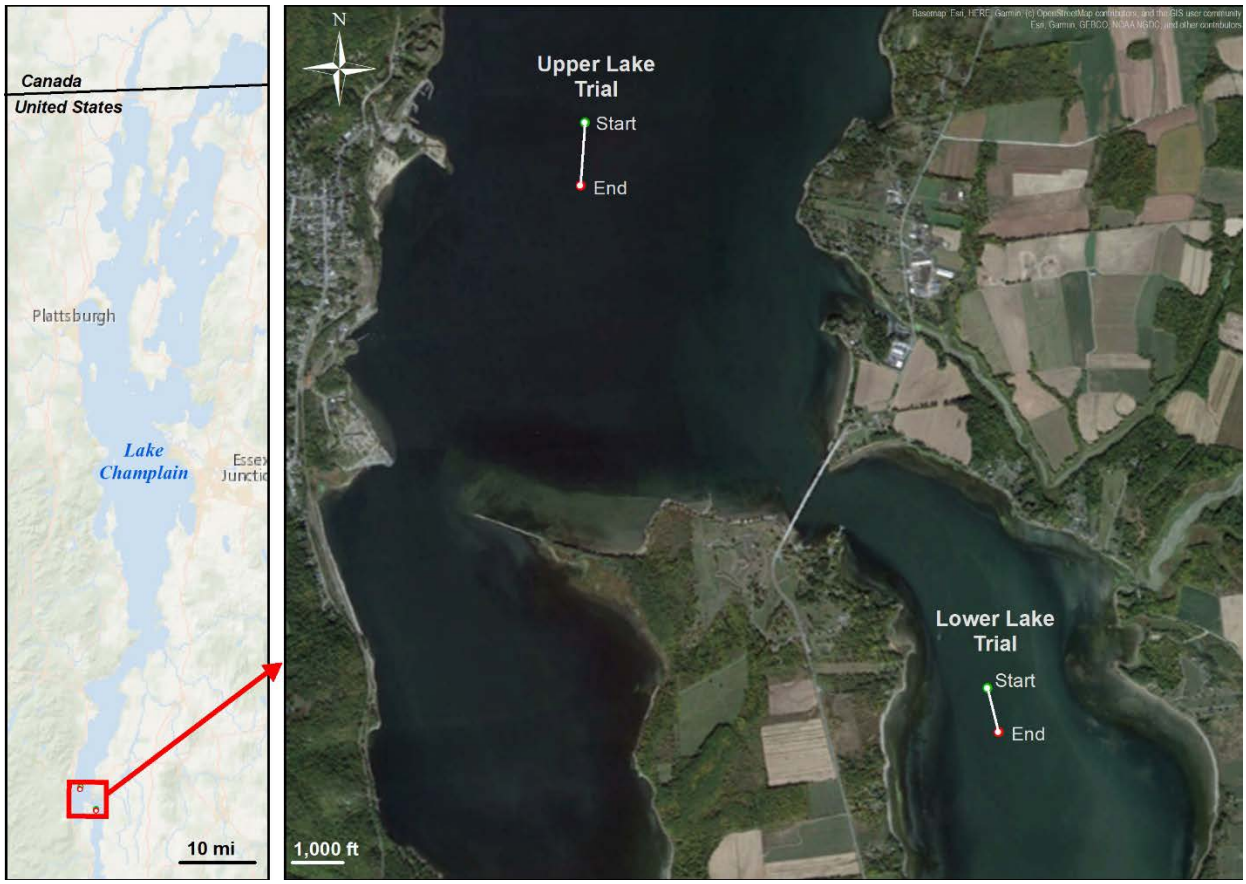

Figure 1-1. Overview of the Project site locations for the Pre-Installation trials in Lake Champlain, in the vicinity of Crown Point, NY and the Lake Champlain Bridge. The planned start and end points of both the Upper and Lower Lake Trials are presented.

2 Methods

2.1 Field Sampling

The survey operation included an acoustic Doppler current profiler ("ADCP") to collect vertical profile measurement of current velocity and relative acoustic backscatter ("ABS"); a multi-parameter sonde to collect vertical profile measurements of conductivity (salinity), temperature, and depth ("CTD"); an optical backscatter ("OBS") sensor to measure turbidity, and a stainless steel Kemmerer water bottle sampler to collect samples for subsequent laboratory measurements of TSS. Data were georeferenced by the Global Positioning System ("GPS").

For each of the Lake Champlain trial events (Upper Lake and Lower Lake), the procedures outlined in the Monitoring Plan were applied for each "TSS sampling event", which consisted of the following sampling activities:

1. ADCP measurements collected at the up- and down-current side of the plow, to confirm current direction, and to potentially estimate the location of a potential suspended sediment plume for down-current sampling;
2. Stationary collection of CTD-OBS measurements as well as water sampling to collect concurrent and collocated water samples for TSS at near-surface, mid-depth, and near-bottom depths in the water column; and
3. Concurrent ADCP measurement at the same near-surface, mid-depth, and near-bottom depths in the water column during the CTD-OBS and water sampling, to provide simultaneous ABS data.

These measurements were performed at approximately 500 ft up- and down-current of the plow as the plow traversed the trial route, as was practicable and safely navigable to achieve. The 500 ft up- and down-current distance was specified in the Monitoring Plan after the requirements in the WQC. The sampling locations on either side of the plow/barge were to be sampled as often as possible given the conditions during the duration each trial, with ADCP transects and discrete sampling conducted as outlined above and described further below.

2.1.1 Equipment

Current velocity and ABS measurements were collected with a Teledyne RD Instruments ("TRDI") 600 kHz Workhorse Sentinel ADCP, attached to a aluminum pole mount deployed from the starboard side of Normandeau's 24-foot survey vessel and submerged 0.67 m below the water surface as measured to the ADCP transducer faces. A Hemisphere Vector V500 Global Navigation Satellite System ("GNSS") receiver and antenna was mounted on the top of the pole 2.33 m directly above the ADCP and was used to collect GPS coordinates for georeferencing the ADCP data and supply positional data to HYPACK navigation software (HYPACK, version 21.0.2.0). A weatherproof laptop computer was used on the vessel to run HYPACK navigation software for real-time positioning of the vessel, and TRDI's WinRiver II (WinRiver II, version 2.23) data acquisition software was used for ADCP calibration, testing, and measurements. The software allowed configuration and saving of the ADCP sampling parameters for the survey, confirmation of the GPS signal, and the ability to review the raw data in real-time while the survey was underway. The ADCP, V500 GNSS antenna, survey laptop, and additional computer monitor were powered from a sine wave power inverter onboard the vessel. A Garmin® handheld laser rangefinder was used in the field to assess distance from the barge/plow in real-time for setting the location of the ADCP transects and CTD-OBS sampling stations.

Prior to each day's survey activities, the ADCP passed all internal system and sensor tests performed with WinRiver II. ADCP compass calibrations were also conducted at the Project area each day with the

ADCP in the deployed configuration per the manufacturer recommendations (TRDI 2020, 2021; Mueller et al. 2013). The ADCP was configured such that the acoustic signal would adequately profile the entire water column under the anticipated water quality conditions and expected site depths (up to 13 m [42 ft]). The ADCP was configured to collect data in 0.5-m bins with transmit acoustic pulses (pings) set as fast as possible, which yielded a raw profile sampling rate of approximately two pings per second (2 Hz) for most profiles. This configuration was chosen to allow for the transects to be sampled as densely as possible with respect to the vertical axis while ensuring an acoustic profile range to the lake bottom and allow for maximum data retention for analysis.

Water quality and turbidity measurements were collected with a YSI EXO3 multi-parameter sonde for CTD-OBS data collection and recorded digitally with the sonde's handheld controller during sample collection. The CTD-OBS was configured to sample at the fastest rate possible (2 Hz) to capture as much data per sample location as possible. The YSI sensors were calibrated prior to each survey per the manufacturer's recommendations and methods (YSI 2019).

Water samples for laboratory analysis of TSS were collected with a 2.2-liter Wildco® stainless-steel Kemmerer sampler. The Kemmerer sampler and CTD-OBS were mounted together with two bracket clamps such that the sampling depth of the water sample and CTD-OBS data would be collocated with respect to the water column, as practicable given the current flow. A diagram of the sampling equipment with respect to the vessel and deployment with depth is presented in Figure 2-1.

All field data collection methods followed recommendations, guidelines, procedures, and methods outlined in the respective manuals for sampling equipment (i.e., ADCP, GPS, CTD-OBS, and Kemmerer samplers).

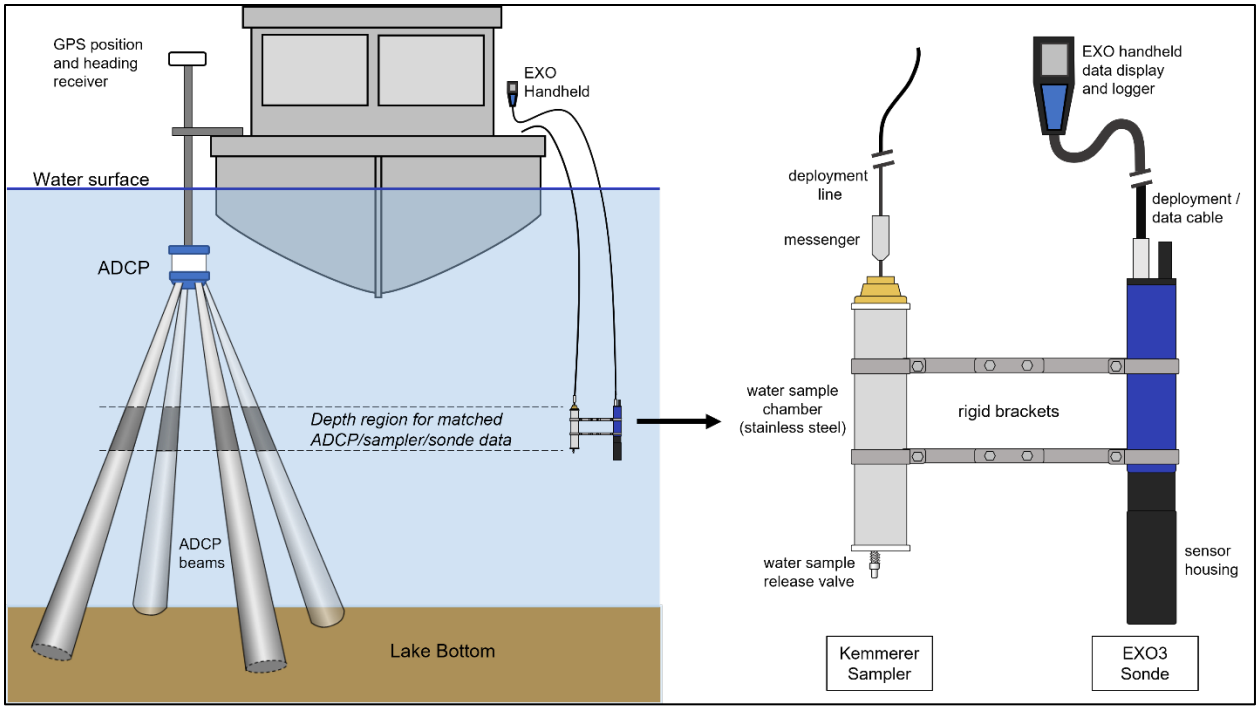

Figure 2-1. Sampling equipment schematic diagram showing the relative deployment positioning of the ADCP, CTD-OBS, and Kemmerer sampler with respect to the vessel and water column on the left-hand side. To the right is a zoomed diagram of the design of the CTD-OBS-Kemmerer mount used during TSS monitoring.

2.1.2 Sample Collection

During the pre-installation trials, sampling occurred at approximately 500 ft up- and down-current of the jet or shear plow. Once notified by personnel from CMI that the plow had commenced the trial, the procedure for each "sampling event" was performed until the approximately 1,000-ft long trial route was completed. For each sampling event, the shipboard processing occurred iteratively as follows:

1. Survey vessel attempted to verify current direction by performing two ADCP transects to collect current velocity data and confirm which side of the plow and barge were up- and down-current.
    a. Note: that for the Lake Champlain Trials, this was difficult to assess in real-time due to the extremely low current speeds (<10-15 cm/s). The transect-averaged estimated flow direction was assessed after the transects were completed and used to identify the up- and down-current locations. These were later reviewed in post-processing to determine if the Up/Down-current locations assigned in the field needed should be modified.
2. After collecting the ADCP transects, the vessel navigated to the up-current side of the plow, approximately 500 ft distance from the jet plow and in line with the plow route as best as possible, and recorded GPS coordinates and station metadata for the up-current sampling station (e.g., date/time, weather and sea state conditions, etc.).
3. A "stationary" ADCP measurement, as practicable given conditions, was started once on-station at the up-current sampling location to record concurrent ABS data with the CTD-OBS and water samples for TSS. This station's file was used to collect ABS data during the entire up-current station's sampling for CTD-OBS and water samples.

4. After starting the ADCP measurement, the CTD-OBS and Kemmerer sampler were prepared for deployment, with samples collected from near-surface, mid-depth, and near-bottom levels in the water column (but within the valid measurement range of the ADCP's acoustic beams).
5. For each sampling depth, the CTD-OBS and coupled Kemmerer sampler were lowered to the depth being sampled based on the real-time readout from the CTD-OBS handheld controller. Once at depth (e.g., 10 ft), the equipment was held in position for approximately 20 seconds before triggering the Kemmerer sampler to close. The equipment was then held in position for another 20 seconds prior to recovery to provide a sufficient time for data collection of OBS and ABS data to assess for remote sensing correlation to TSS (described in Section 3.2).
6. When the Kemmerer sampler is at the required predetermined depth, a messenger weight was be deployed on the connecting line to the sampler which closes the sampling device. Upon retrieving the Kemmerer sampler the first 10-20 mL of the collected sample was discharged to clear any potential contamination on the valve. The remaining sample was collected in lab-provided 950 mL containers which were labeled, secured, and stored on ice while on the survey vessel.
7. Steps 5 and 6 were repeated for near-surface, mid-depth, and near-bottom at each sampling station.
8. After three samples were collected at the up-current side of the plow, the survey vessel navigated to the down-current side of the plow to repeat Steps 1 through 7. This process generally took from 12-18 minutes for each up-/down-current side of the plow, and 30-40 minutes per pair of up/down-current sampling stations (i.e., "Pass"), when including navigation time.
    a. While collecting ADCP transects on the down-current side of the plow, the raw ABS data from the ADCP were reviewed in real-time to attempt to estimate the position of a suspended sediment plume, if there is one observed at 500 ft distance. When no potential plume was observed, then the down-current samples were also collected as close to in line with the plow route as possible.
9. After the down-current station's sampling was completed, the vessel navigated back to the up-current side of the plow and repeated the entire process.

After being notified by CMI that the pre-installation trial was completed, the survey vessel collected additional data that may have been required to complete the Pass, if necessary. After completion of each day of monitoring, samples were transferred to Alpha Analytical, Inc. ("Alpha"), the laboratory used for the TSS analysis, as described in more detail in Section 2.1.3. In addition to the sampling steps described above, a full-water-column CTD-OBS profile was collected before and after the trial to provide background water column conditions which may assist interpreting some of the data and provide water column temperature values to use in conjunction with ABS data processing.

2.1.3 TSS Sample Handling

After completion of each trial event, the water samples (stored on ice in coolers) were processed onshore in preparation to be transferred to a courier for Alpha, per the specifications required by the lab. All sample jar labels were reviewed against the field notes to confirm sample locations and times, and this information was provided to Alpha in the Chain-of-Custody ("COC") forms. The water samples were packed with enough packing material to prevent movement during shipping, with care taken not to pack materials too tightly. Transfer of samples occurred via couriers provided by Alpha, and all samples were kept on ice in coolers during transport.

2.2 Analytical Methods

2.2.1 Water Quality Data and TSS

The CTD-OBS data were processed using a combination of the manufacturer's software (YSI) and Normandeau-developed post-processing routines in MATLAB software (MATLAB software, Mathworks; Natick, MA). Each CTD-OBS data file corresponded to a concurrent water sample, as described in Section 2.1, and was truncated to the approximately 40-second timeframe of the water sample collection. For each measurement file, the parameters recorded at 2-Hz sampling intervals were averaged over the ~40-second water sampling interval to provide the concurrent CTD-OBS data (i.e., temperature (°C), depth (ft), salinity (PSU), turbidity/OBS [NTU]) with the TSS data from the water sample.

All water samples collected during the trials were analyzed for TSS by Alpha utilizing the laboratory analysis of dry weight TSS following Standard Method ("SM") 2540D (APHA 2018). TSS results were provided by Alpha in form of electronic data deliverables. The water quality (CTD-OBS) and TSS data were then compiled into a data table in MATLAB® with paired up-current and down-current data for each TSS sampling event (i.e., Pass), to assess whether there were observable differences in TSS levels down-current of the jet/shear plow operation during the pre-installation trials.

Additionally, the OBS data were compiled with the paired TSS data to attempt to develop a calibration relationship between OBS measured in the field and the lab-analyzed TSS data, using the OBS (predictor) with the TSS concentration (response). Linear modeling tools in MATLAB software ("fitlm" function) were used to assess the relationship between OBS and TSS, detailed below in Section 3.2.

2.2.2 ADCP Data

2.2.2.1 Relative Acoustic Backscatter

The ABS was processed from the stationary ADCP profile measurements recorded at each up/down-current station collected concurrently with the CTD-OBS and water samples described above. The raw ADCP data were processed using a combination of manufacturer's software (TRDI) and Normandeau-developed post-processing routines in MATLAB software. All raw ADCP data were first reviewed in the manufacturer's software which included checks on all acoustic parameters provided by the ADCP, verification of sampling configuration (e.g., compass and transducer depth offsets), and confirmation of the start and end times for each transect. During preliminary review, the raw ADCP data were pre-processed in WinRiver II using the quality control ("QC") parameters set based on the configuration settings in the field and each data file was examined for potential interference, bottom detection signal issues, and/or impacts from vessel wakes or sea state conditions (Mueller et al. 2013; Engel and Jackson 2017). The pre-processed data were then exported from WinRiver II as ASCII text files and imported into MATLAB for additional post-processing.

The ABS data were collected to attempt to calibrate the ABS to the lab-analyzed TSS from the concurrent water samples for developing a predictive relationship for estimating TSS in the field (*in situ*), following an established approach from numerous studies. The raw echo signal intensity is measured by the ADCP, which is proportional to the concentration of particles (i.e., suspended sediment, plankton, detritus), but to properly calibrate the ABS to TSS requires accounting for the losses due to acoustic beam spreading and acoustic absorption by water. A full derivation of the calculation of ABS is excluded here, but is well-documented in recent literature (Deines 1999 ; Gartner 2004; Wall et al 2006; Gostiaux and van Haren 2010; Wood and Gartner 2010; Mullison 2017). The approach relies on a simplified version of the sonar equation to determine the ABS (in dB) for each ADCP bin per ping shown below:

$$ABS = 10Log_{10}\left[\left(\frac{\sum_{i=i}^{4}\left(10^{K_{ci}(E_i - E_{ri})/10}\right)}{4}\right) - 1\right] + 20Log_{10}(R\gamma) + 2\alpha_w R \qquad \text{(Equation 1)}$$

where K_{ci} = beam-specific ADCP conversion factor from echo intensity counts to decibel (dB),
E_i = raw echo intensity, in counts, for each beam i,
E_{ri} = raw echo intensity noise floor, in counts, for each beam i,
R = range along the acoustic beams, in meters,
γ = near field correction factor for non-spherical spreading of energy close to the ADCP transducers (dimensionless), and
α_w = acoustic attenuation coefficient due to sound absorption by water, in dB/m.

After determining the ABS for each depth bin and ping, the ABS data were paired with the CTD-OBS and water sample data by first truncating the time series to the same ~40-second timeframe as deployed and recorded by the CTD-OBS for the field measurements, averaging the ABS for each depth bin over that truncated timeframe, and identifying the ADCP bin most closely aligned with the average depth of CTD-OBS (and TSS sample) data for each sample duration.

