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-F330-KR-22
Time Frame:	February - November 2023

LOCALITY

State(s):	North Carolina
General Locality:	North Carolina

2023

CHIEF OF PARTY
Nicholas Damm, CH

LIBRARY & ARCHIVES

Date:

NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HYDROGRAPHIC TITLE SHEET

INSTRUCTIONS - The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the office.

REGISTRY No
H13755
H13758
H13760
H13761
H13762
H13763
H13764

FIELD No
Geodynamics LLC

State	North Carolina
General Locality	North Carolina
Sub-Locality	Eastern Albemarle Sound, Central Albemarle Sound, Western Albemarle Sound, North River to Roanoke Sound, Alligator River, Perquimans River to Chowan River, Chowan River to Alligator River
Scale	1:5,000
Date of Survey	February - November 2023
Instructions Dated	February 14, 2023
Project No.	OPR-F330-KR-22
Vessel	R/V 4-Points, R/V Benthos, R/V Chinook, R/V Substantial, X-15, X-19
Chief of Party	Nicholas Damm, CH
Surveyed by	Geodynamics LLC
Soundings by echo sounder	Kongsberg 2040C (MBES), Odom CV100 (SBES), Odom E20 (SBES)
Graphic record scaled by	N/A
Graphic record checked by	N/A
Automated Plot	N/A
Verification by	Atlantic Hydrographic Branch
Soundings in	Meters at Low Water Datum (LWD)

REMARKS:

NAD83 (2011), UTM Zone 18 North
Times are in UTC
The purpose of this contract is to provide NOAA with modern, accurate hydrographic survey data to update the nautical charts of the assigned area.

SUBCONSULTANTS: N/A

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

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Data Acquisition and Processing Report

Geodynamics LLC
Chief of Party: Nicholas Damm, CH
Year: 2023
Version: 1.0
Publish Date: 2024-03-17

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 R/V Benthos

<table>
<tr><td>Vessel Name</td><td colspan="2">R/V Benthos</td></tr>
<tr><td>Hull Number</td><td colspan="2">ACD28CATA212</td></tr>
<tr><td>Description</td><td colspan="2">Geodynamics supplied the R/V Benthos for hydrographic survey operations on OPR-F330-KR-22. The R/V Benthos is a 9.14 meter catamaran built by Armstrong Marine and conducted 12-hour day operations. The R/V Benthos has the following specifications:</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>9.14 m</td></tr>
<tr><td>Beam</td><td>3.20 m</td></tr>
<tr><td>Max Draft</td><td>0.61 m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2021-03-09</td></tr>
<tr><td>Performed By</td><td>Mike Ulmer, 3Space Inc</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2021-03-09</td></tr>
<tr><td>Method</td><td>The R/V Benthos offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.</td></tr>
</table>

Figure 1: R/V Benthos

A.1.2 R/V Chinook

Vessel Name	R/V Chinook		
Hull Number	IAR28CATJ607		
Description	Geodynamics supplied the R/V Chinook for hydrographic survey operations on OPR-F330-KR-22. The R/V Chinook is a 9.44 meter catamaran built by Armstrong Marine and conducted 12-hour day operations. The R/V Chinook has the following specifications:		
Dimensions	*LOA*	9.44 m	
	Beam	3.2 m	
	Max Draft	0.61 m	
Most Recent Full Static Survey	*Date*	2021-04-10	
	Performed By	Mike Ulmer, 3Space Inc	

Most Recent Full Offset Verification	*Date*	2021-04-10
	Method	The R/V Chinook offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.

Figure 2: R/V Chinook

A.1.3 R/V Substantial

<table>
<tr><td>Vessel Name</td><td colspan="2">R/V Substantial</td></tr>
<tr><td>Hull Number</td><td colspan="2">USZ00221D013</td></tr>
<tr><td>Description</td><td colspan="2">Geodynamics supplied the R/V Substantial for hydrographic survey operations on OPR-F330-KR-22. The R/V Substantial is an 18 meter Seaton designed monohull vessel built by Marks Marine and conducted 24-hour operations. The R/V Substantial has the following specifications:</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>18 m</td></tr>
<tr><td>Beam</td><td>5.48 m</td></tr>
<tr><td>Max Draft</td><td>2.22 m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2021-03-08</td></tr>
<tr><td>Performed By</td><td>Mike Ulmer, 3Space Inc</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2021-03-08</td></tr>
<tr><td>Method</td><td>The R/V Substantial offset survey was verified / conducted by measurement specialists Mike Ulmer of 3Space Inc and a team of Geodynamics hydrographers. Survey instrument offsets were measured using a Leica 402 Laser Tracker with Spatial Analyzer software. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.</td></tr>
</table>

Figure 3: R/V Substantial

A.1.4 R/V 4-Points

Vessel Name	R/V 4-Points	
Hull Number	GGG25004C303	
Description	Geodynamics supplied the R/V 4-Points for hydrographic survey operations on OPR-F330-KR-22. The R/V 4-Points is a 7.62 meter monohull vessel built by Lookout Boats and conducted 12-hour operations. The R/V 4-Points has the following specifications:	
Dimensions	*LOA*	7.62 m
	Beam	3.05 m
	Max Draft	0.91 m
Most Recent Full Static Survey	*Date*	2015-04-08
	Performed By	Cain Cutchins (Buchanan & Harper, Inc.)

Most Recent Full Offset Verification	*Date*	2015-04-08
	Method	The R/V 4-Points offset survey was verified / conducted by surveyor Cain Cutchins and a team of Geodynamics hydrographers. The survey was conducted with a total station and land surveying techniques. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.

Figure 4: R/V 4-Points

A.1.5 X-15

Vessel Name	X-15	
Hull Number	n/a	
Description	The XOcean X-15 Uncrewed Survey Vehicle (USV) is a remotely operated vehicle using satellite communications. Each USV sends real-time images and situational awareness data to XOcean's Control Room where a team of qualified USV pilots keep watch and monitor the vessel, allowing for 24/7 operations over a period of up to 18 days. This USV is designed around Autonomy Level 2, as defined in the UK Maritime MASS Code and complies with the requirements of existing IMO instruments. The vessel utilizes two electric thrusters with a battery and diesel generator. The X-15 has the following specifications:	
Dimensions	*LOA*	4.5 m
	Beam	2.2 m
	Max Draft	0.65 m
Most Recent Full Static Survey	*Date*	2021-08-16
	Performed By	XOcean
Most Recent Full Offset Verification	*Date*	2021-08-16
	Method	X-15 offset survey was verified / conducted by XOcean. The survey was conducted with a Topcon OS Series Total Station. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.

Figure 5: XOcean Uncrewed Survey Vehicle (same model as X19)

A.1.6 X-19

<table>
<tr><td>Vessel Name</td><td colspan="2">X-19</td></tr>
<tr><td>Hull Number</td><td colspan="2">N/A</td></tr>
<tr><td>Description</td><td colspan="2">The XOcean X-19 Uncrewed Survey Vehicle is a remotely operated vehicle using satellite communications. Each USV sends real-time images and situational awareness data to XOcean's Control Room where a team of qualified USV pilots keep watch and monitor the vessel, allowing for 24/7 operations over a period of up to 18 days. This USV is designed around Autonomy Level 2, as defined in the UK Maritime MASS Code and complies with the requirements of existing IMO instruments. The vessel utilizes two electric thrusters with a battery and diesel generator. The X-19 has the following specifications:</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>4.5 m</td></tr>
<tr><td>Beam</td><td>2.2 m</td></tr>
<tr><td>Max Draft</td><td>0.65 m</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2022-06-29</td></tr>
<tr><td>Performed By</td><td>XOcean</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2022-06-29</td></tr>
<tr><td>Method</td><td>X-19 offset survey was verified / conducted by XOcean. The survey was conducted with a 2" Nikon Nivo 2.C Total Station. All measurements were performed multiple times and in varying combinations to reduce uncertainty and blunders.</td></tr>
</table>

Figure 6: XOcean Uncrewed Survey Vehicle (same model as X15)

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM2040C

The R/V Benthos, R/V Chinook, R/V 4-Points, and R/V Substantial were equipped with a dual-head Kongsberg EM2040C Multibeam Echo Sounder System (MBES). The R/V Chinook, R/V Benthos, and R/V 4-Points were equipped with pole mounted sonar heads with a bracket holding the sonar heads at 35°/-35°. The R/V Substantial is similarly equipped with sonar heads at 35°/-35°, however, the sonars are hull mounted. On the R/V Benthos, R/V Substantial, and R/V Chinook, two Kongsberg processing units (PU) were combined to enable dual swath mode capabilities. The 4-Points had a single PU setup. The dual-head EM2040C utilizes 512 discretely formed beams of a selectable sector up to 200° in equidistant operation mode. At 300 kHz, the EM2040C focuses an across track and along-track beam width of 1° and 1° respectively. The EM2040C operates at a maximum ping rate of 50 Hz and is designed to comply with International Hydrographic Organization (IHO) standards for depth measurements to a maximum range of 450 meters.

Manufacturer	Kongsberg
Model	EM2040C

Inventory

R/V Benthos

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	385406	Cincoze DS-1202
Serial Number	2549	2548	20188	20159	U743018
Frequency	300 kHz	300 kHz	N/A	N/A	N/A
Calibration	2023-02-22	2023-02-22	N/A	N/A	N/A
Accuracy Check	2023-02-22	2023-02-22	N/A	N/A	N/A

R/V Chinook

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	385406	Cinoze DS-1202
Serial Number	2566	2565	20190	20193	U743019
Frequency	300 kHz	300 kHz	N/A	N/A	N/A
Calibration	2023-02-22	2023-02-22	N/A	N/A	N/A
Accuracy Check	2023-02-22	2023-02-22	N/A	N/A	N/A

R/V Substantial

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Processing Unit 2	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	385406	Cincoze DS-1202
Serial Number	2513	2532	20043	30034	U756909
Frequency	300 kHz	300 kHz	N/A	N/A	N/A
Calibration	2023-02-19	2023-02-19	N/A	N/A	N/A
Accuracy Check	2023-02-20	2023-02-20	N/A	N/A	N/A

R/V 4-Points

Component	Port Sonar Head	Stbd Sonar Head	Processing Unit 1	Hydrographic Workstation
Model Number	EM2040C	EM2040C	385406	Cincoze DS-1202
Serial Number	1014	1013	20209	N/A
Frequency	300 kHz	300 kHz	N/A	N/A
Calibration	2023-02-19	2023-02-19	N/A	N/A
Accuracy Check	2023-02-20	2023-02-20	N/A	N/A

Figure 7: Kongsberg EM2040C dual-head sonar on a pole mount

Figure 8: Kongsberg EM2040C dual-head sonar hull mounted on the R/V Substantial with each transducer labeled

Figure 9: Kongsberg EM2040C hull mount on the R/V Substantial

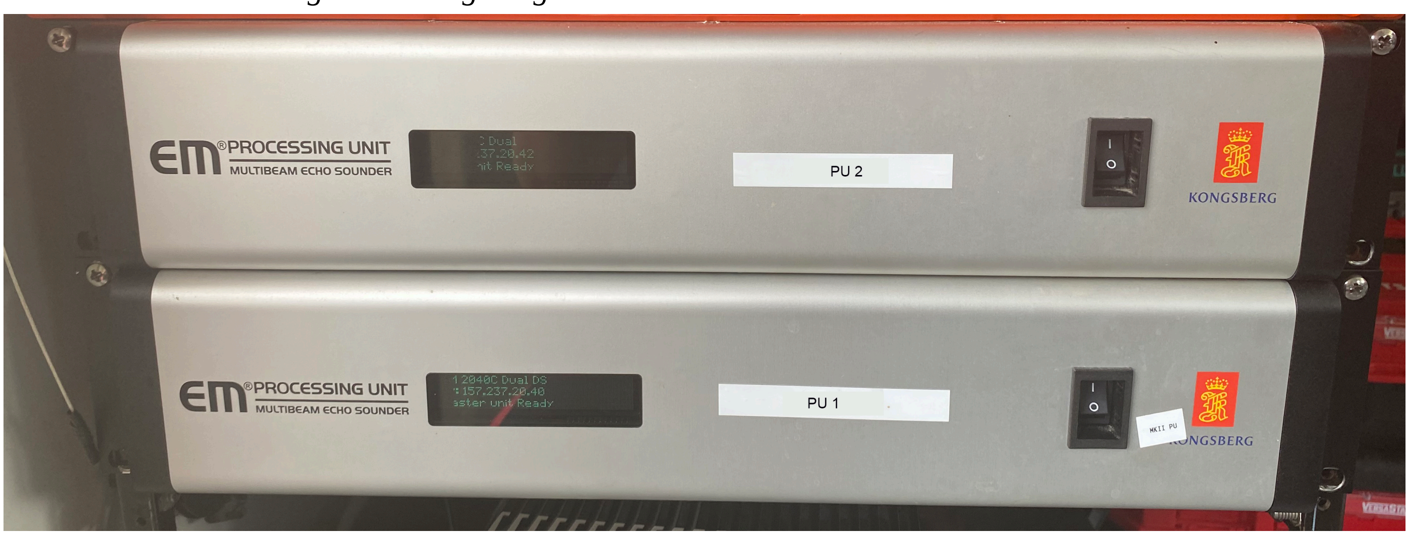

Figure 10: Kongsberg Slim Processing Units (PU) setup in dual swath configuration

A.2.2 Single Beam Echosounders

A.2.2.1 Teledyne Echotrac E20

The Teledyne Echotrac E20 singlebeam echosounder (SBES) has dual-frequency agile channels from 10 kHz - 250 kHz, allowing survey in depths from 0.5 - 6,000m. The hydrographers operated the Echotrac E20 at 200 kHz.

Manufacturer	Teledyne			
Model	Echotrac E20			
Inventory	*R/V Benthos*	*Component*	Processing Unit	Transducer
		Model Number	Echotrac E20	Airmar SS538
		Serial Number	2319019	1473235
		Frequency	N/A	200 kHz
		Calibration	2023-02-21	2023-02-21
		Accuracy Check	2023-02-22	2023-02-22
	R/V 4-Points	*Component*	Processing Unit	Transducer
		Model Number	Echotrac E20	Airmar SS538
		Serial Number	5122004	3567842
		Frequency	N/A	200 kHz
		Calibration	2023-02-18	2023-02-18
		Accuracy Check	2023-02-20	2023-02-20
	X-15	*Component*	Processing Unit	Transducer
		Model Number	Echotrac E20	Airmar SS538
		Serial Number	1021002	2368891
		Frequency	N/A	200 kHz
		Calibration	2023-03-09	2023-03-09
		Accuracy Check	2023-03-11	2023-03-11
	X-19	*Component*	Processing Unit	Transducer
		Model Number	Echotrac E20	Airmar SS538
		Serial Number	5022043	TR9859
		Frequency	N/A	200 kHz
		Calibration	2023-03-09	2023-03-09
		Accuracy Check	2023-03-11	2023-03-11

Figure 11: Teledyne Echotrac E20

Figure 12: Example of an Airmar Singlebeam transducer

A.2.2.2 Odom CV100

The Teledyne Odom Echotrac CV100 singlebeam echosounder (SBES) has dual-frequency channels from 3.5 kHz - 750 kHz, allowing survey in depths from 0.5 - 600m. The hydrographers operated the Echotrac CV100 at 200 kHz.

<table>
<tr><td>Manufacturer</td><td colspan="4">Odom</td></tr>
<tr><td>Model</td><td colspan="4">CV100</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">R/V Chinook</td><td>Component</td><td>Processing Unit</td><td>Transducer</td></tr>
<tr><td>Model Number</td><td>CV-100</td><td>Airmar SS538</td></tr>
<tr><td>Serial Number</td><td>2610</td><td>996351</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>200 kHz</td></tr>
<tr><td>Calibration</td><td>2023-02-21</td><td>2023-02-21</td></tr>
<tr><td>Accuracy Check</td><td>2023-02-21</td><td>2023-02-21</td></tr>
</table>

Figure 13: Teledyne CV100

A.2.3 Side Scan Sonars

A.2.3.1 EdgeTech 4205 Multi-Pulse/Motion Tolerant (MP/MT)

The EdgeTech 4205 MP/MT Sonar System is comprised of a stainless steel towfish that is integrated with a Transceiver/Processing Unit, which interfaces with a hydrographic workstation operating the EdgeTech Discover software for real-time QA/QC and control. The towfish was configured to operate at both 540 kHz and 850 kHz and is capable of operating at two frequencies simultaneously.

