U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	OPR-B315-KR-22
Time Frame:	July - August 2022

LOCALITY

State(s):	Massachusetts Rhode Island
General Locality:	Rhode Island Sound

2022

CHIEF OF PARTY
John R. Bean

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Data Acquisition and Processing Report

Ocean Surveys
Chief of Party: John R. Bean
Year: 2022
Version: 1.0
Publish Date: 2023-02-23

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 MV Northstar Challenger

<table>
<tr><td>Vessel Name</td><td colspan="2">MV Northstar Challenger</td></tr>
<tr><td>Hull Number</td><td colspan="2">Official No. 1043939</td></tr>
<tr><td>Description</td><td colspan="2">MV Northstar Challenger is a 28m commercial utility vessel owned by Northstar Marine. In preparation for this survey, the MV Northstar Challenger was modified by OSI and Northstar Marine for hydrographic survey operations. The MV Northstar Challenger conducted 24-hour survey operations with port calls at approximately 10-day intervals for provisioning at Point Judith State Docks.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>28.0m</td></tr>
<tr><td>Beam</td><td>7.9m</td></tr>
<tr><td>Max Draft</td><td>2.6m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2021-06-30</td></tr>
<tr><td>Performed By</td><td>OSI</td></tr>
<tr><td rowspan="2">Most Recent Partial Offset Verification</td><td>Date</td><td>2022-07-16</td></tr>
<tr><td>Method</td><td>Relevant offsets established by the 2021 total station survey were confirmed during final on-site setup with a steel tape measure.</td></tr>
</table>

Figure 1: MV Northstar Challenger configured for hydrographic survey operations.

A.1.2 RV North Cove

Vessel Name	RV North Cove	
Hull Number	Registration No. CT 9011 BM	
Description	RV North Cove is an 11.1m aluminum forward cabin power boat designed by Specmar, Inc. and powered by twin 250 HP Yamaha outboard engines. The RV North Cove was customized by OSI for hydrographic surveying and conducted daily survey operations out of New England Boat Works in Melville, RI.	
Dimensions	*LOA*	11.1m
	Beam	3.4m
	Max Draft	0.8m
Most Recent Full Static Survey	*Date*	2021-03-08
	Performed By	OSI

Most Recent Partial Offset Verification	*Date*	2022-06-14
	Method	Relevant offsets established by the 2021 total station survey were confirmed during vessel mobilization with a steel tape measure.

Figure 2: RV North Cove configured for hydrographic survey operations.

A.1.3 RV South Cove

Vessel Name	RV South Cove
Hull Number	Registration No. CT 8013 BN
Description	RV South Cove is a 9.4m aluminum forward cabin power boat designed by Specmar, Inc. and powered by twin 250 HP Yamaha outboard engines. The RV South Cove was customized by OSI for hydrographic surveying and conducted daily survey operations out of Safe Harbor Dock (previously Trinity Marina LLC) in Tiverton, RI.

Dimensions	*LOA*	9.4m
	Beam	2.6m
	Max Draft	0.8m
Most Recent Full Static Survey	*Date*	2022-05-21
	Performed By	OSI
Most Recent Full Offset Verification	*Date*	2022-06-22
	Method	Relevant offsets established by the 2022 total station survey were confirmed during vessel mobilization with a steel tape measure.

Figure 3: RV South Cove configured for hydrographic survey operations.

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Teledyne RESON SeaBat T50-R

All vessels used Teledyne RESON SeaBat T50-R multibeam echosounders (MBES). The SeaBat T50-R is a shallow-water MBES system with available operational frequencies of 190 kHz to 420 kHz. The system is roll-stabilized and has multiple options for beam spacing (equidistant or equiangle), swath angle, and range. The manufacturer's stated depth resolution is 6mm. For this project, all vessels operated at 400 kHz, with a maximum swath angle of 140 degrees and the 512-equidistant beam configuration. When approaching some potentially shallow or hazardous areas or features, the system was switched to equiangle beam mode with 15 degree beam steering to starboard, as needed. This provided an added measure of safety when approaching hazards. In addition to sounding data, the SeaBat T50-R systems collected and recorded "normalized" backscatter data (the 7058 datagram).

<table>
<tr><td>Manufacturer</td><td colspan="5">Teledyne RESON</td></tr>
<tr><td>Model</td><td colspan="5">SeaBat T50-R</td></tr>
<tr><td rowspan="18">Inventory</td><td rowspan="6">MV Northstar Challenger</td><td>Component</td><td>Processor</td><td>Receiver</td><td>Projector</td></tr>
<tr><td>Model Number</td><td>T50-R</td><td>T50-R</td><td>T50-R</td></tr>
<tr><td>Serial Number</td><td>8940820103</td><td>1320184</td><td>320026</td></tr>
<tr><td>Frequency</td><td>400 kHz</td><td>400 kHz</td><td>400 kHz</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-07-17</td><td>2022-07-17</td></tr>
<tr><td>Accuracy Check</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="6">RV North Cove</td><td>Component</td><td>Processor</td><td>Receiver</td><td>Projector</td></tr>
<tr><td>Model Number</td><td>T50-R</td><td>T50-R</td><td>T50-R</td></tr>
<tr><td>Serial Number</td><td>8940620100</td><td>1320182</td><td>0320020</td></tr>
<tr><td>Frequency</td><td>400 kHz</td><td>400 kHz</td><td>400 kHz</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-06-15</td><td>2022-06-15</td></tr>
<tr><td>Accuracy Check</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="6">RV South Cove</td><td>Component</td><td>Processor</td><td>Receiver</td><td>Projector</td></tr>
<tr><td>Model Number</td><td>T50-R</td><td>T50-R</td><td>T50-R</td></tr>
<tr><td>Serial Number</td><td>8940820102</td><td>1320183</td><td>320028</td></tr>
<tr><td>Frequency</td><td>400 kHz</td><td>400 kHz</td><td>400 kHz</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-06-23</td><td>2022-06-23</td></tr>
<tr><td>Accuracy Check</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

Figure 4: SeaBat T50-R transducer mounted on the MV Northstar Challenger transducer pole.

Figure 5: SeaBat T50-R transducer mounted on the RV North Cove transducer pole.

Figure 6: SeaBat T50-R transducer mounted on the RV South Cove transducer pole.

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

A.2.5.1 Velodyne LiDAR PUCK VLP-16

The Velodyne VLP-16 is a scanning 3D LiDAR sensor with 16 available beams. According to the manufacturer, it has a range of 100m, a 30 degree vertical field of view, and a 360 degree horizontal field of view. Range accuracy is reported as 3cm at the maximum range. Rotation rate can be set between 300 RPM and 1200 RPM. For this survey, the LiDAR mounting approach and configuration was the same for both the RV North Cove and RV South Cove. The LiDAR was installed on a custom 45 degree mount on the starboard side just forward of the multibeam transducer pole. Of the 16 available beams, only the outer two and the inner two were enabled during data collection. An angle filter and a minimum range filter were applied to filter out returns from survey vessel and its wake. Rotation speed was set at 600 RPM, at which the manufacturer states the horizontal angular (azimuth) resolution is 0.2 degrees. A GoPro Hero7 camera was mounted below the LiDAR mount to capture digital photographs when the LiDAR was collecting data. Photographs were collected with a 4:3 aspect ratio at a 2Hz rate. The camera was interfaced via wireless connection to a mobile device with the GoPro application. Using the GoPro application installed on the mobile device, field crews were able to start and stop recording and see a real time camera field of view from the inside of the cabin.

Manufacturer	Velodyne		
Model	LiDAR PUCK VLP-16		
Inventory	*RV North Cove*	*Component*	Laser Scanner
		Model Number	VLP-16
		Serial Number	11002200823328
		Frequency	N/A
		Calibration	2022-06-16
		Accuracy Check	N/A
	RV South Cove	*Component*	Laser Scanner
		Model Number	VLP-16
		Serial Number	11002200826135
		Frequency	N/A
		Calibration	2022-06-21
		Accuracy Check	N/A

Figure 7: Velodyne VLP-16 LiDAR mounted on the RV North Cove.

Figure 8: Velodyne VLP-16 LiDAR mounted on the RV South Cove.

A.3 Manual Sounding Equipment

A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

A.3.2 Lead Lines

Each vessel was equipped with a lead line for spot soundings and echosounder verification checks. Lead lines were constructed by OSI using a 9 kg metal disk with a diameter of 0.3m attached to a stainless steel cable with permanent index markers established at 1m intervals. Lead lines were calibrated prior to survey operations using a steel tape measure to verify index mark accuracy (see DAPR Appendix V for results).

Manufacturer	OSI		
Model	Lead Line/Bar Check		
Inventory	*MV Northstar Challenger*	*Component*	Lead Line
		Model Number	N/A
		Serial Number	50-2
		Calibration	2022-06-13
	RV North Cove	*Component*	Lead Line
		Model Number	N/A
		Serial Number	NOAA-1
		Calibration	2022-06-13
	RV South Cove	*Component*	Lead Line
		Model Number	N/A
		Serial Number	75-1
		Calibration	2022-06-13

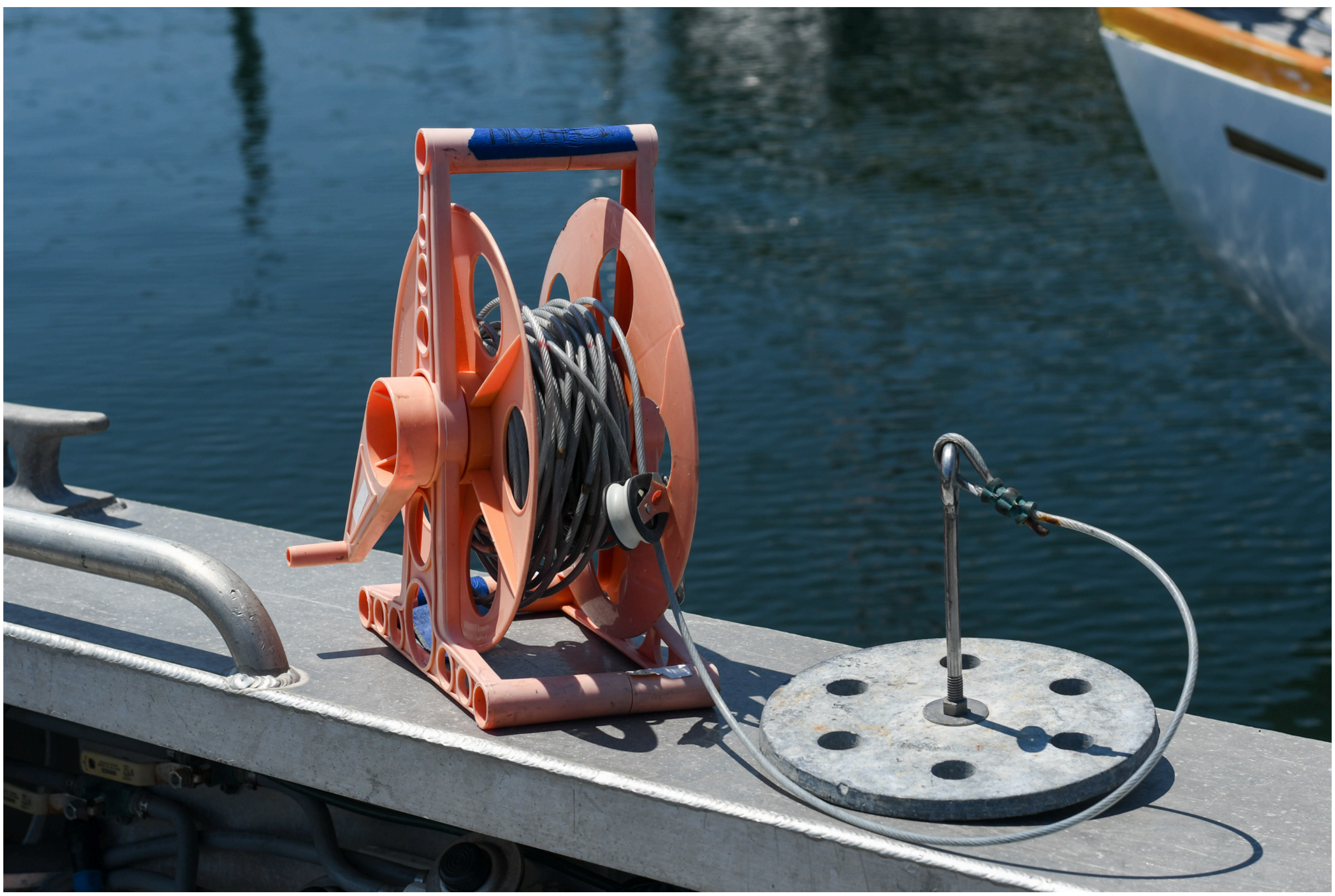


Figure 9: OSI-built lead line.