The ABS-to-TSS calibration approach then consists of performing a linear regression model of the paired ABS-TSS measurements collected concurrently during the TSS monitoring events, with the ABS as the predictor variable and with log10-transformed TSS concentrations as the response variable. Linear modeling tools in MATLAB software were used to assess the relationship between ABS and $\log_{10}$(TSS), as described in Section 3.2.2.

2.2.2.2 Current Velocity

Current velocity data were primarily collected to assess the up/down-current classification of the samples collected during the TSS Monitoring events. The ADCP velocity data were processed as described above and reviewed to verify the up/down-current classifications of the samples made in the field.

Current velocity measurements were reviewed in the Velocity Mapping Toolbox ("VMT") within MATLAB software (developed by U.S. Geological Survey ["USGS"]; Engel and Jackson 2017). ADCP transect data were processed with VMT to produce transect-mean cross section current velocities and any measurements that exceeded QC parameter thresholds for the transects were excluded from the review from each file (Mueller et al. 2013; Engel and Jackson 2017). These spurious points were typically end-of-profile data, low signal-to-noise ratio of the velocities due to little-to-no current flow, bubbles near the transducer faces, and any raw data identified in the data acquisition software as below thresholds or potential fish echoes. Due to the extremely low current velocities for the majority of the monitoring events, the transect current velocity data were filtered with a 2-dimensional moving average filter consisting of a 3-point window in the horizontal and vertical dimensions. This was applied to the data to reduce random errors from measurement noise and high-frequency variability to better resolve the velocity features at the Project site (Parsons et al. 2013; Matte et al. 2014; Engel and Jackson 2017).

3 Results

This section presents the results of the TSS monitoring during the pre-installation trials and developing a calibration relationship (if any) between the remote sensing data (i.e., OBS and ABS) to TSS.

3.1 TSS Monitoring

Table 3-1 presents a summary of the TSS monitoring activities conducted for the two pre-installation trials. A full table, including all TSS monitoring samples collected is included in Appendix Table A-1 and Table A-2.

3.1.1 Upper Lake Champlain Trial

The pre-installation jet plow trial at the Upper Lake Champlain site occurred on August 31, 2022 during 0835-1050 EDT. Conditions during the trial were fair with sunny skies and winds from the S/SW winds in the morning at 5-10 kts, switching to the W/NW at approximately 0930. A pre-trial ambient condition CTD-OBS profile was collected at 0810 (Figure 3-1), The CTD-OBS temperature profile showed a thermocline between 10-15 ft depth, constant salinity (freshwater levels about 0.1 PSU), and effectively zero turbidity from the OBS sensor (OBS <1 NTU for the full water column). Two ADCP transects were performed before the trial started to assess the ambient current velocity. Current flow was almost negligible based on the real-time ADCP data readouts, at levels near the instrument's single-measurement noise floor (<10-15 cm/s), but by reviewing the transect depth-average flow direction output by WinRiver II, the average flow was determined to be towards the south. Based on this it was determined that the north side of the plow would be the up-current location and the south side of the plow would be the down-current location for purposes of assessing the TSS. Pre-trial TSS samples were not collected on the day of the trial because the trial start time was moved earlier than planned. Data from all ADCP transects collected during the Upper Lake Champlain trials are included in Appendix B. A representative pair of the up-/down-current ADCP transects is shown in Figure 3-2 for reference and perspective on the conditions.

During the trial, a total of three Passes of the trial area were conducted consisting of TSS sampling events on both the up- and down-current side of the plow, consisting of 18 total CTD-OBS-TSS samples and 12 ADCP transects (see Table 3-1). A summary of all sample measurements collected during the trial is presented in Table 3-2. As evident in the table, there was effectively no detectable TSS observed during the Upper Lake Champlain trial. Among the water samples collected both up-/down-current during the jet plow trial, there were two times during the trial that a potential plume was suspected based on the raw ADCP data, but invariably it was either propellor-wash, likely fish echoes, or was not able to be seen again in the signal when navigating to the sampling location. TSS was below the detection limit ("BDL") of the laboratory method (<5 mg/L) for all 18 TSS samples collected (i.e., nine up- and down-current pairs). Similar observations were noted in the OBS and ABS data, in that there was effectively no signature of increased suspended material during the jet plow trial. A post-trial ambient condition CTD-OBS profile was collected at 1149 (Figure 3-1). This profile indicated essentially the same conditions as the pre-trial profile, with the thermocline slightly depressed and mixed (likely due to increased winds during midday), constant salinity (freshwater levels <0.1 PSU), and slightly higher turbidity from the OBS sensor in the near-bottom layer (~1-2 NTU). It is noted that in addition to the jet plow trial sampling, there were six samples collected on August 30, 2022 and 15 samples collected after the trial ended, as supplemental data intended to increase the sample size for the TSS-OBS calibration (Appendix Table A-1). In total, 39 water samples were collected at the Upper Lake Champlain jet plow trial site, for all of which TSS was undetectable.

Table 3-1. Achieved sampling design of TSS Monitoring during the monitoring effort for the CHPE Lake Champlain Pre-Installation Trials, including periods before and after each trial, during August and September 2022.

Trial Site	Date	Survey Type[1]	Pass Number[2]	Location[3]	Sample Time[4] (EDT)		N Depth Layers	Total Samples
					Start	End		
Upper Lake Champlain	30-Aug-2022	Pre-Trial (Ambient)	1	Up	0925	0942	3	3
				Down	0959	1004	3	3
	31-Aug-2022	Trial[5]	1	Up	0844	0850	3	3
				Down	0858	0906	3	3
			2	Up	0915	0920	3	3
				Down	0937	0943	3	3
			3	Up	1024	1028	3	3
				Down	1041	1045	3	3
		Post-Trial (Ambient)	NA[7]	NA[7]	1053	1057	3	3
			4	Up	1107	1112	3	3
				Down	1119	1122	3	3
			5	Down	1128	1137	3	3
				Up	1142	1147	3	3
Lower Lake Champlain	31-Aug-2022	Pre-Trial (Ambient)	1	Down	1533	1537	3	3
				Up	1547	1551	3	3
	1-Sep-2022	Pre-Trial (Ambient)	1	Up	0812	0817	3	3
				Down	0835	0839	3	3
		Trial[6]	2	Down	1416	1420	3	3
				Up	1429	1433	3	3
			3	Down	1439	1443	3	3
				Up	1449	1452	3	3
			4	Down	1457	1500	3	3
				Up	1506	1509	3	3
		Post-Trial (Ambient)	5	Down	1516	1520	3	3
				Up	1525	1530	3	3
			NA[8]	NA[8]	1543	1546	3	3

[1]Pre-Trial and Post-Trial "ambient" conditions were assessed primarily to acquire additional data that may support the remote sensing calibrations to TSS.
[2]Pass number is sequential count for the given date of paired Up/Down-current TSS sampling events.
[3]Location refers to the sampling position Up/Down-current of the plow.
[4]Sample times presented are the CTD-OBS and TSS water sample times. The time performing the ADCP transects for each Pass and Location are not included in this table, but typically took between 4-8 minutes prior to the sample start of each Pass in the table.
[5]Notification from CMI during the Upper Lake Trial indicated that the plow started at 0835 and ended at 1050
[6]Notification from CMI during the Lower Lake Trial indicated that the plow started at 1341 and ended at 1456. Due to miscommunication, Normandeau was not notified that the plow had begun the test run until 1413.
[7]The first samples collected following the jet plow trial were collected on the east side of the barge to test a single profile perpendicular to the trial route.
[8]The last samples collected following the shear plow trial were collected at the north end of the trial route.

Table 3-2. Upper Lake Champlain sampling results for monitoring events conducted up-current and down-current of the operating jet plow during the jet plow trial for lab-analyzed total suspended solids ("TSS"), optical backscatter ("OBS"), and acoustic backscatter ("ABS").

Site	Layer	Pass	Location	TSS (mg/L)	OBS (NTU)	ABS (dB)
Upper Lake Champlain	Surface	Pass 1	Up	BDL[1]	0.8	59.2
			Down	BDL	0.7	60.8
		Pass 2	Up	BDL	0.8	55.9
			Down	BDL	0.5	59.2
		Pass 3	Up	BDL	0.8	59.7
			Down	BDL	0.6	56.5
		Mean	Up	BDL	0.8	58.3
			Down	BDL	0.6	58.9
	Midwater	Pass 1	Up	BDL	0.6	51.6
			Down	BDL	0.7	52.7
		Pass 2	Up	BDL	0.7	51.4
			Down	BDL	0.9	53.5
		Pass 3	Up	BDL	0.5	49.3
			Down	BDL	1.9	51.9
		Mean	Up	BDL	0.6	50.8
			Down	BDL	1.2	52.7
	Bottom	Pass 1	Up	BDL	0.4	49.5
			Down	BDL	0.8	50.1
		Pass 2	Up	BDL	0.3	49.3
			Down	BDL	0.6	49.8
		Pass 3	Up	BDL	0.6	49.7
			Down	BDL	0.5	49.8
		Mean	Up	BDL	0.4	49.5
			Down	BDL	0.6	49.9

[1]"BDL" indicates the TSS levels were below the lab's method detection limit (<5 mg/L).

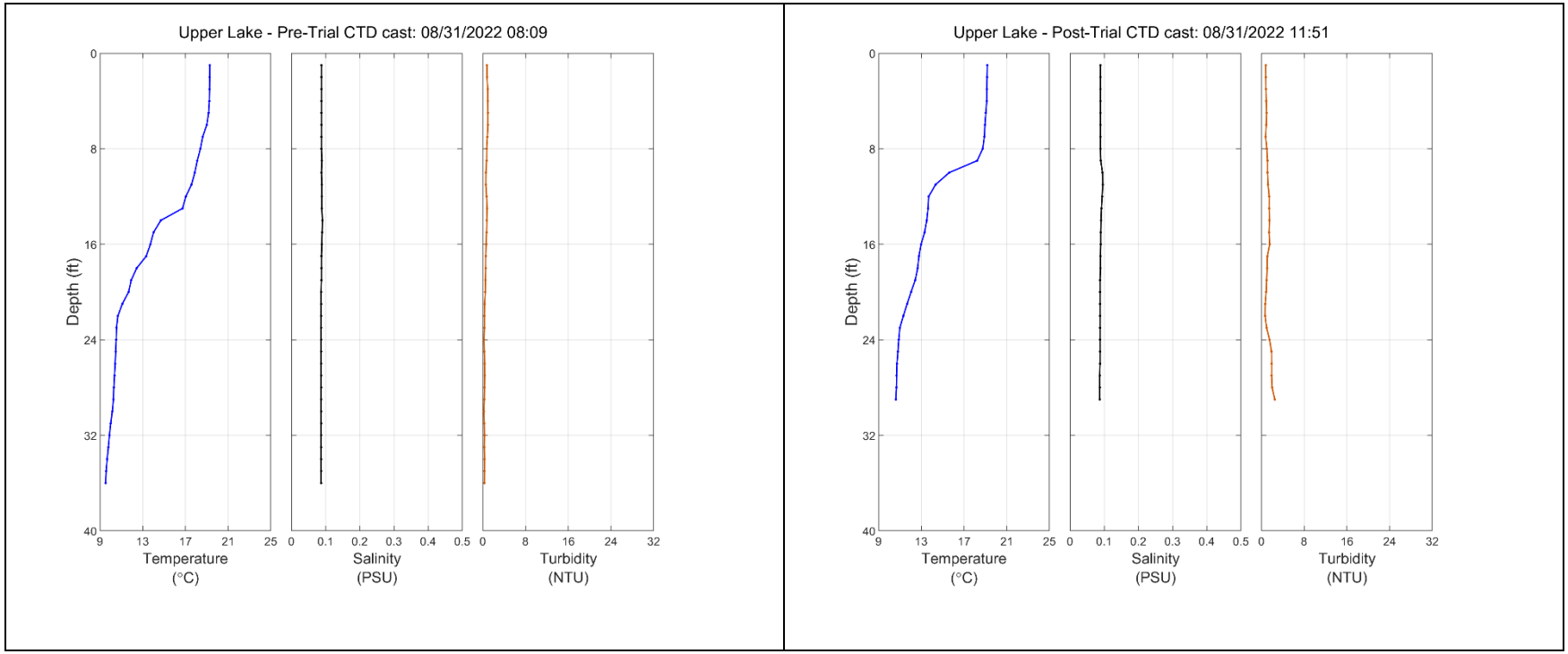

Figure 3-1. CTD-OBS profiles of temperature, salinity, and turbidity (OBS) from Upper Lake Champlain site prior to (left panel) and after the end (right panel) of the jet plow trial.

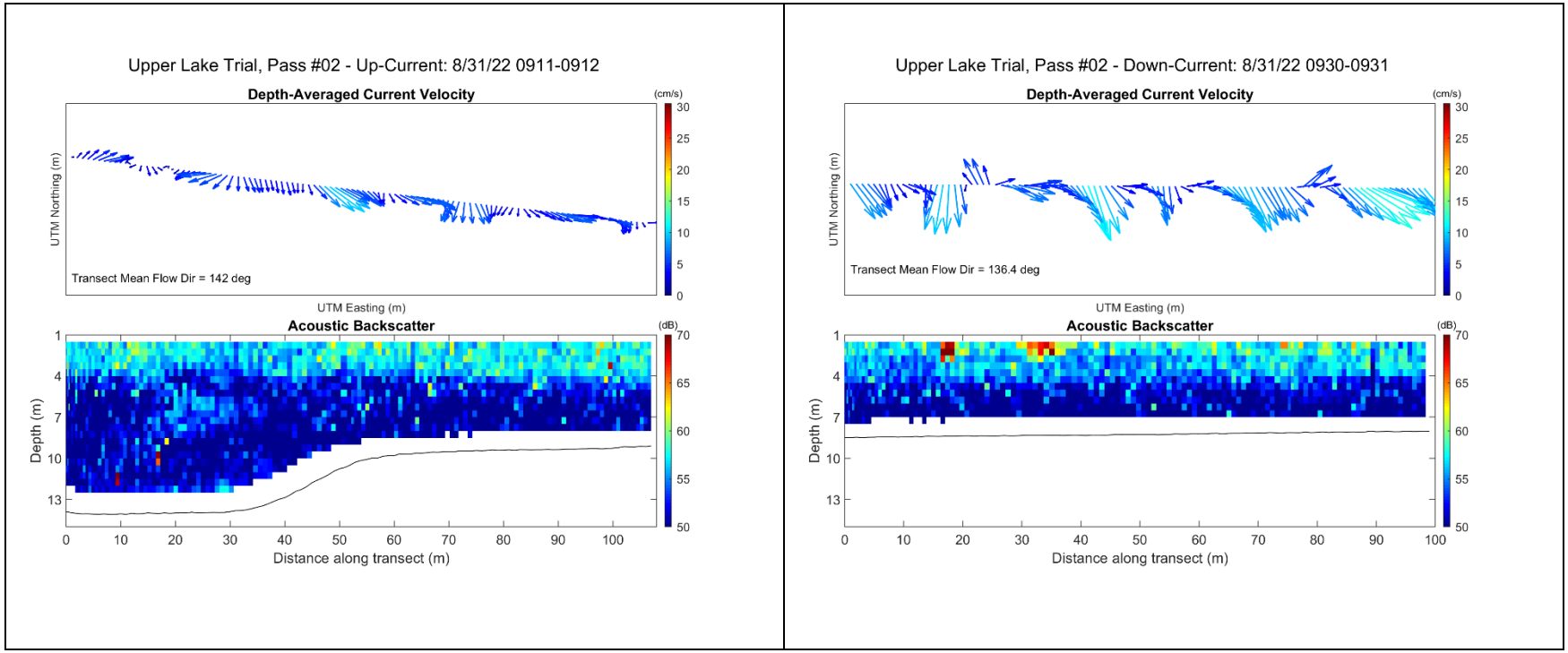

Figure 3-2. ADCP transect data from the second pass during the Upper Lake Champlain trial TSS monitoring: one of the up-current (north side of the plow) transects is shown on the left side and a down-current transect is shown on the right. The top panel on each is a plan-view image of the depth-average current velocity vectors (plotted in UTM coordinates). The bottom panel is the relative acoustic backscatter.

3.1.2 Lower Lake Champlain Trial

The pre-installation shear plow trial at the Lower Lake Champlain site occurred on September 1, 2022 from 1341-1456 EDT. Conditions during the trial were fair with partly cloudy skies and winds from the NW. It is noted herein that the background water column conditions were much different from the Upper Lake trial site. The water at the Lower Lake site was visibly a different color and less clear, as evident when travelling south of the Lake Champlain Bridge in the survey vessel both during the site inspection on August 31, 2022 and the day of the trial. The Lower Lake trial site is also in shallower water, approximately 23-26 ft compared to 24-42 ft at the Upper Lake trial site. Background turbidity levels were slightly higher than at the Upper Lake site, as observed on the day before the trial during the afternoon of August 31, 2022. A pre-trial ambient condition CTD-OBS profile was collected at 0758 (Figure 3-3). The CTD-OBS temperature profile showed a thermocline between 13-17 ft depth, constant salinity (freshwater levels about 0.1 PSU), but higher ambient turbidity levels from the OBS sensor when compared to the Upper Lake with turbidity levels between 16-20 NTU in the surface layer and decreasing to 2-6 NTU in the near-bottom layer.

Two ADCP transects completed before the shear plow trial began helped determine the ambient current velocity. Current flow at the Lower Lake location was more defined than at the Upper Lake site, likely due to the confined section of the lake and response to winds. During the pre-trial transects the average current flow was determined to be towards the south based on the real-time ADCP data readouts, again at low current speed levels near the instrument's single-measurement noise (~10-15cm/s), but somewhat less variable. Based on these observations, it determined that the north side of the plow would be the up-current location and the south side of the plow would be the down-current location for purposes of assessing the TSS. Due to delays with the plow operations, the trial did not commence until a few hours later (1341 EDT) than was expected. By the time the monitoring crew began trial Passes, the water currents had switched directions, with the average flow direction determined to be heading northward. As such, the locations for up-/down-current during the trial were the south/north sides of the plow, respectively (opposite of the pre-trial samples collected during the morning). Data from all ADCP transects collected during the Lower Lake Champlain trials are included in Appendix C. A representative pair of the up-/down-current ADCP transects is shown in Figure 3-4 for reference and perspective on the conditions.

During the trial, a total of three Passes were completed, which consisted of TSS sampling at the up- and down-current side of the plow, resulting in 18 total CTD-OBS-TSS samples and eight ADCP transects (Table 3-1). Due to the delayed notice that that plow operations had commenced, after the first Pass, the monitoring crew determined that only two ADCP transects per Pass (as opposed to four) would be conducted, in effort to save time and collect more TSS samples. The summary of all sample measurements from the Lower Lake trial is presented in Table 3-3. As is evident in the table, TSS, OBS, and ABS levels were all higher at the Lower Lake site compared to the Upper Lake site. Among the water samples collected both up-/down-current during the shear plow trail, TSS was BDL (<5 mg/L) of the method for four of the 18 TSS samples collected.

To assess whether shear plow operations elevated TSS, the change in TSS ("delta-TSS") over "background" was calculated as the difference in TSS level measured at the down-current station (impact) compared to the up-current station (control) at the same depth layer. Table 3-4 presents the results of those calculations. For samples that were BDL of TSS, the TSS value was substituted with the method detection limit divided by 2 (= 2.5 mg/L) for the purposes of calculating delta-TSS, which was the least biased approximation given the sample size limitation (Lafleur et al. 2011). In addition to near-surface, mid-depth, and near-bottom delta-TSS, a depth-averaged calculation was also performed for each Pass, presented in Table 3-4. The highest TSS measurement from water samples collected during the Lower Lake trial was 16 mg/L (surface layer from the first Pass during the trial). This sample represented an

increase of 4 mg/L delta-TSS compared to the up-current samples from the same Pass, and also represented the highest observed increase in TSS (i.e., delta-TSS). Note that the last Pass mid-depth sample (Table 3-4), exhibited a larger magnitude delta-TSS (-4.6 mg/L) but in the opposite direction, with the up-current mid-depth TSS being greater than the down-current measurement. The maximum increase in TSS observed was far below the exceedance threshold of 100 mg/L delta-TSS.