Manufacturer	EdgeTech			
Model	4205 Multi-Pulse/Motion Tolerant (MP/MT)			
Inventory	*R/V Benthos*	*Component*	EdgeTech 4205 Towfish	Topside Processing Unit
		Model Number	21517	701-DL
		Serial Number	ETN58227	57813
		Frequency	540/850kHz	N/A
		Calibration	2023-02-21	N/A
		Accuracy Check	2023-02-21	N/A
	R/V Chinook	*Component*	EdgeTech 4205 Towfish	Topside Processing Unit
		Model Number	21517	701-DL
		Serial Number	ETN62774	62792
		Frequency	540/850kHz	N/A
		Calibration	2023-02-18	N/A
		Accuracy Check	2023-02-18	N/A
	R/V 4-Points	*Component*	EdgeTech 4205 Towfish	Topside Processing Unit
		Model Number	21517	701-DL
		Serial Number	ETN62771	62815
		Frequency	540/850kHz	N/A
		Calibration	2023-06-01	N/A
		Accuracy Check	2023-06-01	N/A

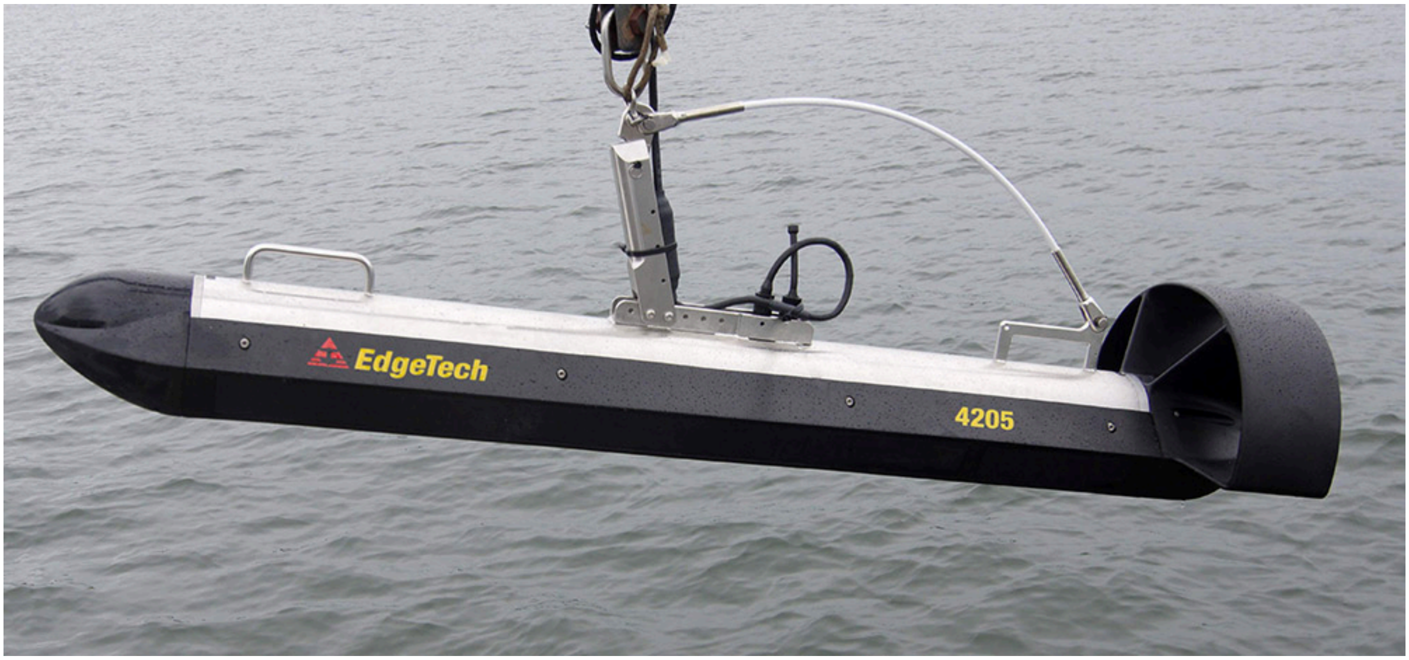

Figure 14: Example of an Edgetech 4205 SSS unit used for this project

A.2.3.2 EdgeTech 4205 Tri-Frequency Side Scan Sonar System

The EdgeTech 4205 Tri-Frequency Sonar System is comprised of a stainless steel towfish that is integrated with a topside Transceiver/Processing Unit, which interfaces with a hydrographic workstation operating the EdgeTech Discover software for real-time QA/QC and control. The towfish can be configured for frequencies of 230/540/850 kHz and is capable of operating at two frequencies simultaneously.

Manufacturer	EdgeTech				
Model	4205 Tri-Frequency Side Scan Sonar System				
Inventory	*R/V Substantial*	*Component*	EdgeTech 4205 Towfish	Topside Processing Unit	Cable Counter
		Model Number	21517	701-DL	S&R Series 74 16"
		Serial Number	ETN62773	62815	1799
		Frequency	230/540/580kHz	N/A	N/A
		Calibration	2023-02-18	N/A	N/A
		Accuracy Check	2023-02-18	N/A	N/A

Figure 15: Edgetech 4205 Towfish Side View

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

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

No lead lines were utilized for data acquisition.

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

No base station equipment was utilized for data acquisition.

A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

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 V5 OceanMaster

The Applanix POS MV V5 OceanMaster systems were used for positioning, attitude, and precise timing of sonar data on the R/V Benthos, R/V Chinook, R/V 4-Points, and the R/V Substantial. The POS MV is a Global Navigation Satellite System (GNSS) aided inertial navigation system that provides georeferencing and motion compensation for hydrographic surveys. The POS MV is comprised of four main components: POS Computer System (PCS), Inertial Measurement Unit (IMU), Primary GNSS Antenna, and the Secondary GNSS Antenna. Position, heading, and ZDA data were transmitted from the POS MV at 10 Hz and attitude was transmitted at 100 Hz to the Kongsberg sonar over RS232 serial connections for the MBES system. These data were also broadcast to Hypack software over Ethernet/UDP. To enable post-processing of the position and attitude data from the POS MV system, the data was recorded through ethernet logging to an internal SSD on the acquisition computer and a redundant, USB logged file was also recorded on a flash drive inserted in the POS MV PCS unit itself. The POS MV also computes vessel heave (both instantaneous and 'delayed' heave values). The Applanix delayed heave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real-time heave data. Delayed heave measurements are logged and applied to data in post-processing for MBES data. The POS MV also provided a pulse per second (PPS) for precise timing and synchronization of sonar data to the Kongsberg PU via coaxial cable. During pre-survey calibrations, and when required, e.g. equipment failure/change, a GNSS Azimuth Measurement System (GAMS) calibration was performed.

Manufacturer	Applanix
Model	POS MV V5 OceanMaster

Inventory

Vessel	*Component*	Deck Unit	IMU	Port Antenna	Starboard Antenna
R/V Benthos	*Model Number*	PCS-100	IMU 65	540AP	540AP
	Serial Number	11164	3250	17985	17989
	Calibration	2023-02-21	2023-02-21	2023-02-21	2023-02-21
R/V Chinook	*Model Number*	PCS-100	IMU 65	540AP	540AP
	Serial Number	11165	5272	17992	17980
	Calibration	2023-02-18	2023-02-18	2023-02-18	2023-02-18
R/V Substantial	*Model Number*	PCS-100	IMU 89	GA830	GA830
	Serial Number	12029	4947	17034	16886
	Calibration	2023-02-18	2023-02-18	2023-02-18	2023-02-18
R/V 4-Points	*Model Number*	PCS-100	IMU 37	540AP	540AP
	Serial Number	6622	2658	21903	21904
	Calibration	2023-02-18	2023-02-18	2023-02-18	2023-02-18

Figure 16: POS MV V5 OceanMaster system

A.5.1.2 Applanix POS MV WaveMaster II

The XOcean vessel's (X-15 and X-19) utilized Applanix POS MV WaveMaster II systems for positioning, attitude, and precise timing of sonar data. The POS MV is a GNSS aided inertial navigation system that provides georeferencing and motion compensation for hydrographic surveys. The POS MV is comprised of four main components: POS Computer System (PCS), Inertial Measurement Unit (IMU), Primary GNSS Antenna, and the Secondary GNSS Antenna. Positioning, heading, and attitude were transmitted from the POS MV to the Odom SBES topside. These data were also broadcast to Hypack software over Ethernet/ UDP. To enable post-processing of the position and attitude data from the POSMV system, the data is recorded through ethernet logging to an internal SSD on the acquisition computer and a redundant, USB logged file is also recorded on a flash drive inserted in the POSMV PCS unit itself. The POS MV also computes vessel heave (both instantaneous and ‘delayed’ heave values). During pre-survey calibrations and when required (equipment failure/change), a GNSS Azimuth Measurement System (GAMS) calibration was performed.

Manufacturer	Applanix
Model	POS MV WaveMaster II

Inventory						
	X-15	*Component*	Deck Unit	IMU	Port Antenna	Starboard Antenna
		Model Number	Wavemaster II	Wavemaster II	Zephyr Model 3 rugged	Zephyr Model 3 rugged
		Serial Number	0100-2004367	0100-2215682	106J5121Z	0512J5441Z
		Calibration	2023-01-26	2023-01-26	2023-01-26	2023-01-26
	X-19	*Component*	Deck Unit	IMU	Port Antenna	Starboard Antenna
		Model Number	Wavemaster II	Wavemaster II	Zephyr Model 3 rugged	Zephyr Model 3 rugged
		Serial Number	0100-2004368	0100-2107842	3341J6221Z	3511J5381Z
		Calibration	2023-01-26	2023-01-26	2023-01-26	2023-01-26

Figure 17: POS MV WaveMaster II system

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

Additional GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

A.5.5 Other Positioning and Attitude Equipment

A.5.5.1 Fugro Marinestar Satellite-Based Augmentation System (SBAS)

All Geodynamics owned vessels deployed on OPR-F330-KR-22 received G2+ GNSS satellite corrections from the Marinestar Satellite-based Augmentation System (SBAS) network. XOcean USVs received G4+ corrections from Marinestar. SBAS settings in the POS MV were configured to receive the G2+ and G4+ corrections at a set frequency and bit rate of 1200 bits/second.

Manufacturer	Fugro		
Model	Marinestar Satellite-Based Augmentation System (SBAS)		
Inventory	*R/V Benthos*	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	R/V Chinook	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	R/V 4-Points	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	R/V Substantial	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	X-15	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A
	X-19	*Component*	Marinestar SBAS
		Model Number	N/A
		Serial Number	N/A
		Calibration	N/A

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 AML Oceanographic MVP30-350

The R/V Substantial was outfitted with an AML Oceanographic Moving Vessel Profiler (MVP) used to obtain sound speed profiles at a greater frequency without stopping the survey vessel. The AML MVP30-350 system consists of a sensor free fall fish, an integrated winch and power unit, an overboard towing sheave, and a remote system controller with a dedicated operating station running the MVP Controller software. Sound speed profiles acquired with the MVP were imported into HydrOffice Sound Speed Manager (SSM) via ethernet/UDP and then broadcast directly to SIS. All relevant calibrated pressure, conductivity, temperature and sound velocity sensors associated with each instrument are listed below.

<table>
<tr><td>Manufacturer</td><td colspan="6">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="6">MVP30-350</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R/V Substantial</td><td>Component</td><td>Deck unit</td><td>SV Sensor</td><td>Temperature Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>MVP30-350</td><td>SV.Xchange</td><td>T.X2change</td><td>P.Xchange</td></tr>
<tr><td>Serial Number</td><td>M12962</td><td>210764</td><td>420023</td><td>308236</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-08-24</td><td>2022-08-31</td><td>2022-09-07</td></tr>
</table>

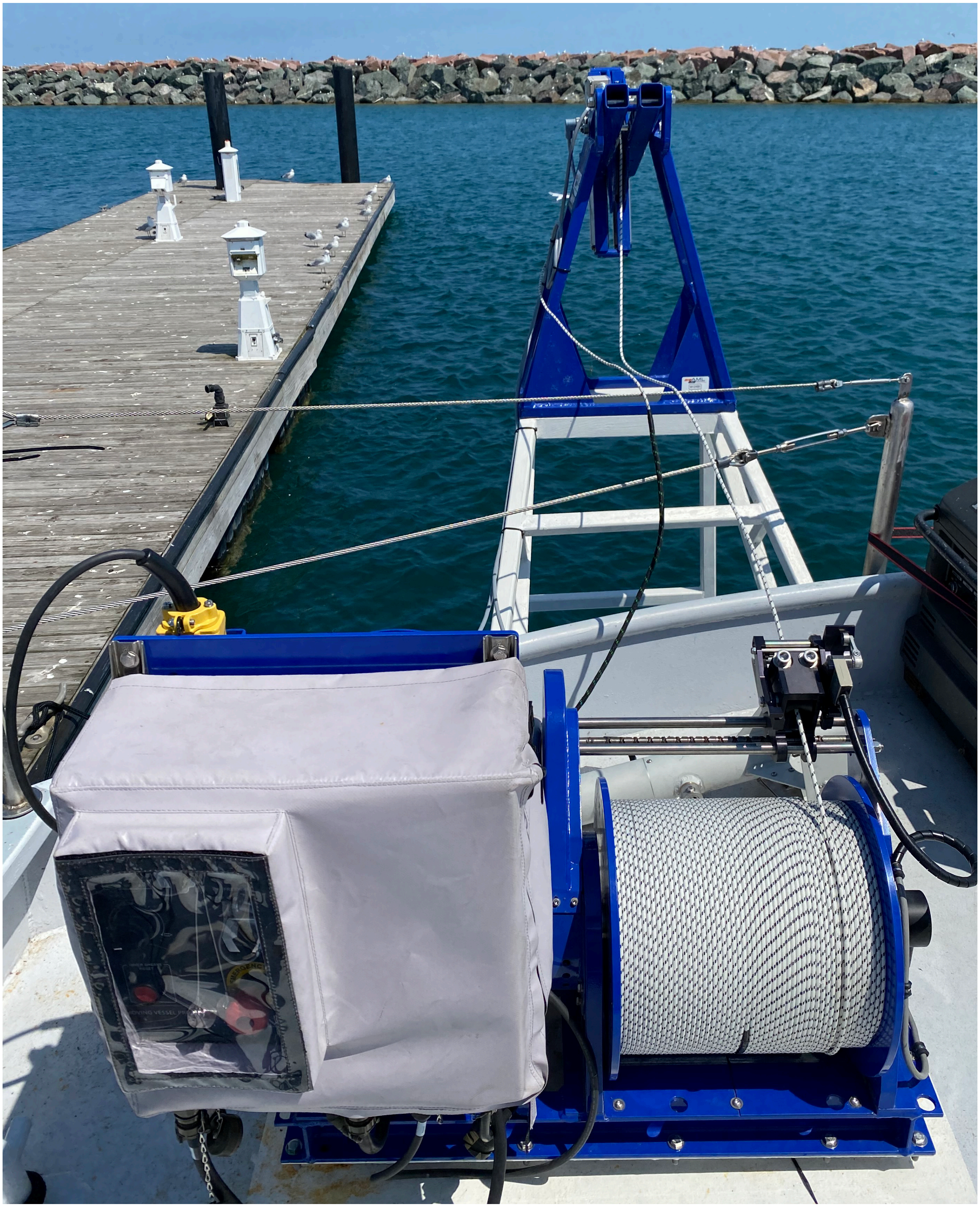

Figure 18: AML Oceanographic MVP30-350

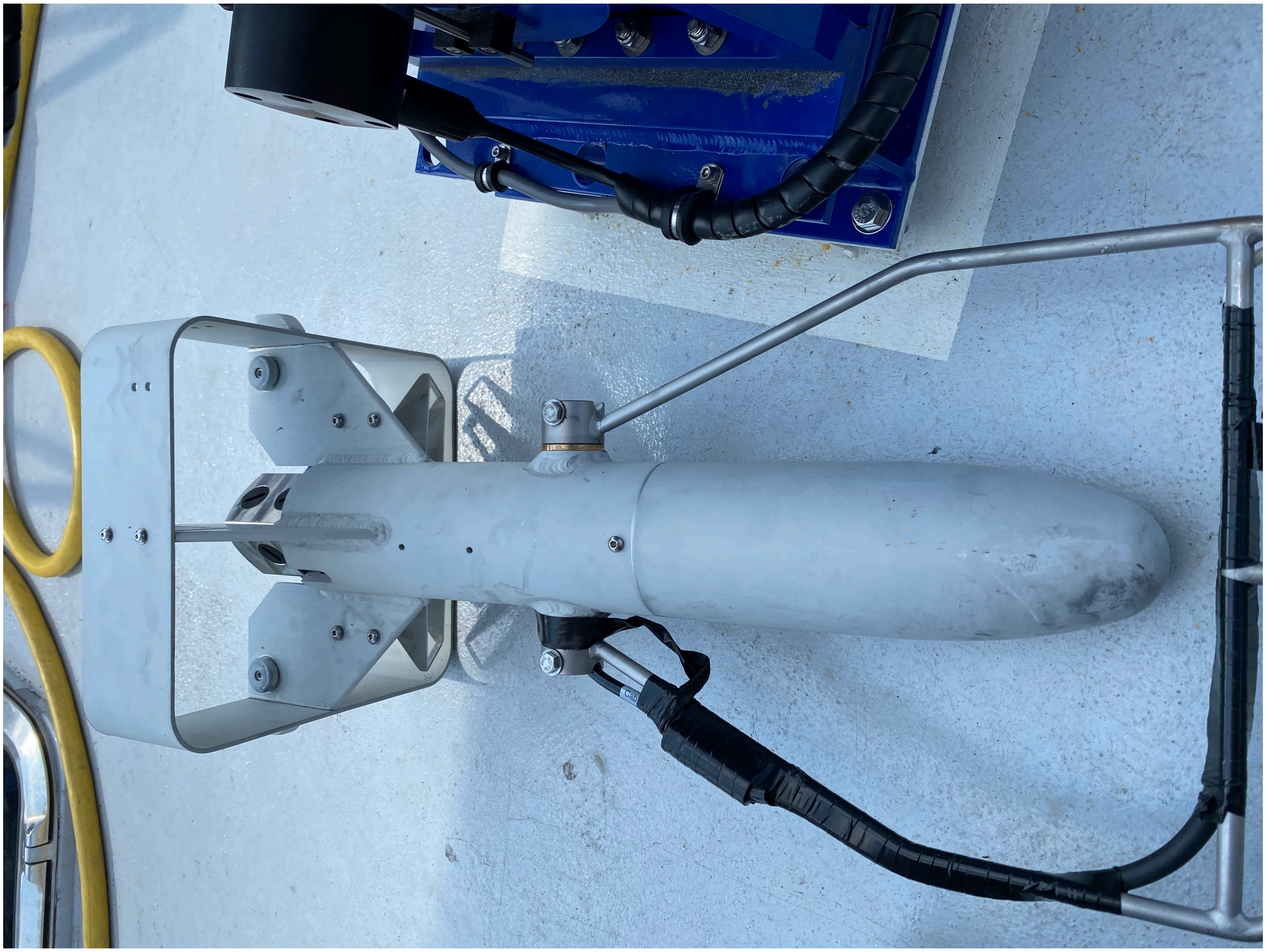

Figure 19: MVP Sensor free fall fish

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

The AML Base X2 is a sound speed profiling instrument integrated with a time-of-flight sound speed sensor (SV.XChange) and pressure sensor (P.XChange) to collect sound speed profiles. The Base X2 transferred sound speed profile data to AML Seacast over Wireless Local Area Network (WLAN) connection and RS232 serial cable when needed.