A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Horizontal and Vertical Control Equipment

A.4.1 Base Station Equipment

A.4.1.1 Trimble NetR9

OSI supplemented the local CORS network with a temporary GNSS base station at Sachuest Beach, locally known as Second Beach, in Middletown, Rhode Island. A Trimble NetR9 GNSS receiver with a Zephyr 3 Geodetic Antenna was configured to record GNSS observables continuously throughout the period of the survey and parse data observables into daily files for each 24-hour period. The configuration of the receiver was based on UNAVCO standard configuration settings for this device. In addition to recording GNSS observables, OSSB was also configured to transmit CMR+RTK correctors to the RV North Cove and RV South Cove for realtime water level measurement and monitoring. On the MV Northstar Challenger, the POS MV's integrated DGPS was activated from the controller software utilizing SBAS (FAA WAAS) corrections to improve real-time positioning.

GNSS observables were recorded on removable media as well as on the receiver's internal storage. Data were delivered to OSI’s home office processing center by regular automated FTP and e-mail “pushes” over a network connection that was established on site for this purpose. The Trimble NetR9 data was included in IAPPK processing and designated as Ocean Surveys Sachuest (Second) Beach or “OSSB.” The coordinates of OSSB were determined using OPUS. A discussion of OPUS data processing and the determination of final coordinates is included in the HVCR.

Manufacturer	Trimble		
Model	NetR9		
Inventory	*Component*	Receiver	Zephyr 3 Geodetic GNSS Antenna
	Model Number	NetR9	115000-00
	Serial Number	5811R52419	6122223813
	Calibration	N/A	N/A

Figure 10: GNSS Base Station OSSB

A.4.2 Rover Equipment

A.4.2.1 Trimble R8 GNSS Rover with TSC3 data collector

The Trimble R8 GNSS is an integrated receiver/antenna combination unit. The rover was operated in RTK-GNSS mode and was used to install temporary navigation confidence checks for each vessel at their respective docks. See the HVCR for a discussion of these points.

Manufacturer	Trimble		
Model	R8 GNSS Rover with TSC3 data collector		
Inventory	*Component*	GNSS Rover	Data Collector
	Model Number	R8-3	TSC3
	Serial Number	5221488422	RS5ND03254
	Calibration	N/A	N/A
	Component	GNSS Rover	Data Collector
	Model Number	R8-3	TSC3
	Serial Number	5111463256	RS5ID00363
	Calibration	N/A	N/A

A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.4.4 Levels

No levels were utilized for data acquisition.

A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

A.5 Positioning and Attitude Equipment

A.5.1 Positioning and Attitude Systems

A.5.1.1 Applanix POS MV 320 V5

The POS MV is a GNSS inertial navigation and attitude system made up of 2 GNSS antennas and an inertial measurement unit (IMU) interfaced with a topside processor. The POS MV combines the IMU and GNSS sensor data into an integrated and blended navigation solution.

The POS MV generates attitude data in three axes (roll, pitch, and heading). Roll and pitch measurements are made within an accuracy of 0.02°. The GNSS Azimuth Measurement Subsystem (GAMS) uses two the GNSS receivers and antennas to determine a GNSS-enhanced heading that is accurate to 0.02° or better (using an antenna baseline greater than or equal to 2m) when blended with the inertial navigation solution. GAMS heading was employed for all survey data acquisition and GAMS status was monitored continuously during survey operations using POSView, the POS MV's controller software.

Heave measurements supplied by the POS MV maintain an accuracy of 0.05m or 5% of the measured vertical displacement for movements that have a period of up to 20 seconds.

On both RV North Cove and RV South Cove, the POS MV was operating in RTK mode in order to map realtime water levels. On the MV Northstar Challenger, it was configured to operate using SBAS (FAA WASS) positioning correctors.

Manufacturer	Applanix
Model	POS MV 320 V5

Inventory

MV Northstar Challenger	*Component*	Topside	IMU	GPS Antenna (Stbd.)	GPS Antenna (Port)
	Model Number	POS MV V5	LN200	Trimble GA830	Trimble GA830
	Serial Number	11273	405162	11330	16009
	Calibration	2022-07-17	2022-07-17	2022-07-17	2022-07-17
RV North Cove	*Component*	Topside	IMU	GPS Antenna (Stbd.)	GPS Antenna (Port)
	Model Number	POS MV V5-1	82	Trimble GA830	Trimble GA830
	Serial Number	12016	5487	15406	17027
	Calibration	2022-06-15	2022-06-15	2022-06-15	2022-06-15
RV South Cove	*Component*	Topside	IMU	GPS Antenna (Stbd.)	GPS Antenna (Port)
	Model Number	POS MV V5	64	Trimble GA830	Trimble GA830
	Serial Number	10351	5018	8367	8360
	Calibration	2022-06-21	2022-06-21	2022-06-21	2022-06-21

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

A.5.3.1 Trimble SPS850 Extreme GPS

On all three vessels, a Trimble SPS850 Extreme GPS served as an independent check of the POS MV reported position. On both RV North Cove and RV South Cove, the instrument was operated in RTK mode. On the MV Northstar Challenger, the instrument was configured to operate using SBAS (FAA WASS) positioning.

Manufacturer	Trimble			
Model	SPS850 Extreme GPS			
Inventory	*RV North Cove*	*Component*	Receiver	Antenna
		Model Number	58555-01	Zephyr 2
		Serial Number	5023K67948	30572609
		Calibration	N/A	N/A
	RV South Cove	*Component*	Receiver	Antenna
		Model Number	58805-66	Zephyr 2
		Serial Number	4726K06460	4611118555
		Calibration	N/A	N/A
	MV Northstar Challenger	*Component*	Receiver	Antenna
		Model Number	58805-66	Zephyr 2
		Serial Number	4605K00522	11884478
		Calibration	N/A	N/A

A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 AML Oceanographic MVP30-350

On the MV Northstar Challenger, sound speed profiles were acquired at approximately 20-minute intervals using an AML Oceanographic MVP 30-350 moving vessel profiler. This instrument consists of towfish-mounted sensors, an electro-mechanical conducting cable, and an electric winch. The MVP may be deployed manually using the winch controls or automatically using the MVP Controller software. During an automatic profile, the winch "free-wheels" and the towfish falls near-vertically to a preset depth off the bottom, collecting sound speed, temperature, and pressure (depth) measurements at a rate of 10 Hz. The data are then transmitted to the system topside computer and the towfish is recovered. On day 228, the towfish cable electrical connection failed. The towfish cable was replaced on day 229 while docked for weather in Pt. Judith.

<table>
<tr><td>Manufacturer</td><td colspan="7">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="7">MVP30-350</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">MV Northstar Challenger</td><td>Component</td><td colspan="5">MVP</td></tr>
<tr><td>Model Number</td><td colspan="5">30-350</td></tr>
<tr><td>Serial Number</td><td colspan="5">M12730</td></tr>
<tr><td>Calibration</td><td colspan="5">N/A</td></tr>
<tr><td rowspan="4">MV Northstar Challenger</td><td>Component</td><td>Sonde</td><td>Sound Speed Sensor</td><td>Pressure Sensor</td><td>Temperature Sensor</td></tr>
<tr><td>Model Number</td><td>MVP-X</td><td>SV Xchange</td><td>P Xchange</td><td>T-Xchange</td></tr>
<tr><td>Serial Number</td><td>9062</td><td>203524</td><td>307282</td><td>404600</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-03-11</td><td>2022-03-11</td><td>2022-02-14</td></tr>
</table>

Figure 11: MVP30-350 Moving Vessel Profiler mounted on the starboard quarter of the MV Northstar Challenger.

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 AML Oceanographic Base X2 Sound Speed Profilers

On the RV North Cove, the majority of sound speed profiles were acquired using an AML Oceanographic Base-X2 logging profiler. An AML Base-X2 was also onboard the MV Northstar Challenger as a backup for the MVP. The AML Oceanographic Base-X2 instrument collects high-precision direct sound speed and pressure measurements. The instrument was configured to take measurements at a rate of 5 Hz. The data was stored internally and downloaded via a serial connection to the SeaCast software program on the logging laptop computer.

Manufacturer	AML Oceanographic
Model	Base X2 Sound Speed Profilers

Inventory					
RV North Cove	*Component*	Sonde	Sound Speed Sensor	Pressure Sensor
	Model Number	Base-X2	SV-Exchange	P-Exchange
	Serial Number	26280	201521	307286
	Calibration	N/A	2022-02-16	2022-02-16
MV Northstar Challenger	*Component*	Sonde	Sound Speed Sensor	Pressure Sensor
	Model Number	Base-X2	SV-Exchange	P-Exchange
	Serial Number	25838	208179	306268
	Calibration	N/A	2022-02-16	2022-02-15

A.6.3.2 AML Oceanographic AML-3 LGR Sound Speed Profiler

On the RV South Cove and some survey days on the RV North Cove, sound speed profiles were acquired using an AML Oceanographic AML-3 LGR logging profiler. This instrument collects high-precision direct sound speed and pressure measurements. It also has the capability to be configured with a third sensor which measures both temperature and conductivity. The instruments were configured to take measurements at a rate of 5 Hz. Data were stored internally and downloaded via Bluetooth connection to the Sailfish software program on the vessel's logging laptop.

Manufacturer	AML Oceanographic
Model	AML-3 LGR Sound Speed Profiler

Inventory							
RV North Cove	*Component*	Sonde	Sound Speed Sensor	Pressure Sensor	Temperature Sensor	Conductivity Sensor
	Model Number	AML-3 LGR	SV X2change	P X2change	CT X2change	CT X2change
	Serial Number	A30011	210009	307638	450956	450956
	Calibration	N/A	2022-03-11	2022-03-17	2022-03-12	2022-03-12
RV South Cove	*Component*	Sonde	Sound Speed Sensor	Pressure Sensor		
	Model Number	AML-3 LGR	SV X2change	P X2change		
	Serial Number	A30130	210737	307349		
	Calibration	N/A	2022-05-05	2022-03-17		

A.6.3.3 AML Oceanographic Micro-X Sound Speed Sensor

An AML Micro-X was mounted within the forward faring of each MBES and supplied real-time surface sound speed data to the MBES for beam forming and to the HYPACK acquisition computer via the RESON interface. The Micro-X uses a direct read sound speed “exchange” sensor.

Manufacturer	AML Oceanographic			
Model	Micro-X Sound Speed Sensor			
Inventory	*MV Northstar Challenger*	*Component*	Sonde	Sound Speed Sensor
		Model Number	Micro-X	SV Xchange
		Serial Number	10315	211299
		Calibration	N/A	2022-03-16
	RV North Cove	*Component*	Sonde	Sound Speed Sensor
		Model Number	Micro-X	SV Xchange
		Serial Number	12736	201527
		Calibration	N/A	2022-02-16
	RV South Cove	*Component*	Sonde	Sound Speed Sensor
		Model Number	Micro-X	SV Xchange
		Serial Number	12739	203108
		Calibration	N/A	2022-02-16

A.6.4 TSG Sensors

No TSG sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No other surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
HYPACK	HYPACK Survey	20.3.2.0	Acquisition
Applanix	POSPac MMS	8.8	Processing
Applanix	MV POS View	11.0	Acquisition
Teledyne RESON	Teledyne Sonar UI	5.2.0.1	Acquisition
AML Oceanographic	MVP Controller	2.48	Acquisition
AML Oceanographic	SeaCast	4.4.0	Acquisition
AML Oceanographic	Sailfish	1.3.0.10	Acquisition
Teledyne CARIS	HIPS/SIPS	11.4	Processing
Global Mapper Software, LLC	Global Mapper	23.0	Processing
Microsoft	Office Suite 360	16	Acquisition and Processing
National Geodetic Survey	OPUS Projects	4.0.1	Processing
NOAA	Pydro Programs (Sound Speed Manager, QC Tools, CA Tools, Compare Grids, XMLDR)	v22.1 (r10242)	Processing
Mathworks	MATLAB	R2022a	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 WILDCO Petite Ponar Dredge

The WILDCO Petite Ponar Dredge is a stainless steel bottom sampler with 6 inch scoops. During deployment, the sampler is held in the open position by a spring-loaded catch pin. Once the sampler reaches the bottom and the retrieval line slacks, the catch pin is released. Hauling on the retrieval line causes the scoops to close and capture the bottom sample, which is then brought to the surface for description and documentation.