Similar observations were noted in the OBS and ABS data, in that there was an increase in magnitude of signal observed, but the differences between up-/down-current samples was low (i.e., increased signal was primarily due to the ambient conditions at the Lower Lake site). For purposes of increasing the sample size of calibration data, six samples were collected the day before the trial on the afternoon of August 31, 2022, and on September 1, 2022, six samples were collected before the trial began and nine samples were collected after the trial ended (Appendix Table A-2). In total, 39 water samples were collected at the Lower Lake Champlain shear plow trial site. Of those 39 TSS samples, eight of these were BDL. The highest TSS measurement observed was the first sample collected on the day before the trial, a near-surface measurement of 43 mg/L (Appendix Table A-2). This measurement is discussed in the remote sensing calibration section below, but appears to be a randomly higher observation, possibly attributable to the higher amount of debris and detritus in the surface water on August 31, 2022.

Table 3-3. Lower Lake Champlain sampling results for monitoring events conducted up-current and down-current of the operating shear plow during the shear plow trial for lab-analyzed total suspended solids ("TSS"), optical backscatter ("OBS"), and acoustic backscatter ("ABS").

Site	Layer	Pass	Location	TSS (mg/L)	OBS (NTU)	ABS (dB)
Lower Lake Champlain	Surface	Pass 2	Up	12.0	21.5	66.0
			Down	16.0	34.0	62.6
		Pass 3	Up	13.0	22.8	60.0
			Down	12.0	21.7	58.3
		Pass 4	Up	9.4	22.1	57.6
			Down	11.0	22.6	59.8
		Mean	Up	11.5	22.1	61.2
			Down	13.0	26.1	60.3
	Midwater	Pass 2	Up	6.0	9.5	54.9
			Down	6.4	5.7	59.9
		Pass 3	Up	6.8	6.2	58.4
			Down	6.9	9.8	57.2
		Pass 4	Up	12.0	8.2	57.1
			Down	7.4	8.1	56.9
		Mean	Up	8.3	8.0	56.8
			Down	6.9	7.9	58.0
	Bottom	Pass 2	Up	5.7	3.0	60.7
			Down	BDL	2.7	59.4
		Pass 3	Up	BDL	3.5	61.3
			Down	BDL	3.1	61.2
		Pass 4	Up	5.7	5.9	60.9
			Down	BDL	3.2	61.8
		Mean	Up	4.6	4.1	61.0
			Down	BDL	3.0	60.8

[1]"BDL" indicates the TSS levels were below the lab's method detection limit (<5 mg/L).

Table 3-4. Total suspended solids (TSS) measurements taken up-current and down-current of the operating shear plow at the Lower Lake Champlain trial site during the shear plow trial, with the change in TSS ("delta-TSS") relative to the up-current location for the same depth layer.

Pass	Layer	TSS (mg/L)		
		Down-current	Up-curent	delta-TSS
2	Surface	16.0	12.0	4.0
	Midwater	6.4	6.0	0.4
	Bottom	BDL[1]	5.7	-3.2
	Depth-Avg	8.3	7.9	0.4
3	Surface	12.0	13.0	-1.0
	Midwater	6.9	6.8	0.1
	Bottom	BDL[1]	BDL[1]	0.0
	Depth-Avg	7.1	7.4	-0.3
4	Surface	11.0	9.4	1.6
	Midwater	7.4	12.0	-4.6
	Bottom	BDL[1]	5.7	-3.2
	Depth-Avg	7.0	9.0	-2.1
Mean	Surface	13.0	11.5	1.5
	Midwater	6.9	8.3	-1.4
	Bottom	BDL[1]	4.6	-2.1
	Depth-Avg	7.5	8.1	-0.7

[1]These samples were below the method detection limit. For the purposes of the delta-TSS calculations above, BDL values were substituted with the method detection limit divided by 2 (2.5 mg/L).

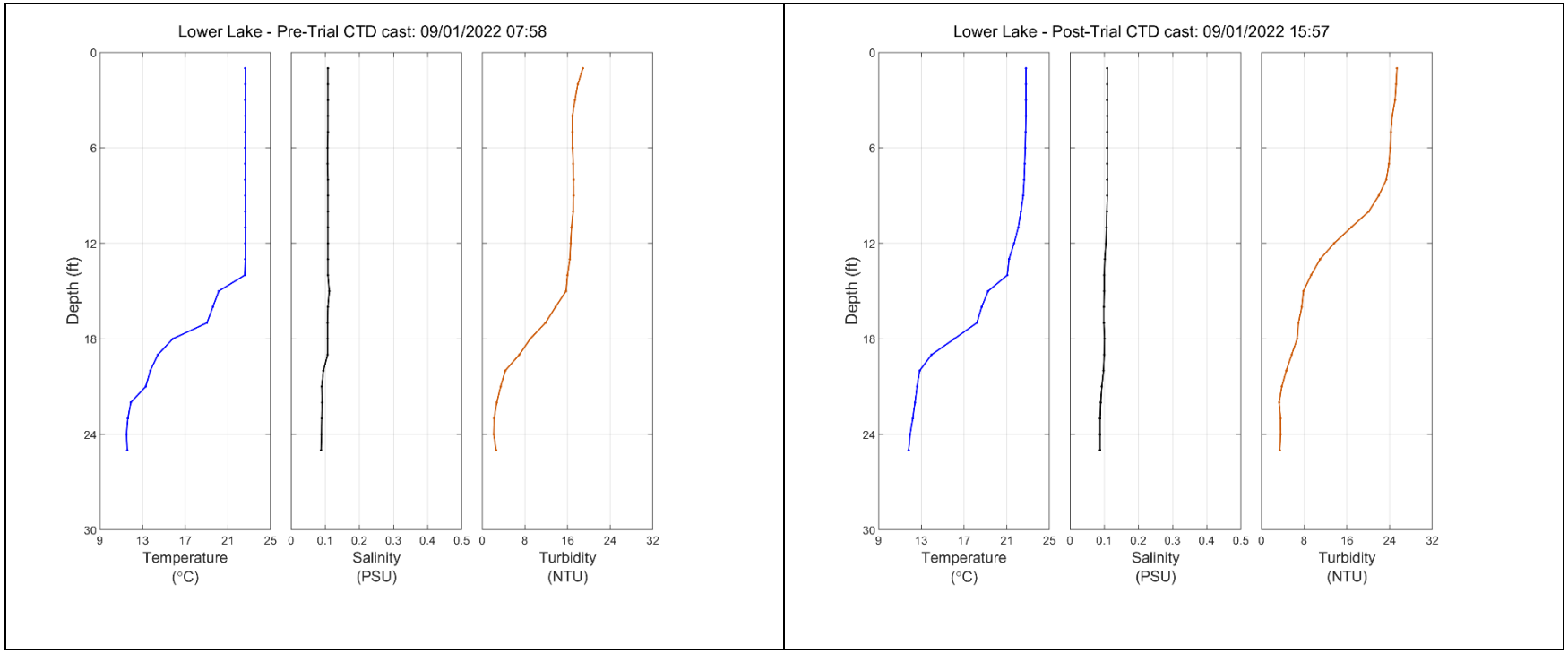

Figure 3-3. CTD-OBS profiles of temperature, salinity, and turbidity (OBS) from Lower Lake Champlain site prior to (left panel) and after the end (right panel) of the shear plow trial.

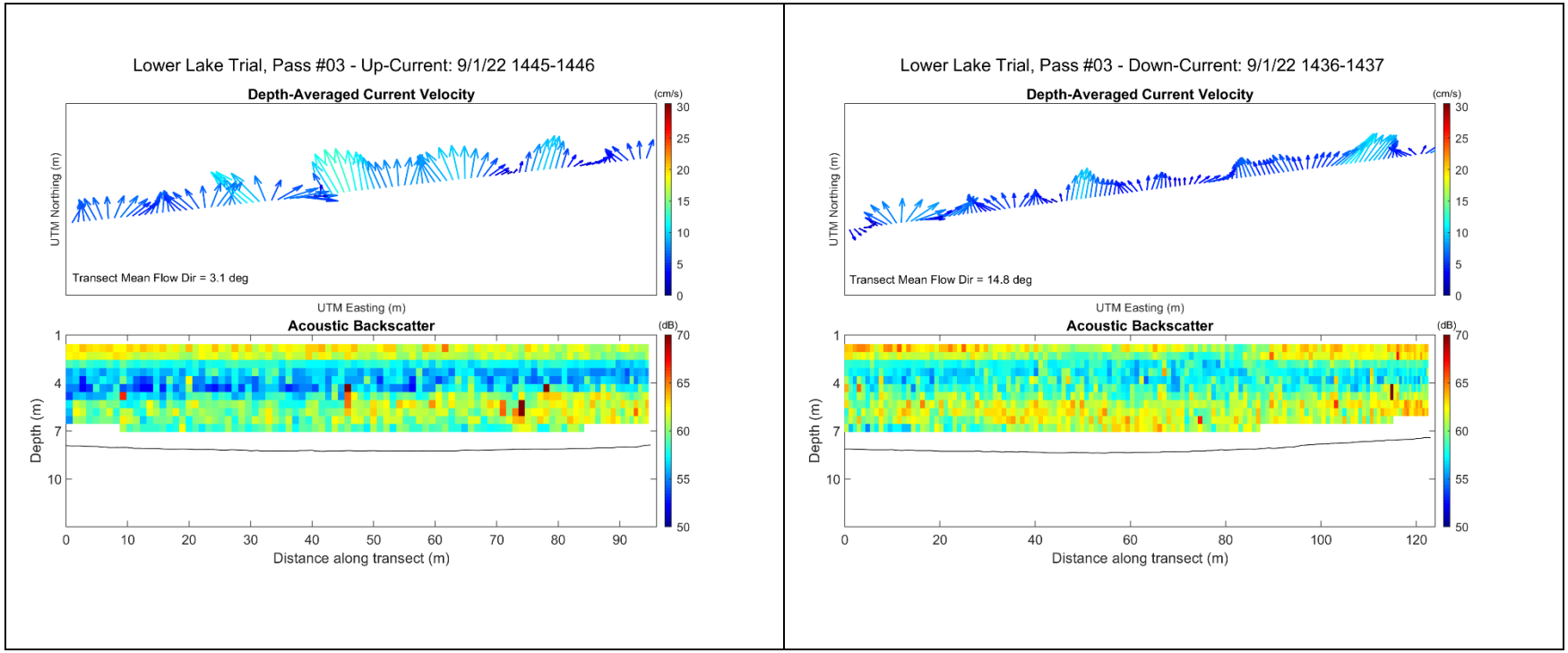

Figure 3-4. **ADCP transect data from the second pass (numbered Pass 03 during field sampling) during the Lower Lake Champlain trial TSS monitoring: one of the up-current (north side of the plow) transects is shown on the left side and a down-current transect is shown on the right. The top panel on each is a plan-view image of the depth-average current velocity vectors (plotted in UTM coordinates). The bottom panel is the relative acoustic backscatter.**

3.2 Remote Sensing Calibrations to TSS

The secondary objective to the TSS monitoring activities during the pre-installation trials of the jet plow and shear plow was to use the sample data collected to investigate development of calibration curves describing quantitative relationships (if any) between remote sensing data and the laboratory measured TSS, to potentially use ABS and/or OBS as remote sensing methods for near real-time TSS estimates during monitoring for the submarine cable installation. Sample data used for the simple linear regression analyses were subset for samples where only a valid TSS measurement was detected; i.e. samples where TSS was reported as BDL were excluded from the correlation analyses. This subset of the sample data was used to extract paired remote sensing and TSS measurements for linear regression analysis, and is presented in Table 3-5. The highest TSS value from the samples collected (43 mg/L) was observed at the Lower Lake Champlain site on August 31, 2022, during the afternoon after the Upper Lake trial was completed. This TSS value was considered as an influential outlier and excluded from in the regression analyses based on several outlier influence metrics. These included but were not limited to, three times the scaled median absolute deviation ("MAD") via outlier removal functions in MATLAB and review of linear model diagnostics and residuals (e.g., Cook's distance, delete-1 scaled change in fitted values ["DFFITS"], and raw, standard, and studentized residuals). The linear regression models were performed using the "fitlm" MATLAB function and the results for both were reviewed and are included in Appendix D (i.e., both with and without the outlier included in the model data set). MATLAB output for the full model parameters is included in Appendix D to illustrate the influence on the regression by including the statistical outlier.

3.2.1 Optical Backscatter

The calibration curve resulting from the linear regression analyses of TSS on OBS is shown in Figure 3-5. The regression was significantly improved by exclusion of the outlier, with $R^2 = 0.647$, $p<0.0001$, and as shown in model statistics not presented on the graph, e.g., the root mean square error ("RMSE"), model percent standard error ("MPSE"), t-statistic values, etc. (see Appendix D). The changes in OBS values account for 64.7% of the observed variance in TSS values with the outlier excluded from the analysis, but only 8.3% of the variance when all data points are included in the model. It should be noted that a log-log calibration curve was also assessed for the TSS-OBS correlation, with statistically significant results but slightly lower correlation statistics (R^2, p-value, MPSE), and as such only the linear model is presented herein (Rasmussen et al. 2009).

3.2.2 Acoustic Backscatter

The calibration curve resulting from the linear regression analyses of $\log_{10}$(TSS) on ABS is shown in Figure 3-6. Exclusion of the outlier moderately improved the regression, as indicated in the R^2, model p-value, and model statistics not presented on the graph, e.g. the RMSE, MPSE, t-statistic values, etc. (see Appendix D). The TSS-ABS model is statistically significant but weakly correlated for TSS-ABS ($R^2 = 0.249$, $p=0.005$) relationship, with the changes in ABS values accounting for only 24.9% of the observed variance in TSS values with the outlier excluded from the analysis, and only 20.8% of the variance when all data points are included in the model. It should be noted that the correlations for TSS-ABS are potentially weak due to the low levels of TSS observed in the sample data in general, as some studies have suggested that the ADCP ABS is only capable of being estimating TSS levels of greater than 10 mg/L (Landers et al. 2016; Gray and Gartner 2009).

Table 3-5. TSS monitoring sample results collected in Lake Champlain and used in regression analysis for developing a relationship to calibrate OBS and ABS for estimating TSS. The table below only includes sample pairs where valid TSS measurements were collected (i.e. samples with TSS below the method detection limit were excluded).

Site	Date	Time (EDT)	Latitude (DD)	Longitude (DD)	Type	Location	Pass	Layer	Depth (ft)	OBS (NTU)	TSS (mg/L)	ABS (dB)
Lower Lake Champlain	8/31/2022	15:33:27	44.02227	-73.41069	Pre-trial (Ambient)	Down	1	SUR	6.4	10.92	43.0	61.3
Lower Lake Champlain	8/31/2022	15:35:17	44.02227	-73.41072	Pre-trial (Ambient)	Down	1	MID	13.1	5.12	5.0	52.8
Lower Lake Champlain	8/31/2022	15:47:47	44.01973	-73.40976	Pre-trial (Ambient)	Up	1	SUR	6.5	11.10	6.7	61.7
Lower Lake Champlain	8/31/2022	15:49:28	44.01961	-73.40961	Pre-trial (Ambient)	Up	1	MID	11.1	10.58	5.5	53.5
Lower Lake Champlain	9/1/2022	8:12:26	44.02330	-73.41165	Pre-trial (Ambient)	Up	1	SUR	6.2	18.26	9.5	64.5
Lower Lake Champlain	9/1/2022	8:14:29	44.02318	-73.41189	Pre-trial (Ambient)	Up	1	MID	10.2	14.72	7.0	57.0
Lower Lake Champlain	9/1/2022	8:17:08	44.02331	-73.41152	Pre-trial (Ambient)	Up	1	BOT	15.5	19.21	9.7	62.3
Lower Lake Champlain	9/1/2022	8:35:25	44.01982	-73.40907	Pre-trial (Ambient)	Down	1	SUR	6.1	18.04	9.3	64.0
Lower Lake Champlain	9/1/2022	8:37:10	44.01962	-73.40908	Pre-trial (Ambient)	Down	1	MID	10.7	10.29	9.3	57.0
Lower Lake Champlain	9/1/2022	8:39:35	44.01951	-73.40903	Pre-trial (Ambient)	Down	1	BOT	14.1	10.35	5.9	55.1
Lower Lake Champlain	9/1/2022	14:16:48	44.02228	-73.41080	Trial	Down	2	SUR	7.3	34.01	16.0	62.6
Lower Lake Champlain	9/1/2022	14:18:42	44.02217	-73.41084	Trial	Down	2	MID	14.1	5.68	6.4	59.9
Lower Lake Champlain	9/1/2022	14:29:14	44.01861	-73.40947	Trial	Up	2	SUR	7.5	21.47	12.0	66.0
Lower Lake Champlain	9/1/2022	14:31:05	44.01852	-73.40940	Trial	Up	2	MID	14.3	9.46	6.0	54.9
Lower Lake Champlain	9/1/2022	14:33:11	44.01845	-73.40947	Trial	Up	2	BOT	19.8	2.96	5.7	60.7
Lower Lake Champlain	9/1/2022	14:39:36	44.02081	-73.41022	Trial	Down	3	SUR	7.4	21.65	12.0	58.3
Lower Lake Champlain	9/1/2022	14:41:08	44.02074	-73.41026	Trial	Down	3	MID	13.7	9.83	6.9	57.2
Lower Lake Champlain	9/1/2022	14:49:04	44.01773	-73.40895	Trial	Up	3	SUR	7.6	22.76	13.0	60.0
Lower Lake Champlain	9/1/2022	14:50:37	44.01758	-73.40887	Trial	Up	3	MID	15.1	6.19	6.8	58.4
Lower Lake Champlain	9/1/2022	14:57:06	44.02004	-73.41022	Trial	Down	4	SUR	7.5	22.56	11.0	59.8
Lower Lake Champlain	9/1/2022	14:58:34	44.02004	-73.41032	Trial	Down	4	MID	13.6	8.09	7.4	56.9
Lower Lake Champlain	9/1/2022	15:06:36	44.01759	-73.40900	Trial	Up	4	SUR	8.5	22.05	9.4	57.6
Lower Lake Champlain	9/1/2022	15:08:07	44.01764	-73.40905	Trial	Up	4	MID	13.9	8.23	12.0	57.1
Lower Lake Champlain	9/1/2022	15:09:50	44.01768	-73.40910	Trial	Up	4	BOT	17.3	5.87	5.7	60.9
Lower Lake Champlain	9/1/2022	15:16:24	44.02002	-73.41014	Post-trial	Down	5	SUR	5.8	21.85	11.0	59.4
Lower Lake Champlain	9/1/2022	15:18:15	44.02007	-73.41019	Post-trial	Down	5	MID	14.1	9.65	7.2	58.0
Lower Lake Champlain	9/1/2022	15:25:54	44.01772	-73.40873	Post-trial	Up	5	SUR	7.2	25.06	15.0	60.9
Lower Lake Champlain	9/1/2022	15:28:08	44.01775	-73.40875	Post-trial	Up	5	MID	13.8	9.62	6.8	59.7
Lower Lake Champlain	9/1/2022	15:43:05	44.02173	-73.41013	Post-trial	NA	6	SUR	7.3	22.30	15.0	59.5
Lower Lake Champlain	9/1/2022	15:44:33	44.02160	-73.41019	Post-trial	NA	6	MID	12.4	17.51	7.1	58.5
Lower Lake Champlain	9/1/2022	15:46:12	44.02168	-73.41021	Post-trial	NA	6	BOT	16.8	7.65	11.0	60.9

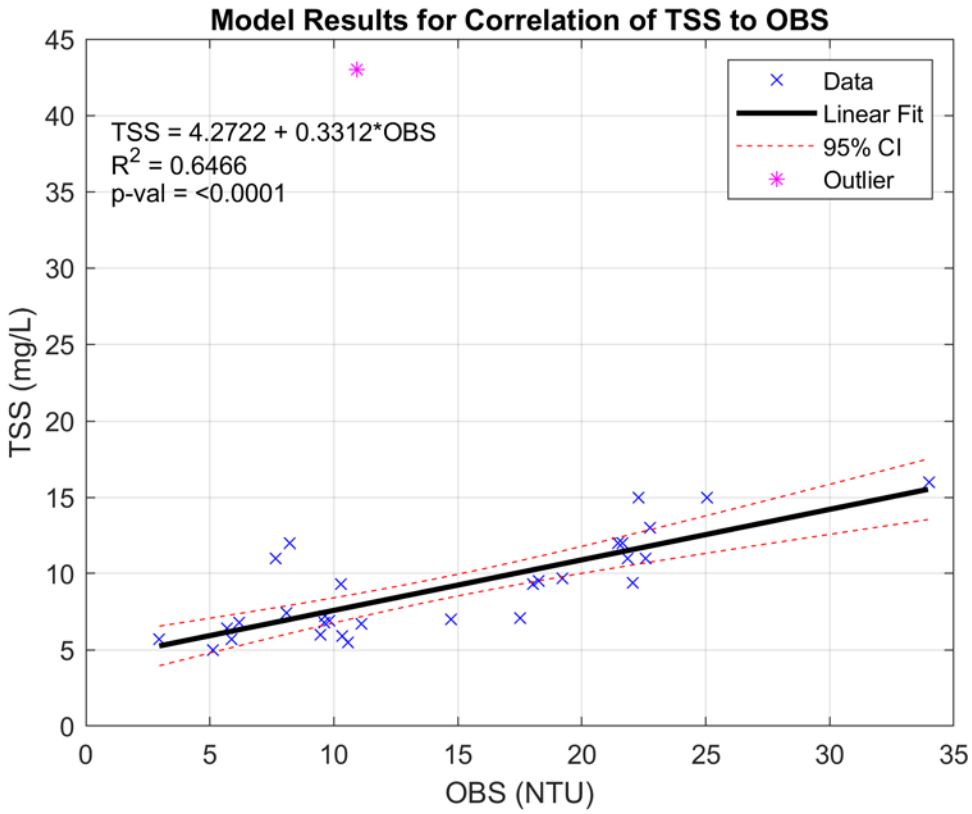

Figure 3-5. Calibration curve from linear regression analysis for TSS to OBS. The data point with the TSS outlier from pre-trial ambient sampling (TSS = 43 mg/L, OBS = 10.92 NTU) was presented for perspective, but was not included in the final regression model.