<table>
<tr><td>Manufacturer</td><td colspan="5">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="5">Base X2</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Benthos</td><td>Component</td><td>Instrument Body</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Base X2</td><td>SV.XChange</td><td>P.XChange</td></tr>
<tr><td>Serial Number</td><td>26005</td><td>204291</td><td>308487</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-12-06</td><td>2022-12-15</td></tr>
<tr><td rowspan="4">R/V Chinook</td><td>Component</td><td>Instrument Body</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>SV.XChange</td><td>P.XChange</td></tr>
<tr><td>Serial Number</td><td>26270</td><td>209304</td><td>146220</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-12-06</td><td>2022-09-07</td></tr>
</table>

Figure 20: AML Base X2

A.6.3.2 AML Oceanographic Minos X

The AML MinosX is a sound speed profiling instrument integrated with a time-of-flight sound speed sensor (SV.XChange) and pressure sensor (P.XChange) to collect sound speed profiles. The MinosX transferred sound speed profile data to AML Seacast via a RS232 serial cable. This sound speed profiler was used on the R/V Substantial on 3/2/2023 when the MVP had a brief malfunction.

<table>
<tr><td>Manufacturer</td><td colspan="5">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="5">Minos X</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R/V Substantial</td><td>Component</td><td>Instument Body</td><td>SV Sensor</td><td>Pressure Sensor</td></tr>
<tr><td>Model Number</td><td>MinosX</td><td>SV XChange</td><td>P.XChange</td></tr>
<tr><td>Serial Number</td><td>8234</td><td>211148</td><td>306273</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-07-17</td><td>2022-09-07</td></tr>
</table>

Figure 21: AML MinosX

A.6.3.3 AML Oceanographic AML-3 LGR

The AML-3 LGR (Logger) is a sound speed profiling instrument integrated with a time-of-flight sound speed sensor (SV.XChange) and pressure sensor (P.XChange) to collect sound speed profiles. The AML-3 LGR transferred sound speed profile data to AML Sailfish over Wireless Local Area Network (WLAN) connection and USB cable when needed. The instrument body A30358 was swapped with A30878 on 7/3/2023 due to connectivity and data transfer issues but the interchangeable pressure and SV sensors were retained.

<table>
<tr><td>Manufacturer</td><td colspan="6">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="6">AML-3 LGR</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R/V 4-Points</td><td>Component</td><td>Instrument Body</td><td>SV Sensor</td><td>Pressure Sensor</td><td>Instrument Body</td></tr>
<tr><td>Model Number</td><td>AML-3 LGR</td><td>SV.XChange</td><td>P.XChange</td><td>AML-3 LGR</td></tr>
<tr><td>Serial Number</td><td>A30358</td><td>210783</td><td>308183</td><td>A30878</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-08-24</td><td>2022-09-07</td><td>N/A</td></tr>
</table>

Figure 22: AML-3 LGR

A.6.3.4 AML Oceanographic MicroX

The AML MicroX is a single port real-time instrument body for surface sound speed applications. The MicroX provided surface sound speed to the Kongsberg PU at 1 Hz over RS232 serial connection. The sensor, installed on the sonar head mount, was powered from a 12 volt power source. The AML MicroX SV.XChange sensor on the R/V Chinook SN207350 was replaced on 4/11/2023 with SN209320 due to a malfunction with the sensor.

Manufacturer	AML Oceanographic				
Model	MicroX				
Inventory	*R/V Benthos*	*Component*	Instrument Body	SV Sensor	
		Model Number	MicroX	SV.XChange	
		Serial Number	7762	211283	
		Calibration	N/A	2022-12-06	
	R/V Chinook	*Component*	Instrument Body	SV Sensor	SV Sensor
		Model Number	MicroX	SV.XChange	SV.XChange
		Serial Number	12368	207350	209320
		Calibration	N/A	2022-12-06	2022-09-07
	R/V Substantial	*Component*	Instrument Body	SV Sensor	
		Model Number	MicroX	SV.XChange	
		Serial Number	12854	211142	
		Calibration	N/A	2022-07-17	

Figure 23: AML Oceanographic MicroX with SV.Xchange

A.6.3.5 AML Oceanographic AML-1 RT (Real-Time)

The AML-1 RT is a single port real-time instrument body for surface sound speed applications. The AML-1 RT provided surface sound speed to the Kongsberg PU at 1 Hz over RS232 serial connection. The sensor, installed on the sonar head mount, was powered from a 12 volt power source. The SV.XChange sensor with SN210835 was replaced on 6/14/2023 with SN211699 to remain within manufacturer recommended calibration frequency (annually).

Manufacturer	AML Oceanographic				
Model	AML-1 RT (Real-Time)				
Inventory	*R/V 4-Points*	*Component*	Instrument Body	SV Sensor	SV Sensor
		Model Number	AML-1 RT	SV.XChange	SV.XChange
		Serial Number	A10174	210835	211699
		Calibration	N/A	2022-06-15	2023-04-05

Figure 24: AML-1 RT

A.6.3.6 Valeport Swift SVP

Valeport Swift SVP sound speed profiling instruments were utilized on the USVs. The instrument is integrated with a digital time of flight sound velocity sensor, temperature compensated piezo-resistive pressure transducer, and a PRT temperature sensor. The Swift SVP transferred sound speed profile data to the Teledyne SBES UI software via Bluetooth, and was remotely deployed and retrieved on the X-15 and X-19 USV platforms when triggered by the operator.

Valeport was contacted about the manufacturer's recommendation for calibrating their sensors. Valeport stated that they recommended re-calibration every two years.

Manufacturer	Valeport					
Model	Swift SVP					
Inventory	*X-15*	*Component*	Instrument Body	SV Sensor	Pressure Sensor	Temperature Sensor
		Model Number	Swift SVP	N/A	N/A	N/A
		Serial Number	78758	175268	230776	11234
		Calibration	2021-09-16	2021-09-16	2021-09-16	2021-09-16
	X-19	*Component*	Instrument Body	SV Sensor	Pressure Sensor	Temperature Sensor
		Model Number	Swift SVP	N/A	N/A	N/A
		Serial Number	75572	173217	222861	10428
		Calibration	2021-11-04	2021-11-04	2021-11-04	2021-11-04

Figure 25: Valeport Swift SVP

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*
Xylem US	Hypack	2022.Q3	Acquisition and SBES Processing
AML Oceanographic	Seacast	4.4.0	Acquisition
AML Oceanographic	Sailfish	2023	Acquisition
AML Oceanographic	MVP Controller	2.4.8	Acquisition
Applanix	POSView	10.5	Acquisition
Kongsberg	Seafloor Information System (SIS)	4.3.2	Acquisition
NOAA (HSTB)	Pydro Explorer	22.1	Acquisition and Processing
Blue Marble Geographics	Global Mapper	21.0	Processing
Microsoft	Office 365	2023	Processing
Teledyne CARIS	HIPS Professional	11.4.20, 11.4.22, 11.4.26	Processing
Teledyne CARIS	BASE Editor	5.5	Processing
Edgetech	Discover 4205 Tri-Frequency / MPMT Dual Frequency	42.0.1.115	Acquisition
Chesapeake Technologies	SonarWiz 7	7.10.02	Processing
Teledyne	Odom eChart	1.4	Acquisition
Teledyne	SBES UI	2.0.12.0	Acquisition
Valeport	Valeport Ocean	1.1.0.35	Acquisition
Beamworks	NAVAQ	23.1	Acquisition
Synology	Synology Drive	3.1.0	Acquisition
ESRI Inc.	ArcGIS Pro	3.1.2	Processing
QPS	FMGeocoder Toolbox (FMGT)	7.10.1	Processing
Golden Software LLC	Surfer	26.1.216	Processing
Applanix	POSPac MMS with Centerpoint RTX	8.7	Processing
Adobe	Acrobat DC	2023	Processing
TechSmith	Snagit	2020.1.1	Processing
ESRI	ArcGIS Enterprise	10.8	Processing
ESRI	ArcGIS Online	2022	Acquisition and Processing
Geodynamics	Albemarle SIMS (Survey Information System)	2023	Acquisition and Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Wildco 1728-G40

The Wildco Petite Ponar sampler was used aboard the R/V Benthos and R/V Chinook to acquire bottom samples. Ponar samplers are widely used for sediment sampling on a variety of bottom types such as silt, sand, gravel, consolidated marl, or clay.

Figure 26: Wildco Petite Ponar

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Static surveys were performed to determine offsets on R/V Benthos, R/V Chinook, R/V Substantial, R/V 4-Points, X-15, and X-19. The R/V Benthos, R/V Chinook, and R/V Substantial's static surveys were performed by 3Space Inc. These static surveys were conducted with a Leica 402 Laser Scanner and Spatial Analyzer software. R/V 4-Points static survey was professionally surveyed by Buchanan & Harper, Inc. using a total station and land surveying techniques. XOcean performed static surveys on X-15 and X-19 using a Topcon OS Series Total Station and a 2" Nikon Nivo 2.C Total Station, respectively. For the static surveys, all sensor locations were surveyed, as well as several pre-determined punch mark locations across the vessel frame.

The static survey results were confirmed prior to the project start via hand measurement and confirmed again for accuracy from the patch test and pre-survey verifications. All offsets, correctors, and values used in TPU calculation can be found in the Caris HVF file, with separate configurations used for SBES and MBES acquisition.

All Geodynamics owned vessels (R/V Substantial, Benthos, Chinook, and 4-Points) were configured with the POS MV using the IMU as the reference point. Position/attitude were output from the POS MV to sensor 1, which is the MBES tangent point located between each Kongsberg sonar head (dual-head). The location and angular offsets from sensor 1 to each sonar head and waterline were entered into SIS. All other offsets (singlebeam, sss tow point etc) are compensated for in Hypack hardware settings.

For XOcean vessels, all lever arm offsets were compensated for in the POS MV software. The acoustic center of the singlebeam transducer on these vessels is the reference in POS MV and therefore, sensor 1 is zeroed out. Offsets from the waterline to singlebeam transducer were entered in the E20 software to capture accurate real-time depths.

A complete listing of Vessel Offset Correctors used can be found within Appendix III.

Figure 27: Static survey of R/V Substantial

B.1.1.1 Vessel Offset Correctors

Vessel offset correctors were not applied.

B.1.2 Layback

On R/V Substantial, the cable payout values were obtained through a cable payout indicator system and sent to Hypack via RS232 cable. On R/V Benthos, R/V Chinook, and R/V 4-Points, the cable payout values were measured by marks spaced every 1 meter on the SSS cable, and then manually entered into Hypack. Hypack then calculated the cable layback values on the fly using the "Hypack Standard" layback method with a calibrated catenary factor of ~0.7 in the figure below.

Layback correctors were applied in real-time in Hypack and the layback corrected position of the tow fish was then output from Hypack and integrated into Discover. Offsets from the established vessel reference frame to the tow point were integrated into the appropriate Hypack driver (Towfish.dll) in A-frame offsets.

The Layback error was evaluated from a pre-survey calibration to confirm layback is within acceptable tolerances (associated dates). The calibration included running pre-determined sets of lines over a known contact (imaged with MBES) and correlating identified contacts in the different SSS passes to the known position. Daily confidence checks were also performed to ensure proper identification and position of features. Refer to section C.2.2 for more information.

X,Y,Z values below for tow point are the physical measurements from Vessel COG to the tow point in the Hypack lever arm convention (X, stbd+, y fwd+, Z down).

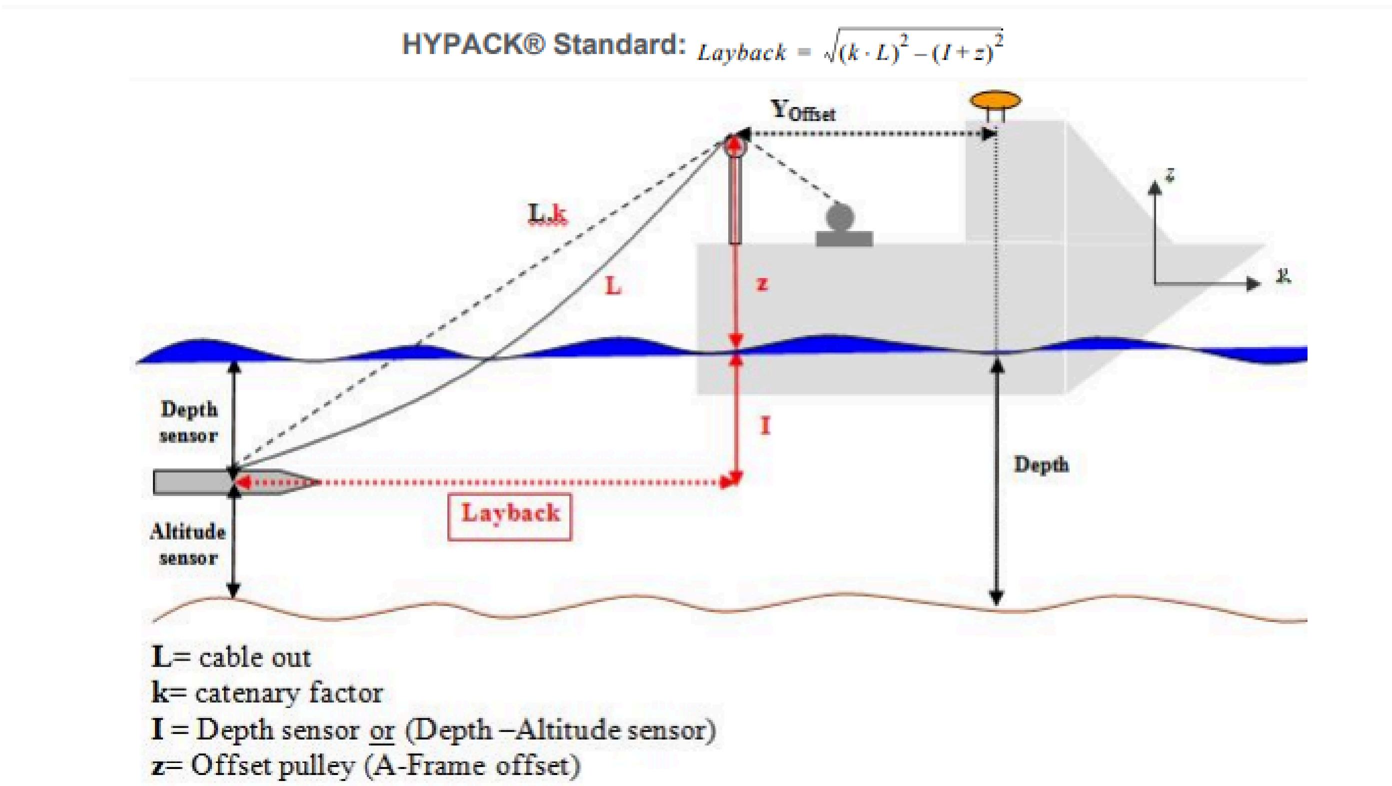

Figure 28: Hypack Standard layback calculation

B.1.2.1 Layback Correctors

<table>
<tr><td>Vessel</td><td colspan="2">R/V Benthos</td></tr>
<tr><td>Echosounder</td><td colspan="2">Edgetech 4205</td></tr>
<tr><td>Frequency</td><td colspan="2">540.0 kHz</td></tr>
<tr><td>Date</td><td colspan="2">2023-02-21</td></tr>
<tr><td rowspan="2">Layback</td><td>Towpoint</td><td><table><tr><td>x</td><td>0.290 meters</td></tr><tr><td>y</td><td>-3.840 meters</td></tr><tr><td>z</td><td>-2.140 meters</td></tr></table></td></tr>
<tr><td>Layback Error</td><td>0.000 meters</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>R/V Chinook</td></tr>
<tr><td>Echosounder</td><td>Edgetech 4205</td></tr>
<tr><td>Frequency</td><td>540.0 kHz</td></tr>
<tr><td>Date</td><td>2023-02-18</td></tr>
<tr><td>Layback</td><td><table><tr><td>Towpoint</td><td><table><tr><td>x</td><td>0.000 meters</td></tr><tr><td>y</td><td>-5.700 meters</td></tr><tr><td>z</td><td>-2.320 meters</td></tr></table></td></tr><tr><td>Layback Error</td><td>0.000 meters</td></tr></table></td></tr>
</table>

<table>
<tr><td>Vessel</td><td>R/V 4-Points</td></tr>
<tr><td>Echosounder</td><td>Edgetech 4205</td></tr>
<tr><td>Frequency</td><td>540.0 kHz</td></tr>
<tr><td>Date</td><td>2023-06-01</td></tr>
<tr><td>Layback</td><td><table><tr><td>Towpoint</td><td><table><tr><td>x</td><td>2.270 meters</td></tr><tr><td>y</td><td>0.680 meters</td></tr><tr><td>z</td><td>-2.170 meters</td></tr></table></td></tr><tr><td>Layback Error</td><td>0.000 meters</td></tr></table></td></tr>
</table>

<table>
<tr><td>Vessel</td><td>R/V Substantial</td></tr>
<tr><td>Echosounder</td><td>Edgetech 4205</td></tr>
<tr><td>Frequency</td><td>540.0 kHz</td></tr>
<tr><td>Date</td><td>2023-02-18</td></tr>
<tr><td>Layback</td><td><table><tr><td>Towpoint</td><td><table><tr><td>x</td><td>-0.920 meters</td></tr><tr><td>y</td><td>-9.010 meters</td></tr><tr><td>z</td><td>-3.500 meters</td></tr></table></td></tr><tr><td>Layback Error</td><td>0.000 meters</td></tr></table></td></tr>
</table>

B.2 Static and Dynamic Draft

B.2.1 Static Draft

This project incorporated an Ellipsoid Referenced Survey (ERS) workflow and as a result, static draft was accounted for in the soundings by using post-processed ellipsoid-based corrections in addition to the real-time corrections. The combined correctors work to factor out the static draft, squat, and settlement of the survey vessel.