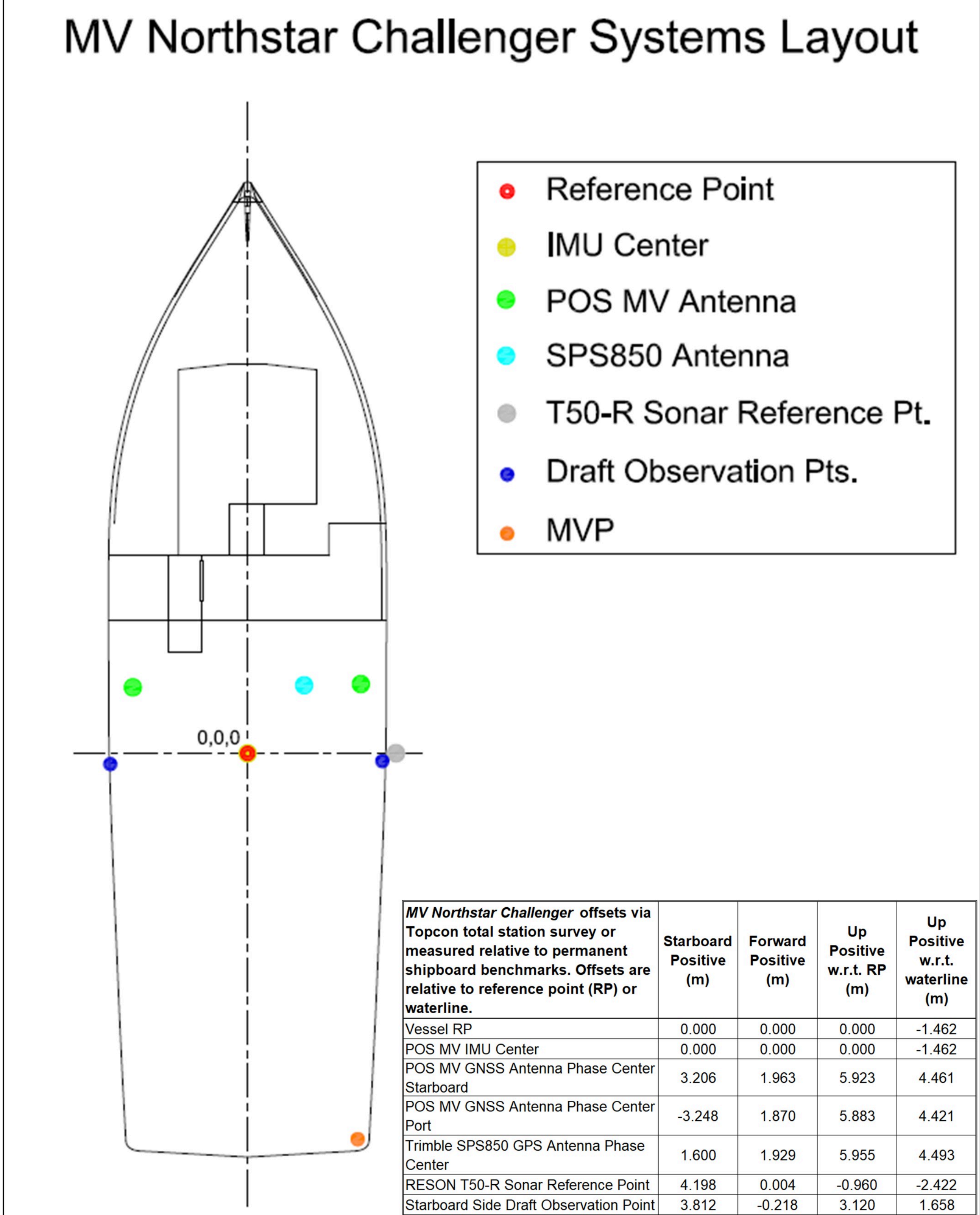
Figure 12: WILDCO Petite Ponar Dredge Bottom Sampler used on the RV North Cove and RV South Cove.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

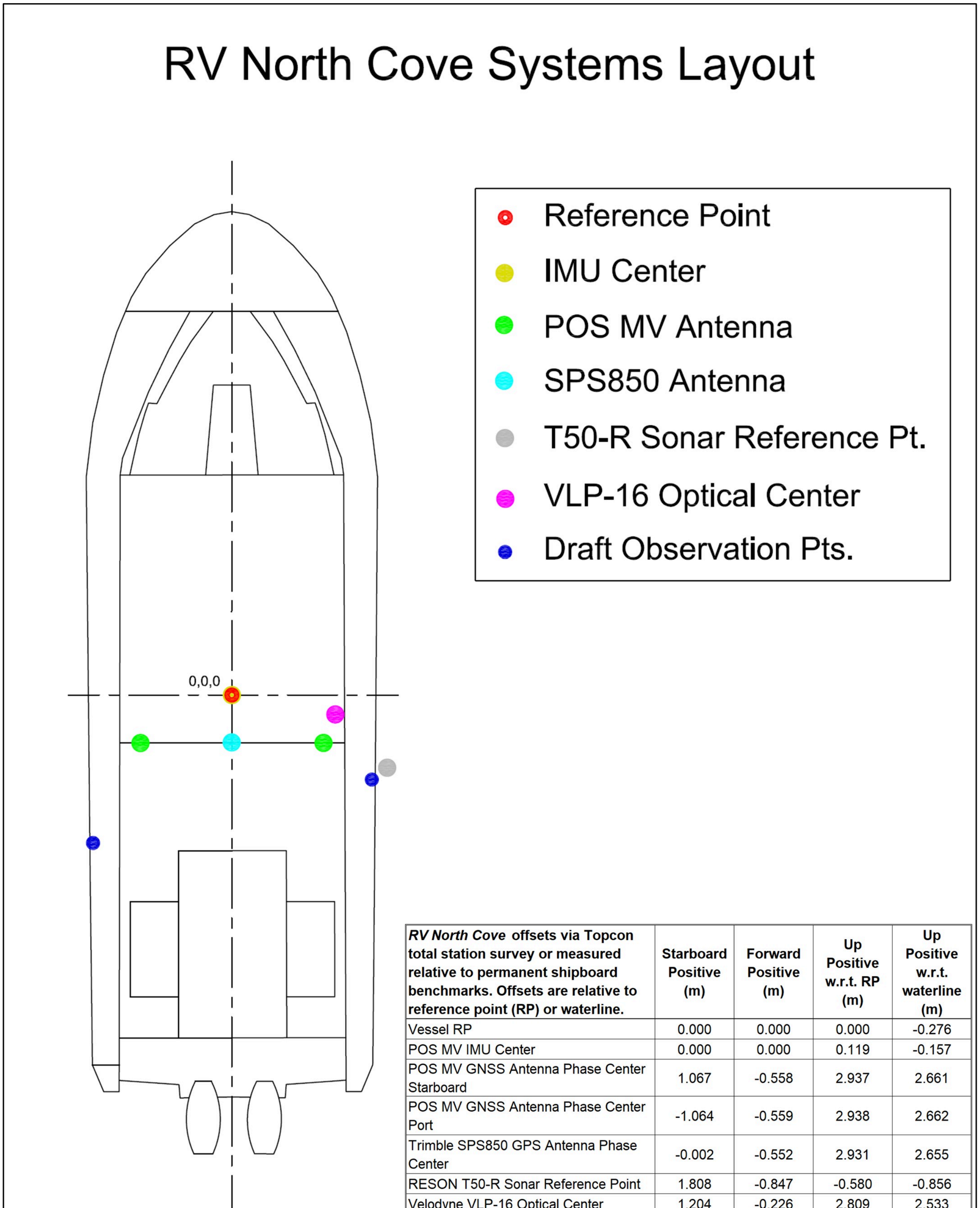
B.1.1 Vessel Offsets

Sensor offsets for each vessel were measured relative to their respective reference point (RP) and are depicted in the vessel layout figures below. Offsets and on-board benchmarks were established in the vessel reference frame during full static surveys when the vessels were on land or in dry dock and confirmed in the field using a steel tape measure. For all vessels, the RP to IMU and RP to primary GNSS antenna lever arm offsets are applied in the POS MV's controller software, POSView. Multibeam transducer and LiDAR offsets were measured and applied relative to each vessel's RP in HYPACK and did not change during the survey. All sensor offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file (HVF) for each vessel for data processing.



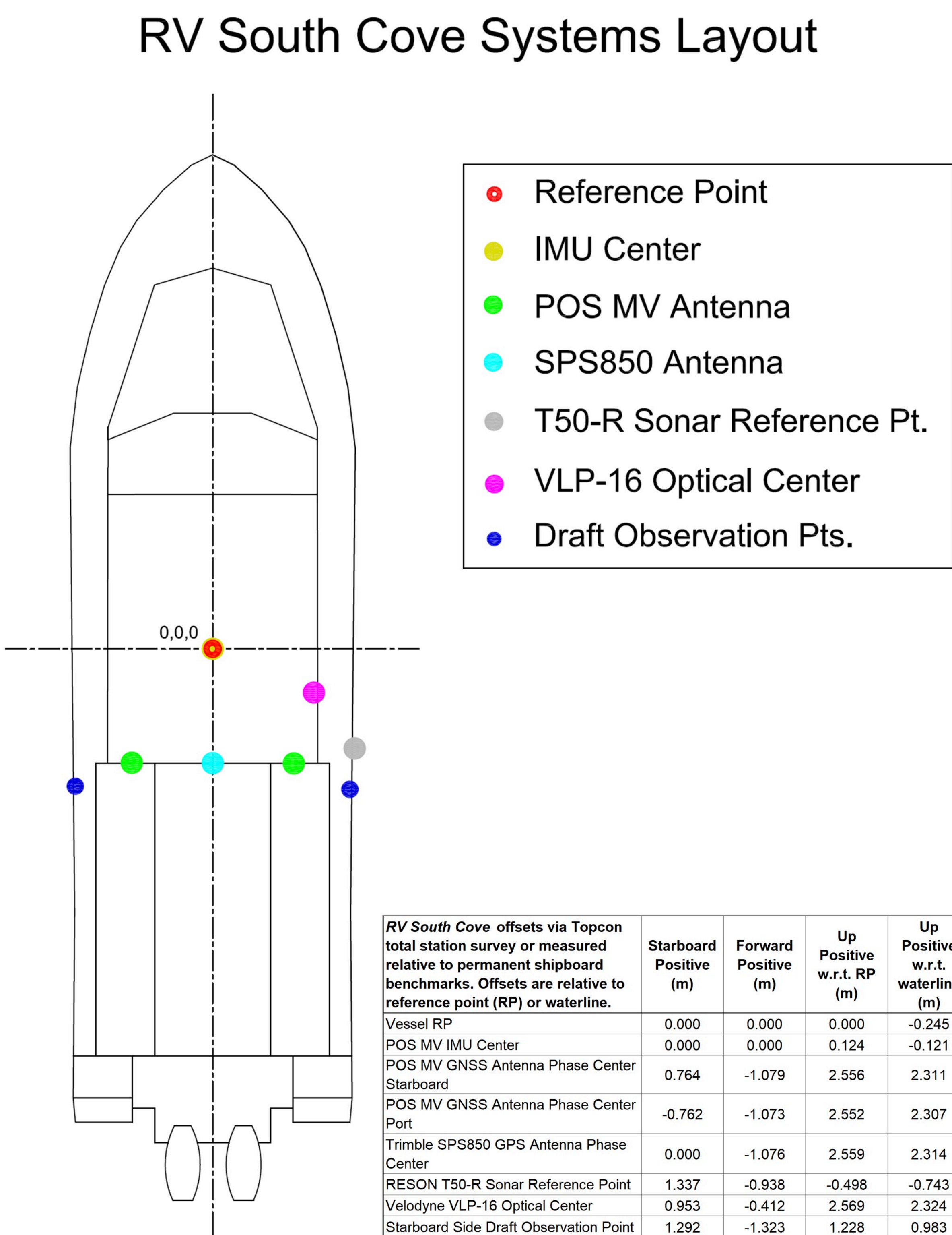
MV Northstar Challenger **offsets via Topcon total station survey or measured relative to permanent shipboard benchmarks. Offsets are relative to reference point (RP) or waterline.**	**Starboard Positive (m)**	**Forward Positive (m)**	**Up Positive w.r.t. RP (m)**	**Up Positive w.r.t. waterline (m)**
Vessel RP	0.000	0.000	0.000	-1.462
POS MV IMU Center	0.000	0.000	0.000	-1.462
POS MV GNSS Antenna Phase Center Starboard	3.206	1.963	5.923	4.461
POS MV GNSS Antenna Phase Center Port	-3.248	1.870	5.883	4.421
Trimble SPS850 GPS Antenna Phase Center	1.600	1.929	5.955	4.493
RESON T50-R Sonar Reference Point	4.198	0.004	-0.960	-2.422
Starboard Side Draft Observation Point	3.812	-0.218	3.120	1.658
Port Side Draft Observation Point	-3.886	-0.302	3.118	1.656

Figure 13: MV Northstar Challenger Systems Layout.



RV North Cove **offsets via Topcon total station survey or measured relative to permanent shipboard benchmarks. Offsets are relative to reference point (RP) or waterline.**	**Starboard Positive (m)**	**Forward Positive (m)**	**Up Positive w.r.t. RP (m)**	**Up Positive w.r.t. waterline (m)**
Vessel RP	0.000	0.000	0.000	-0.276
POS MV IMU Center	0.000	0.000	0.119	-0.157
POS MV GNSS Antenna Phase Center Starboard	1.067	-0.558	2.937	2.661
POS MV GNSS Antenna Phase Center Port	-1.064	-0.559	2.938	2.662
Trimble SPS850 GPS Antenna Phase Center	-0.002	-0.552	2.931	2.655
RESON T50-R Sonar Reference Point	1.808	-0.847	-0.580	-0.856
Velodyne VLP-16 Optical Center	1.204	-0.226	2.809	2.533
Starboard Side Draft Observation Point	1.629	-0.985	1.382	1.106
Port Side Draft Observation Point	-1.617	-1.724	1.329	1.053

Figure 14: RV North Cove Systems Layout.