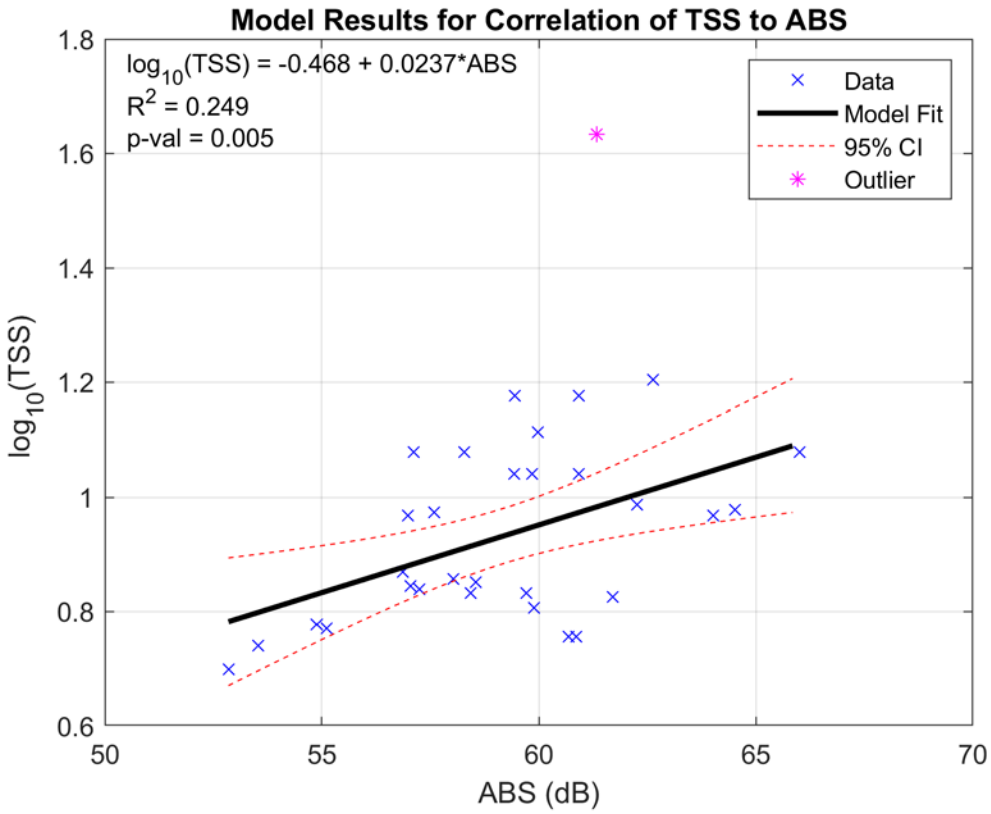

Figure 3-6. Calibration curve for the linear regression analysis for $\log_{10}$(TSS) to ABS. The data point with the TSS outlier from pre-trial ambient sampling (TSS = 43 mg/L, ABS = 61.3 dB) was presented for perspective, but was not included in the final regression model.

4 Summary

4.1 Lake Champlain Trials

TSS monitoring during the pre-installation trials for CHPE showed that the levels of TSS ranged from non-detectable (for the Upper Lake) to indistinguishable from ambient conditions with the highest increase in TSS 96% lower than the exceedance limit (Lower Lake). The standards in the WQC for the TSS levels require that changes in TSS in reference to up-current background conditions (i.e., the delta-TSS as presented herein) at 500 ft down-current from the construction barge are maintained below 200 mg/L in the Upper Lake and 100 mg/L in the Lower Lake. Observations from both trials showed that, when measured at the prescribed 500 ft distance from the construction barge, changes in TSS levels (where detectable) were far below than permitted standards. A more conservative estimate could be viewed by simply using the single maximum TSS level observed during the trials altogether (16 mg/L) and comparing that value to zero. This would indicate a potential maximum delta-TSS of 16 mg/L. However, given the higher ambient TSS levels observed at the Lower Lake trial site, this value did not show a significant increase in TSS.

4.2 Optical and Acoustic Backscatter Calibrations

Results from the regression analyses indicated that the OBS exhibited a stronger relationship with TSS concentrations and, as such, may provide better estimates of TSS for future monitoring in similar conditions. The TSS-ABS regression, while statistically significant, was weakly correlated ($R^2 = 0.249$) compared to the TSS-OBS results ($R^2 = 0.647$), which could be due to several factors. Notably, the conditions encountered during the Lake Champlain trials exhibited relatively low levels of TSS in general, and it has been documented that acoustic methods for estimating TSS may have a lower limit of applicability around 10 mg/L (Gray and Gartner 2009). The differences observed may also be attributable to varying sensitivities to different particle sizes and sediment characteristics, for which the OBS sensors and ABS from ADCP have different responsiveness. The OBS sensor is typically more sensitive to smaller particle sizes than the ABS from the 600 kHz ADCP (e.g., particles in the silt and clay range <40-60 µm versus larger sizes for the ADCP) (Gartner 2004; Jay et al. 2015). However, both the OBS and ABS instruments have the limitation that they cannot differentiate changes in concentration from changes in particle size distribution of the sediments that may be suspended (Gartner 2004; Wall et al. 2006; Landers 2010).

The predictive power and the observation ranges of the remote sensing calibrations presented here may improve with samples collected from water with higher concentrations of suspended sediment of the same characteristics of the sediments encountered during the trials, as the overall TSS levels observed for all samples collected were exceptionally low. For perspective on this, and in relation to the standards in the WQC, the TSS-OBS calibration curve was re-plotted on a larger TSS scale, approximating values that would likely need to be observed to exceed those thresholds (Figure 4-1).

4.3 Conclusions

TSS levels observed during the pre-installation trials were most often indistinguishable from ambient TSS levels (where they were of detectable levels) which, based on these data, suggest that TSS monitoring requirements could potentially be relaxed for Lake Champlain (e.g., less frequent sampling). This is assuming the jet and shear plows will operate in a similar manner during the full cable installation and, equally important, that results of the monitoring at these two trial sites are representative of the hydrological and sediment conditions along the full route in Lake Champlain. Particularly at the Upper

Lake trial site, it appears likely that any sediments that are resuspended due to the plow operations do not remain in suspension long enough to form a plume.

While statistically significant calibration curves were established for TSS to both OBS and ABS, the R^2 of the regressions and model diagnostic parameters for the OBS-TSS regression clearly indicate OBS was the better predictor of TSS values between the two methods in the conditions that were sampled during the trials. Different hydrological or background sediment characteristics could result in variability of these calibrations. This is not to imply that the ABS from ADCP is not useful, as it has the advantage of being a remote profiling instrument capable of sampling the entire water column (i.e., without being physically lowered from a vessel at a point) for mapping or locating sediment plumes. Based on the results from the Lake Champlain trials, the ADCP may have limited utility in estimating TSS levels for compliance monitoring during the installation phase of the Project in Lake Champlain. For conditions encountered in these regions of Lake Champlain, the OBS sensor may be more appropriate for guiding compliance decisions during active construction in the lake.

In summary, the trials in Lake Champlain demonstrated that (1) jet and shear plow activities produced no observable plume or a narrow range of slightly elevated TSS levels; (2) the ADCP may not be appropriate for estimating TSS levels in real-time during the installation phase in Lake Champlain; and (3) both the remote sensing calibrations to TSS exhibited low (ABS) to moderate (OBS) predictive power and may be subject to modification during the installation phase of the Project to reflect hydrological and sediment conditions encountered that were not observed during the trials.

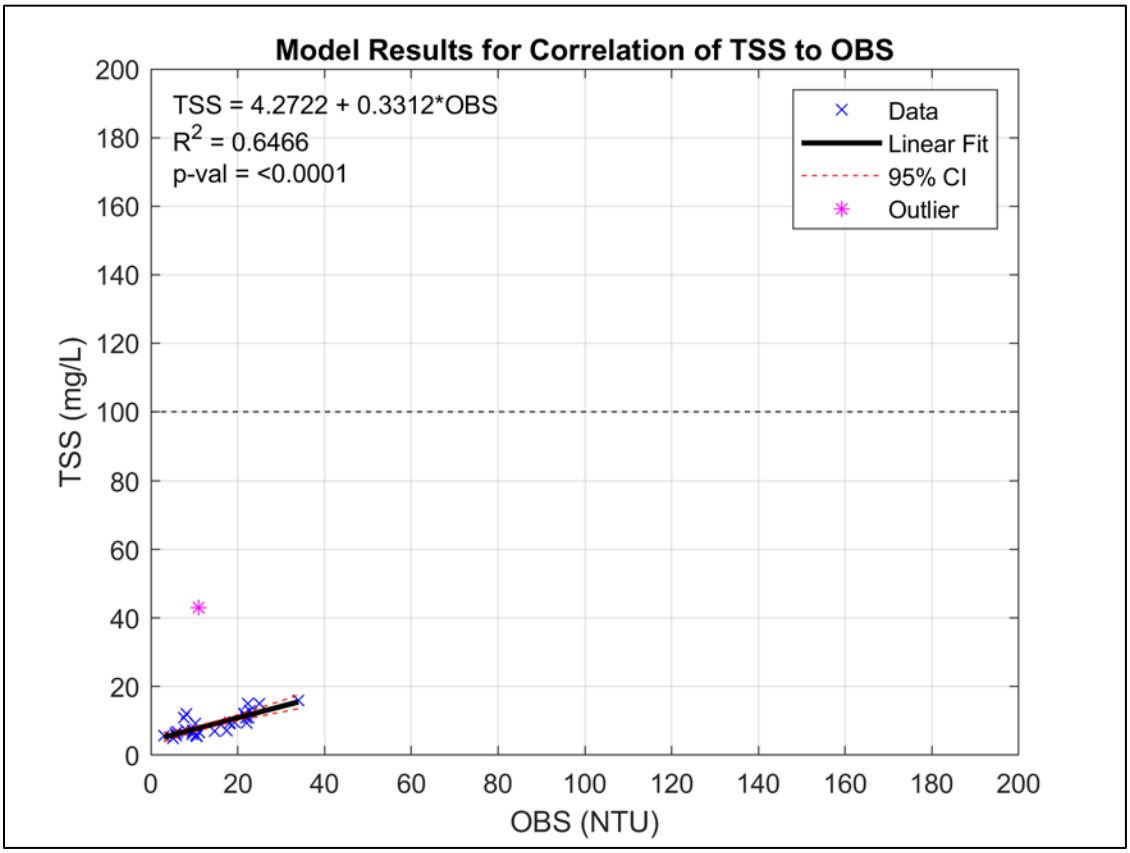

Figure 4-1. **Calibration curves from linear regression analysis for TSS to OBS, plotted on increased scale to illustrate levels observed during the trials relative to the standards. The dashed line at 100 mg/L is intended to show the standard for Lower Lake Champlain. The left panel shows the correlation results for the model with all TSS-OBS data pairs included in the regression. The right panel shows the correlation results with the outlier data point removed from the regression (TSS = 43 mg/L, OBS = 10.92 NTU).**

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Appendix A. TSS Monitoring Sample Results for All Samples Collected in Lake Champlain During TSS Monitoring for the CHPE Pre-installation Trials

Table A-1. TSS monitoring sample results collected in Upper Lake Champlain during the monitoring effort for the CHPE Lake Champlain Pre-Installation Trials, including periods before and after the jet plow, during August 2022.

Site	Date	Time (EDT)	Latitude (DD)	Longitude (DD)	Type	Location	Pass	Layer	Depth (ft)	OBS (NTU)	TSS (mg/L)	ABS (dB)
Upper Lake Champlain	8/30/2022	9:25:53	44.05662	-73.44235	Pre-trial (Ambient)	Up	1	SUR	6.0	1.26	BDL[1]	58.2
Upper Lake Champlain	8/30/2022	9:35:02	44.05793	-73.44332	Pre-trial (Ambient)	Up	1	MID	13.5	1.25	BDL	54.9
Upper Lake Champlain	8/30/2022	9:42:56	44.05894	-73.44467	Pre-trial (Ambient)	Up	1	BOT	20.5	0.39	BDL	49.5
Upper Lake Champlain	8/30/2022	9:59:04	44.05098	-73.44034	Pre-trial (Ambient)	Down	1	SUR	6.0	1.66	BDL	57.8
Upper Lake Champlain	8/30/2022	10:02:49	44.05079	-73.44004	Pre-trial (Ambient)	Down	1	MID	14.0	0.62	BDL	51.7
Upper Lake Champlain	8/30/2022	10:04:54	44.05070	-73.44033	Pre-trial (Ambient)	Down	1	BOT	21.7	0.54	BDL	48.5
Upper Lake Champlain	8/31/2022	8:44:42	44.05318	-73.44009	Trial	Up	1	SUR	5.9	0.84	BDL	59.2
Upper Lake Champlain	8/31/2022	8:46:36	44.05334	-73.43988	Trial	Up	1	MID	18.4	0.6	BDL	51.6
Upper Lake Champlain	8/31/2022	8:50:29	44.05319	-73.43977	Trial	Up	1	BOT	28.4	0.41	BDL	49.5
Upper Lake Champlain	8/31/2022	8:58:49	44.05001	-73.44057	Trial	Down	1	SUR	6.8	0.7	BDL	60.8
Upper Lake Champlain	8/31/2022	9:00:28	44.05006	-73.44050	Trial	Down	1	MID	13.5	0.71	BDL	52.7
Upper Lake Champlain	8/31/2022	9:06:08	44.04939	-73.44068	Trial	Down	1	BOT	18.6	0.78	BDL	50.1
Upper Lake Champlain	8/31/2022	9:15:59	44.05169	-73.44044	Trial	Up	2	SUR	6.1	0.75	BDL	55.9
Upper Lake Champlain	8/31/2022	9:17:49	44.05187	-73.44039	Trial	Up	2	MID	16.2	0.68	BDL	51.4
Upper Lake Champlain	8/31/2022	9:20:36	44.05139	-73.44010	Trial	Up	2	BOT	22.3	0.31	BDL	49.3
Upper Lake Champlain	8/31/2022	9:37:49	44.04836	-73.44031	Trial	Down	2	SUR	6.2	0.54	BDL	59.2
Upper Lake Champlain	8/31/2022	9:39:15	44.04842	-73.44030	Trial	Down	2	MID	13.6	0.87	BDL	53.5
Upper Lake Champlain	8/31/2022	9:43:22	44.04839	-73.44028	Trial	Down	2	BOT	19.8	0.6	BDL	49.8
Upper Lake Champlain	8/31/2022	10:24:13	44.05121	-73.44067	Trial	Up	3	SUR	6.8	0.81	BDL	59.7
Upper Lake Champlain	8/31/2022	10:26:00	44.05121	-73.44054	Trial	Up	3	MID	17.9	0.46	BDL	49.3
Upper Lake Champlain	8/31/2022	10:28:30	44.05117	-73.44088	Trial	Up	3	BOT	30.9	0.57	BDL	49.7
Upper Lake Champlain	8/31/2022	10:41:27	44.04796	-73.44054	Trial	Down	3	SUR	6.1	0.64	BDL	56.5
Upper Lake Champlain	8/31/2022	10:43:00	44.04787	-73.44058	Trial	Down	3	MID	13.1	1.93	BDL	51.9
Upper Lake Champlain	8/31/2022	10:45:00	44.04789	-73.44042	Trial	Down	3	BOT	19.4	0.52	BDL	49.8
Upper Lake Champlain	8/31/2022	10:53:11	44.04945	-73.43875	Post-trial	NA	4	SUR	6.7	1.06	BDL	60.3
Upper Lake Champlain	8/31/2022	10:55:03	44.04935	-73.43867	Post-trial	NA	4	MID	13.3	1.16	BDL	56.5
Upper Lake Champlain	8/31/2022	10:57:05	44.04927	-73.43835	Post-trial	NA	4	BOT	18.2	1.24	BDL	51.5
Upper Lake Champlain	8/31/2022	11:07:08	44.05066	-73.44052	Post-trial	Up	4	SUR	7.0	0.83	BDL	56.6
Upper Lake Champlain	8/31/2022	11:09:38	44.05044	-73.44079	Post-trial	Up	4	MID	14.5	0.48	BDL	52.5
Upper Lake Champlain	8/31/2022	11:12:09	44.05035	-73.44070	Post-trial	Up	4	BOT	23.2	0.32	BDL	49.1
Upper Lake Champlain	8/31/2022	11:19:09	44.04861	-73.43931	Post-trial	Down	4	SUR	6.3	1.01	BDL	55.8
Upper Lake Champlain	8/31/2022	11:20:55	44.04860	-73.43940	Post-trial	Down	4	MID	13.2	1.42	BDL	52.4
Upper Lake Champlain	8/31/2022	11:22:55	44.04855	-73.43920	Post-trial	Down	4	BOT	18.8	0.83	BDL	51.3
Upper Lake Champlain	8/31/2022	11:28:23	44.04826	-73.44146	Post-trial	Down	5	SUR	6.7	0.74	BDL	55.5
Upper Lake Champlain	8/31/2022	11:30:31	44.04822	-73.44132	Post-trial	Down	5	MID	14.7	1.6	BDL	52.3
Upper Lake Champlain	8/31/2022	11:37:32	44.04836	-73.44124	Post-trial	Down	5	BOT	19.3	0.92	BDL	50.1
Upper Lake Champlain	8/31/2022	11:42:33	44.04966	-73.44191	Post-trial	Up	5	SUR	6.3	0.78	BDL	59.0
Upper Lake Champlain	8/31/2022	11:44:44	44.04956	-73.44202	Post-trial	Up	5	MID	14.1	0.71	BDL	52.0
Upper Lake Champlain	8/31/2022	11:47:00	44.04952	-73.44197	Post-trial	UP	5	BOT	21.1	0.45	BDL	49.6