B.2.1.1 Static Draft Correctors

Static draft correctors were not applied.

B.2.2 Dynamic Draft

This project incorporated an ERS workflow and as a result, dynamic draft was accounted for in the soundings by using post-processed ellipsoid-based corrections in addition to the real-time corrections. The combined correctors work to factor out the static draft, squat, and settlement of the survey vessel.

B.2.2.1 Dynamic Draft Correctors

Dynamic draft correctors were not applied.

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Multibeam patch tests were performed on each survey vessel prior to arrival to the survey site to establish installation mounting biases between the attitude reference frame and the sonar reference frame. The patch tests also determined any latency bias between the sonar systems and positioning systems. Patch tests were conducted prior to the start of data acquisition and whenever a major system hardware change was made. Patch tests were conducted in accordance with section 5.2.4.1 of the March 2022 Hydrographic Survey Specifications and Deliverables (HSSD). Patch test data were assessed in CARIS by multiple hydrographers and an uncertainty was assigned to patch test biases. Patch test biases were entered into the appropriate locations in the CARIS HVF and SIS Installation Parameters. To ensure quality in system alignment and the integrity of the sonar data, roll lines were collected frequently on the R/V Chinook, R/V Benthos, and R/V 4-Points since these vessels utilized a deployable over-the-side pole mount.

Singlebeam data calibrations were performed for each vessel equipped with a singlebeam transducer. Calibrations consisted of a latency test by running reciprocal lines across a surveyed object along the seafloor, a leadline check to identify any small biases in the system, and a bar check when feasible. Results from the leadline checks can be found in Appendix V. Any offset determined in these tests were accounted for in Hypack and/or the E20 software. To further ensure alignment between sensors, SBES and MBES data were collected over the same area and depths were compared between each vessel and each sensor (see Appendix V).

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>R/V Benthos</td></tr>
<tr><td>Echosounder</td><td>Kongsberg EM2040C Dual Patch Test Values</td></tr>
<tr><td>Date</td><td>2023-02-22</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>-0.194 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>34.205 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>359.495 degrees</td><td>0.085 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>
<tr><td>Date</td><td>2023-02-22</td></tr>
<tr><td>Patch Test Values (Transducer 2)</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>-0.207 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>-35.925 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>359.450 degrees</td><td>0.085 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	R/V Chinook		
Echosounder	Kongsberg EM2040C Dual Patch Test Values		
Date	2023-02-22		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.850 degrees	0.050 degrees
	Roll	35.518 degrees	0.050 degrees
	Yaw	0.120 degrees	0.085 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
Date	2023-02-22		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	0.950 degrees	0.050 degrees
	Roll	-34.965 degrees	0.050 degrees
	Yaw	359.110 degrees	0.085 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	R/V 4-Points		
Echosounder	Kongsberg EM2040C Dual Patch Test Values		
Date	2023-02-19		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	1.590 degrees	0.050 degrees
	Roll	36.800 degrees	0.050 degrees
	Yaw	1.000 degrees	0.085 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

Date	2023-02-19

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	1.700 degrees	0.050 degrees
Roll	-33.420 degrees	0.050 degrees
Yaw	0.800 degrees	0.085 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	R/V Substantial
Echosounder	Kongsberg EM2040C Dual Patch Test Values
Date	2023-02-19

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	-0.990 degrees	0.050 degrees
Roll	37.210 degrees	0.050 degrees
Yaw	0.020 degrees	0.085 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

Date	2023-02-19

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.500 degrees	0.050 degrees
Roll	-35.020 degrees	0.050 degrees
Yaw	2.040 degrees	0.085 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

<table>
<tr><td>Vessel</td><td>R/V Benthos</td></tr>
<tr><td>Echosounder</td><td>Odom Echotrac E20 Calibration Values</td></tr>
<tr><td>Date</td><td>2023-02-21</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>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.085 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>R/V Chinook</td></tr>
<tr><td>Echosounder</td><td>Odom Echotrac CV100 Calibration Values</td></tr>
<tr><td>Date</td><td>2023-02-20</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>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.085 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	R/V 4-Points
Echosounder	Odom Echotrac E20 Patch Test Values
Date	2023-02-21
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.000 degrees	0.050 degrees
Roll	0.000 degrees	0.050 degrees
Yaw	0.000 degrees	0.085 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	X-15
Echosounder	Odom Echotrac E20 Patch Test Values
Date	2023-03-11
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.000 degrees	0.050 degrees
Roll	0.000 degrees	0.050 degrees
Yaw	0.000 degrees	0.085 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

<table>
<tr><td>Vessel</td><td>X-19</td></tr>
<tr><td>Echosounder</td><td>Odom Echotrac E20 Patch Test Values</td></tr>
<tr><td>Date</td><td>2023-03-11</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>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.085 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>

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

All data planning, calibrations, acquisition, processing, QC, quality assurance (QA), and reporting were performed under the direct supervision of the Chief of Party. Field data collection and processing were done under the supervision of a highly qualified team including the Chief of Party, Lead Hydrographer, Senior Hydrographer, and Data Processing Manager. Project manager David Bernstein, and Lead Hydrographers Ben Sumners and Nick Damm, are all NSPS-THSOA Certified Hydrographers. Prior to the start of data acquisition, and following static vessel surveys and verification measurements, a series of calibrations and tests took place on each vessel to prepare and validate the setup and integration of all survey systems across all vessels.

For this project, multibeam bathymetry was acquired in H13755, H13758, and H13760 concurrently with SSS data to meet complete coverage requirements of HSSD section 5.2.2.3. In H13763 and H13764, the coverage type was complete coverage SBES with concurrent SSS (see project instructions). However, in certain areas of those sheets, the R/V Substantial collected MBES with concurrent SSS to meet complete coverage requirements and allow for further utilization of the R/V Substantial and promote efficiency (see project correspondence and associated DRs).

In all sheets, multibeam bathymetry was also collected to investigate and develop contacts as required by HSSD section 7.3.3 and 6.1.3.3, as well as for feature development. As mentioned in the project correspondence, this project had many challenging environmental influences (bait balls, thermoclines), which were discussed throughout the project with NOAA HSD OPS. In all sheets, multibeam bathymetry was used as a recovery technique to ensure full coverage atop these SSS mosaic artifacts. The decision to use multibeam in this manner instead of SSS with concurrent bathymetry as the primary recovery system, was dictated by depth (swath coverage) and was vital to minimize the need to run recoveries multiple times.

Line plans for multibeam acquisition were created in ArcPro and Hypack. For areas of full coverage mainscheme, line plan spacing was adjusted appropriately based on SSS range to ensure at least 100% of the seafloor was ensonified with SSS. Kongsberg SIS was utilized for MBES data logging and real-time QA/QC. Hypack was used for navigation, monitoring of system health, real-time progress tracking, and QC assessments. MBES data were examined to ensure the sonar data extended at least across the sidescan nadir gap. Using a custom NMEA output driver and WWAN connection, vessel tracking information was streamed over an ESRI GeoEvent Server to a Survey Information Management System (SIMS) hosted through ArcGIS Online. This combined progress tracker and dashboard system provided real-time situational awareness of each vessel and calculated various project tracking metrics, providing critical guidance for management and hydrographers in real-time. Each vessel and survey system were optimized for data collection to meet the requirements of the PI and HSSD. The R/V Benthos, R/V Chinook, and R/V 4-Points operated on a 12-hour day operation schedule while the R/V Substantial operated on a 24-hour schedule.

The R/V Benthos, R/V Chinook, R/V 4-Points and R/V Substantial were configured with dual-head EM2040C systems. Sonar systems were aided by the POS MV, which provided real-time QC of position and attitude data, and logged ancillary POSPac data (.000 files) for post-processing. All Kongsberg systems were controlled and operated with SIS.

It should be noted that the acquisition of multibeam splits were based off guidance from NOAA HSD OPS and deviated from the requirements outlined in the HSSD. A majority of charted soundings within the project area were found to be shoaler than the surveyed depths. Because of this, the traditional guidance for acquiring splits would be insufficient. Therefore, with field efficiency in mind, the COR provided guidance relying more heavily on hydrographer discretion to determine where splits were needed. For more information, please see the project correspondence.

An additional component to this project was interpolated grids for the National Water Center (PIs). Those gridding methods are further described in C.1.4.

Data Processing Methods and Procedures

Multibeam data processing was accomplished with CARIS and POSPac MMS. Immediately following acquisition, data were transferred via Synology Sync drive, to the network attached server (NAS) hosting an array of SSDs. Initial data processing consisted of data transfer, file conversion, application of delayed heave and associated RMS, SBET/SMRMSG generation and application, and georeferenced bathymetry (application of GPS Tide, sound velocity corrections, and TPU calculation), and lastly CUBE surface generation (Phase 1). CARIS Process Models and Pydro QC Tools were used for the Phase 1 processing steps such that an initial surface and related QC data were generated before the next survey day. Phase 1 QC included assessing initial QC Tools results, SBET QC, surface inspection, assessment of data quality and system performance, and daily survey reporting.

Phase 2 processing began with a thorough QC of data quality using the CUBE surfaces, followed by data cleaning and feature identification/designation.

Phase 3 processing included QC and finalization of features/designations and bathymetric surfaces. During this stage, rigorous QC was performed to ensure completeness and adequacy of the final deliverables and associated reporting.

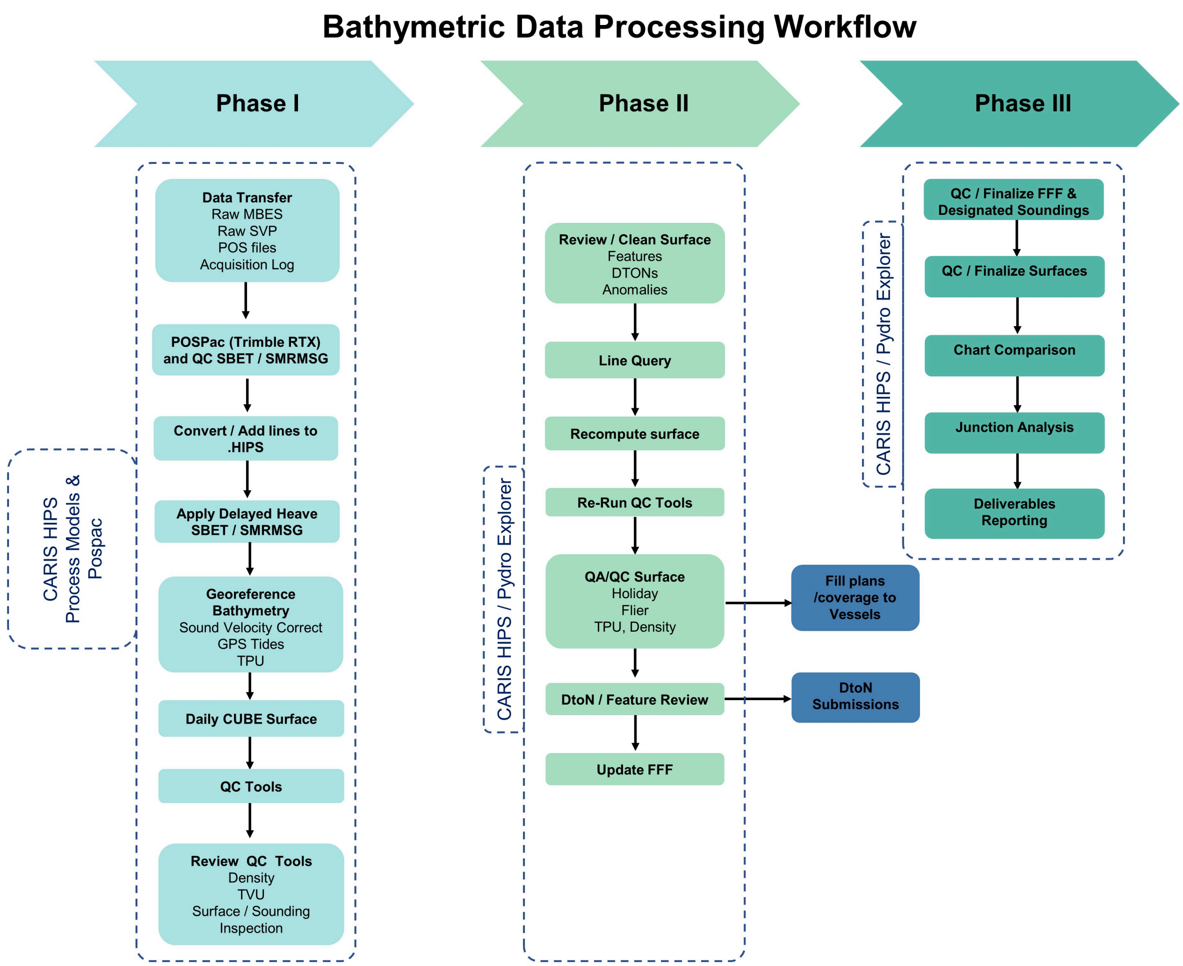

Figure 29: Multibeam processing workflow

C.1.2 Single Beam Echosounder

Data Acquisition Methods and Procedures

For this project, singlebeam bathymetry was acquired in H13761, H13762, H13763, and H13764. These were mixed coverage sheets of full coverage singlebeam with concurrent SSS and set line spacing singlebeam (PI). The distinction of coverage type within mixed coverage sheets is described in the PI, however, parameters were further developed for the coverage type distinction based on observations in the field. These additional parameters were developed with NOAA HSD OPS and allowed hydrographer's discretion to treat areas deeper than the coverage distinction depth (3.5m) as set line spacing singlebeam instead of full coverage side scan with singlebeam based on several parameters. These parameters included areas deeper than 3.5m that were disconnected from main navigation areas and/or small "dips" in the bottom near the distinction depth. Additionally, Geodynamics provided maps prior to field closure that displayed the coverage obtained in water sheds and tributaries, areas where these developed parameters were most frequently used. The maps were provided to NOAA HSD OPS to assure compliance and welcome feedback to the employed parameters. See project correspondence for more information on this subject.

Line plans for singlebeam acquisition were created in ArcPro and Hypack. When the coverage type was full coverage SSS with concurrent singlebeam, line spacing was dictated by SSS range to ensure 100% SSS coverage was met. When coverage type was singlebeam set line spacing, lines were spaced every 50 m and developed in Hypack. Orientation of lines were determined based on the most efficient and safest way to collect data. All vessels utilized Hypack for navigation, monitoring of system health, data logging, real-time progress tracking, and QC assessments.

The USV's utilized on this project were given a line plan to follow and acquired data 24/7, only stopping when maintenance was required and to transfer large amounts of data. All other vessels collecting singlebeam were on a 12-hour day operation schedule (R/V Benthos, R/V Chinook and R/V 4-Points). Odom eChart software was used to operate the CV100 singlebeam echosounder (SBES) hardware and Echotrac E20 software was used to operate the E20 hardware. Manual adjustments of the power and gain settings within the SBES software were occasionally required due to changes in bottom type throughout the survey extents and when surface conditions became marginal. Singlebeam data were collected with special care and extra caution as a majority of these data were acquired along shorelines with depths shoaler than 3.5 m. Features identified in the field and during off-site processing were appropriately developed based on guidance from the HSSD and direction from NOAA's HSD OPS team (see project correspondence). Where sheet limits or the 2 m LWD depth could not be reached, hydrographer discretion was used to define NALL. Given the complex, feature-rich shoreline, NALL was often defined by hydrographer discretion (safety). This was discussed in our meeting with AHB and NOAA OPS on 02/12/2024 (see project correspondence) and examples of where NALL is defined by hydrographer discretion are in the accompanying DRs.

It should be noted that the acquisition of multibeam splits were based off guidance from NOAA HSD OPS and deviated from the requirements outlined in the HSSD. A majority of charted soundings within the project area were found to be shoaler than the surveyed depths. Because of this, the traditional guidance for acquiring splits would be insufficient. Therefore, with field efficiency in mind, the COR provided guidance relying more heavily on hydrographer discretion to determine where splits are needed. For more information, please see the project correspondence.

Data Processing Methods and Procedures

Singlebeam data processing were accomplished with Hypack, CARIS, and POSPAC MMS. Phase 1 processing consisted of copying all raw data off each vessel after the completion of the survey day to an SSD and transferring data to a NAS using a Synology Sync drive. Once all data were synced to the Geodynamics server and files organized in their respective locations, an SBET was generated and QC'ed using POSPAC MMS software.

Phase 2 processing began with importing the .RAW files and their associated .BIN files into Hypack's Single Beam Editor (64-Bit) where sound velocity, SBET application, GPS tide calculations, and all other necessary correctors were applied to the soundings. After all vessel/sensor offsets and corrections were applied, all erroneous soundings were cleaned using the echogram (.BIN) as a guide. While cleaning the soundings, significant soundings were marked as Golden Soundings for further review. These Golden Soundings were reviewed by a Data Processing Lead in Hypack and exported as a shapefile to be brought into CARIS for further evaluation if needed. Once cleaning and review was complete, sounding data were then exported as HS2x files. The data exported from Hypack and stored in the HS2x files were fully processed (XYZ data in project datums) except for TPU.

Phase 3 processing started with running a Process Model created in CARIS HIPS. The Process Model assigned the HS2x file the correct survey date, imported fully processed singlebeam data to the HIPS file, applied TPU based on HVF values, and georeferenced the data with project specific TPU parameters. This Process Model also filtered out all data shoaler than 1 m upon import (as discussed in the meeting with AHB on 02/12/24). The reason for applying this depth filter is because CARIS does not differentiate between Depth 1 and Depth 2 in the HS2x file and would use Depth 2 soundings when creating the singlebeam surface. Since all Depth 2 soundings were shoaler than 1 m and are not associated with depth readings, the filter was set to ignore all soundings shoaler than 1m, to ensure Depth 2 soundings were not used when creating the Uncertainty surface in CARIS. Additionally, the hydrographer confirmed no Depth 1 readings were incidentally removed (were re-accepted if necessary). Once all HS2x files had been imported to the correct HIPS file in CARIS, an Uncertainty surface was generated, and various child layers assessed. This surface was reviewed to ensure all specifications defined in the PI and HSSD had been met.