RV South Cove **offsets via Topcon total station survey or measured relative to permanent shipboard benchmarks. Offsets are relative to reference point (RP) or waterline.**	**Starboard Positive (m)**	**Forward Positive (m)**	**Up Positive w.r.t. RP (m)**	**Up Positive w.r.t. waterline (m)**
Vessel RP	0.000	0.000	0.000	-0.245
POS MV IMU Center	0.000	0.000	0.124	-0.121
POS MV GNSS Antenna Phase Center Starboard	0.764	-1.079	2.556	2.311
POS MV GNSS Antenna Phase Center Port	-0.762	-1.073	2.552	2.307
Trimble SPS850 GPS Antenna Phase Center	0.000	-1.076	2.559	2.314
RESON T50-R Sonar Reference Point	1.337	-0.938	-0.498	-0.743
Velodyne VLP-16 Optical Center	0.953	-0.412	2.569	2.324
Starboard Side Draft Observation Point	1.292	-1.323	1.228	0.983
Port Side Draft Observation Point	-1.294	-1.283	1.212	0.967

Figure 15: RV South Cove Systems Layout.

B.1.1.1 Vessel Offset Correctors

Vessel	MV Northstar Challenger			
Echosounder	Teledyne RESON SeaBat T50-R Multibeam Echosounder			
Date	2022-07-16			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	4.198 meters	0.020 meters
		y	0.004 meters	0.020 meters
		z	0.960 meters	0.020 meters
	Nav to Transducer	*x*	0.992 meters	0.020 meters
		y	-1.959 meters	0.020 meters
		z	6.883 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	RV North Cove			
Echosounder	Teledyne RESON SeaBat T50-R Multibeam Echosounder			
Date	2022-06-15			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.808 meters	0.020 meters
		y	-0.847 meters	0.020 meters
		z	0.669 meters	0.020 meters
	Nav to Transducer	*x*	0.741 meters	0.020 meters
		y	-0.289 meters	0.020 meters
		z	3.517 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	RV South Cove			
Echosounder	Teledyne RESON SeaBat T50-R Multibeam Echosounder			
Date	2022-06-23			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	1.337 meters	0.020 meters
		y	-0.938 meters	0.020 meters
		z	0.622 meters	0.020 meters
	Nav to Transducer	*x*	0.573 meters	0.020 meters
		y	0.141 meters	0.020 meters
		z	3.054 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	RV North Cove			
Echosounder	Velodyne VLP-16 LiDAR			
Date	2022-06-16			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	1.204 meters	0.020 meters
		y	-0.226 meters	0.020 meters
		z	-2.690 meters	0.020 meters
	Nav to Transducer	*x*	0.137 meters	0.020 meters
		y	0.332 meters	0.020 meters
		z	0.128 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	RV South Cove			
Echosounder	Velodyne VLP-16 LiDAR			
Date	2022-06-23			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.953 meters	0.020 meters
		y	-0.412 meters	0.020 meters
		z	-2.445 meters	0.020 meters
	Nav to Transducer	*x*	0.189 meters	0.020 meters
		y	0.667 meters	0.020 meters
		z	-0.013 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

B.1.2 Layback

All sensors were rigidly mounted. No towed sensors requiring layback corrections were employed during this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

Static draft is the vertical distance of the echosounder transducer phase center below the water line with the vessel at rest. On all vessels, a draft observation point was established so that a direct measurement could be made to the surface of the water. Refer to the figures in section B.1.1 Vessel Offsets for the location of the draft observation point for each boat. During the full static survey, the vertical offset between the transducer phase center and RP and the vertical offset between the draft observation point and RP were recorded. The vertical offset between the transducer phase center and the RP was entered into the HVF in CARIS for each vessel. On all vessels, during mobilization and prior to the start of the survey, direct measurements were made from a calm water surface to the draft observation point using a steel tape. These initial measure-downs were performed with the vessel at normal load and full of fuel and while keeping the roll of the boat as close to zero as possible. Starting static waterline height was then calculated by difference. Over the course of the survey, measure-downs were performed at dock to account for changes in waterline height due to fuel consumption and loading. Since ERS tides were applied, the time-stamped updated waterline heights were not needed in the HVF files.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
MV Northstar Challenger	2022-07-16	0.030 meters	-2.422 meters	0.030 meters
RV North Cove	2022-06-15	0.030 meters	-0.856 meters	0.030 meters
RV South Cove	2022-06-23	0.030 meters	-0.743 meters	0.030 meters

B.2.2 Dynamic Draft

Dynamic draft for each vessel was measured using IAPPK SBET height measurements at average load and trim and while configured for survey operations. Pairs of reciprocal lines were run at increasing speed intervals in order to mitigate the effect of current. "Drift lines" were recorded with the vessel at rest between reciprocal test runs in order to account for tidal variations. The sea-state was calm during collection. For the vessels, RV North Cove and RV South Cove, dynamic draft measurements were made near OSI's home office in Old Saybrook, CT prior to the survey. Pydro's POSPac Auto QC Dynamic Draft tool was used to confirm the values once the vessels were on-site. For the MV Northstar Challenger, dynamic draft values were calculated using Pydro's Auto QC Dynamic Draft tool on the calibration data collected in Long Island Sound.

The table below summarizes the dynamic draft results for all vessels and are included in DAPR Appendix III. Since ERS tides were applied, dynamic draft corrections were not needed, but were entered into CARIS in the vessels' calibration HVFs for documentation only.

B.2.2.1 Dynamic Draft Correctors

Vessel	MV Northstar Challenger		RV North Cove		RV South Cove	
Date	2022-07-17		2022-06-15		2022-06-30	
Dynamic Draft	*Speed (kt)*	*Draft (m)*	*Speed (kt)*	*Draft (m)*	*Speed (kt)*	*Draft (m)*
	0.00	0.00	0.00	0.00	0.00	0.00
	1.00	-0.03	1.00	-0.02	1.00	0.01
	2.00	-0.06	2.00	-0.03	2.00	0.01
	3.00	-0.08	3.00	-0.04	3.00	0.00
	4.00	-0.09	4.00	-0.04	4.00	-0.01
	5.00	-0.11	5.00	-0.04	5.00	-0.03
	6.00	-0.13	6.00	-0.03	6.00	-0.04
	7.00	-0.14	7.00	-0.02	7.00	-0.06
	8.00	-0.16	8.00	-0.00	8.00	-0.07
	9.00	-0.17	9.00	0.01	9.00	-0.08
Uncertainty	*Vessel Speed (kt)*	*Delta Draft (m)*	*Vessel Speed (kt)*	*Delta Draft (m)*	*Vessel Speed (kt)*	*Delta Draft (m)*
	0.97	0.01	0.97	0.01	0.97	0.01

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

A multibeam sonar calibration was completed for each vessel in order to determine residual navigation timing error and angular biases in roll, pitch, and heading (yaw) in the echosounder transducer alignment. Standard patch tests were conducted by each boat before data collection commenced. The patch tests for all three survey vessels were performed in Long Island Sound near OSI's headquarters in Old Saybrook, CT. Final patch values for the CARIS HVF for each vessel were determined using final SBETs. Each vessel developed a reference surface near its patch test area in order to evaluate outer beam performance.

All vessels were equipped with retractable MBES pole mounts. To monitor any potential variability resulting from multiple pole deployments during the survey, each vessel performed abbreviated "interim" patch tests once per operating day or after each deployment. For the interim patch tests, reciprocal multibeam data were collected on a short set of lines at a convenient time each day and processed on board. If small changes in alignment (typically roll) were observed, the HVF was updated with a time-stamped entry of the new value.

On July 25 (DN 206) while docked at Pt. Judith State Docks, the MV Northstar Challenger's multibeam head was bumped by another vessel coming into port resulting in damage to the fiberglass mounting bracket. The multibeam was disassembled onboard and the fiberglass bracket was replaced. Approximately 2 hours later, the multibeam was reassembled, tested, and ready for an additional patch test. The subsequent patch test values were verified with the previous patch test values allowing data acquisition to resume.

A LiDAR calibration was also completed for each vessel in order to determine the angular biases of the LiDAR sensor. A mooring dolphin, a set of pilings, and a railroad bridge were selected near OSI headquarters, and multiple LiDAR lines were collected from various angles and approach distances alongside these features. The lines were processed in both Hypack and CARIS to iteratively determine angular offsets. Final LiDAR patch values for the CARIS HVF for each vessel were determined using final SBETs.

Calibration reports and statistics for initial calibrations are included in DAPR Appendix V.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>MV Northstar Challenger</td></tr>
<tr><td>Echosounder</td><td>Teledyne RESON SeaBat T50-R Multibeam Echosounder</td></tr>
<tr><td>Date</td><td>2022-07-17</td></tr>
<tr><td>Patch Test Values</td><td><table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>-1.500 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Roll</td><td>1.450 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Yaw</td><td>1.200 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Vessel</td><td>RV North Cove</td></tr>
<tr><td>Echosounder</td><td>Teledyne RESON SeaBat T50-R Multibeam Echosounder</td></tr>
<tr><td>Date</td><td>2022-06-15</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>1.400 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Roll</td><td>1.620 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Yaw</td><td>2.400 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>RV South Cove</td></tr>
<tr><td>Echosounder</td><td>Teledyne RESON SeaBat T50-R Multibeam Echosounder</td></tr>
<tr><td>Date</td><td>2022-06-23</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>-0.950 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Roll</td><td>1.010 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Yaw</td><td>0.500 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

Vessel	RV North Cove
Echosounder	Velodyne VLP-16 LiDAR
Date	2022-06-15

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	-42.300 degrees	0.020 degrees
Roll	1.250 degrees	0.020 degrees
Yaw	0.500 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	RV South Cove
Echosounder	Velodyne VLP-16 LiDAR
Date	2022-06-23

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	-44.300 degrees	0.020 degrees
Roll	-1.000 degrees	0.020 degrees
Yaw	2.200 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Unless specifically noted, the acquisition steps and settings described in this section apply to all vessels.

Raw sounding data were output directly from the RESON SeaBat T50-R processor to the HYPACK acquisition computer via a dedicated network card. HYPACK Survey and HYSWEEP Survey were configured to record position, heading, attitude and depth to RAW and HSX data files. For the real-time display, system offsets for the IMU and for the transducer phase center were entered into the HYPACK configuration files. These offsets were subsequently incorporated into the CARIS data processing routine. During operations, the HYSWEEP real-time MBES sounding wedge and digital terrain model (DTM) waterfall displays were monitored, and survey coverage was tracked in the HYPACK Survey display window with a matrix file updating in real time.

To accurately time-stamp the RESON output data string, the RESON T50-R processor received a pulse-per-second (PPS) signal and a serial $ZDA NMEA timing string from the POS MV. The POS MV also supplied a “TSS1” message to the RESON processor for real-time roll stabilization. Surface sound speed, measured at the transducer head with the AML Micro-X, was output to the RESON T50-R processor for beam-forming. The T50-R's “Normal” filter was used for sound speed filtering.

The RESON T50-R was operated at 400 kHz with a maximum swath angle of 140 degrees and the 512-equidistant beam configuration. When approaching some potentially shallow or hazardous areas or features, the system was switched to equiangle beam mode and 15 degree beam steering to starboard, as needed. This provided an added measure of safety as the vessel appraoched potential hazards. In addition to sounding data, the SeaBat T50-R systems collected and recorded "normalized" backscatter data (the 7058 datagram).

Sonar perfomance was optimized by adjusting power, gain, pulse length, absorption and spreading settings. Although bottom detection was given priority, care was taken to minimize changes in system settings in order to promote quality backscatter acquisition. “Tracker” mode, which automatically adjusts settings to achieve optimal bottom detection, was employed during early on-site deployment. Once good bottom detection was achieved, tracker was turned off. Absorption was adjusted to reflect the actual local absorption value, and power was adjusted to prevent saturation. Local acoustic absorption was estimated using the calculator available at http://resource.npl.co.uk/acoustics/techguides/seaabsorption/ and input data from CTD casts acquired on site. Additional minor adjustments were made to remaining sonar settings, as needed, to maintain reliable bottom detection.

To better track and organize operations, each sheet (registry number) was divided into sub areas. Line plans and investigations were organized by sub areas within each sheet. Sub area designations were carried through the processing workflow as well, and were used to manage feature tracking and coverage checks.