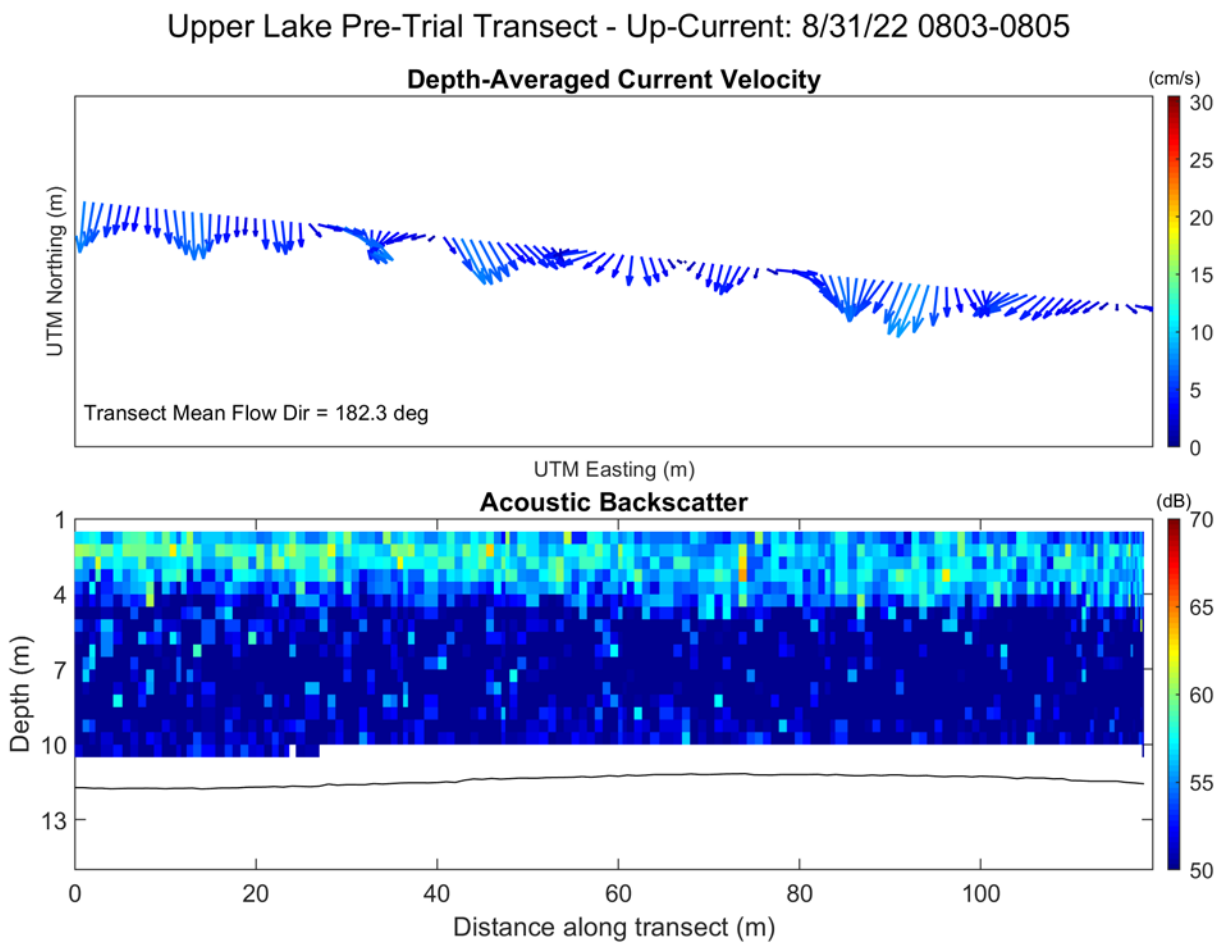
[1]"BDL" indicates the TSS levels were below the lab's method detection limit (<5 mg/L).

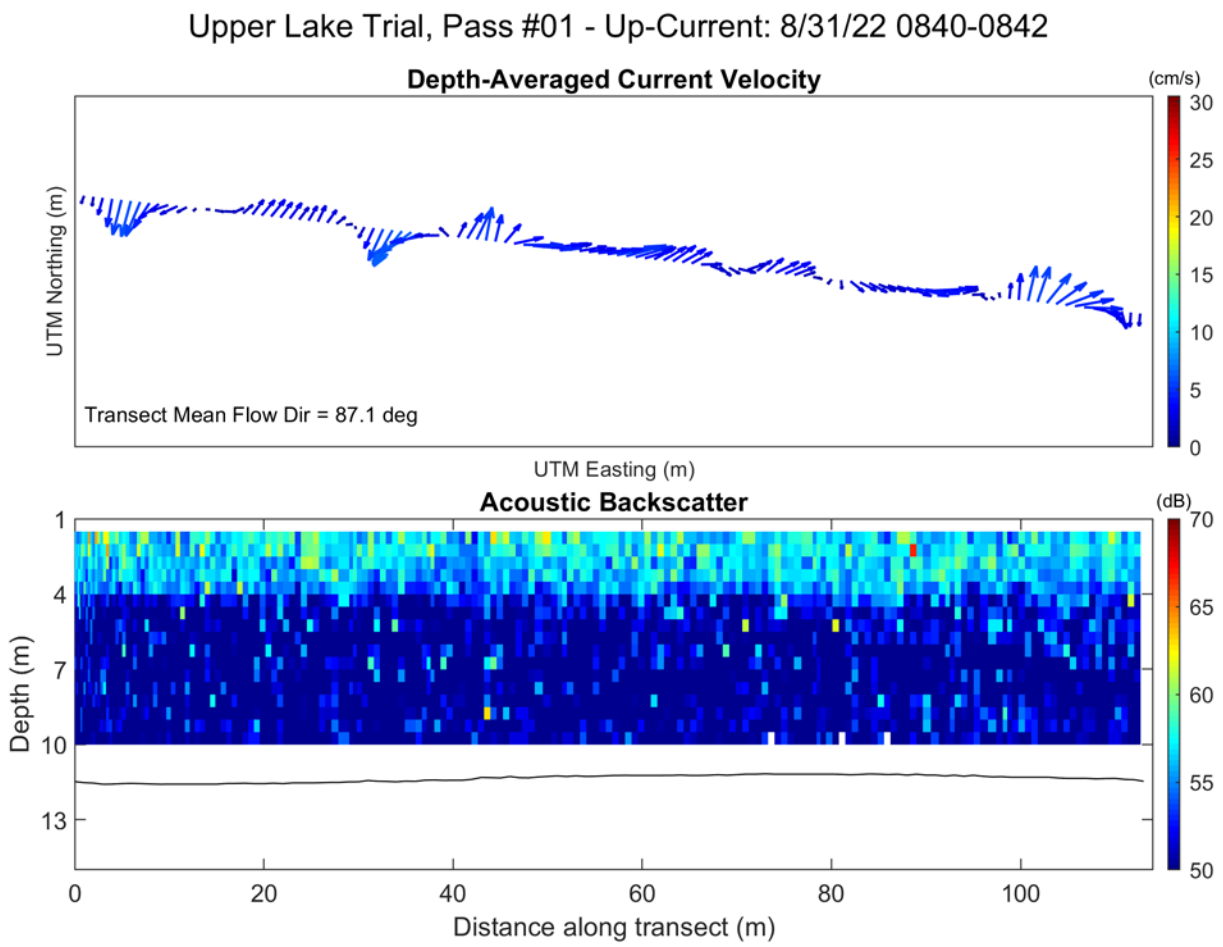
Table A-2. TSS monitoring sample results collected in Lower Lake Champlain during the monitoring effort for the CHPE Lake Champlain Pre-Installation Trials, including periods before and after the shear plow, during August and September 2022.

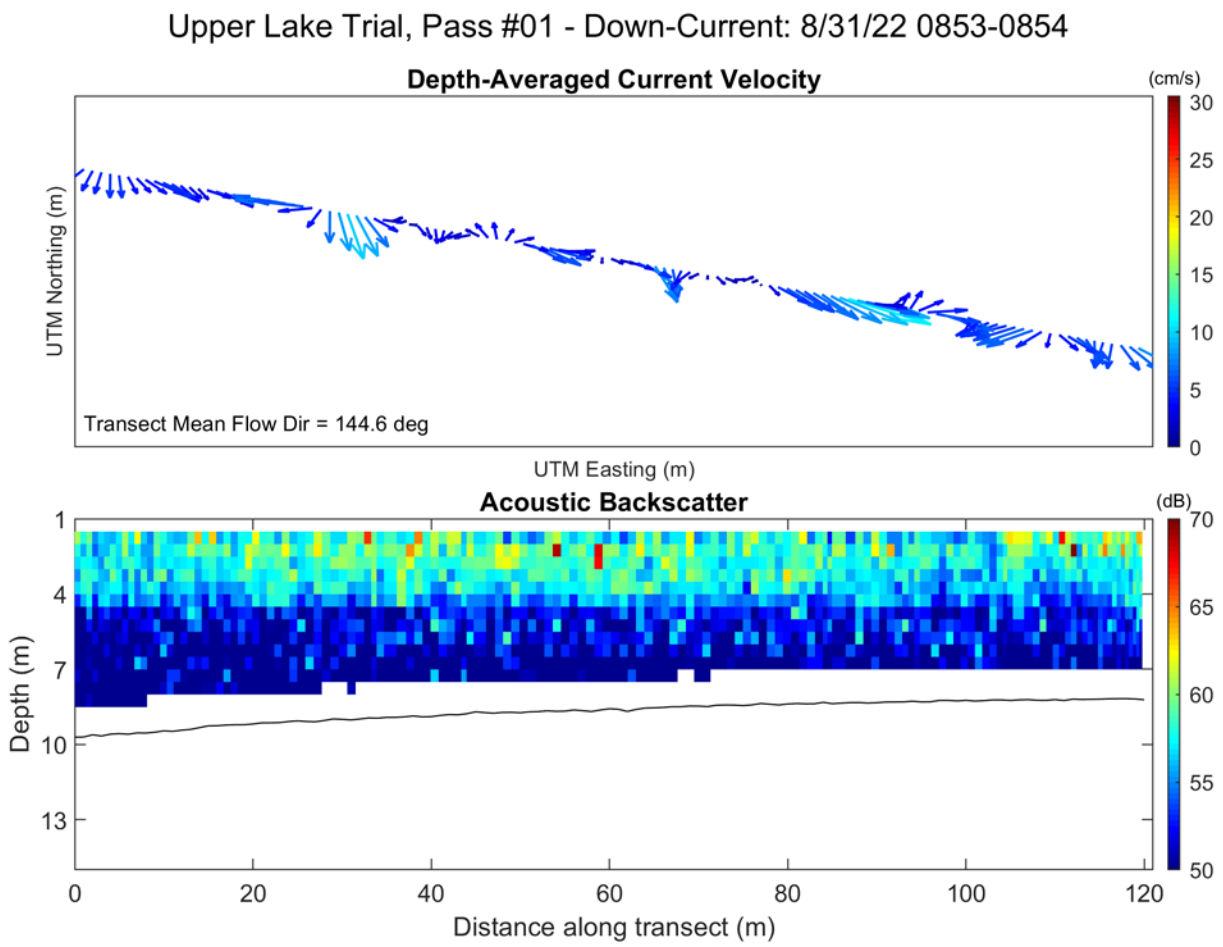
Site	Date	Time (EDT)	Latitude (DD)	Longitude (DD)	Type	Location	Pass	Layer	Depth (ft)	OBS (NTU)	TSS (mg/L)	ABS (dB)
Lower Lake Champlain	8/31/2022	15:33:27	44.02227	-73.41069	Pre-trial (Ambient)	Down	1	SUR	6.4	10.92	43.0	61.3
Lower Lake Champlain	8/31/2022	15:35:17	44.02227	-73.41072	Pre-trial (Ambient)	Down	1	MID	13.1	5.12	5.0	52.8
Lower Lake Champlain	8/31/2022	15:37:35	44.02233	-73.41058	Pre-trial (Ambient)	Down	1	BOT	19.6	1.25	BDL[1]	53.7
Lower Lake Champlain	8/31/2022	15:47:47	44.01973	-73.40976	Pre-trial (Ambient)	Up	1	SUR	6.5	11.1	6.7	61.7
Lower Lake Champlain	8/31/2022	15:49:28	44.01961	-73.40961	Pre-trial (Ambient)	Up	1	MID	11.1	10.58	5.5	53.5
Lower Lake Champlain	8/31/2022	15:51:45	44.01971	-73.40924	Pre-trial (Ambient)	Up	1	BOT	19.7	1.45	BDL	54.5
Lower Lake Champlain	9/1/2022	8:12:26	44.02330	-73.41165	Pre-trial (Ambient)	Up	1	SUR	6.2	18.26	9.5	64.5
Lower Lake Champlain	9/1/2022	8:14:29	44.02318	-73.41189	Pre-trial (Ambient)	Up	1	MID	10.2	14.72	7.0	57.0
Lower Lake Champlain	9/1/2022	8:17:08	44.02331	-73.41152	Pre-trial (Ambient)	Up	1	BOT	15.5	19.21	9.7	62.3
Lower Lake Champlain	9/1/2022	8:35:25	44.01982	-73.40907	Pre-trial (Ambient)	Down	1	SUR	6.1	18.04	9.3	64.0
Lower Lake Champlain	9/1/2022	8:37:10	44.01962	-73.40908	Pre-trial (Ambient)	Down	1	MID	10.7	10.29	9.3	57.0
Lower Lake Champlain	9/1/2022	8:39:35	44.01951	-73.40903	Pre-trial (Ambient)	Down	1	BOT	14.1	10.35	5.9	55.1
Lower Lake Champlain	9/1/2022	14:16:48	44.02228	-73.41080	Trial	Down	2	SUR	7.3	34.01	16.0	62.6
Lower Lake Champlain	9/1/2022	14:18:42	44.02217	-73.41084	Trial	Down	2	MID	14.1	5.68	6.4	59.9
Lower Lake Champlain	9/1/2022	14:20:49	44.02205	-73.41100	Trial	Down	2	BOT	20.2	2.68	BDL	59.4
Lower Lake Champlain	9/1/2022	14:29:14	44.01861	-73.40947	Trial	Up	2	SUR	7.5	21.47	12.0	66.0
Lower Lake Champlain	9/1/2022	14:31:05	44.01852	-73.40940	Trial	Up	2	MID	14.3	9.46	6.0	54.9
Lower Lake Champlain	9/1/2022	14:33:11	44.01845	-73.40947	Trial	Up	2	BOT	19.8	2.96	5.7	60.7
Lower Lake Champlain	9/1/2022	14:39:36	44.02081	-73.41022	Trial	Down	3	SUR	7.4	21.65	12.0	58.3
Lower Lake Champlain	9/1/2022	14:41:08	44.02074	-73.41026	Trial	Down	3	MID	13.7	9.83	6.9	57.2
Lower Lake Champlain	9/1/2022	14:43:00	44.02071	-73.41032	Trial	Down	3	BOT	20.5	3.05	BDL	61.2
Lower Lake Champlain	9/1/2022	14:49:04	44.01773	-73.40895	Trial	Up	3	SUR	7.6	22.76	13.0	60.0
Lower Lake Champlain	9/1/2022	14:50:37	44.01758	-73.40887	Trial	Up	3	MID	15.1	6.19	6.8	58.4
Lower Lake Champlain	9/1/2022	14:52:10	44.01754	-73.40897	Trial	Up	3	BOT	19.9	3.46	BDL	61.3
Lower Lake Champlain	9/1/2022	14:57:06	44.02004	-73.41022	Trial	Down	4	SUR	7.5	22.56	11.0	59.8
Lower Lake Champlain	9/1/2022	14:58:34	44.02004	-73.41032	Trial	Down	4	MID	13.6	8.09	7.4	56.9
Lower Lake Champlain	9/1/2022	15:00:23	44.01994	-73.41025	Trial	Down	4	BOT	20.3	3.19	BDL	61.8
Lower Lake Champlain	9/1/2022	15:06:36	44.01759	-73.40900	Trial	Up	4	SUR	8.5	22.05	9.4	57.6
Lower Lake Champlain	9/1/2022	15:08:07	44.01764	-73.40905	Trial	Up	4	MID	13.9	8.23	12.0	57.1
Lower Lake Champlain	9/1/2022	15:09:50	44.01768	-73.40910	Trial	Up	4	BOT	17.3	5.87	5.7	60.9
Lower Lake Champlain	9/1/2022	15:16:24	44.02002	-73.41014	Post-trial	Down	5	SUR	5.8	21.85	11.0	59.4
Lower Lake Champlain	9/1/2022	15:18:15	44.02007	-73.41019	Post-trial	Down	5	MID	14.1	9.65	7.2	58.0
Lower Lake Champlain	9/1/2022	15:20:04	44.02008	-73.41032	Post-trial	Down	5	BOT	19.6	3.35	BDL	60.3
Lower Lake Champlain	9/1/2022	15:25:54	44.01772	-73.40873	Post-trial	Up	5	SUR	7.2	25.06	15.0	60.9
Lower Lake Champlain	9/1/2022	15:28:08	44.01775	-73.40875	Post-trial	Up	5	MID	13.8	9.62	6.8	59.7
Lower Lake Champlain	9/1/2022	15:30:00	44.01766	-73.40875	Post-trial	Up	5	BOT	16.9	4.64	BDL	61.7
Lower Lake Champlain	9/1/2022	15:43:05	44.02173	-73.41013	Post-trial	NA	6	SUR	7.3	22.3	15.0	59.5
Lower Lake Champlain	9/1/2022	15:44:33	44.02160	-73.41019	Post-trial	NA	6	MID	12.4	17.51	7.1	58.5
Lower Lake Champlain	9/1/2022	15:46:12	44.02168	-73.41021	Post-trial	NA	6	BOT	16.8	7.65	11.0	60.9

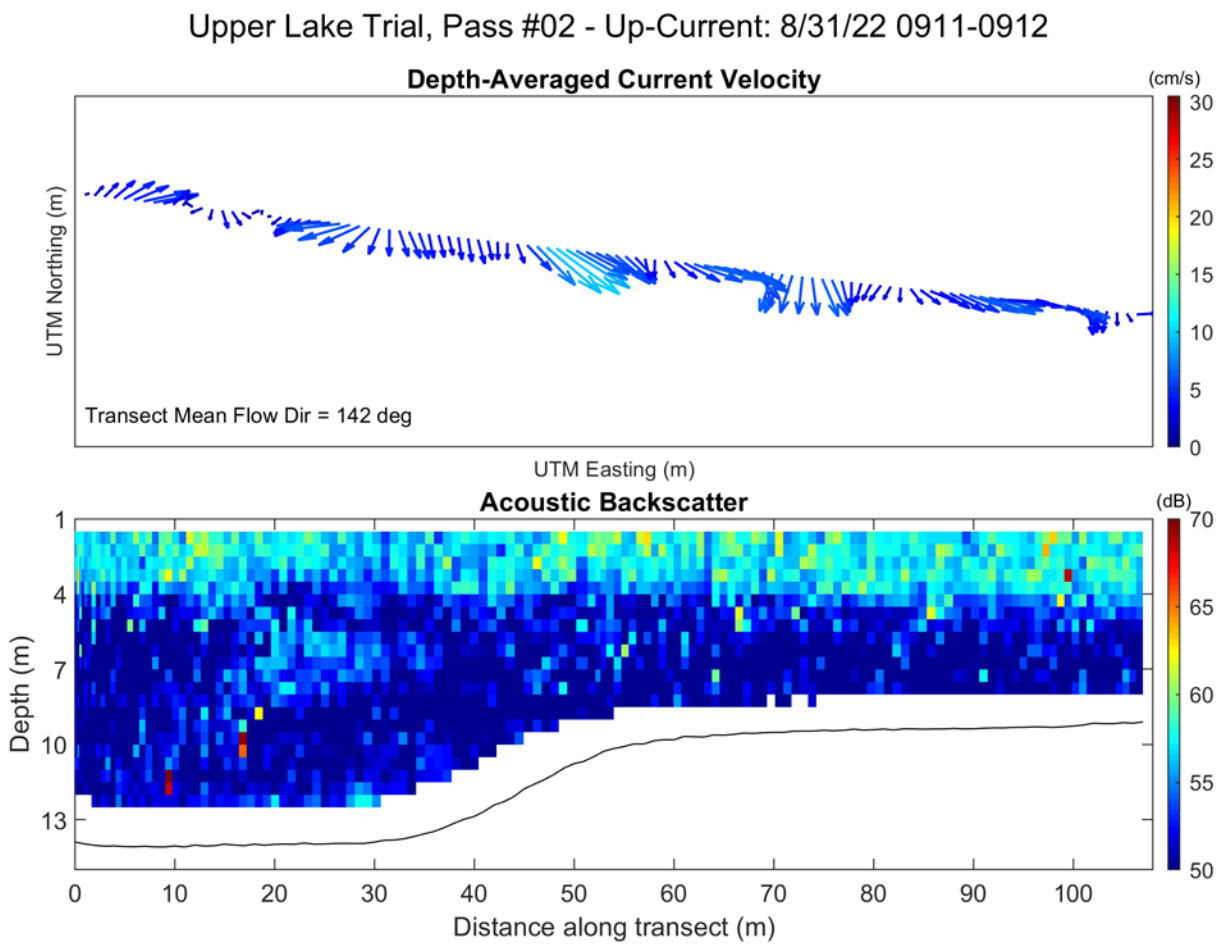
[1]"BDL" indicates the TSS levels were below the lab's method detection limit (<5 mg/L).