As discussed in our meeting with AHB on 02/12/2024 (see project correspondence), there was a desire to use one software to fully process the singlebeam data, apply TPU, and grid the data. However, an adapted workflow was the better solution given the limitations of each software (Hypack/CARIS). Hypack does an excellent job of applying corrections and cleaning the soundings (filters, editors etc), it was also the acquisition software utilized. However, Hypack does not apply TPU values to the singlebeam sounding data nor creates gridding products that mimic a charting workflow. On the other hand, CARIS is great for TPU and gridding products for charting. CARIS does have a singlebeam data editor, however it is inferior to Hypack's singlebeam editor and tools. Additionally, the importation of Hypack .RAW files were shifting soundings and we, as well as CARIS support, were having difficulty with getting HVF offsets determined as well as the echogram functioning correctly, making it impossible to clean and digitize the data as efficiently and accurately as Hypack allowed. Therefore, Geodynamics worked with CARIS support to develop a workflow that essentially used a null tide in CARIS to add TPU to the fully processed singlebeam data (HS2x file) without affecting the X, Y, Z locations of the processed singlebeam data from Hypack. Thus, utilizing an adapted software workflow using the superior aspects of each individual software, Hypack for its singlebeam processing and CARIS for TPU/gridding.

It should be noted that since the Tide Option in CARIS had to be utilized for this adapted methodology, the TPU associated with the SEP model had to be placed in Tide Zoning (0.08m) instead of GPS Sounding Data when georeferencing. This is the listed uncertainty value in the project instructions. See project correspondence for more information on the SEP models for this project.

Additionally, it should also be noted Geodynamics did not use any singlebeam editing tools in CARIS. CARIS was simply used for gridding, surface analysis, and TPU. If singlebeam sounding data were viewed in CARIS, Subset 2D and 3D views were utilized. If a sounding was in question, it was assessed in Hypack using the echogram and if soundings needed to be edited, they were edited in Hypack and an updated HS2x file was then re-brought into CARIS.

An additional component to this project was interpolated grids for the National Water Center (PIs). Those gridding methods are further described in C.1.4.

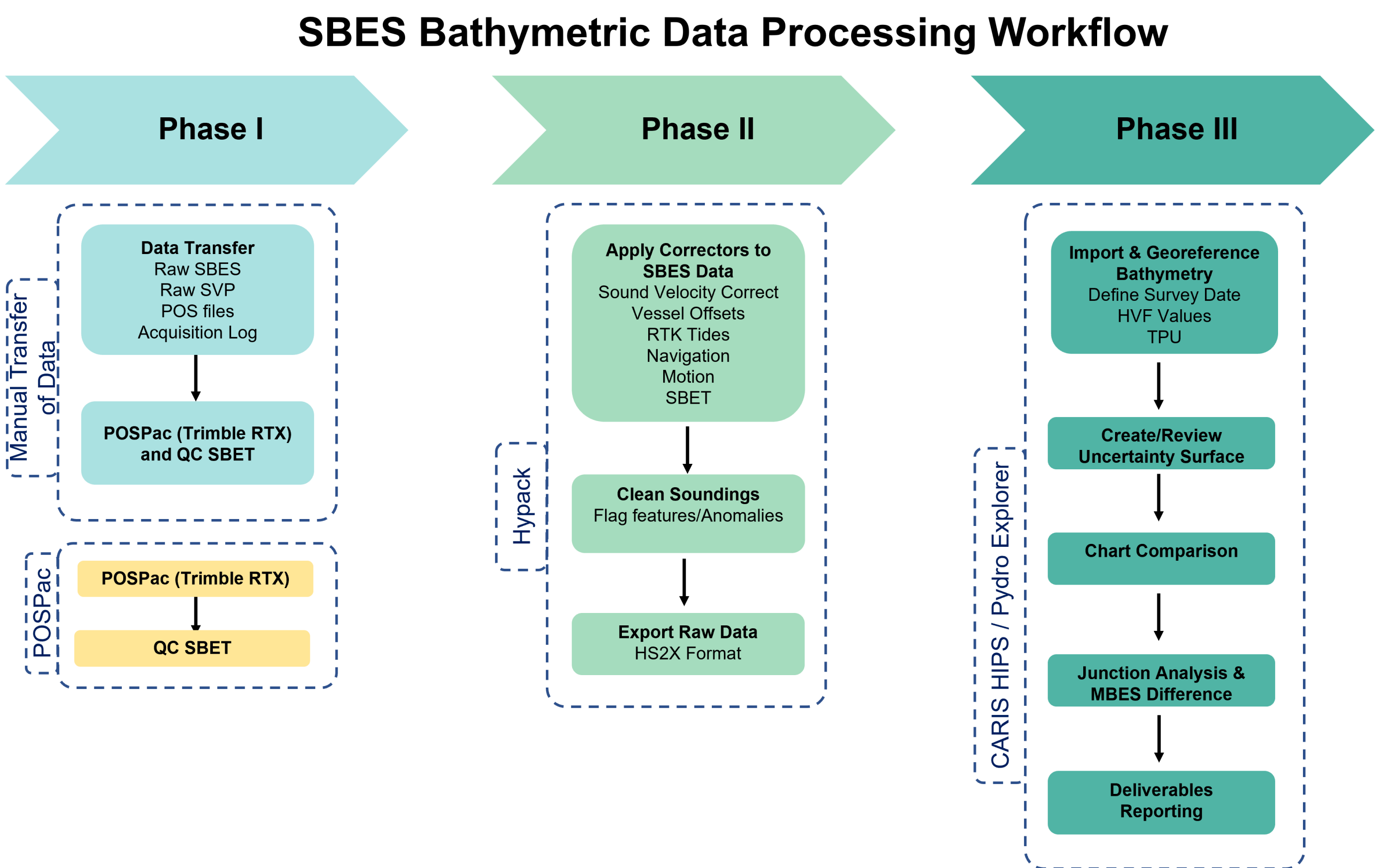

Figure 30: Singlebeam processing workflow

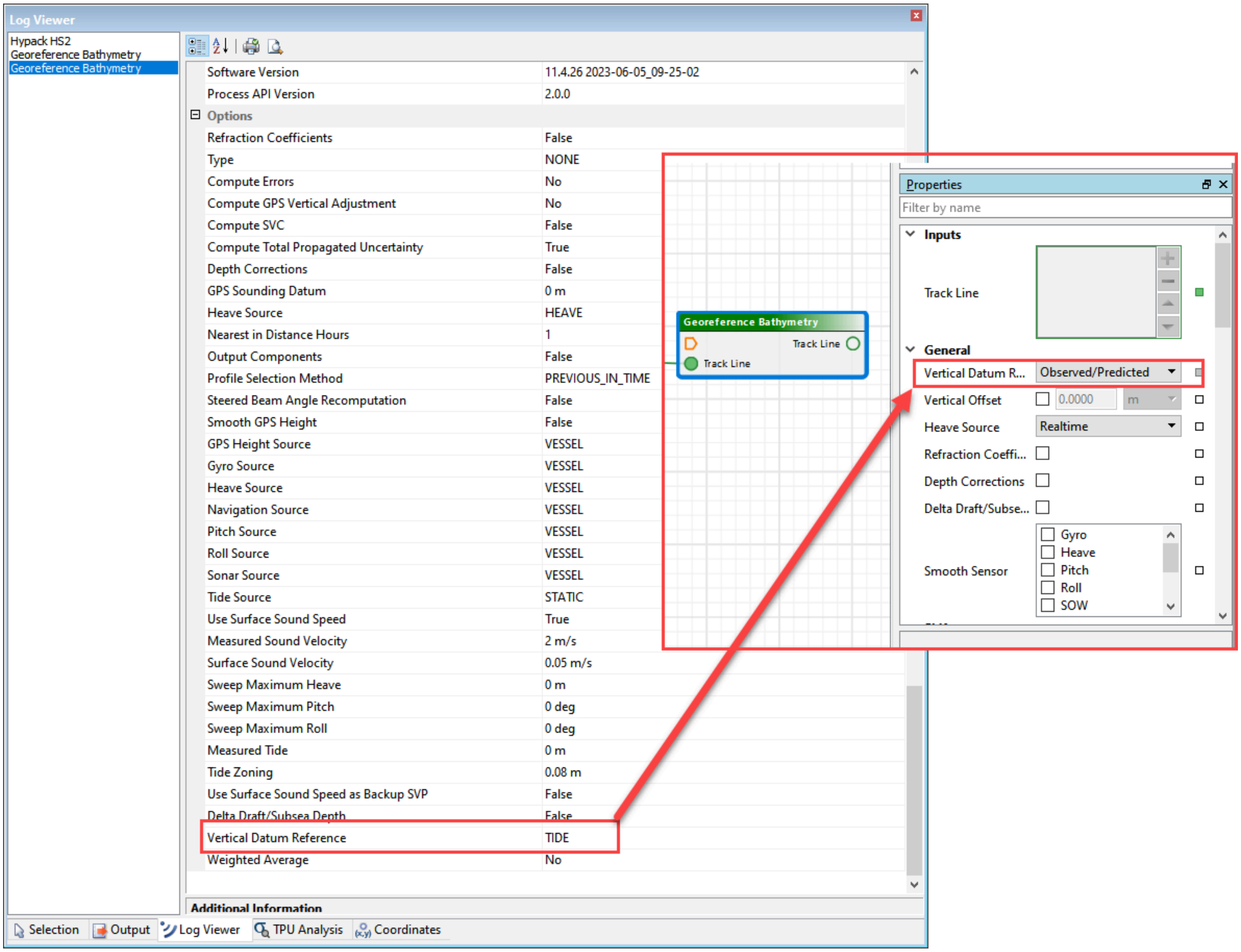

Figure 31: Singlebeam georeference settings in CARIS. Since HS2x files were fully processed in Hypack to the project datum (ERS workflow), tidal options in CARIS were utilized to have a "Null" tide. These settings were developed with CARIS Support to ensure no re-processing of the XYZ sounding data occurred in CARIS.

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

All non-interpolated bathymetric surfaces were computed from fully corrected data in CARIS HIPS. For MBES non-interpolated grids, a CUBE surface was generated with parameters specified in the CUBEParams_NOAA_2023.xml to meet the standards specified in section 5.2.2 of the HSSD. For singlebeam non-interpolated grids, a CARIS Weighted Uncertainty surface was used to generate depth estimates. A CARIS Weighted Uncertainty surface was utilized for singlebeam instead of CUBE because, during testing it proved a more robust gridding model for singlebeam. It depicted a better representation of bottom depths and offered a more streamlined process for cleaning. Generating a CARIS Uncertainty Weighted Grid is in line with the PIs, as well as HSSD 5.2.2.4 Option C. Using this gridding method for singlebeam was communicated with our COR early on during initial testing (see project correspondence). Additionally, utilization of the shoal vs depth child layer for singlebeam surface analysis was discussed with AHB. Refer to project correspondence for more information.

Both CUBE and Uncertainty weighted parent surfaces and depth controlled (critical sounding snapped) finalized surfaces were provided in CSAR format for each survey. The finalization method of using Uncertainty or Standard Deviation for assigning uncertainty to each node in the finalized surface was dependent on survey area / survey systems. For multibeam, the CUBE surfaces were finalized with Uncertainty attributed to each node since the TPU model for multibeam is more robust. Generally, for singlebeam, Uncertainty surfaces were finalized with standard deviation since the singlebeam TPU model is less robust, and values are often more static. Additionally, since the grid is 4m and has fewer soundings than multibeam, it often was a better representation of areas where the grid depicts more complex morphology (steep slopes etc).

For interpolated grids provided to the National Water Center (NWC), the workflow is as follows. The first step is exporting a single XYZ file of the bathymetric parent (non-critical sounding snapped) surface in CARIS. This is exported from the depth layer for the multibeam surface and the Shoal layer for singlebeam surfaces. In sheets that had both SBES and MBES data, the bathymetric surfaces were mosaiced together at a 4m resolution before exporting it as a single XYZ file. It should be noted the exported XYZs did contain crosslines, as they did not hinder the end product (see project correspondence). This XYZ file was then imported into Surfer software, where the Moving Average method was used for data interpolation. As defined by the Surfer software: “Moving Average is a smoothing interpolator that assigns cell values by averaging data within the cell’s search ellipse. This method is most applicable to large or dense data sets. Moving Average extracts intermediate-scale trends and variations from large, noisy data sets, and it is fast even for very large data sets. This gridding method is a reasonable alternative to Nearest Neighbor for generating grids from large, regularly spaced data sets.” The parameters assigned to the grid are as follows: 100m search radius, adjusting minimum and maximum extents to ensure the interpolated grid covers the appropriate area, and adjusting the resolution to 10m. This workflow and gridding parameters were described to NOAA HSD OPS in project correspondence, additionally during the pre-submission meeting with AHB, and also a separate write-up was provided with the required NWC 30-day deliverables detailing these methods, as well as welcoming any feedback (see project correspondence).

The interpolated grid was exported as a .GRD file from Surfer and then imported into ArcPro where it was assessed for quality. In ArcPro, the first step of quality control was to create contours every 25cm. These contours highlighted any immediate errors or artifacts created during the gridding process. The interpolated grid was then subtracted from the parent surface to highlight major differences between the non-interpolated surface and the interpolated surface. The extents of the interpolated surface were then manually edited, at the discretion of the hydrographer, in efforts to maximize coverage while minimizing errors caused by overreaching or extrapolating beyond the data extents. For more information on interpolated grid data extents and clipping, reference the project correspondence. After clipping the interpolated grids based on hydrographer discretion, the grids were exported to the required format (GeoTiff).

For datum conversion methods, please reference Section C.3, as interpolated grids were required to be converted to NAVD88 instead of chart datum. It should also be noted that all deliverable products generated for NWC are detailed heavily in project correspondence and files/formats do not directly reflect the PIs.

C.1.4.2 Depth Derivation

Prior to finalizing surfaces, data were thoroughly and redundantly reviewed for completeness and adherence to specifications in the HSSD. This included manual and automated QA/QC checks to ensure compliance with HSSD standards. Please reference the above data processing sections for each sensor for more details on cleaning methods, depth QA/QC checks, and filters used to ensure adherence, as well as software used to perform these methods (CARIS vs Hypack). Navigation Editor in CARIS was used to clip lines if data were unnecessary or recovered. Additionally, crosslines were clipped to sheet boundaries when crosslines extended through multiple sheets.

For critical sounding selection and feature assessment, processed soundings were reviewed in Subset Editor using both 2D and 3D views. Designation of critical soundings were assessed and designated appropriately in accordance with the HSSD. Finalized surfaces were computed utilizing the “Apply Designated Sounding” function. The method for attributing final uncertainty in the finalized grids is detailed above in section C.1.4.1

C.1.4.3 Surface Computation Algorithm

For multibeam surfaces, the 2023 NOAA CUBE Parameters were used for CUBE surface computation. Multibeam surface generation used the following settings:

Gridding Method: CUBE
Bounding Polygon Type: Buffered
IHO Order: 1a
Disambiguation Method: Density and Local
Cube Configuration: NOAA_1m (with respect to depth range and coverage requirements)

For singlebeam surfaces, the CARIS weighted uncertainty surface generation used the following settings:

Gridding Method: Uncertainty
IHO Order: 1a

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Multibeam backscatter data collected with the Kongsberg EM2040C systems were stored in the .ALL file, which is directly importable into QPS FMGT. Data were acquired at 300 kHz with no major changes to settings. Hydrographers utilized real-time displays of backscatter and saturation to help assess any potential system-wide backscatter issues. Backscatter calibrations were not specifically acquired for this project, although the MBES patch test calibrations are available to process for normalization values.

Data Processing Methods and Procedures

Backscatter files were routinely processed throughout field acquisition for QA purposes with QPS FMGT. The .ALL files were paired with HDCS files from CARIS to create mosaics. Mosaics were then reviewed to assure adequate coverage and quality of the backscatter.

In post-processing following bathymetric edits, a new FMGT project was created for each sheet / vessel / sonar frequency. In this case, only 300 kHz was utilized, so the projects were only split by sheet/vessel. Metadata within the .ALL files ensures that sonar-specific characteristics were captured during mosaic processing. The .ALL files were again paired with HDCS files from CARIS (this time HDCS files with final bathymetric edits), and GSF files were generated.

A mosaic was created for each FMGT project from the paired .ALL and HDCS files. The minimum resolution utilized was 2m for 300 kHz. The mosaic was exported as a floating point GeoTIFF grid with a value for no data set to -9999.

C.2.2 Side Scan Sonar

Data Acquisition Methods and Procedures

R/V Benthos, R/V Chinook, and R/V Substantial deployed the side scan sonar (SSS) towed astern, running through a block and sheave on the aft A-frame. R/V 4-Points towed the SSS from a J-Frame on the starboard side of the vessel. The SSS was operated in dual frequency mode at 540/850 kHz or in single frequency mode at 540 kHz (depending on stage of project). Discover was utilized for operating/control of the SSS and settings, monitoring data quality, and data logging (.JSFs). Hypack was used for vessel navigation, line planning, and outputting a layback corrected position of the SSS to Discover (section B.1.2).

The range scale was adjusted appropriately in acquisition to adhere to altitude requirements, as well as to exclude acquisition of imagery with excessive environmental influence, which would prevent the detecting of an object on the seafloor that measures 1 m x 1 m x 1 m from shadow length measurements.

The towfish altitude was maintained at the standard 8-20% of range scale for depths >8m (PI), 4-20% of the range scale in <8m of depth (PI), and 3-20% in 2-3.5m of water when operating at 25 m range scale in sheets 1-3 (see project correspondence). This further adjustment, as well as the allowance of small, intermittent exceedances of altitude were approved by NOAA HSD OPS based on field observations (see project correspondence). This project required very shallow tows in a very shallow environment (inland sound). Throughout acquisition, altitude was consistently monitored during acquisition to confirm adherence.