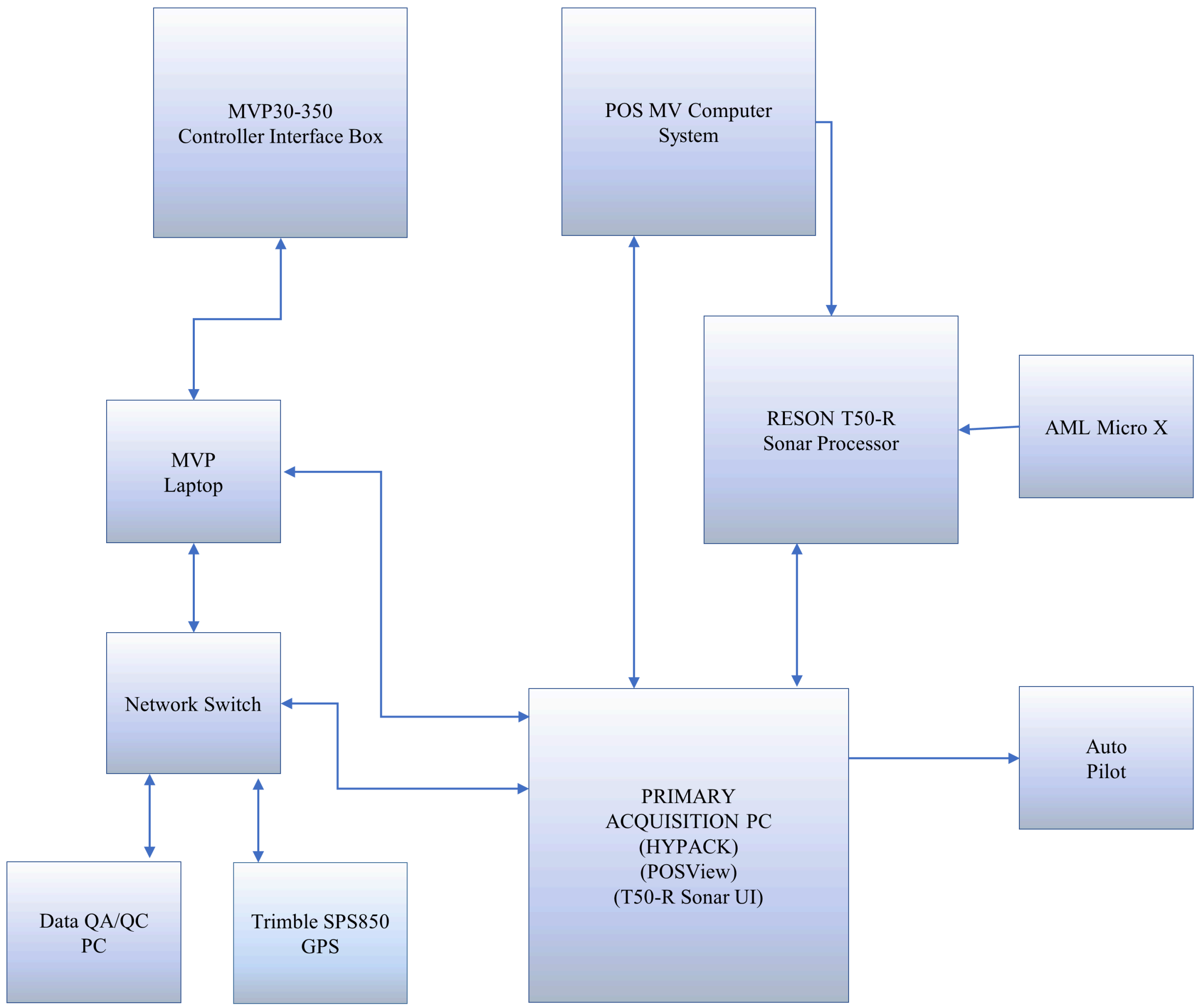


Figure 16: MV Northstar Challenger Acquisition Wiring Diagram

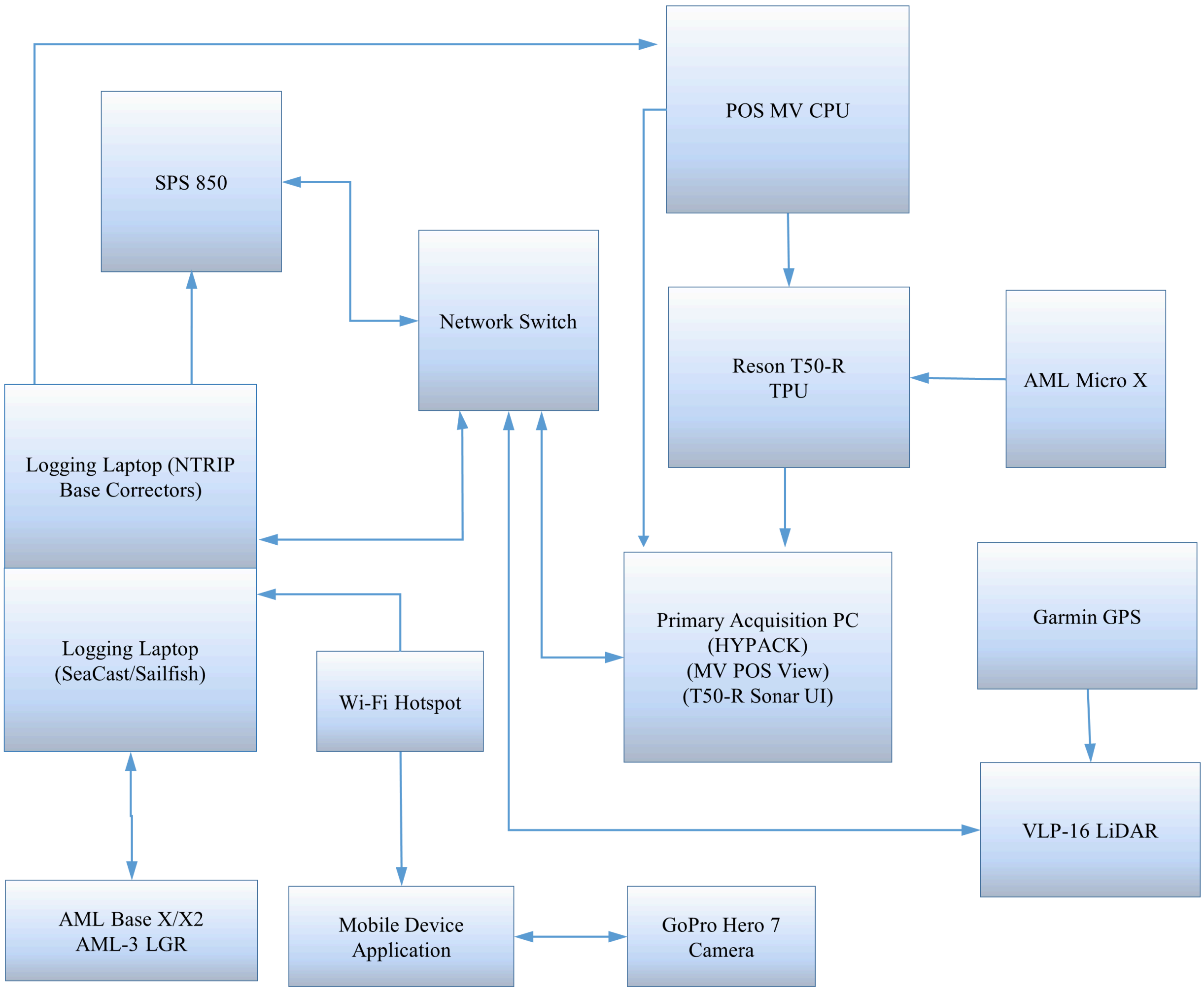


Figure 17: RV North Cove Acquisition Wiring Diagram

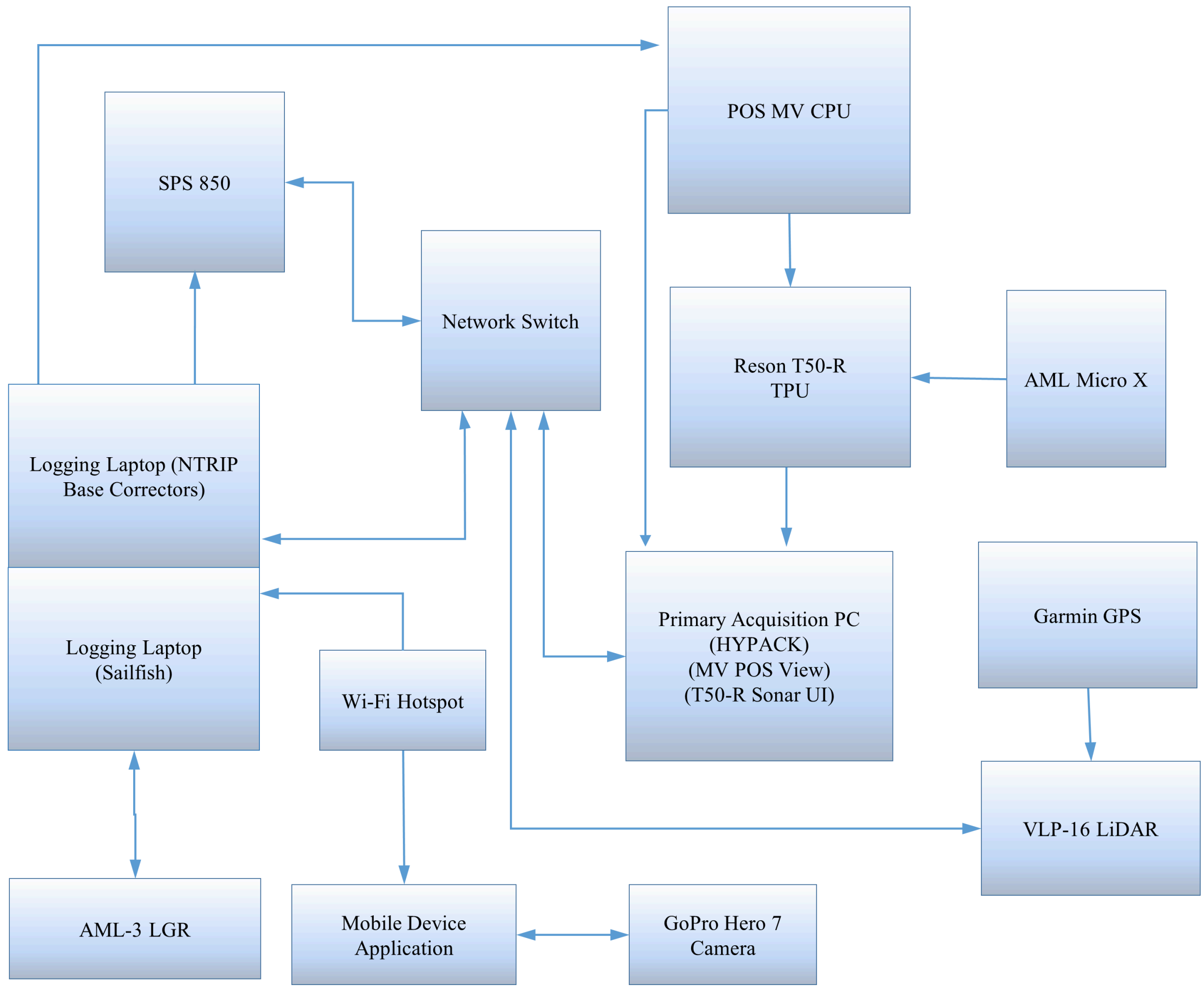


Figure 18: RV South Cove Acquisition Wiring Diagram

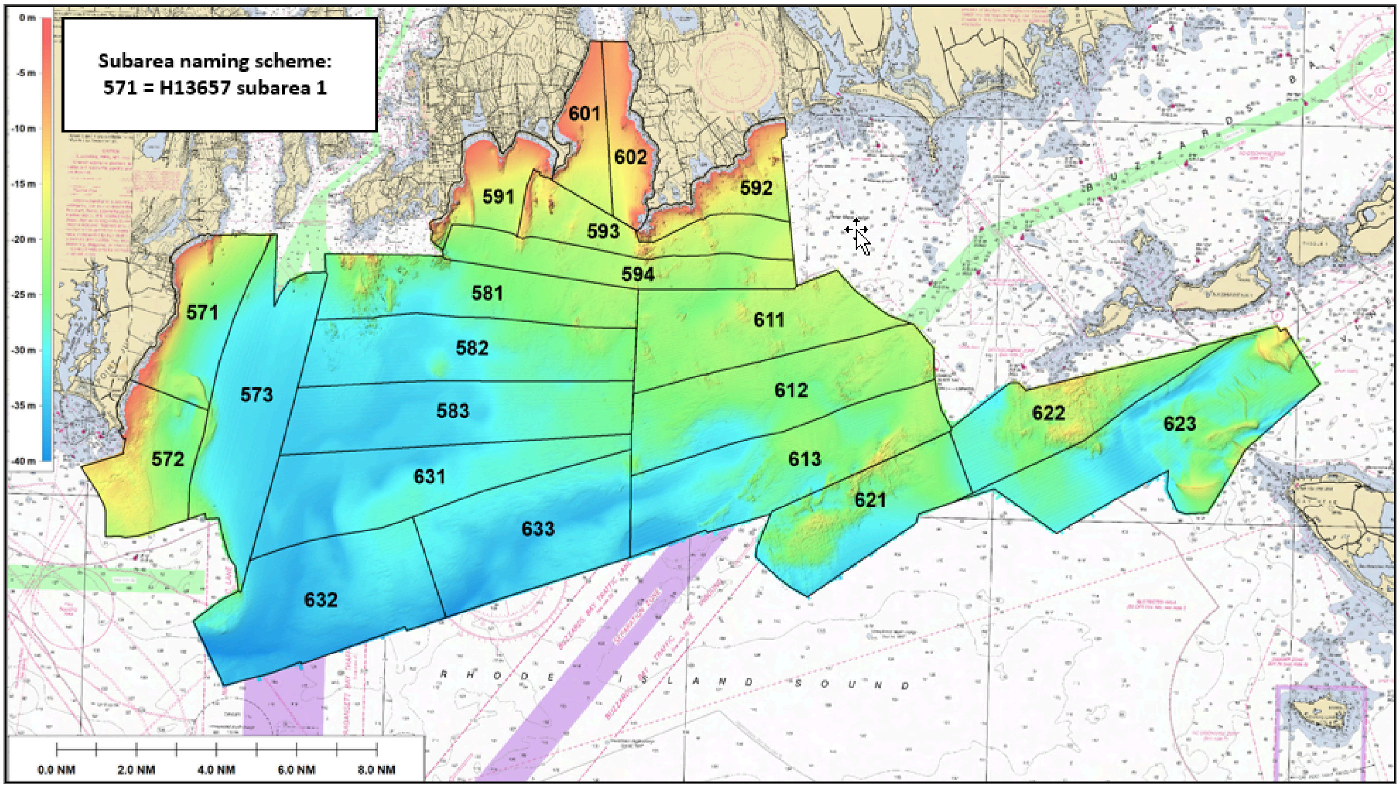


Figure 19: Subarea designations for Sheets H13657, H13658, H13659, H13660, H13661, H13662, and H13663.

<u>Data Processing Methods and Procedures</u>

QA/QC level processing was completed on board the survey vessels, however, all final data processing occurred at OSI's home office. For the two small vessels working daytime operations, field data were backed up daily to a portable data disk. Every night after data collection, data were uploaded from the portable data disk to OSI's file share site for the home office processing center to download. During field crew changes, back up data disks were also hand delivered to the office. On the MV Northstar Challenger, which worked 24-hour operations, field data were backed up daily to a portable data disk, and when the vessel made a port call the disk was hand delivered to OSI's home office for processing. On two occasions (DN 227 and 232), the RV North Cove rendevouzed with the MV Northstar Challenger at sea and collected the portable data disk for return to the office to reduce the time between acquisition and data check-in.

Upon receipt of nightly uploads and/or data disks, information contained in the daily acquisition log was compared to the data package to ensure that no files were lost or omitted. The acquisition log was consulted to verify file names and file sizes and to remove any aborted lines from the preprocess folder before converting the data in CARIS HIPS.

Multibeam sonar data conversion and the application of sounding correctors were completed using routines developed in CARIS' Process Designer. The Process Designer (model) runs a user-defined script which accomplished the following standard tasks:

1) Convert the HSX data to the HDCS data format, establish UTM grid.
2) Enable all multibeam beams.
3) Load daily TrueHeave (delayed heave) files.
4) Run the CARIS process Georeference Bathymetry, which includes the following steps:
a) Load and apply sound speed profile data. Sound speed profiles were loaded with the CARIS nearest in distance within time method. During CARIS SVP Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.
b) Run “Compute GPS Tides” employing the provided VDatum ellipsoid separation model (SEP).
c) Merge data to apply vessel offsets/alignment, attitude, heading, and horizontal/vertical position correctors to bathymetry. CARIS HIPS computes the fully corrected depth and position of each sounding during the merge process.
d) Compute Total Propagated Uncertainty (TPU). TPU is calculated in CARIS HIPS from contributing uncertainties in the echosounder, positioning and motion sensor measurements as well as uncertainties associated with sound speed and water level correction.

C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

Preliminary field sheets and Bathymetry Associated with Statistical Error (BASE) surfaces were created for reviewing and cleaning of full-density soundings using the Combined Uncertainty and Bathymetry Estimator (CUBE) process. BASE surfaces were “finalized” for each survey based on the coverage requirements outlined in the Project Instructions and the HSSD. Designated soundings were incorporated into the finalized BASE surfaces making certain that the least depth sounding was honored in the grid.

C.1.4.2 Depth Derivation

Attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude data or navigation jumps.

Swath Editor was used to clean fish noise, multipath returns, and gross fliers. Soundings were reviewed in multi-directional profile and plan view displays. Tracklines and swath boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data, and field annotations (HYPACK target files).