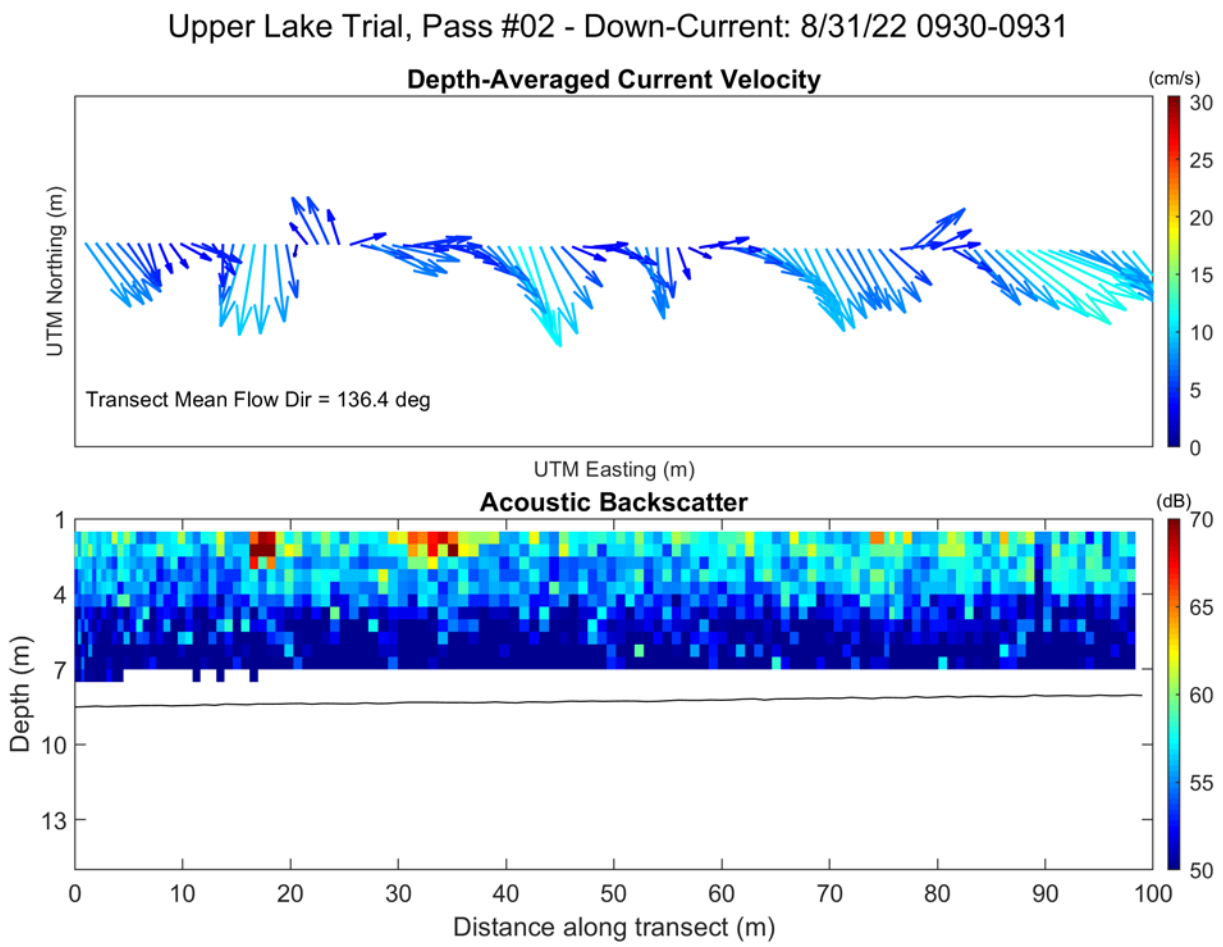
Appendix B. ADCP Velocity and ABS Transects from the Upper Lake Champlain Trial

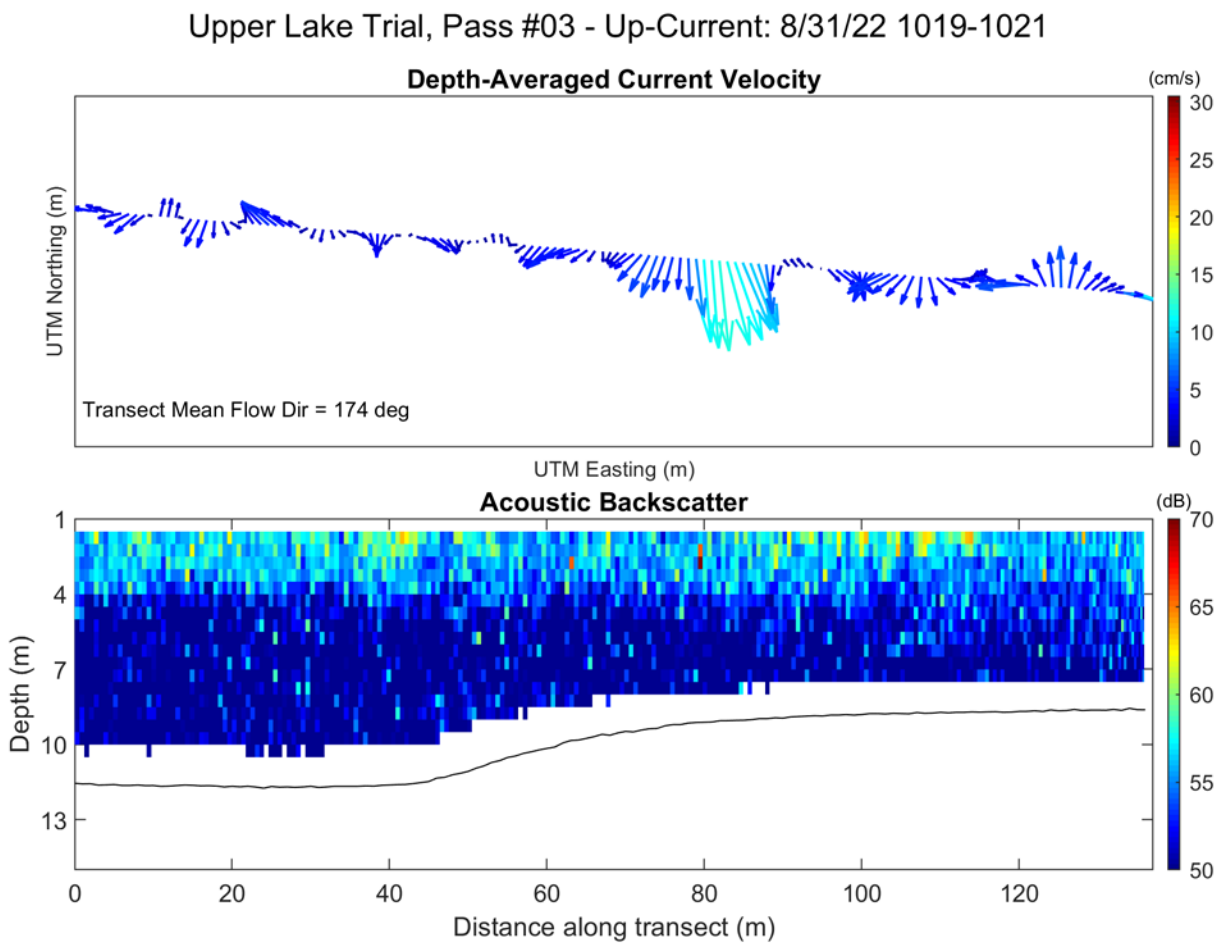

Upper Lake Pre-Trial Transect - Up-Current: 8/31/22 0803-0805
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 182.3 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
20
40
60
80
100
Distance along transect (m)

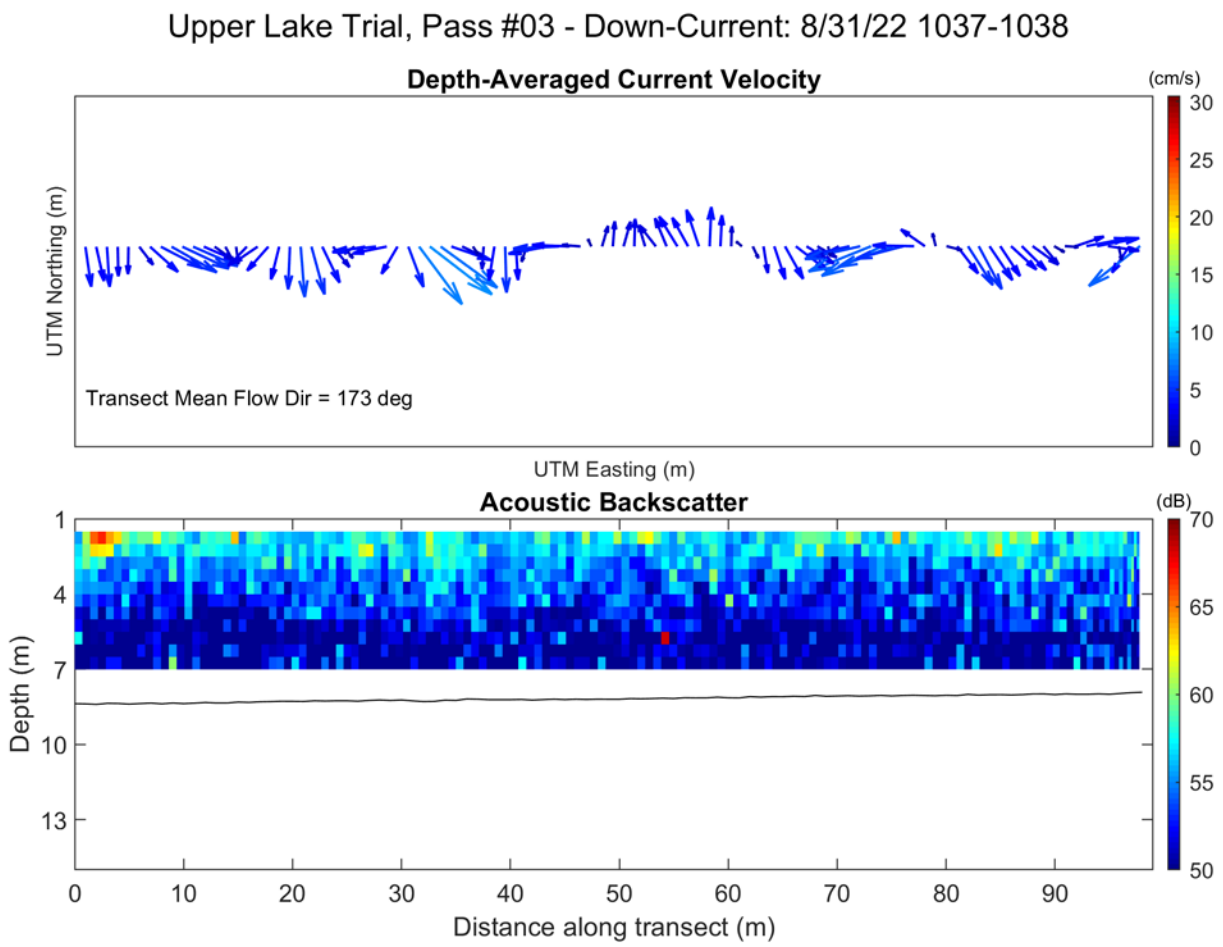

Upper Lake Trial, Pass #01 - Up-Current: 8/31/22 0840-0842
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 87.1 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
20
40
60
80
100
Distance along transect (m)


Upper Lake Trial, Pass #01 - Down-Current: 8/31/22 0853-0854
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 144.6 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
20
40
60
80
100
120
Distance along transect (m)

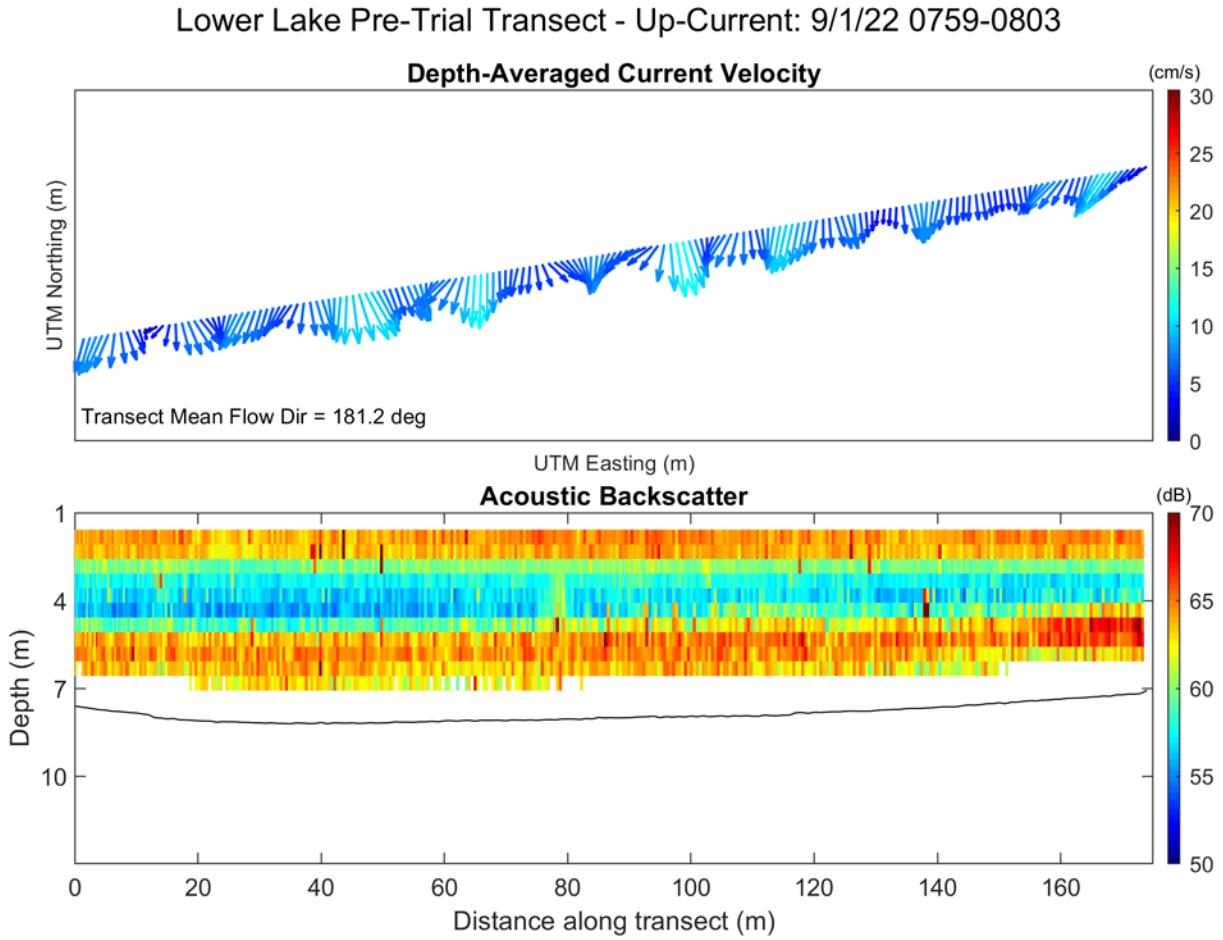

Upper Lake Trial, Pass #02 - Up-Current: 8/31/22 0911-0912
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 142 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
10
20
30
40
50
60
70
80
90
100
Distance along transect (m)

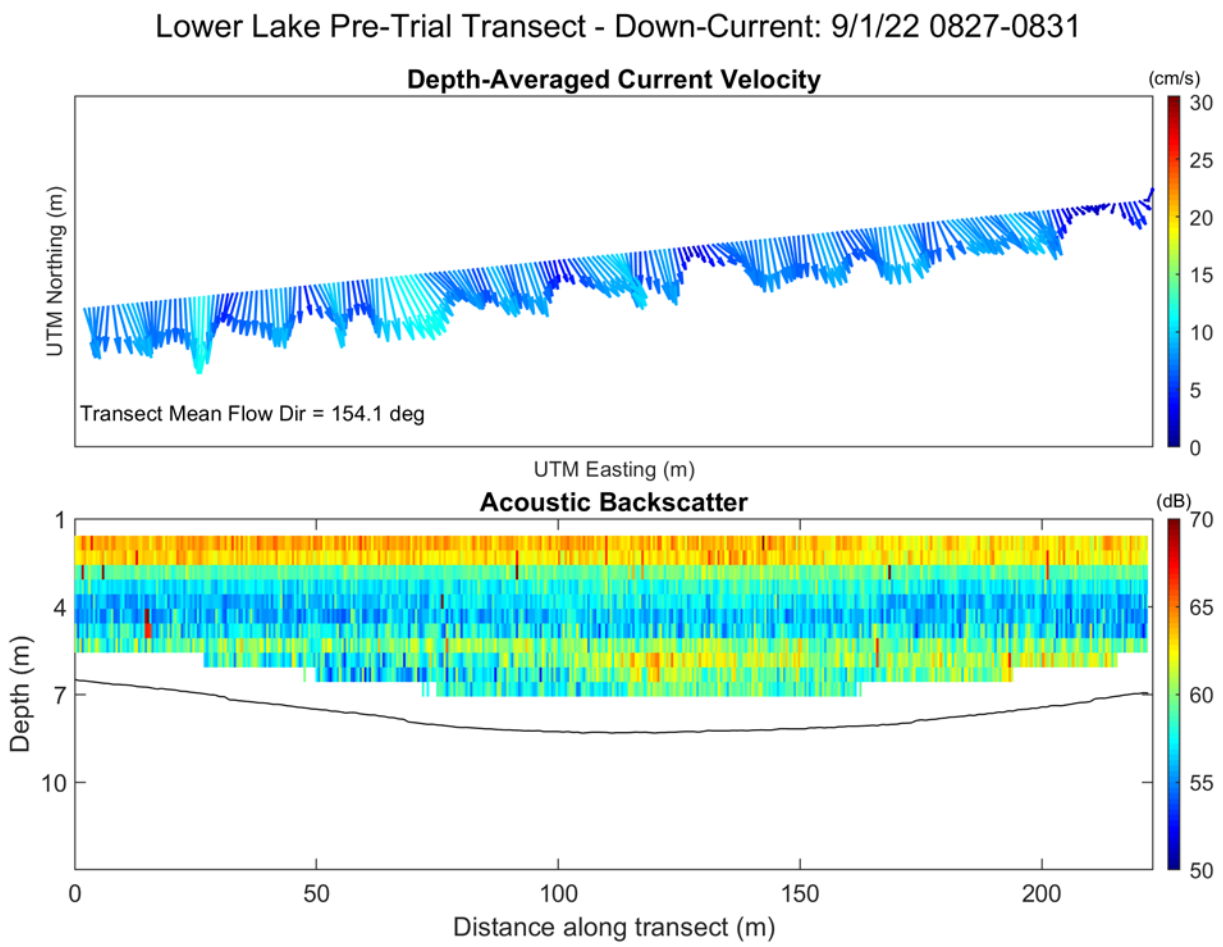

Upper Lake Trial, Pass #02 - Down-Current: 8/31/22 0930-0931
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 136.4 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
10
20
30
40
50
60
70
80
90
100
Distance along transect (m)