The vessel speed was maintained between 2.5 - 3.0 meters per second with a ping rate of 10 Hz, adhering to section 6.1.2.2 of the HSSD. The real-time waterfall display of SSS imagery was closely monitored for contacts and image quality degradation due to environmental influences. Although little can be done to address most refraction issues (very small water column), changes to SSS range scale, vessel speed or altitude of the towfish, can and were adjusted to attempt to restore data quality when degradation was observed.

Daily confidence checks were performed to ensure proper identification and positioning of potential features by marking targets in the acquisition software of visible, distinct features in both the port and starboard beams of the SSS. Confidence checks were recorded in the daily acquisition logs. All identified SSS contacts that met the criteria for contact development and were safe to develop were investigated to complete coverage requirements standards to obtain the least depth determined from multibeam. All attempts were made to develop SSS contacts within the recommended 30° of NADIR, however, because of safety concerns, some contacts may have been developed greater than the 30°of NADIR based on hydrographer discretion. To ensure no major shoals or navigational hazards existed in real-time, the hydrographer monitored for contacts real-time in Discover and relayed to the office any major findings in the field.

Data Processing Methods and Procedures

SSS data processing was accomplished using a combination of Sonarwiz and Global Mapper. ArcPro was used for additional QA/QC.

Immediately following the acquisition day, the .JSF side scan data recorded in Discover was copied to an SSD and transferred to a NAS using a Synology Sync drive. Once all data were synced to the Geodynamics server and files organized in their respective locations, JSFs were imported in Sonarwiz for SSS processing and mosaic creation. The bulk of Sonarwiz processing was completed on local internal SSDs, not the server, due to limitations with the software. SSS processing is broken down further below into phases.

Phase 1 processing: As described in the Layback methods and procedures Section B.1.2, towfish layback corrected positions were calculated in Hypack and recorded directly by the Discover software to the raw .JSF file. Only 540 kHz data were processed in Sonarwiz, using the vessel Course Made Good (CMG) for towfish heading and contact positioning. The Discover software automatically bottom tracked the data, which was manually reviewed and edited by the hydrographer as necessary. Navigation was smoothed by 30 records for each line file using Execute Smoothing Filter to reduce navigation errors. Automatic Time Varying Gain (TVG) was applied to all side scan data. Object detection was conducted line by line in waterfall view, receiving two separate hydrographer reviews, followed by a Sidescan Data Processing Lead (DPL) review. Contacts were uniquely named, and heights were calculated using the Capture Contact Tool, which performs a slant range correction from the measured shadow length. Contacts measuring >0.85m in height or were of anthropogenic interest were marked and reported for further investigation. Data containing environmental influences such as bait balls or thermocline interference which prohibited clear detection of potential seafloor objects were marked with polygons and reported as QC features in SonarWiz.

Phase 2 processing: After examination by the DPL, the QC features and marked contacts were exported from SonarWiz as shapefiles, and then examined in ArcPro where recovery and contact development lines were created. Individual 0.25m resolution .TIFs were created using TVG corrections for each .JSF file, which were imported into Global Mapper, where the .TIFs were layered, and sheetwide mosaic exports were created. A combination of individual 0.25m TIFs for each line were used in ArcPro to create a Raster Mosaic Dataset, which allowed for the quick examination of adequate coverage, and helped further direct the DPLs ability to identify whether 100% complete coverage had been achieved. The Raster Mosaic Dataset in ArcPro allowed the DPLs to quickly adjust layering of the dataset between individual .TIFs (for each line) at a 0.25m resolution and ensure that all sections of the imagery that were affected by poor environmental conditions were sufficiently covered by adjacent SSS or MBES data. If portions of imagery with environmental influences were not adequately covered by other existing data sources, additional recovery lines were created for subsequent acquisition.

Phase 3 processing: Following the completion of all SSS acquisition and data processing, file parity checks were conducted between raw .JSF files, SonarWiz processed CSF files, and exported .TIFs that were to be included in the final mosaic. Shapefile exports of the SSS contacts were imported to a .HOB file, and all fields properly addressed before being exported to the S-57 $CSYMB contact file. Final sheetwide mosaics were exported from the Global Mapper project, which contained the individual .TIFs from Sonarwiz and adjusted layering. The final sheetwide mosaics were then converted to the NOAA required data format in ArcPro (-9999 GeoTIFF). Prior to final data submission, an example SSS mosaic was sent to AHB for data format evaluation (see project correspondence). Final sheetwide mosaics were provided for each sheet. This consisted of two mosaics. A sheetwide mosaic for mainscheme and a second mosaic for disprovals (the second set of lines to get an additional 100% coverage), as required by Section 8.2.1.

It should be noted that special guidance from the NOAA HSD OPS team allowed post-processed swath range trimming of SSS TIFs (individual TIFs per line) to ensure altitude adherence (see project correspondence). This was due to field observations and the very shallow tow required in the project area. The TIFs were trimmed using a SonarWiz tool and “trimmed” tiffs were brought into Global Mapper to be used in the Final Sheetwide Mosaics. Additionally, in the final mosaics, it should be noted that it is not possible to simply re-layer or clip the TIFs to provide a 1m sheetwide mosaic free of environmental influences. There were far too many environmental influences (bait balls, thermoclines etc). Additionally, recoveries often had to be conducted several times and also would contain artifacts of poor environmental conditions but in different geographic locations than the intent of the recovery. These challenging environmental influences were brought to the attention of NOAA HSD OPS early on in the project during field acquisition, as well as in post-processing during the 02/12/24 meeting with AHB pre-submission (see project correspondence). Although the final sheetwide mosaic is not “free” of negative environmental influences, methods were developed to ensure adequate complete coverage and the detection of objects. Please reference Section D.2.1 for more information on SSS .TIF trimming and also methods to ensure complete coverage / detection of 1x1x1m objects amidst abundant negative environmental influences.

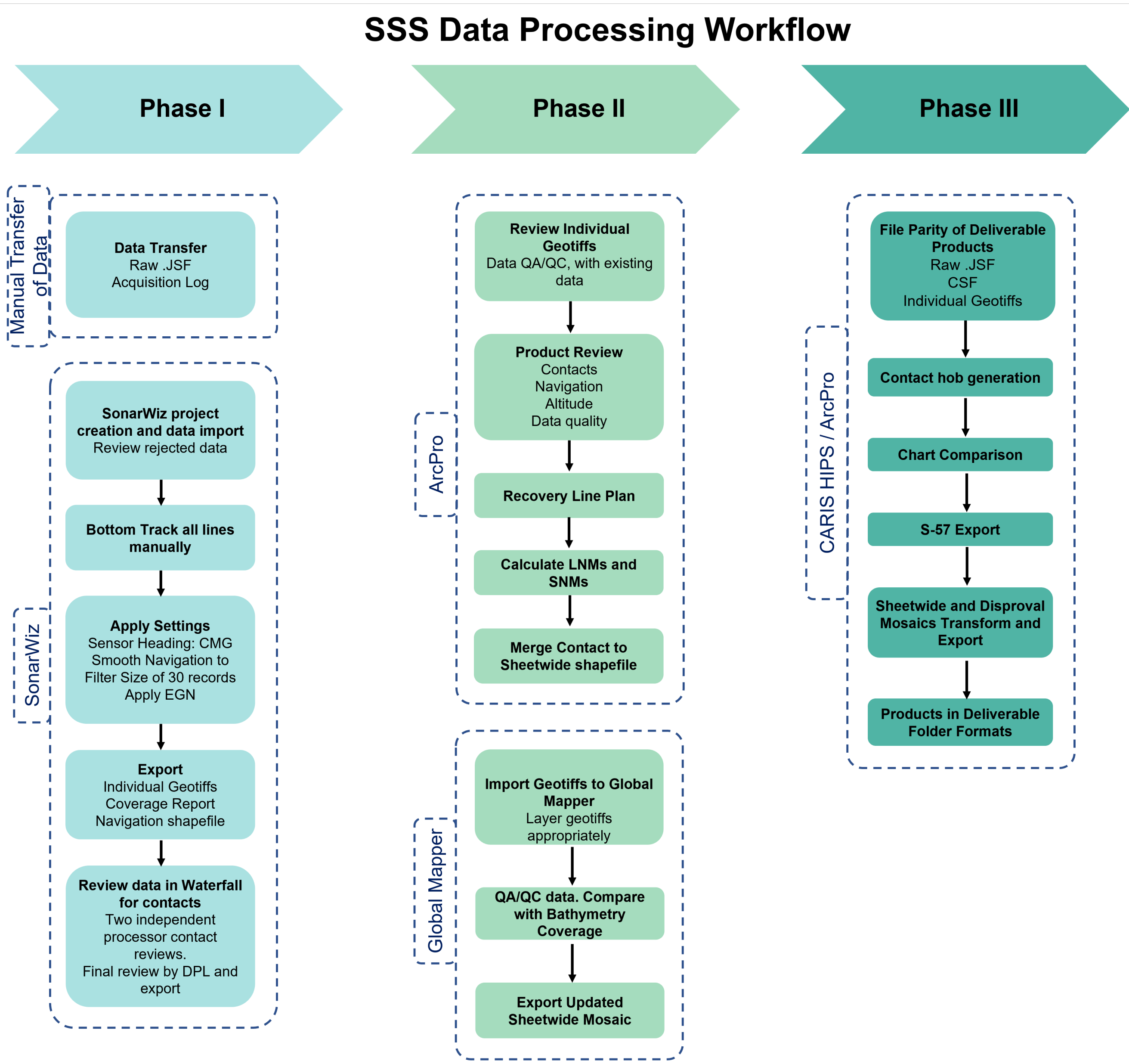

Figure 32: SSS data processing workflow

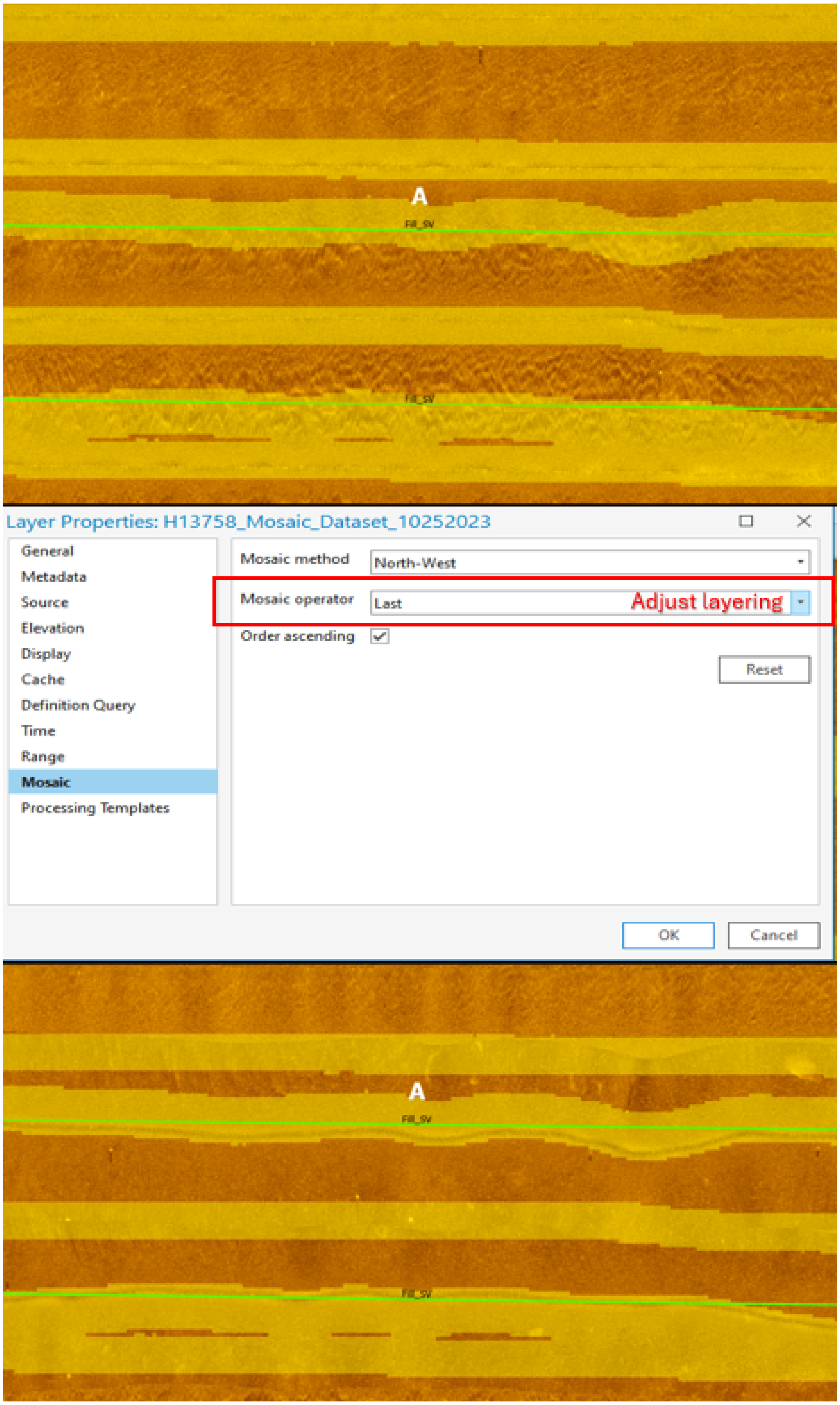

Figure 33: Example of the use of a Raster Mosaic Dataset in ArcPro for SSS Coverage Assessment (ability to quickly re-layer individual SSS .TIFs) Top and bottom are the same spatial extents re-layered using the Raster Mosaic Dataset function highlighted in the red box.

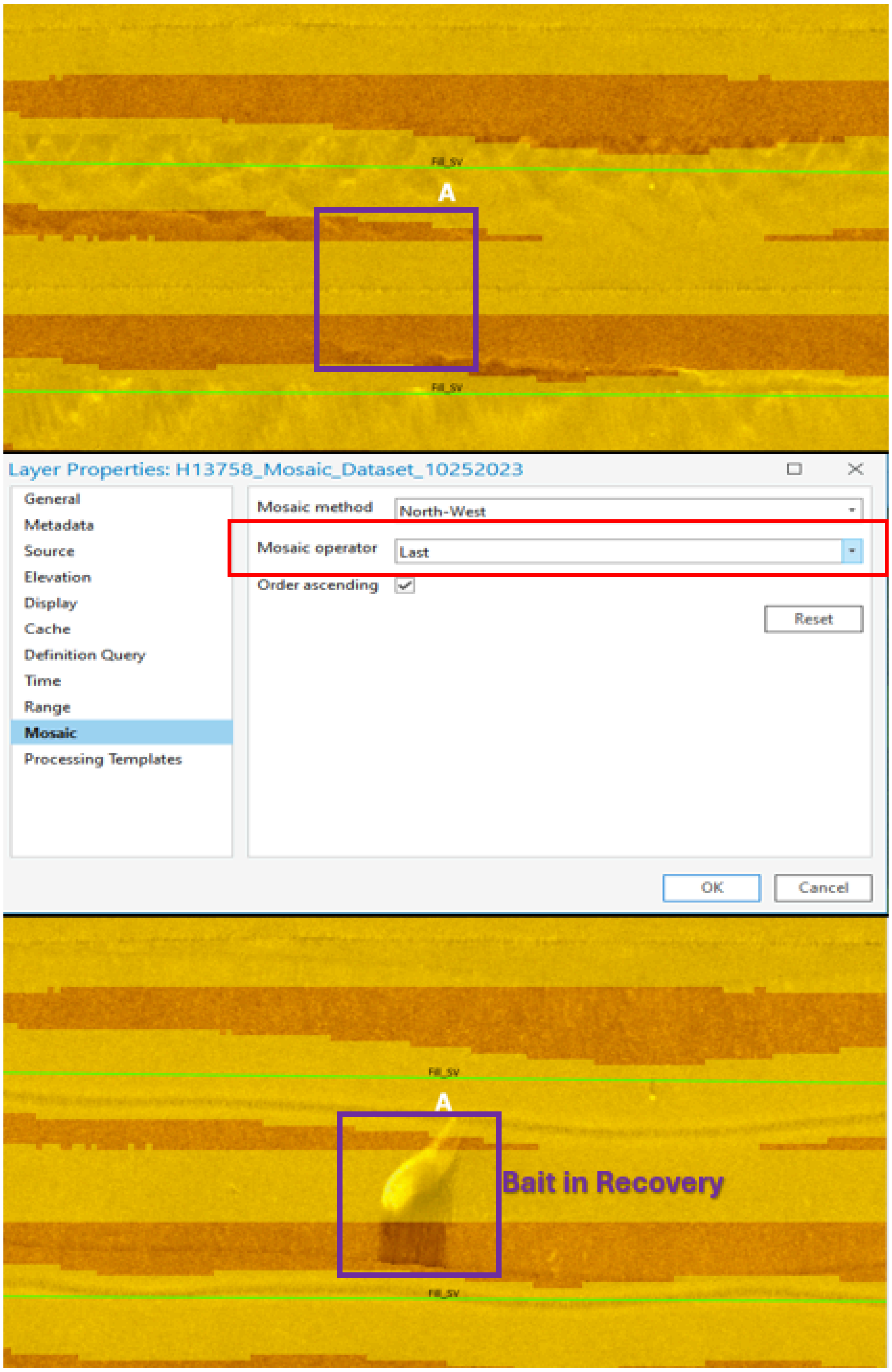

Figure 34: Example where sound velocity (thermocline) negatively affected mainscheme SSS imagery. Recoveries were successful; however, a bait ball was imaged in the recovery line in an area where previous, adequate full coverage mainscheme existed.