The CARIS Subset Editor was used to clean fully-corrected, georeferenced soundings in 2-D and 3-D displays. Areas with multiple sounding coverages from adjacent survey lines were evaluated to increase confidence in outer beams and over significant features. Overlapping soundings were colored by line and reviewed to verify the validity of bathymetric features and to reject fish or water column noise. Subset boundaries were viewed in the CARIS Map window in reference to BASE surfaces and charted data.

C.1.4.3 Surface Computation Algorithm

After MBES sounding editing was complete, final BASE surfaces were created using the CUBE algorithm in CARIS HIPS. The CUBE algorithm generates surface models from multiple hypotheses. Hypotheses with lower combined Total Propagated Uncertainty (TPU) are given higher significance for incorporation into the final surfaces. Also, soundings closest to a grid node have a greater weight on the node depth value than soundings that are further away.

The CUBE algorithm and specific parameters used to create BASE surfaces were contained in the NOAA "CUBEParams_NOAA_2022.xml" file as included in the Pydro software suite.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Coincident multibeam backscatter data were collected as snippets with the SeaBat T50-R system. The T50-R backscatter data includes an optional "normalized" backscatter feature (the 7058 datagram) which generates an intensity magnitude data signal that is compensated for the effects of the sonar itself (beam pattern, source level, sensitivity and gain). Backscatter data were logged in HYSWEEP Survey simultaneously with MBES soundings. The sonar was operated in Continuous Wave mode (CW), and snippet size was set to 25 samples. Backscatter file names were composed of the year, vessel, day number, UTC time and line number, for example: 2022CH2101722_123.7K where “CH” stands for MV Northstar Challenger. Care was taken to minimize changes in sonar system settings in order to promote quality backscatter acquisition. Absorption was adjusted to reflect the actual local absorption value, and power was adjusted to prevent saturation. Local acoustic absorption was estimated using the calculator available at http://resource.npl.co.uk/acoustics/techguides/seaabsorption/ and input data from CTD casts acquired on site. Spreading was based on expected salinity and manufacturer's recommendation as modified during testing and calibrations. Within the project area, a backscatter test bed was selected which contained many of the representative natural bottom types (mud, sand, and rock) for the project and a reasonable range of depths. All three vessels collected multiple reciprocal lines over this test bed. These data were used to determine and account for inter-vessel variation in backscatter intensity.

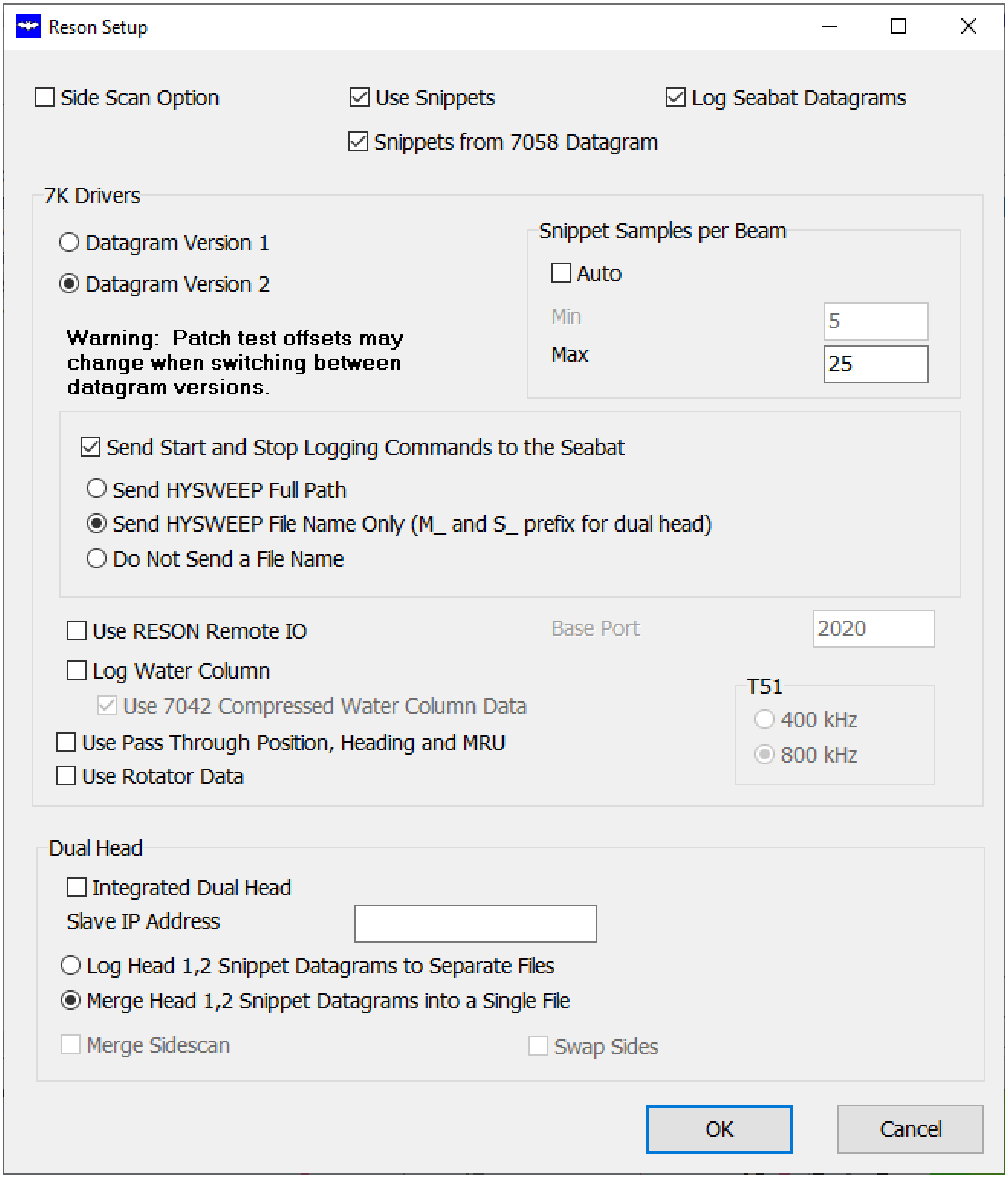


Figure 20: HYSWEEP Survey settings used for backscatter acquisition.

Data Processing Methods and Procedures

After MBES data was converted and processed in CARIS HIPS, a Generic Sensor Format (GSF) file containing bathymetry data was outputfrom CARIS HIPS and SIPS Data Export utility for each survey line. These GSF files were imported into Fledermaus Geocoder Toolbox (FMGT) software program, which created the backscatter mosaic, along with the corresponding RESON *.7k files. To create the mosaics, the pixel size was set to 2 meters and automatic processing was used with Beam Time Series selected as Backscatter Source. A GeoTIF of each mosaic was exported from Export Surface in FMGT. When the mosaics were created, the software also created another GSF file of the combined RESON 7k file and the CARIS processed depths file. To determine inter-vessel variation in backscatter intensity, data from all three vessels were imported and mosaicked from a common on-site test bed area. The intensity of the overlapping data between vessels were examined. Using the Cascading Backscatter Normalization and Line Backscatter Adjustment tools, adjustments/offsets in the intensity were applied to individual lines as needed. The return intensity values were similar among all three survey vessels with some line to line adjustments on the order of approximately 1 - 4 dB.