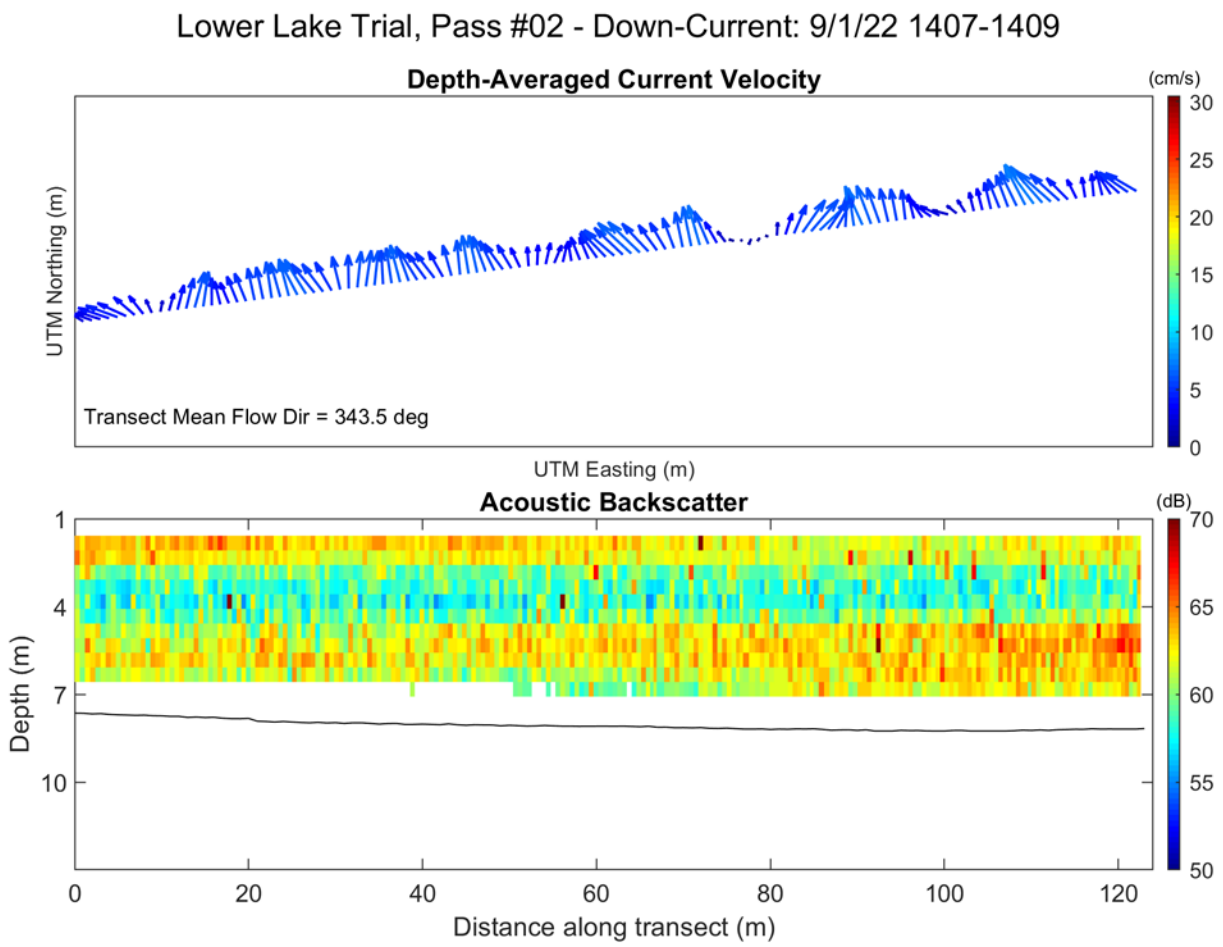

Upper Lake Trial, Pass #03 - Up-Current: 8/31/22 1019-1021
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 174 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
20
40
60
80
100
120
Distance along transect (m)

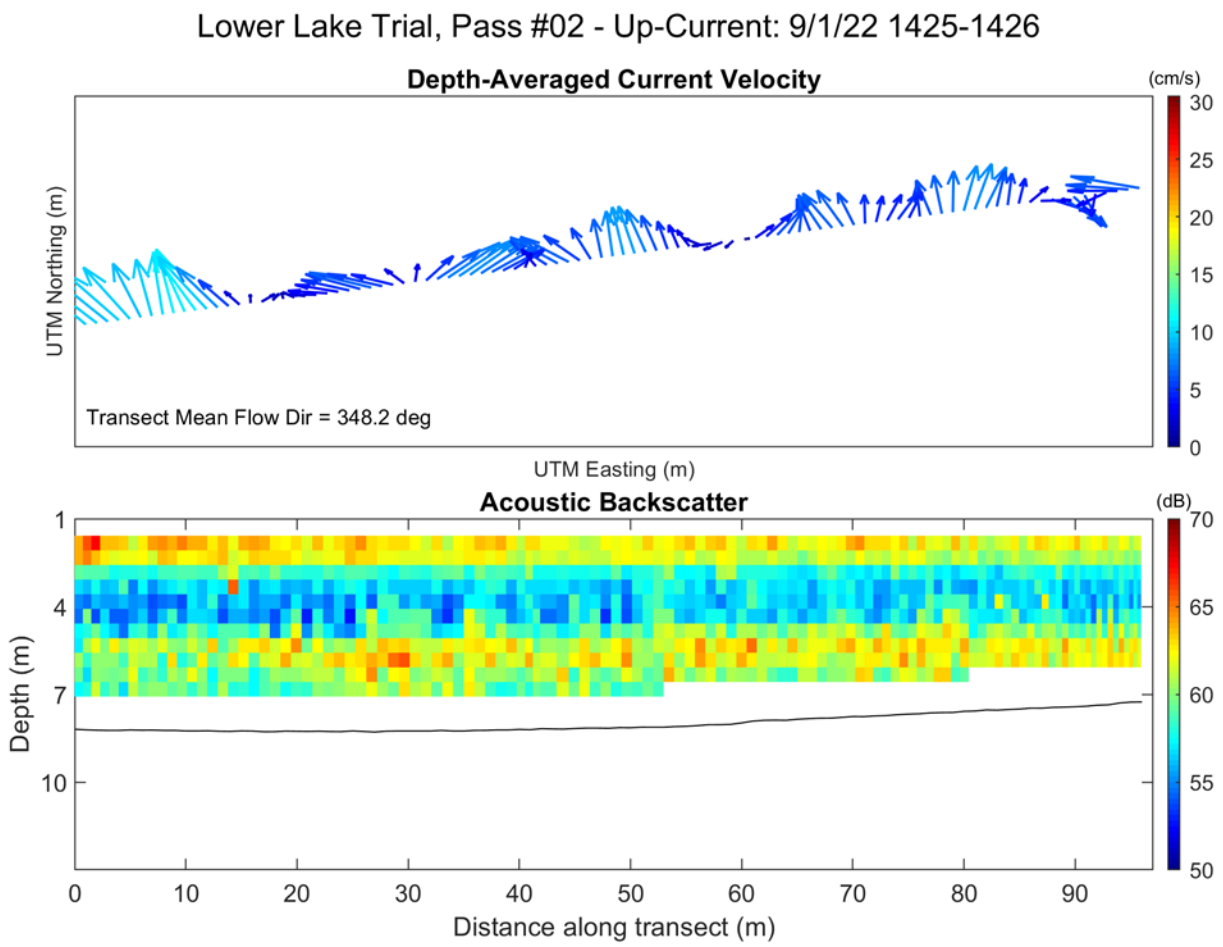

Upper Lake Trial, Pass #03 - Down-Current: 8/31/22 1037-1038
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 173 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
13
0
10
20
30
40
50
60
70
80
90
Distance along transect (m)

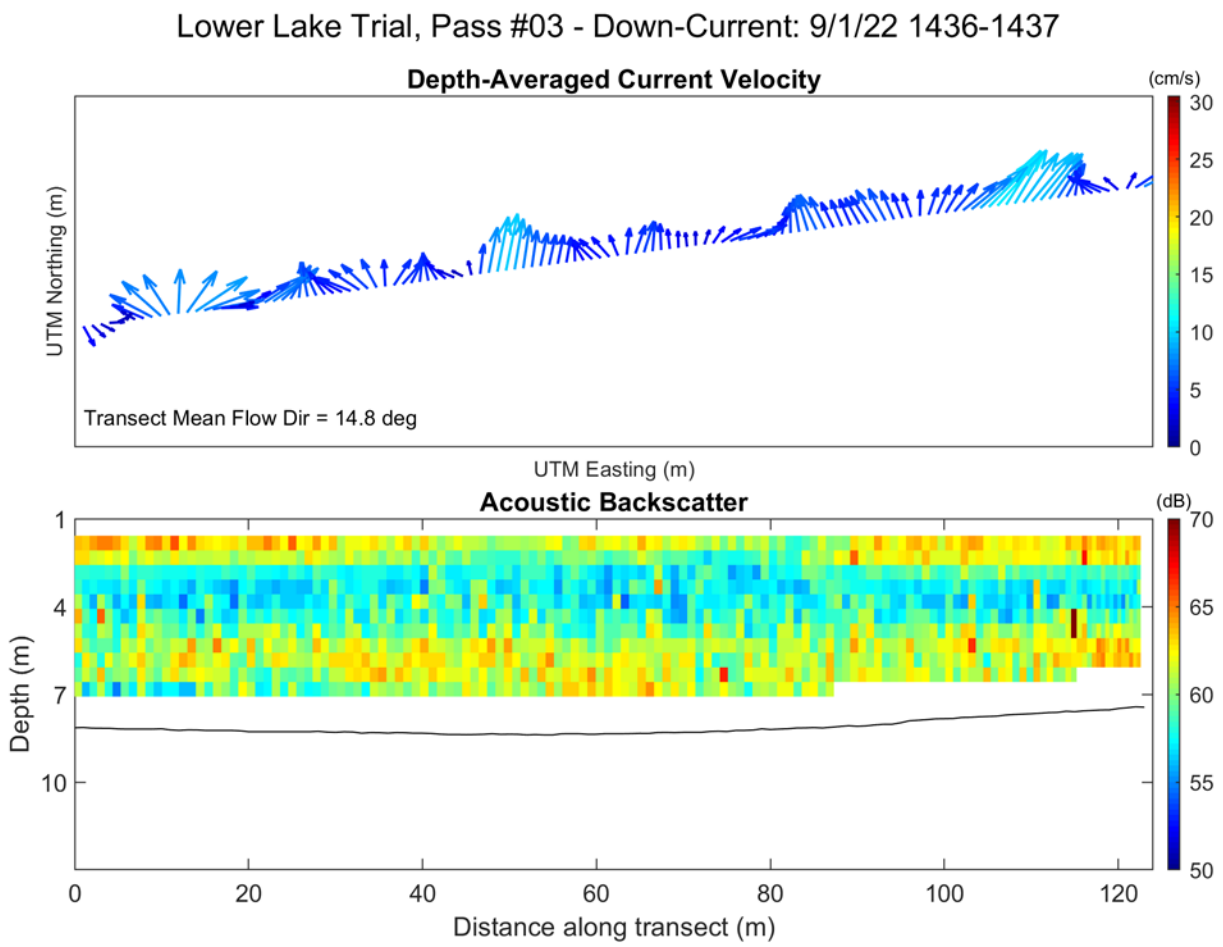
Appendix C. ADCP Velocity and ABS Transects from the Lower Lake Champlain Trial

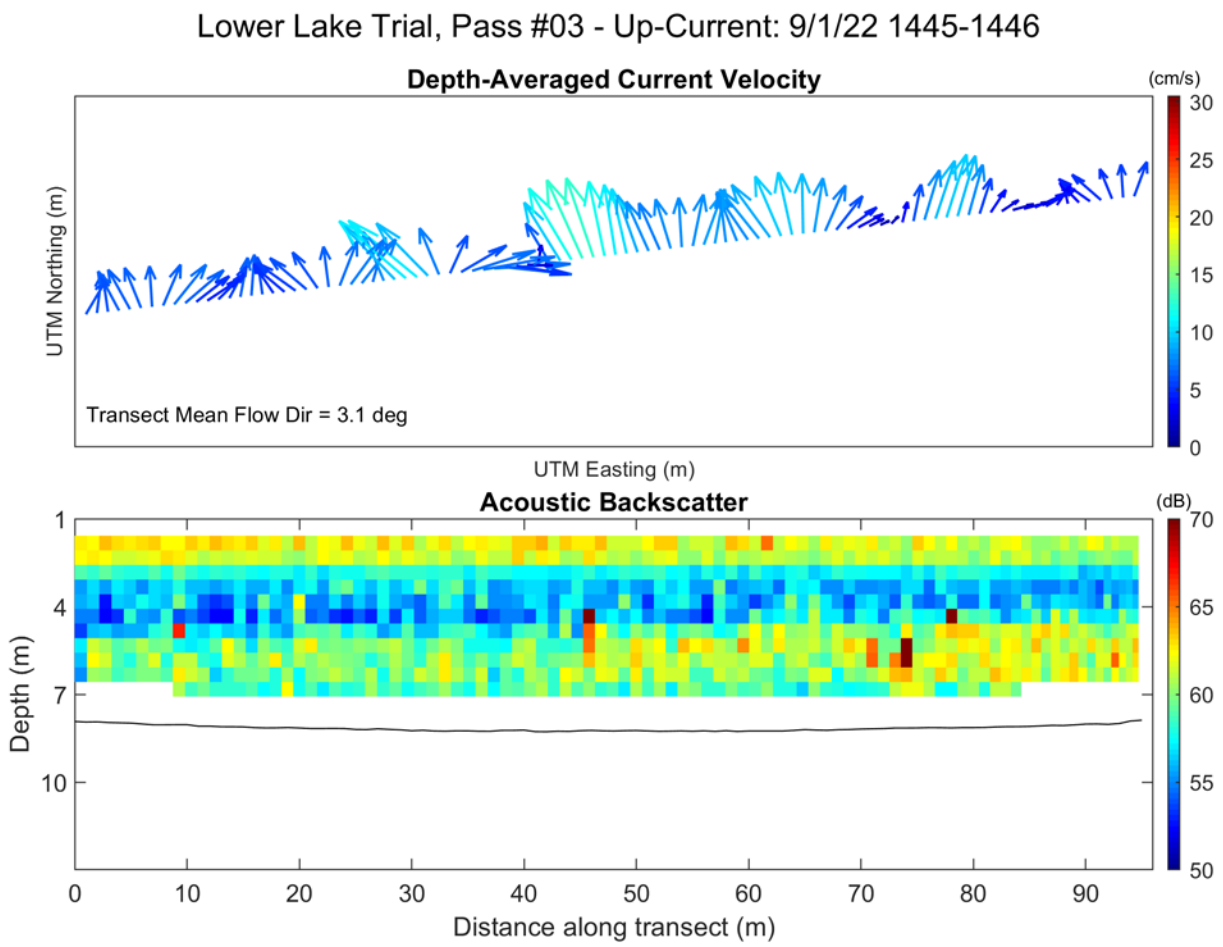

Lower Lake Pre-Trial Transect - Up-Current: 9/1/22 0759-0803
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 181.2 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
20
40
60
80
100
120
140
160
Distance along transect (m)

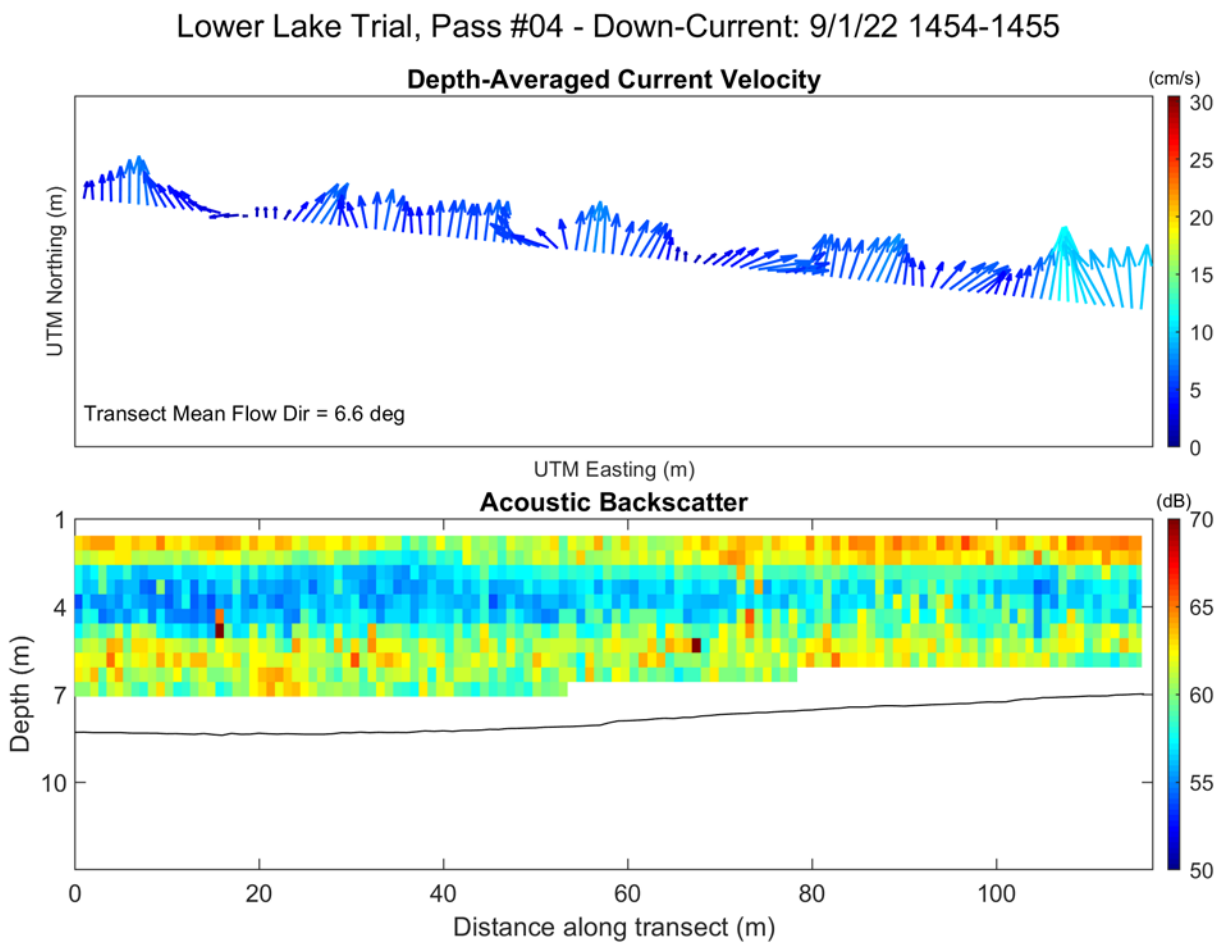

Lower Lake Pre-Trial Transect - Down-Current: 9/1/22 0827-0831
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 154.1 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
50
100
150
200
Distance along transect (m)