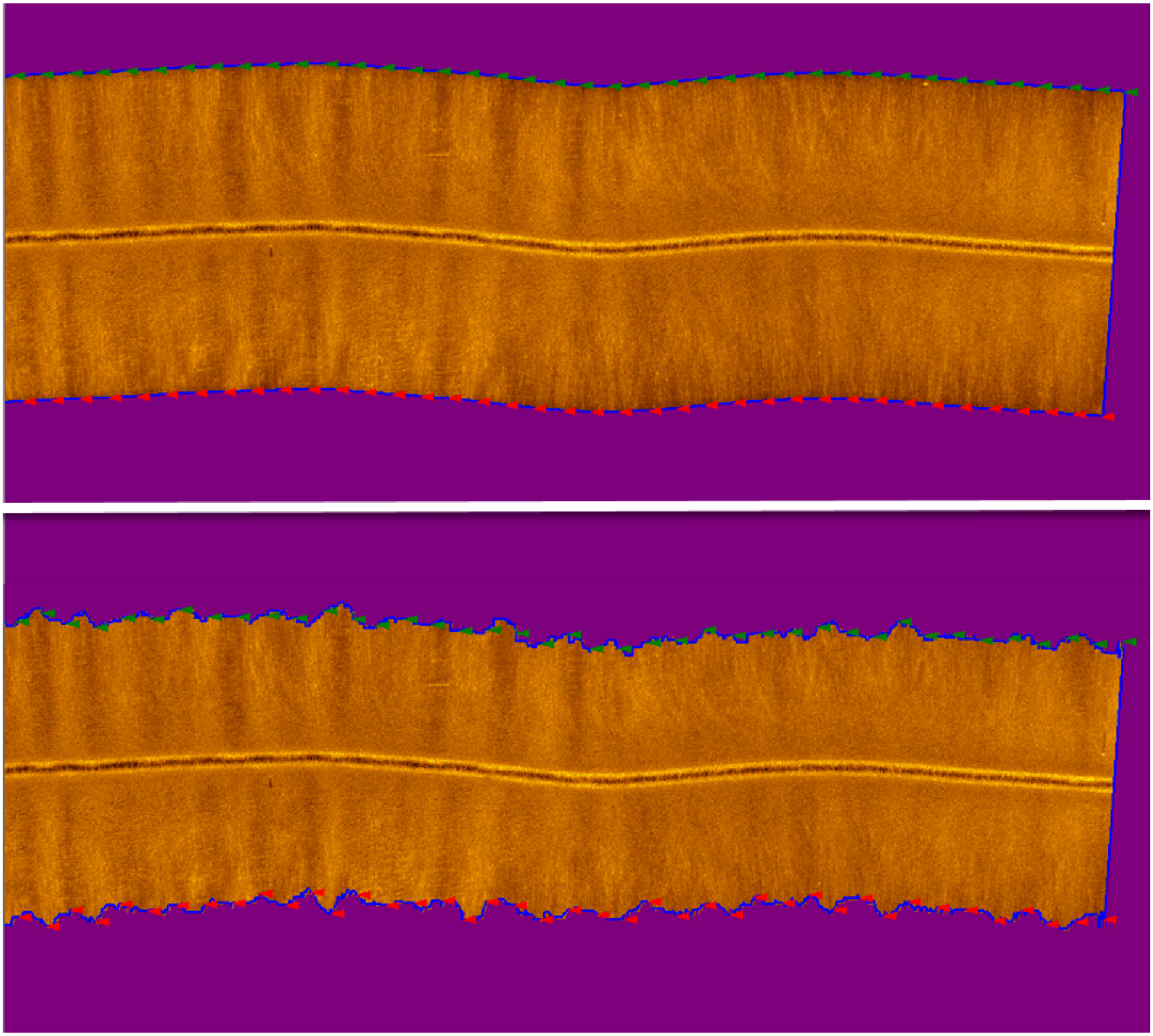

Figure 35: Example of SSS .TIF Trimming (in post-processing) to ensure altitude compliance. The top image is an untrimmed .TIF and the bottom image is the same .TIF trimmed based on a range (distance) to meet minimum altitude requirements. As you can see, the range (distance) retained in the SSS image varies based on altitude.

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

GNSS base station data was not acquired.

C.3.1.2 DGPS Data

DGPS data was not acquired.

C.3.1.3 Other Horizontal Control Equipment

Data Acquisition Methods and Procedures

Geodynamics survey vessels received G2+ corrections from the Fugro Marinestar SBAS network while XOcean vessels received G4+ corrections. The corrections went directly through the Applanix POS MV to provide real-time corrections to positioning. The Marinestar G2+ and G4+ service provides corrections for GPS and GLONASS from a network of base stations around the world via geo-stationary satellites. Solution status was continuously monitored through the POSView controller software for dropouts or degraded accuracy. It should be noted Marinestar corrections are in the ITRF14 ellipse, therefore, data were transformed to the desired ellipse real-time in Hypack and/or using post-processing techniques (e.g POSPac).

Data Processing Methods and Procedures

For all hydrographic survey activities, POSPac data were collected through the POSView controller via Ethernet Logging and/or USB Logging. All position data were post-processed in POSPac MMS software using Trimble Centerpoint RTX solutions. The workflow for MBES and SBES slightly differ because of the processing software used (CARIS vs Hypack).

For all MBES data, the SBET was exported from POSPAC MMS software in NAD83 (2011) coordinate system and was applied in CARIS. Applying the SBET overwrites all position data and improves upon the real-time Marinestar G2+ accuracies while minimizing Total Horizontal Uncertainty (THU). The application of the SBET in CARIS also transformed the data to the required horizontal datum (NAD83 2011) instead of the real-time ellipse (SIS is used for MBES data logging not Hypack).

For all SBES data, the SBET was exported from POSPAC MMS software in ITRF14 coordinate system and applied in Hypack. Hypack Geodetics account for the transformation from the ITRF14 ellipse to NAD83 (2011), which is the main difference in workflows between MBES and SBES. Applying the SBET in Hypack overwrites all position data and improves upon the real-time Marinestar G2+/G4+ accuracies.

For all processed positions and data products (other than S-57 Final Feature File), the horizontal datum is North American Datum of 1983 (NAD83) (2011) Universal Transverse Mercator (UTM) Zone 18N, as required by the HSSD.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

All surveys utilized an ERS workflow to reduce ellipsoid derived depths to chart datum (Low Water Datum).

Geodynamics survey vessels received G2+ corrections from the Fugro Marinestar SBAS network while XOcean vessels received G4+ corrections. The corrections went directly through the Applanix POS MV to provide real-time corrections to ellipsoid heights. Solution status was continuously monitored through the POSView controller software for dropouts or degraded accuracy.

As dictated in the PI, water levels were determined from ellipsoid measurements throughout this ERS and soundings were reduced to Low Water Datum (LWD) real-time in Hypack.

Data Processing Methods and Procedures

NOAA's HSD OPS provided VDatum SEP model packages. The originally provided SEPs included: the ITRF-LWD, NAD83-LWD, and NAD83-NAVD88. On April 26th 2023, an updated SEP model package with extended SEP model coverage was provided, as there was missing SEP coverage in H13755 and H13761 in the original provided files (see project correspondence). Additionally, given the unique aspects of this project (custom SEPs for this region, NWC products in NAVD88, extended SEPs), please reference project correspondence for all provided SEP and associated .log file information.

All ellipsoid data were post-processed using the Applanix POSPac MMS software. Post-processed corrections were implemented with Trimble's CenterPoint RTX service.

For all MBES data, the SBET was applied in CARIS to overwrite all position data, improve upon the real-time Marinestar G2+ accuracies to minimize Total Vertical Uncertainty (TVU), and transform the data to the desired vertical datum (NAD83 2011) before SEP model application. The NAD83 to LWD SEP model was then utilized in CARIS HIPS to reduce the sonar data to LWD.

For all SBES data, the SBET was applied in Hypack to overwrite all position data and improve upon the real-time Marinestar G2+ accuracies. Because Hypack does account for the horizontal transformation between ITRF14 and NAD83 (2011) and the way Hypack Geodetics are setup (split horizontal and vertical), the SBET created for singlebeam data was retained in the ITRF14 coordinate system and the ITRF-LWD SEP model was applied in Hypack, reducing the sonar data to LWD.

For NWC products (interpolated grids and additional source parent grids), charting products in LWD were further translated to NAVD88 using the LWD to NAVD88 SEP model provided. This transformation was done in ArcPro using a raster transformation method, where the bathymetric surface in LWD and the SEP model (as a raster) were differenced to each other, resulting in the desired vertical datum. The transformation from LWD to NAVD88 resulted in an average difference of about ~21 cm, where the NAVD88 surface was deeper than the parent LWD surface. All NWC products have _NAVD88 in their filenames.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Vessel position, attitude, and trajectory data were acquired and logged with an Applanix POS MV v5 OceanMaster and POS MV WaveMaster II. All vessels had the offsets precisely measured and entered into the POSView controller software appropriately prior to data acquisition. Methodology for vessel offsets and layback are described in section B.1.1 and vessel offset diagrams are provided in DAPR Appendix III.

Prior to the start of surveys, GAMS calibrations were performed to align the Secondary GNSS antenna with the Primary GNSS antenna and IMU alignment with respect to the vessel reference frame (see DAPR Appendix IV). For the duration of the project, all survey vessels maintained subscriptions with Fugro's Marinestar Global Correction System and received G2+/G4+ corrections. Position, attitude, and trajectory data were logged via Ethernet Logging and/or USB Logging whenever survey activities occurred. This included five minutes before and after acquisition for adequate post-processing of kalman filtered data.

Data Processing Methods and Procedures

All position and attitude data were post-processed using Applanix POSPac MMS software and Trimble CenterPoint RTX corrections to produce an SBET file with centimeter level positioning accuracy. Post-processed solutions were reviewed for position and elevation RMS accuracies and altitude consistencies prior to exporting the SBET.

For all MBES data, SBET position data were applied to the sounding data in CARIS and further reviewed for error or inconsistencies in the post-processed data. All integrated SBETs for MBES data were accompanied with a SMRMSG file for post-processed position error contributions to TPU estimates.

For all SBES data, SBET position data were applied to the sounding data in Hypack. Once applied, the post-processed data were reviewed for errors or inconsistencies in Hypack's Single Beam Editor (64 Bit) software. No SMRMSG files were applied to SBES data due to limitations in the singlebeam processing workflow. However, SBETs were thoroughly QC'ed in POSPac for RMS accuracies.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

All sound speed instruments for R/V Benthos, R/V Chinook, R/V 4-Points and R/V Substantial, were AML Oceanographic Xchange sensors and were calibrated within one year of survey operations. Calibration certificates for these sensors can be viewed in DAPR Appendix II.

On the R/V Benthos and the R/V Chinook, sound speed profiles were collected using BaseX2 profiling instruments equipped with pressure and time-of-flight sound speed sensors. R/V 4-Points sound speed profiles were collected using an AML-3 LGR profiling instrument equipped with pressure and time-of-flight sound speed sensors. For MBES, casts were routinely conducted approximately every two hours or less, and no greater than four hours. For SBES, casts were taken less frequently, dictated by water properties and the HSSD requirements pertaining to SBES. Profilers were deployed and recovered by hand. Once retrieved, profile data were automatically sent to SeaCast via WLAN connection on the R/V Benthos and R/V Chinook. On the R/V 4-Points, the AML-3 LGR would automatically connect to a dedicated WLAN for a wireless download into Sailfish software once retrieved. SeaCast and Sailfish were setup to calculate sound velocity, use UTC time, record in meters, split the up/down cast, and delete out of range or invalid points. Casts were reviewed and the down casts were then exported as .VELs and were stored for SBES processing (if collecting singlebeam). For MBES acquisition, the .VEL files were imported into the SSM database, attributed a position from a SSM/SIS communication link, and then transmitted to SIS as an extended .ASVP file. All vessels' daily casts were exported as an .SVP file from SSM.

The R/V Substantial was equipped with an AML MVP mounted on the stern. The MVP integrated position and real-time depth via serial data communication from Hypack. The free fall fish was deployed approximately every 30 - 120 minutes, depending on location, bathymetry, and water properties (no greater than four hours). The free fall fish was equipped with pressure, temperature, and time-of-flight sound speed Xchange sensors. The system recorded samples on deployment at 1 Hz and was programmed to automatically retrieve when it was a set distance from the seafloor. Casts were transferred via TCP connection to the acquisition station for QC and application to sonar data. The casts were then imported into the SSM database and transmitted to SIS as an extended .ASVP file. While the MVP was the main method for collecting sound speed on the R/V Substantial, an AML MinosX profiler was also used on this project (see Section A.6.3.2). This workflow was identical to the one described above for the R/V Benthos and R/V Chinook. R/V Substantial’s daily casts were exported as an .SVP file from SSM for MBES post-processing.

XOcean vessels X-15 and X-19 utilized Valeport Swift SVP sensors, which were calibrated within 2 years of survey operations (as recommended by the manufacturer). The SVP sensors were automatically deployed and recovered from a stern tube when prompted by the remote pilot. Profiler deployment on the USVs followed all temporal and spatial requirements outlined in the HSSD for singlebeam acquisition.

Data Processing Methods and Procedures

Sound speed profiles collected during acquisition were thoroughly reviewed for date, time, location, depth of cast, and erroneous data.

When casts were acquired for MBES data, sound speed profiles were stored in each vessel's Raw and Processed SVP folders and also a concatenated master cast file, which stored all SVPs collected within a particular survey area (multi-vessel). In CARIS HIPS, sound speed profiles contained in the master concatenated SVP file were applied using the "Nearest in Distance within Time" within 4 hours.

Sound speed profiles collected for SBES data were saved as a .VEL in each vessel's Raw SVP folder and as a .SVP in each vessel's Processed SVP folder. Sound speed profiles for SBES data were not concatenated. .VEL files were applied to SBES data during post-processing in Hypack. The application of sound speed correctors were in accordance with specifications described in HSSD Section 5.2.2.3 (Sound Speed Corrections for Singlebeam Surveys).

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

For real-time MBES beam forming and sound speed depiction of the upper water column, vessels used a MicroX sound speed instrument mounted at the sonar heads. The MicroX transmitted sound speed data (m/s) through a serial RS232 connection at 1 Hz. The systems received the surface sound speed data on the operator station through SIS.

Data Processing Methods and Procedures

In SIS, an alarm was set to warn the hydrographer when real-time surface sound speed and the most recent profile differed by more than 2m/s.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Total Propagated Uncertainty (TPU) was calculated to provide an assessment of quality for the position and depth of individual soundings. Many aspects of the TPU model are based on manufacturer RMS values, while others can be more accurately modeled and minimized throughout the mobilization, acquisition, and processing phases.

The HVF contains all of the 1-sigma RMS values for the survey equipment used throughout the project for each vessel. Values for the position and attitude uncertainties are provided by Applanix and prescribed based on our correction service, while uncertainty values with respect to sonars and frequencies are built-in to the HIPS device library or the raw files themselves (e.g .ALLs).

To more accurately model position uncertainties for MBES data, inputs for position/navigation and GPS height were overwritten with 1-sigma RMS values stored in the SMRMSG file associated with each SBET file. Additionally, upon the application of delayed heave, 1-sigma RMS values for delayed heave were applied when the .000 file is applied in CARIS. This was true only for the multibeam workflow since no SMRMSG or delayed heave RMS file is applied to singlebeam data because of limitations with the singlebeam workflow. Therefore, singlebeam uncertainties relied more heavily on HVF inputs. Other values stored within the HVF include lever arm distances, measurement error, and patch test uncertainties. Potential uncertainties with lever arms were minimized by performing highly accurate static vessel surveys. Uncertainties for the alignment of sensors were minimized by integrating SBET solutions to more accurately determine biases from the MBES patch tests. MBES Patch tests were evaluated by multiple hydrographers. Motion Reference Unit (MRU) alignment for gyro and roll/pitch biases were issued a standard deviation, which was placed in the HVF accordingly.

During acquisition, careful consideration was made to minimize artifacts and their contribution to uncertainty. Hydrographers made considerable efforts to reduce the impact of sound speed issues during acquisition. These efforts often included increasing the frequency of casts. For MBES, hydrographers closely monitor real-time swath “smiling” or “frowning”, utilized alerts for surface-to-profile sound speed deviation, observed the real-time grid for sound speed errors, and utilized SSM displays.

TPU calculations were performed using the CARIS Compute TPU process. The Compute TPU process utilizes the a-priori uncertainty estimates from the HVF, as well as the ability to incorporate real-time uncertainties. The Compute TPU function used real-time uncertainty from the SMRMSG data and delayed heave RMS for MBES (as mentioned earlier), a-priori uncertainties from the HVF, information from the CARIS sonar device library or the raw files themselves (.ALL files), and static values set for water level (SEP Model) and sound speed uncertainty to calculate the estimated horizontal and vertical TPU for each sounding.

The uncertainty of the SEP models used to reduce soundings from NAD83 (2011)-LWD and ITRF-LWD were provided in the PI (0.08m at 2 sigma). See project correspondence for more information. This value was utilized in the Compute TPU process in CARIS. For singlebeam, this value was entered into “Tide Zoning” and for multibeam in the "GPS Sounding Datum". The difference in placing the value in “Tide Zoning” for singlebeam and “GPS Sounding Datum” for multibeam is based on each sensor’s specific workflow. Singlebeam processing had a unique workflow further described in Section C.1.2 (ERS but HS2x files had to be brought in with a “null” tide). Uncertainty input to “Sound Speed - Measured” was derived from the field tolerance of 2 m/s deviance between surface and profile sound speed and the temporal distribution of casts. The "Sound Speed - Surface" value of 0.05 m/s reflects manufacturer accuracy at 2-sigma.