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

C.3 Horizontal and Vertical Control

C.3.1 Horizontal Control

C.3.1.1 GNSS Base Station Data

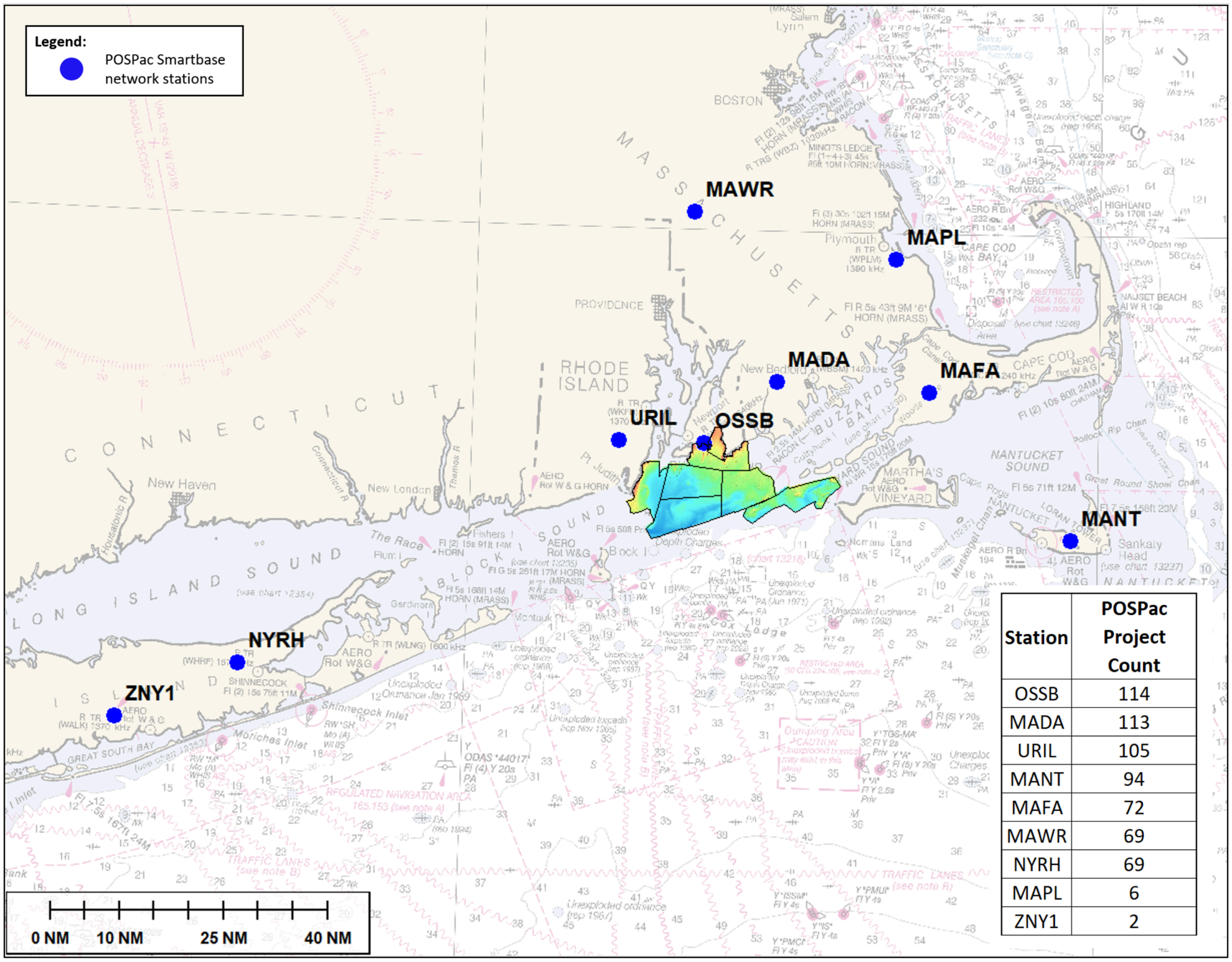
Data Acquisition Methods and Procedures

To supplement CORS-based IAPPK SBET processing, OSI installed a temporary GNSS base station at Sachuest Beach, locally known as Second Beach, in Middletown, Rhode Island. Specifically, a Trimble NetR9 GNSS receiver with a Zephyr 3 Geodetic antenna was installed on the roof of the main building facing the beach. The NetR9 was configured to record GNSS observables continuously throughout the period of the survey and parse data observables into daily files for each 24-hour period.

The configuration of the NetR9 was based on UNAVCO standard configuration settings for this device. GNSS observables were recorded on removable media as well as on the NetR9’s internal storage. Data were delivered to OSI’s home office processing center via regular automated FTP and e-mail “pushes.” Pushes were transmitted over a network connection that was established on site for this purpose. The Trimble NetR9 was included in IAPPK processing and designated as Ocean Surveys Sachuest Beach or "OSSB".

Data Processing Methods and Procedures

For all vessels, real-time positioning was replaced by Applanix SmartBase (ASB) derived SBET positioning in NAD83 during the processing workflow. On each vessel, POS *.000 files (for POSPac) were logged continuously each day on the main acquisition computer and directly to a USB drive on the POS MV topside processor. The POS *.000 files were imported into POSPac MMS for ASB processing, which was organized into POSPac projects by vessel and day. The total number of CORS stations included in ASB processing was occasionally varied from one POSPac project to the next (i.e. vessel-day) based on CORS data availability and solution quality. OSSB was used in all solutions, with the exception of DN240 for RV North Cove, and the final coordinates of OSSB were determined using OPUS. A discussion of OPUS data processing and the determination of final station coordinates are included in the HVCR.



Station	POSPac Project Count
OSSB	114
MADA	113
URIL	105
MANT	94
MAFA	72
MAWR	69
NYRH	69
MAPL	6
ZNY1	2

Figure 21: Local CORS network used in Applanix Smart Base (ASB) IAPPK processing with POSPac project count.

C.3.1.2 DGPS Data

DGPS data was not acquired.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

Per the Project Instructions, the determination of MLLW and MHW water levels for sounding reduction was perfomed with Ellipsoidally Referenced Survey (ERS) methods. On each vessel, POS *.000 files (for POSPac) were logged continously each day on the main acquisition computer and directly to a USB drive on the POS MV topside processor. Inertially Aided Post Processed Kinematic (IAPPK) ellipsoid heights were computed by importing the POS *.000 files into POSPac MMS for Applanix SmartBase (ASB) processing. The ellipsoid heights in the resulting Smoothed Best Estimate Trajectory (SBET) data were used as the basis for the development of ERS Tide. A VDatum Separation Model (SEP) was provided with the original project files and described in the Project Instructions.

MHW VDATUM Model				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
3.9	2012	RICTbis22_8301 and MENHMAgome13_8301	1	9.9 centimeters
MLLW VDATUM Model				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
3.9	2012	RICTbis22_8301 and MENHMAgome13_8301	1	10.4 centimeters

Figure 22: VDATUM Separation Model (SEP) Parameters as provided in the Project Instructions.

Data Processing Methods and Procedures

ASB processing was organized into POSPac projects by vessel and by day using the steps described above to generate a set of preliminary SBETs. SBET altitude corrected for heave, dynamic draft, and static draft were reviewed graphically and compared to local NOAA tide gauge water levels for trend and general agreement. If invalid or poor-quality altitude data were contained in the preliminary SBET, additional CORS stations were added to the ASB network and reprocessed to create an improved SBET. As a final step, NOAA's

POSPacAutoQC application was used to interpolate through and replace any periods of poor-quality or invalid data that remained.

ASB derived ERS tides were smoothed before application to sounding data. After SBETs were exported, a MATLAB script was used to isolate the NAVD 88 tide component of SBET altitude by removing the following components: static draft based on time, dynamic draft based on speed, delayed heave based on time, and SEP based on position. The NAVD 88 tide was then smoothed with a 4th order Butterworth low-pass filter, with 1 and 2 hour cutoff frequencies for the smaller vessels and large vessel respectively, using MATLAB's "filtfit" function. Filtfit runs the filter in forward and reverse resulting in a zero-lag solution. Once the NAVD 88 tide was smoothed, new SBETs were exported after re-applying the SBET altitude components that were removed to isolate the NAVD88 tide. Once a “smoothed” SBET was generated, it was imported to CARIS HIPS and the CARIS “Compute GPS Tides” function was used in conjunction with the NOAA-provided SEP to create MLLW tide correctors.

Graphical analysis was the primary QA/QC tool used during the development phase of the ERS smoothing routine described above. MATLAB graphs were generated for all conversion and correction steps to identify erroneous source data or MATLAB program code. A discussion of the choice of smoothing parameters is included in the HVCR.

Qualitative and quantitative crossline analysis, as well as junction analysis, indicate that the final ERS correctors employed in reducing soundings to MLLW were adequate for the purpose. The results of crossline and junction analysis are presented in the Descriptive Report (DR) for each survey.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

All vessels were equipped with a POS MV inertial navigation system for primary positioning and attitude, and a Trimble SPS-850 Extreme GPS as an independant underway check on the POS-MV position. On all vessels, positioning, attitude, and timing data from the POS MV were transmitted to the data acquisition computer via Ethernet through a dedicated network card and were recorded in the HYSWEEP *.HSX files. POS *.000 files were also logged continuously each day on the main acquisition computer and directly to a USB drive on the POS MV topside processor.

On the MV Northstar Challenger, the POS MV's integrated DGPS was activated to receive SBAS (FAA WAAS) corrections for real-time positioning.

The RV North Cove and RV South Cove were both equipped to receive CMR+ correctors for real time RTK-GNSS positioning from the OSI-installed GNSS base station “OSSB”. Correctors were received via cellular network stream using NTRIP client software aboard each vessel. RTK correctors on the 2 small boats provided supplemental vertical positing for evaluating final ERS tides and enabled both vessels to safely map to the NALL in real time.

Navigation system confidence checks were performed for all vessels during mobilization and periodically thereafter during acquisition (see the HVCR and DAPR Appendix IV for results).

Data Processing Methods and Procedures

For all vessels, real-time positioning and attitude data were replaced with IAPPK SBET solutions using POSPac MMS and Applanix SmartBase (ASB) processing.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Sound speed profiles (casts) were acquired inside the bounds of the survey area, with a few exceptions when casts were acquired on the approach to a survey line.

On the MV Northstar Challenger, sound speed profile data were acquired with the MVP30-350 system at approximately 20-minute intervals. MVP Controller software was configured to receive navigation data from HYPACK via the MVP.dll. HYSWEEP Survey was configured to receive MVP casts in real time to correct waterfall and profile displays with the most recent sound speed profile. MVP cast position, sound speed, and depth data were recorded in *.CALC file format and named by day number and cast number, i.e. MVP_DN207_005.calc.

On the RV North Cove and RV South Cove, profiles were acquired using AML Base X, Base X2, or AML-3 LGR hand-deployed sound speed profilers. The profilers collected direct sound speed and depth readings with AML SV and pressure exchange sensors. Manual profile interval times varied depending on site conditions with an average profile interval of 1 to 2 hours. The hydrographers acquired more frequent profiles if high variability was noted in the surface sound speed from the AML Micro-X installed on the head of the transducer, or when the surface sound speed comparison threshold was exceeded (> 2 meters/ second change) between the profile reading at the draft of the transducer and the Micro-X. Manual profiles were uploaded to a laptop computer on the vessels using AML SeaCast or AML Sailfish software which outputted a *.csv file per profile. The *.csv files were converted to HYPACK *.vel format file for import to HYSWEEP survey.

Data Processing Methods and Procedures

HydrOffice Sound Speed Manager was used to process and organize sound speed profiles for the project. Separate databases for each vessel within each survey sheet were created, and profiles were reviewed and added to the appropriate database on an ongoing basis at the OSI home office. MVP profiles were imported directly into Sound Speed Manager. AML Base X, Base X2 and AML-3 profiles collected in *.csv and *.AML formats, respectively, were converted to CARIS SVP format using an OSI custom macro in Microsoft Excel. Individual cast *.SVP files were imported into Sound Speed Manager for organization into the master sound speed database for each vessel within each survey sheet.

Sound speed profiles were applied to the sounding data in CARIS HIPS using primarily the "nearest in distance within time" correction method with 2 hours as the time parameter. At times, SVP application settings varied due to factors including the tide, weather, water depth, and bathymetric features, such as slopes or sand waves. Details for each sheet are discussed in the DR.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed, measured at the transducer head with the AML Micro-X equipped with an SV Xchange sensor, was transmitted to the RESON T50-R processor for beam forming. The T-50 R “Normal” filter was used for sound speed filtering. Raw surface sound speed data was recorded in the HYSWEEP *.HSX files during MBES logging.

Data Processing Methods and Procedures

No additional processing was performed on surface sound speed data, but the data were used as a QA/QC flag in MBES processing. Surface sound speed data were extracted from the HYSWEEP *.HSX files and plotted by vessel and by day. Sounding data collected during periods of high surface sound speed variability were carefully scrutinized for outer beam artifacts.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Estimates for the uncertainty of all measurements associated with sounding collection were gathered from either reported manufacturer system accuracy or from calculated statistics.

The combined uncertainty value per sounding, or the Total Propagated Uncertainty (TPU), was calculated using CARIS HIPS via the ‘Compute TPU tool’. The various uncertainty values for input into the TPU model result from a combination of vessel sources, static values, and real-time values derived from post-processing (e.g. POSPac MMS RMS values).

The standard deviation values for the XYZ offset and static draft measurements were calculated from distances acquired with the steel tape, the coarsest tool used to verify vessel offsets.

The standard deviation for the loading measurement was calculated from the measure down values acquired on the port and starboard sides of each vessel.

Sound speed TPU values were estimated from sensor manufacturer-stated accuracy and from guidance in the OCS Field Procedures Manual (FPM).