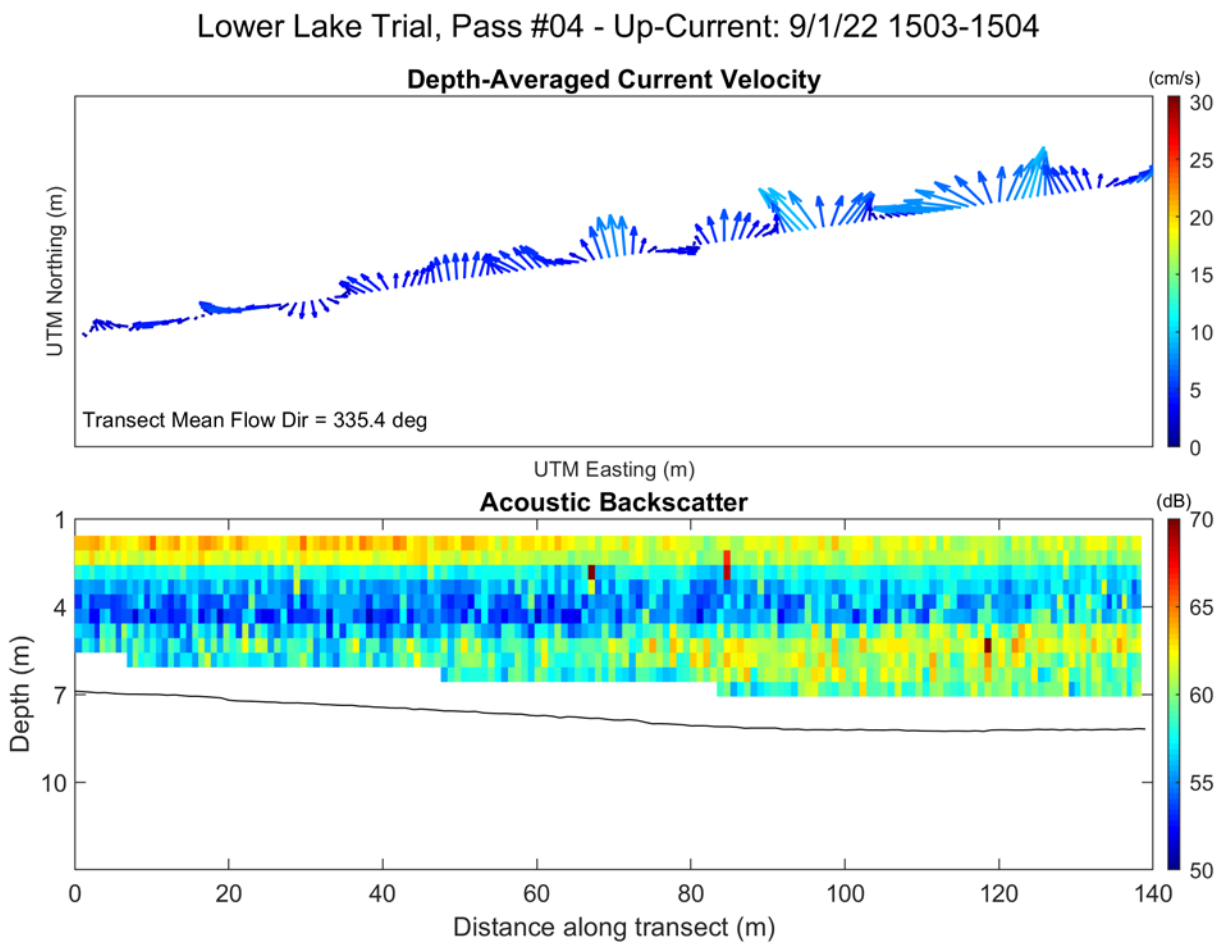

Lower Lake Trial, Pass #02 - Down-Current: 9/1/22 1407-1409
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 343.5 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
20
40
60
80
100
120
Distance along transect (m)


Lower Lake Trial, Pass #02 - Up-Current: 9/1/22 1425-1426
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 348.2 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
10
20
30
40
50
60
70
80
90
Distance along transect (m)


Lower Lake Trial, Pass #03 - Down-Current: 9/1/22 1436-1437
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 14.8 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
20
40
60
80
100
120
Distance along transect (m)


Lower Lake Trial, Pass #03 - Up-Current: 9/1/22 1445-1446
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 3.1 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
10
20
30
40
50
60
70
80
90
Distance along transect (m)


Lower Lake Trial, Pass #04 - Down-Current: 9/1/22 1454-1455
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 6.6 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
20
40
60
80
100
Distance along transect (m)


Lower Lake Trial, Pass #04 - Up-Current: 9/1/22 1503-1504
Depth-Averaged Current Velocity
(cm/s)
30
25
20
15
10
5
0
UTM Northing (m)
Transect Mean Flow Dir = 335.4 deg
UTM Easting (m)
Acoustic Backscatter
(dB)
70
65
60
55
50
Depth (m)
1
4
7
10
0
20
40
60
80
100
120
140
Distance along transect (m)

Appendix D. Linear Regression Model Results from MATLAB Output for TSS to OBS and TSS to ABS

```
----------------------------------------------------------------
*** SUMMARY of Linear Model for OBS-TSS with All Data Included:
----------------------------------------------------------------
 Model Information:

    TSS = 6.4044 + 0.2613*OBS

Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate       SE       tStat       pValue
                   ________    ______    ______    ________

    (Intercept)     6.4044      2.6037    2.4597    0.020105
    x1              0.2613     0.16183    1.6146     0.11723

Number of observations: 31, Error degrees of freedom: 29
Root Mean Squared Error: 6.66
R-squared: 0.0825,  Adjusted R-Squared: 0.0508
F-statistic vs. constant model: 2.61, p-value = 0.117
Model Standard Percentage Error (MPSE): 65.70%
----------------------------------------------------------------
```

Model Residuals and Diagnostics:

ObsNo	OBS	TSS	Raw_r	Pearson_r	Standardized_r	Studentized_r	CooksD	DFFITS
1	10.92	43	33.742	5.068	5.1697	18.141	0.54194	3.6533
2	5.12	5	-2.7422	-0.41187	-0.42986	-0.42374	0.008248	-0.12661
3	11.1	6.7	-2.6048	-0.39123	-0.39894	-0.39308	0.0031671	-0.078418
4	10.58	5.5	-3.6689	-0.55105	-0.56253	-0.55579	0.0066608	-0.11404
5	18.26	9.5	-1.6756	-0.25167	-0.25707	-0.25289	0.0014329	-0.052662
6	14.72	7	-3.2506	-0.48824	-0.49634	-0.48979	0.0041201	-0.089578
7	19.21	9.7	-1.7239	-0.25892	-0.26516	-0.26087	0.0017164	-0.057641
8	18.04	9.3	-1.8181	-0.27308	-0.27879	-0.27431	0.0016429	-0.0564
9	10.29	9.3	0.2069	0.031075	0.031744	0.031193	2.1935e-05	0.0065084
10	10.35	5.9	-3.2088	-0.48195	-0.49226	-0.48573	0.0052375	-0.10099
11	34.01	16	0.70895	0.10648	0.12395	0.12183	0.0027268	0.072583
12	5.68	6.4	-1.4885	-0.22357	-0.23259	-0.22876	0.0022272	-0.065642
13	21.47	12	-0.014394	-0.0021619	-0.0022331	-0.0021942	1.668e-07	-0.00056753
14	9.46	6	-2.8762	-0.432	-0.4423	-0.43609	0.0047219	-0.095813
15	2.96	5.7	-1.4778	-0.22196	-0.23503	-0.23116	0.0033483	-0.080487
16	21.65	12	-0.061427	-0.0092262	-0.0095377	-0.0093718	3.1229e-06	-0.0024557
17	9.83	6.9	-2.0729	-0.31134	-0.31843	-0.31344	0.0023345	-0.067259
18	22.76	13	0.64853	0.097408	0.10126	0.099516	0.00041345	0.028261
19	6.19	6.8	-1.2218	-0.18351	-0.1904	-0.1872	0.001386	-0.051767
20	22.56	11	-1.2992	-0.19514	-0.20264	-0.19925	0.0016084	-0.05577
21	8.09	7.4	-1.1183	-0.16796	-0.17277	-0.16986	0.00086836	-0.04097
22	22.05	9.4	-2.7659	-0.41544	-0.43028	-0.42416	0.0067351	-0.11441
23	8.23	12	3.4452	0.51745	0.53201	0.52532	0.0080728	0.12547
24	5.87	5.7	-2.2382	-0.33617	-0.34937	-0.34402	0.0048886	-0.097365
25	21.85	11	-1.1137	-0.16727	-0.17308	-0.17016	0.0010586	-0.045237
26	9.65	7.2	-1.7259	-0.25922	-0.26526	-0.26096	0.0016572	-0.056638
27	25.06	15	2.0476	0.30754	0.32431	0.31925	0.0058931	0.10687
28	9.62	6.8	-2.118	-0.31812	-0.32556	-0.32048	0.0025059	-0.069691
29	22.3	15	2.7687	0.41585	0.43126	0.42512	0.0070154	0.11677
30	17.51	7.1	-3.8797	-0.58271	-0.59423	-0.58748	0.0070461	-0.11736
31	7.65	11	2.5967	0.39002	0.40191	0.39603	0.0050021	0.098556

```
-----------------------------------------------------------------
*** SUMMARY of Linear Model for OBS-TSS with Outlier Excluded:
-----------------------------------------------------------------
 Model Information:

    TSS = 4.2722 + 0.33124*OBS

Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate       SE        tStat       pValue
                   ________    ________    ______    _________

    (Intercept)     4.2722      0.75124    5.6869    4.2638e-06
    x1             0.33124     0.046279    7.1574     8.659e-08

Number of observations: 30, Error degrees of freedom: 28
Root Mean Squared Error: 1.9
R-squared: 0.647,  Adjusted R-Squared: 0.634
F-statistic vs. constant model: 51.2, p-value = 8.66e-08
Model Standard Percentage Error (MPSE): 21.00%
-----------------------------------------------------------------
```

Model Residuals and Diagnostics:

ObsNo	OBS	TSS	Raw_r	Pearson_r	Standardized_r	Studentized_r	CooksD	DFFITS
1	5.12	5	-0.96813	-0.51026	-0.53332	-0.52639	0.013145	-0.16004
2	11.1	6.7	-1.2489	-0.65825	-0.67176	-0.66504	0.0093593	-0.13545
3	10.58	5.5	-2.2767	-1.1999	-1.226	-1.2376	0.032974	-0.25923
4	18.26	9.5	-0.82058	-0.43249	-0.44191	-0.43547	0.0042999	-0.091383
5	14.72	7	-2.148	-1.1321	-1.1515	-1.1585	0.022903	-0.21533
6	19.21	9.7	-0.93526	-0.49293	-0.50496	-0.49813	0.0062982	-0.11072
7	18.04	9.3	-0.94771	-0.49949	-0.51011	-0.50326	0.0055906	-0.10432
8	10.29	9.3	1.6194	0.8535	0.87264	0.86882	0.017276	0.18506
9	10.35	5.9	-1.8005	-0.94896	-0.9701	-0.96904	0.0212	-0.20569
10	34.01	16	0.46244	0.24373	0.28372	0.27901	0.014291	0.16625
11	5.68	6.4	0.24638	0.12985	0.13528	0.13289	0.00078072	0.038816
12	21.47	12	0.61615	0.32474	0.33549	0.33011	0.0037862	0.085624
13	9.46	6	-1.4057	-0.74088	-0.75928	-0.75339	0.014494	-0.16894
14	2.96	5.7	0.44734	0.23577	0.25009	0.24586	0.0039147	0.086987
15	21.65	12	0.55652	0.29332	0.30327	0.2983	0.0031744	0.078372
16	9.83	6.9	-0.62826	-0.33112	-0.33897	-0.33355	0.0027564	-0.07306
17	22.76	13	1.1889	0.62659	0.65145	0.64462	0.017174	0.18339
18	6.19	6.8	0.47745	0.25164	0.26143	0.25703	0.0027099	0.072381
19	22.56	11	-0.7449	-0.3926	-0.40775	-0.40159	0.0065376	-0.11262
20	8.09	7.4	0.4481	0.23617	0.24321	0.23908	0.0017894	0.058808
21	22.05	9.4	-2.176	-1.1469	-1.188	-1.1972	0.051582	-0.32367
22	8.23	12	5.0017	2.6362	2.7133	3.1034	0.21841	0.75595
23	5.87	5.7	-0.51656	-0.27225	-0.28333	-0.27862	0.0033326	-0.080285
24	21.85	11	-0.50972	-0.26865	-0.27803	-0.2734	0.0027453	-0.072864
25	9.65	7.2	-0.26863	-0.14158	-0.14502	-0.14246	0.00051602	-0.031558
26	25.06	15	2.427	1.2792	1.349	1.37	0.1021	0.45891
27	9.62	6.8	-0.6587	-0.34717	-0.35562	-0.35	0.0031149	-0.077683
28	22.3	15	3.3412	1.761	1.8265	1.911	0.12637	0.52601
29	17.51	7.1	-2.9722	-1.5665	-1.598	-1.6461	0.051918	-0.33193
30	7.65	11	4.1938	2.2104	2.2804	2.4816	0.16736	0.62958

```
-----------------------------------------------------------------
*** SUMMARY of Model for ABS-TSS with All Data Included:
-----------------------------------------------------------------
 Model Information:

     log10(TSS) = -0.73463 + 0.028515*ABS

Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate        SE         tStat       pValue
                   ________    ________    ______    ________

    (Intercept)    -0.73463     0.61348    -1.1975      0.24082
    x1             0.028515    0.010341     2.7574    0.0099757

Number of observations: 31, Error degrees of freedom: 29
Root Mean Squared Error: 0.173
R-squared: 0.208,  Adjusted R-Squared: 0.18
F-statistic vs. constant model: 7.6, p-value = 0.00998
Model Standard Percentage Error (MPSE): [-32.84%, +48.91%]
-----------------------------------------------------------------
```

Model Residuals and Diagnostics:

ObsNo	ABS	log10TSS	Raw_r	Pearson_r	Standardized_r	Studentized_r	CooksD	DFFITS
1	61.336	1.6335	0.61914	3.5806	3.6695	4.9264	0.33829	1.1043
2	52.847	0.69897	-0.07331	-0.42397	-0.46786	-0.46147	0.023833	-0.21534
3	61.698	0.82607	-0.19861	-1.1486	-1.1808	-1.1892	0.039584	-0.28337
4	53.537	0.74036	-0.051597	-0.2984	-0.32346	-0.3184	0.0091535	-0.13319
5	64.522	0.97772	-0.12748	-0.73725	-0.79122	-0.78599	0.047499	-0.30618
6	57.038	0.8451	-0.046685	-0.26999	-0.27697	-0.27251	0.0020074	-0.062342
7	62.262	0.98677	-0.05399	-0.31224	-0.32287	-0.31783	0.0036089	-0.083631
8	64.024	0.96848	-0.12251	-0.70852	-0.75266	-0.7469	0.036388	-0.2677
9	56.983	0.96848	0.07827	0.45266	0.46457	0.4582	0.0057531	0.1058
10	55.11	0.77085	-0.065974	-0.38155	-0.40074	-0.39486	0.0082814	-0.12681
11	62.629	1.2041	0.15291	0.88431	0.91854	0.91599	0.033288	0.25731
12	59.886	0.80618	-0.16681	-0.96473	-0.98141	-0.98077	0.016802	-0.18319
13	66.014	1.0792	-0.068558	-0.39649	-0.44218	-0.43596	0.023832	-0.21525
14	54.875	0.77815	-0.051967	-0.30054	-0.31691	-0.31194	0.0056202	-0.10436
15	60.69	0.75587	-0.24005	-1.3883	-1.4167	-1.4428	0.041476	-0.29334
16	58.282	1.0792	0.15192	0.8786	0.89467	0.8915	0.014772	0.17128
17	57.244	0.83885	-0.058817	-0.34015	-0.34837	-0.34303	0.0029675	-0.075858
18	59.983	1.1139	0.13818	0.79913	0.81315	0.80828	0.011703	0.15208
19	58.422	0.83251	-0.09875	-0.5711	-0.58127	-0.57452	0.0060726	-0.10892
20	59.848	1.0414	0.069475	0.40179	0.40871	0.40276	0.002899	0.075037
21	56.865	0.86923	-0.017615	-0.10187	-0.10466	-0.10286	0.00030393	-0.024231
22	57.596	0.97313	0.065439	0.37845	0.38667	0.38092	0.0032795	0.079785
23	57.115	1.0792	0.18519	1.071	1.098	1.102	0.030745	0.24889
24	60.866	0.75587	-0.24506	-1.4173	-1.4477	-1.4769	0.045505	-0.30776
25	59.435	1.0414	0.081247	0.46987	0.47767	0.47122	0.0038181	0.086205
26	58.03	0.85733	-0.062758	-0.36294	-0.36996	-0.36439	0.0026708	-0.071985
27	60.919	1.1761	0.17365	1.0043	1.0262	1.0271	0.023219	0.2157
28	59.717	0.83251	-0.13567	-0.78462	-0.79791	-0.79278	0.010878	-0.14655
29	59.452	1.1761	0.21548	1.2462	1.2669	1.2808	0.026876	0.23439
30	58.548	0.85126	-0.083601	-0.48348	-0.49192	-0.4854	0.0042598	-0.091077
31	60.92	1.0414	0.038919	0.22508	0.22999	0.2262	0.0011668	0.04751

```
-----------------------------------------------------------------
*** SUMMARY of Model for ABS-TSS with Outlier Excluded:
-----------------------------------------------------------------
 Model Information:

     log10(TSS) = -0.46797 + 0.02366*ABS

Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate        SE         tStat       pValue
                   ________    _________    ______    _________

    (Intercept)    -0.46797       0.46015    -1.017       0.31787
    x1              0.02366     0.0077655    3.0468     0.0050017

Number of observations: 30, Error degrees of freedom: 28
Root Mean Squared Error: 0.129
R-squared: 0.249,  Adjusted R-Squared: 0.222
F-statistic vs. constant model: 9.28, p-value = 0.005
Model Standard Percentage Error (MPSE): [-25.66%, +34.52%]
-----------------------------------------------------------------
```

Model Residuals and Diagnostics:

ObsNo	OBS	TSS	Raw_r	Pearson_r	Standardized_r	Studentized_r	CooksD	DFFITS
1	52.847	0.69897	-0.083411	-0.64762	-0.71478	-0.70839	0.055724	-0.33086
2	61.698	0.82607	-0.16574	-1.2868	-1.3247	-1.3436	0.052463	-0.32855
3	53.537	0.74036	-0.058348	-0.45303	-0.4911	-0.48434	0.021119	-0.20269
4	64.522	0.97772	-0.0809	-0.62812	-0.6762	-0.66951	0.036338	-0.26691
5	57.038	0.8451	-0.03644	-0.28293	-0.29028	-0.28548	0.0022171	-0.065489
6	62.262	0.98677	-0.018381	-0.14272	-0.14782	-0.14522	0.00079596	-0.039195
7	64.024	0.96848	-0.078351	-0.60833	-0.648	-0.64115	0.028274	-0.23528
8	56.983	0.96848	0.088248	0.68518	0.70329	0.6968	0.013253	0.1613
9	55.11	0.77085	-0.065086	-0.50534	-0.53076	-0.52384	0.014528	-0.16823
10	62.629	1.2041	0.1903	1.4775	1.5376	1.578	0.098072	0.45451
11	59.886	0.80618	-0.14274	-1.1083	-1.1283	-1.134	0.02319	-0.21646
12	66.014	1.0792	-0.014735	-0.11441	-0.12817	-0.1259	0.0020945	-0.063574
13	54.875	0.77815	-0.052221	-0.40545	-0.42754	-0.42122	0.010229	-0.14092
14	60.69	0.75587	-0.21207	-1.6466	-1.682	-1.742	0.061453	-0.36309
15	58.282	1.0792	0.16821	1.306	1.3303	1.3497	0.033289	0.26179
16	57.244	0.83885	-0.04757	-0.36935	-0.37833	-0.37247	0.0035247	-0.082659
17	59.983	1.1139	0.16272	1.2634	1.2866	1.3025	0.030628	0.25056
18	58.422	0.83251	-0.081784	-0.63499	-0.64654	-0.63969	0.0076734	-0.12257
19	59.848	1.0414	0.093363	0.7249	0.73791	0.73176	0.0098636	0.13928
20	56.865	0.86923	-0.0082104	-0.063748	-0.0655	-0.064325	0.00011957	-0.015187
21	57.596	0.97313	0.078392	0.60865	0.622	0.61505	0.0085741	0.12949
22	57.115	1.0792	0.19581	1.5203	1.5588	1.6018	0.062347	0.36286
23	60.866	0.75587	-0.21623	-1.6789	-1.7168	-1.7823	0.067313	-0.38091
24	59.435	1.0414	0.10313	0.80073	0.81452	0.80949	0.011524	0.15088
25	58.03	0.85733	-0.047694	-0.3703	-0.37757	-0.37171	0.0028253	-0.074004
26	60.919	1.1761	0.20273	1.5741	1.6102	1.6599	0.060145	0.35753
27	59.717	0.83251	-0.11242	-0.87284	-0.88825	-0.8848	0.014049	-0.16697
28	59.452	1.1761	0.23744	1.8435	1.8753	1.9693	0.061145	0.36723
29	58.548	0.85126	-0.066022	-0.51261	-0.52176	-0.51487	0.0049043	-0.09773
30	60.92	1.0414	0.06801	0.52804	0.54016	0.53321	0.0067708	0.11487