Standard deviation values for vessel offsets, motion, draft, and alignment measurements were entered into the HVF “TPU values” section at the 1-sigma level. The HVF uncertainty values, along with uncertainties associated with tide and sound speed, were used in combination with the sonar model in the DeviceModels.xml file to assign a total horizontal uncertainty (THU) and total vertical uncertainty (TVU) for every sounding. For the Velodyne LiDAR, a custom "sonar" model was developed with a range sampling distance of 5 cm.

The POS MV manufacturer-recommended uncertainty values for the heading, heave, roll, pitch, and timing measurements were entered in the HVFs. However, the uncertainty of certain parameters (heave, pitch, roll, heading, and position) were superseded later using TrueHeave and SBET RMS. The ellipsoid height uncertainty is variable and is applied in CARIS HIPS based on post-processed uncertainties from SBET RMS files generated in POSPac MMS.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		MV Northstar Challenger	RV North Cove	RV South Cove
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		0.25 meters	0.25 meters	0.25 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
MV Northstar Challenger	Some real-time uncertainty values are incorporated into the depth estimates of each survey by way of post-processing. On all survey vessels, Applanix TrueHeave files are recorded including an estimate of the heave uncertainty. The Applanix TrueHeave files are applied during post-processing. Additionally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac MMS software.
RV North Cove	Some real-time uncertainty values are incorporated into the depth estimates of each survey by way of post-processing. On all survey vessels, Applanix TrueHeave files are recorded including an estimate of the heave uncertainty. The Applanix TrueHeave files are applied during post-processing. Additionally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac MMS software.
RV South Cove	Some real-time uncertainty values are incorporated into the depth estimates of each survey by way of post-processing. On all survey vessels, Applanix TrueHeave files are recorded including an estimate of the heave uncertainty. The Applanix TrueHeave files are applied during post-processing. Additionally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac MMS software.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

The locations of the CSF assigned features were imported into HYPACK's target database for each vessel, enabling the field crews to see the locations of the CSF items in the HYPACK Survey display window. Crews were able to anticipate that a potential feature was approaching, log if it was observed, and take any notes to help data processors if necessary.

The RV North Cove and RV South Cove were both equipped with a Velodyne VLP-16 LiDAR and GoPro Hero7 camera for recording xyz data and imagery of near-NALL shoreline features and isolated baring features. The data were transmitted to the acquisition computer via Ethernet through a network switch and interfaced with HYSWEEP survey. LiDAR data was recorded in the *.HSX HYSWEEP files, often while simultaneously recording MBES. HYSWEEP supplied the realtime control of the LiDAR for beam enabling/disabling, angle and range filtering. Four of the 16 available beams were enabled, and angle and range filters were applied to mask the boat and the boat's wake from the recorded data. The LiDAR was monitored in realtime using the 3D Point Cloud Display in HYSWEEP SURVEY and realtime coverage matrix updates in HYPACK SURVEY. Simultaneously with LiDAR collection, a GoPro Hero7 camera recorded digital photographs of shoreline and above water features. Photographs were collected in 4K with 4:3 aspect ratio at a 2Hz rate.

Prior to the conclusion of survey operations, the home office project manager reviewed the data to ensure the CSF assigned items, other unassigned features were adequately addressed and photos were obtained of above-water features. Where appropriate, investigation lines were run over features with the multi-detect and compressed water column turned on in the RESON T50-R sonar interface. Water column imagery was used to support least depth selection over the feature.

Data Processing Methods and Procedures

Once data was converted and processed in CARIS HIPS and added to the CUBE surface, data density layers were reviewed to verify that the Multibeam Coverage requirement of 5 soundings per grid node was met. Each CSF item location and its assigned search radius were examined in CARIS Subset Editor to see if the feature was present and to check for nadir coverage or ensure the search radius was adequately covered. A designated sounding was selected from the nadir coverage if a feature was present. The data processing team also reviewed the data and CUBE surfaces for other features not assigned and selected a designated sounding for each feature.

Shoal and designated soundings were compared to the largest scale charts in the survey area to locate potential Dangers to Navigation (DTONs). Chart comparisons were conducted using Pydro's Chart Adequacy (CA) Tools and also by comparing the soundings (shoal and designated) to the ENC charts manually. CARIS BAG files and ENC charts were imported into CA Tools which exports soundings that are potential DTONs and those that have a high discrepancy from charted soundings. Processors manually reviewed the exported soundings with consideration for water depth and the magnitude of discrepancy from the chart.

All DTONs were submitted to AHB as attributed S-57 *.000 files per the specifications laid out for Contractors in the HSSD. Submitted DTONs, CSF assigned features, and unassigned features are included in the FFF.

Processed lidar in CARIS HIPS format and associated time-tagged shoreline imagery formatted as .MP4s are provided as supporting data for shoreline features.

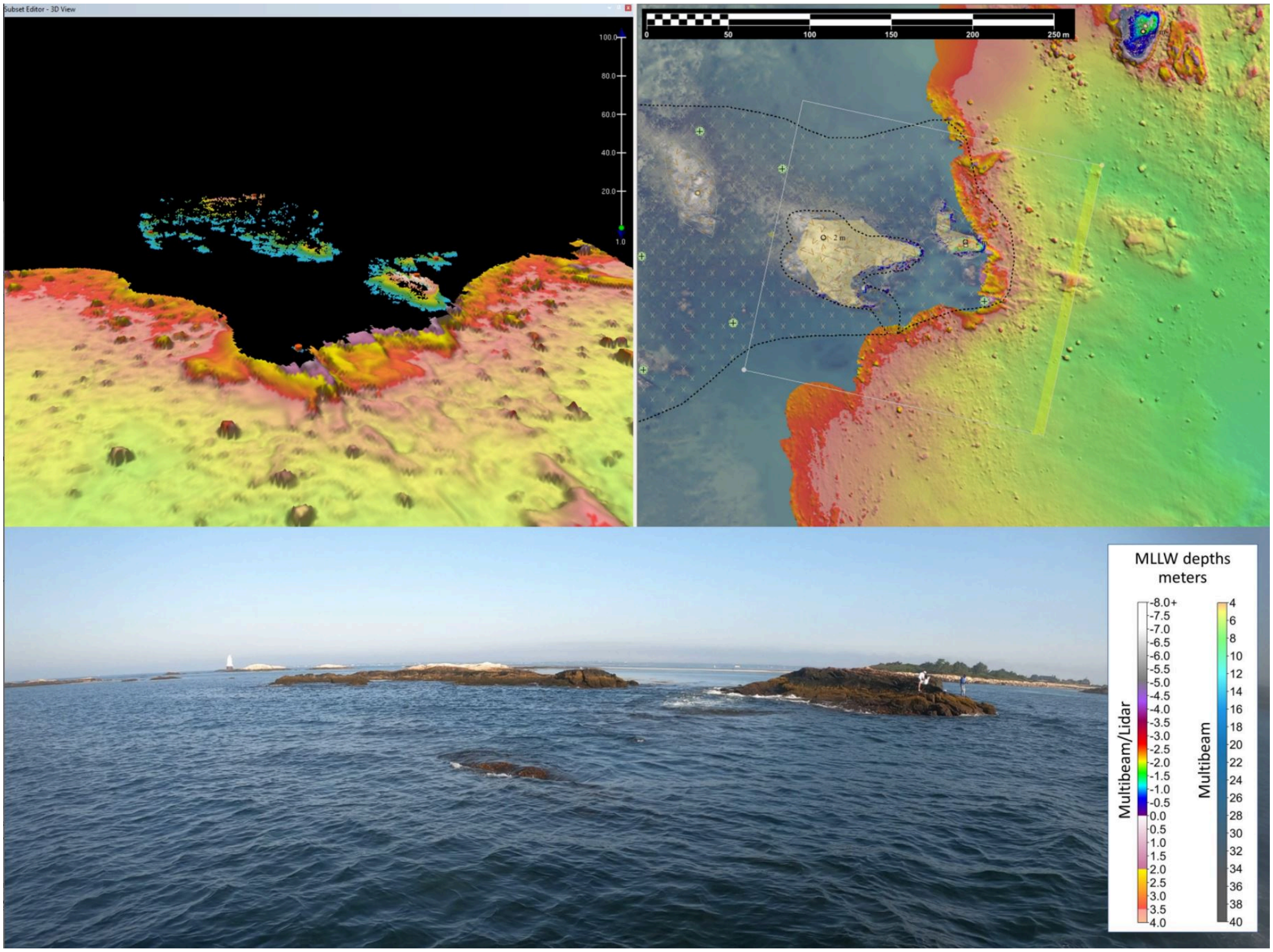


Figure 23: Example of shoreline feature displayed with multibeam, lidar, and associated imagery.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

Bottom samples were acquired by the RV North Cove and RV South Cove at the locations specified in the Project Instructions. At each bottom sample location, a sample was collected using a WILDCO Petite Ponar Dredge and brought on deck. Sample time and position were recorded and each sample was photographed and described.

Data Processing Methods and Procedures

Bottom sample descriptions and photographs were included in the FFF and attributed in accordance with HSSD Appendix G.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

After the lines were run through the appropriate Process Designer model, they were added to cleaning/ coverage surfaces. Depth, standard deviation and shoal surface models were viewed with sun illumination and/or vertical exaggeration to highlight areas that would require immediate investigation. Standard deviation surfaces were reviewed to evaluate data for consistency between overlapping coverage and crosslines, and to detect any systematic position, motion, tide, or sound velocity errors. The highest standard deviation values were observed over obstruction features, sloping seafloors, and areas with high sound speed variability. Additional directed editing was performed using CARIS HIPS Swath Editor and Subset Editor to remove fliers and noise, while taking care to preserve features.

D.1.2 Designated Sounding Selection

Full-density soundings were reviewed for each significant MBES feature in the CARIS Subset Editor and a sounding was designated for the representative least depth.

The “Designated” flag was used to identify the least depth of a significant feature and ensure that the least depth would be represented in the finalized CUBE surfaces. When a designated sounding was assigned to a feature, it indicated that no further investigation was required. OSI followed Section 5.2.1.2.3 of the HSSD guidance on the criteria for choosing designated soundings. Near-nadir soundings were designated as least depths on features in lieu of outer beam soundings, whenever possible.

D.1.3 Holiday Identification

Coverage surfaces were checked for any data gaps meeting the criteria described in HSSD Section 5.2.2.3 (Complete Coverage). All surfaces were reviewed to ensure that the appropriate coverage was obtained over significant shoals and features. Density layers were reviewed and analyzed to verify that at least 95% of all nodes were populated with at least 5 soundings.

D.1.4 Uncertainty Assessment

To assess uncertainty, the bathymetric surfaces were finalized in CARIS HIPS using the "uncertainty" option to select the combination of a priori and realtime uncertainty estimates as the surface TVU source. Finalized surfaces were analyzed using the Grid QA function within the NOAA Pydro "QC Tools" application, which plots the node uncertainty as a fraction of allowable IHO TVU. Passing nodes are those with uncertainty fractions between 0 and 1. The uncertainty assessment is included in the DR for each sheet.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

To evaluate crossline to mainscheme line differences, separate CUBE surfaces were created for crosslines and mainscheme lines in each sheet. Comparisons were made by computing the overlapping node to node differences using the NOAA Pydro "Compare Grids" tool. Histograms, basic statistics, and a discussion of the comparison are included in the DR for each sheet.

D.1.5.2 Junctions

Junction analysis between individual sheets in OPR-B315-KR-22 and the bordering sheets assigned in the Project Instructions were evaluated using the same method as Crossline to Mainscheme comparisons. Results are included in the DR for each sheet.

D.1.5.3 Platform to Platform

Vessel to vessel comparisons were made by computing the overlapping node to node differences in CUBE surfaces for each vessel. A histogram and basic statistics of the vessel to vessel differences are included in DAPR Appendix V.

D.2 Imagery data Integrity and Quality Management

Imagery data integrity and quality management were not conducted for this survey.

E. Approval Sheet

Field operations contributing to the accomplishment of OPR-B315-KR-22 surveys H13657, H13658, H13659, H13660, H13661, H13662, and H13663 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data and accompanying records have been closely reviewed, and are considered complete and adequate per the Statement of Work and Project Instructions.

This report and associated data are considered complete and adequate for its intended purpose.

Approver Name	Approver Title	Date	Signature
John R. Bean	Chief of Party	02/23/2023	John R. Bean 2023.02.23 15:41:00 -05'00'
David T. Somers	Data Processing Manager	02/23/2023	David T. Somers 2023.02.23 15:41:19 -05'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	OPR-B315-KR-22_DAPR_Appendices-I.pdf
Sound Speed Sensor Calibration	OPR-B315-KR-22_DAPR_Appendices-II.pdf
Vessel Offset	OPR-B315-KR-22_DAPR_Appendices-III.pdf
Position and Attitude Sensor Calibration	OPR-B315-KR-22_DAPR_Appendices-IV.pdf
Echosounder Confidence Check	OPR-B315-KR-22_DAPR_Appendices-V.pdf
Echosounder Acceptance Trial Results	N/A