It should be noted that in the A Priori Uncertainty table below the values for Navigation Position for R/V Benthos, R/V Chinook, and R/V 4-Points are representative of the singlebeam HVFs not MBES HVFs. This is because real-time uncertainties are used in place of that value for MBES processing (application of SMRMSG). The position value in singlebeam HVFs is based off Applanix listed values for RTX (SBETs were applied to all SBES data), while the value in the MBES HVF is based off Marinestar accuracies (only would be utilized if no real-time uncertainty was applied from SMRSMG). Uncertainty models for both sensors were heavily tested to ensure proper application of uncertainty values per each sensor's respective workflow.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		R/V Benthos	R/V Chinook	R/V 4-Points	R/V Substantial	X-15	X-19
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.03 degrees	0.03 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees	0.02 degrees	0.02 degrees
	Pitch	0.01 degrees	0.01 degrees	0.01 degrees	0.01 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		0.03 meters	0.03 meters	0.03 meters	0.08 meters	0.03 meters	0.03 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
R/V Benthos, R/V Chinook, R/V 4-Points, R/V Substantial	Real-time uncertainty values are incorporated during post-processing for MBES data. This includes real-time uncertainties from the SMRMSG file for GPS Height RMS and Position Navigation RMS, as well as Delayed Heave RMS from the .000 file.

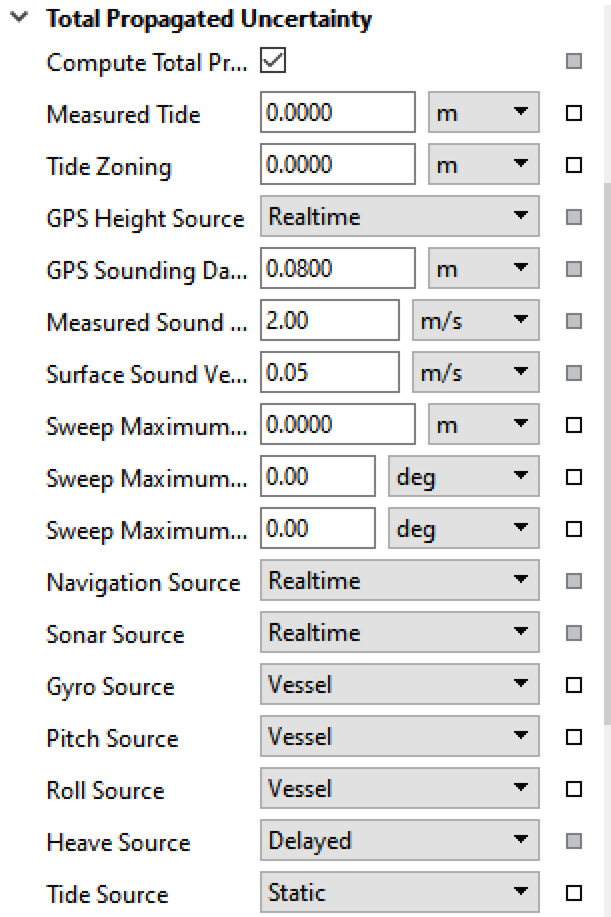

Figure 36: Uncertainty estimates parameters in the CARIS HIPS TPU Dialog within the georeference bathymetry process (multibeam settings)

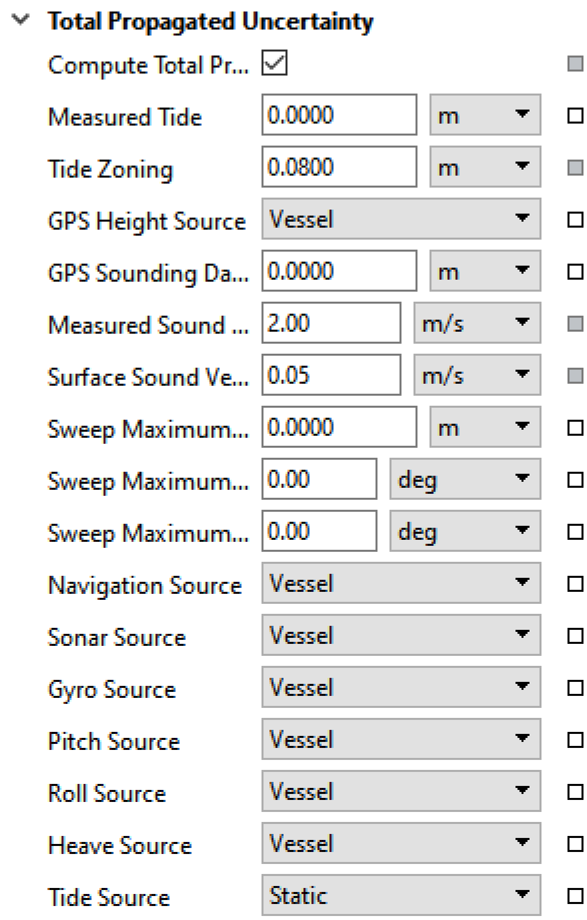

Figure 37: Uncertainty estimates parameters in the CARIS HIPS TPU Dialog within the georeference bathymetry process (singlebeam settings)

C.7 Shoreline and Feature Data

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

No shoreline investigations or shoreline data collection were required for OPR-F330-KR-22.

Assigned features were investigated based on requirements found in the CSF, HSSD, and guidance from NOAA HSD OPS team. For assigned features and disprovals, please reference project correspondence as this was a topic heavily discussed with NOAA HSD OPS and AHB throughout this project. Disproval's for assigned features in complete coverage areas (SSS/SBES & SSS/MBES) were completed using 200% side scan coverage techniques. Because of the numerous negative environmental influences in this project, SSS disproval's often had to be run several times / re-recoveries on certain sections of lines to ensure 200% coverage. Techniques to ensure adequate coverage are similar to those techniques described in Section D.2.1. Assigned features that are located within singlebeam set line spacing areas were investigated based on hydrographer discretion with safety heavily in mind (in 2-3.5m of water, see project correspondence).

The best attempts were made to provide updates on assigned features in set line spacing areas and visually confirm if the feature was above water. Disproval radii were based on the chart rescheme, not the existing chart scale (see project correspondence), and if disproval radii protruded into set line spacing coverage or were near the depth derivation (3.5m), hydrographer discretion was used to whether a disproval would be conducted. This decision was based on safety and navigational significance (see project correspondence).

New features identified were investigated and developed in accordance with the HSSD and guidance from NOAA HSD OPS. When possible, MBES coverage was acquired to develop these new features to adequately determine the least depth of new features. Some SSS contacts and identified features were unsafe for MBES development and are addressed appropriately in the FFF. Safety was a huge driving factor for MBES feature development as this project was in very shallow water (see project correspondence).

Above water features that were not developed with multibeam bathymetry were documented through an internally developed and customized ArcGIS Survey 123 mobile data collection application. The application reduced errors, streamlined the workflow, and quality-controlled feature development from collection to delivery in the FFF. Hydrographers recorded feature attributes through a series of guided questions using predefined selections that eliminated erroneous descriptions and guaranteed completeness and accuracy required to attribute the FFF. GPS-tagged photos for each feature were acquired and associated with the corresponding feature when stored in the SIMS ArcGIS Online Processing Manager Application (PMA), where the Lead Hydrographer and Data Processing Manager reviewed each feature in near real-time. This tool was extremely critical given the abundance of new features encountered throughout this project and management of those features in the field and post-processing.

Additional new feature guidance was required because of the abundance of new features encountered throughout this project and safety/efficiency concerns from field observations. Large submerged/partially submerged stump fields were abundant in the survey area, as well as clusters of what appear to be fish stakes. It should be noted fish stakes were treated as new features given the difficulty in identification, shallow nature of this survey, and unknown temporal nature (see project correspondence). Stump fields and fish stake areas were particularly dense in the west. With safety in mind, NOAA HSD OPS and Geodynamics worked collaboratively to develop guidance on how to address these features safely and efficiently. Some of this guidance included using the charting re-scheme to address discrete point features as areas and improve efficiencies in the field as well as in reporting. The guidance was as follows: if discrete features were located within 8mm at the largest re-scheme scale chart, then the most significant feature within the 8 mm radius should be investigated (if safe to do so). The re-scheme chart scale is 1:10,000 (80m radius). Using this guidance, 80m radii were employed on the numerous SSS contacts for a single area (for example a stump field) and permitted the investigation of only the largest/shoalest contact/feature per an area. This replaced the need to develop each individual contact or feature in these situations (often 100's of contact per area feature). ArcPro buffer/intersect tool was used to establish 80m radii and buffer into each other to determine areas. Occasionally the largest contact/feature per established area was unsafe to develop. These were treated as foul areas. Please reference project correspondence for more information.

Lastly, it should be noted ArcPro was a critical tool to keep up with feature and contact investigations. This included layers for above water features identified in the field by Survey123 (with geotagged images), as mentioned earlier. Additionally, shapefiles for contacts, assigned features, and lines for contact/feature investigation were hosted in ArcPro projects. Because this was a multi-sensor effort with various processing software, ArcPro projects offered a great solution to manage field decisions and recovery plans, bringing various file types into a single platform.

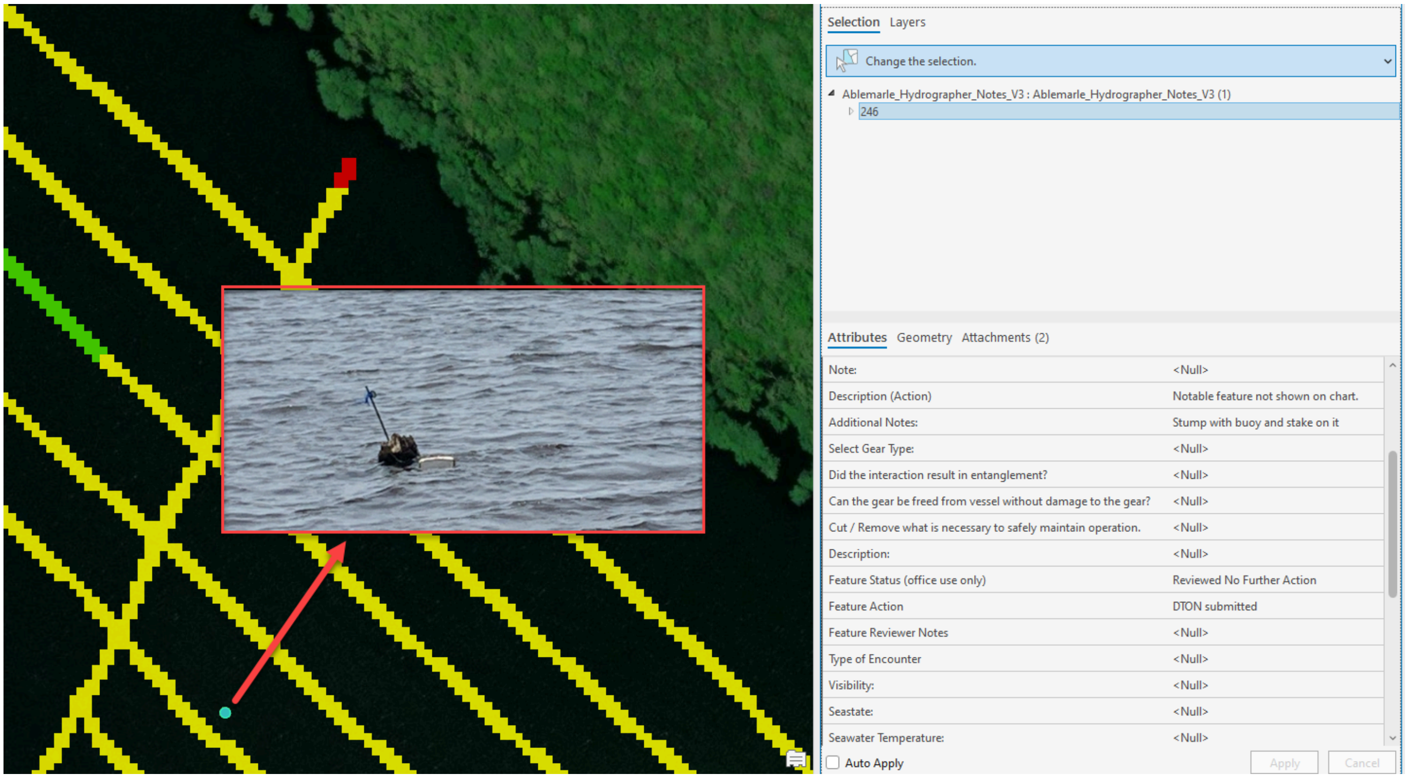

Figure 38: Example of the use of Survey 123 layers in ArcPro for Above Water Features

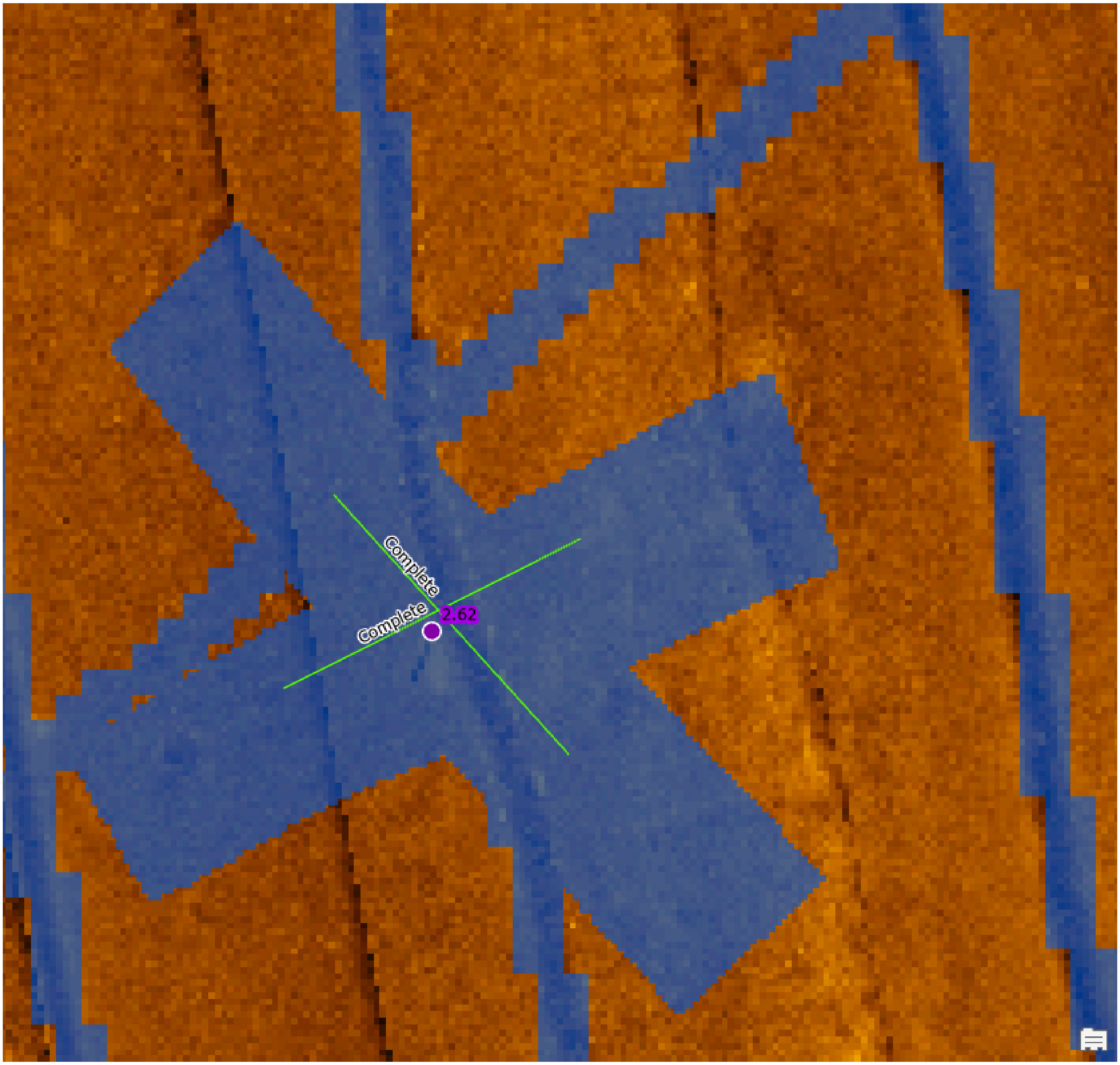

Figure 39: Example of feature investigations in ArcPro. Lines were marked to "complete" following successful multibeam development. It should be noted the SSS contact is in purple and height labeled. Contact heights were heavily considered when drawing recovery lines (safety) in this shallow environment.

Data Processing Methods and Procedures

Feature data processing consisted of addressing all assigned features in the Composite Source File (CSF) provided with the PI package and adding all new features to a single .000 S-57 file for each survey.
All multibeam data were reviewed for features, and least depths over navigationally and/or potentially

significant features were flagged as “designated soundings” in CARIS. All SSS data were reviewed for contact development. Development of each feature was completed in accordance with the HSSD including S-57 attribution and hydrographer remarks/recommendations. Each feature included in the FFF was assigned a unique identifier, attributed in the Unique ID field of the FFF. Associated images in the FFF utilized the unique identifier as a filename, followed by letters if there were more than one associated image. Attribution and Unique IDs from DTON submission were retained for organizational purposes as this project was DTON heavy. All features were delivered in LWD as specified by the project instructions.

If MBES on features or SSS contacts were unsafe to obtain and least depths not determined, these features were attributed appropriately in the FFF and/or SSS contact file as needed and documented in the accompany DRs. Above water feature attribution was discussed with NOAA HSD OPS and a scheme for addressing these features was approved by the NOAA OPS PM. Given the nature of this project, equipment agreed upon, unique datum, and keeping safety in mind, height / water level / technique of sounding was not required for above water features (see project correspondence).

As mentioned in the acquisition sections, a significant number of discrete features and contacts (stump fields, fish stakes) were within the project area. These often were detected by SSS and deemed unsafe to develop with MBES. These areas of dense stumps/fish stakes, co-located within 8.0mm at the rescheme chart scale of 1:10,000 (80m), were approved to be submitted in the SSS contact file as single features instead of numerous individual contacts. Similarly, in the FFF, these features were treated as a single area polygon using the 8mm rescheme guidance and utilizing buffer intersect tools. Often these areas’ largest contact/feature was unsafe to develop and therefore are attributed as obstruction foul area with no Valsou. Reference project correspondence for more details.

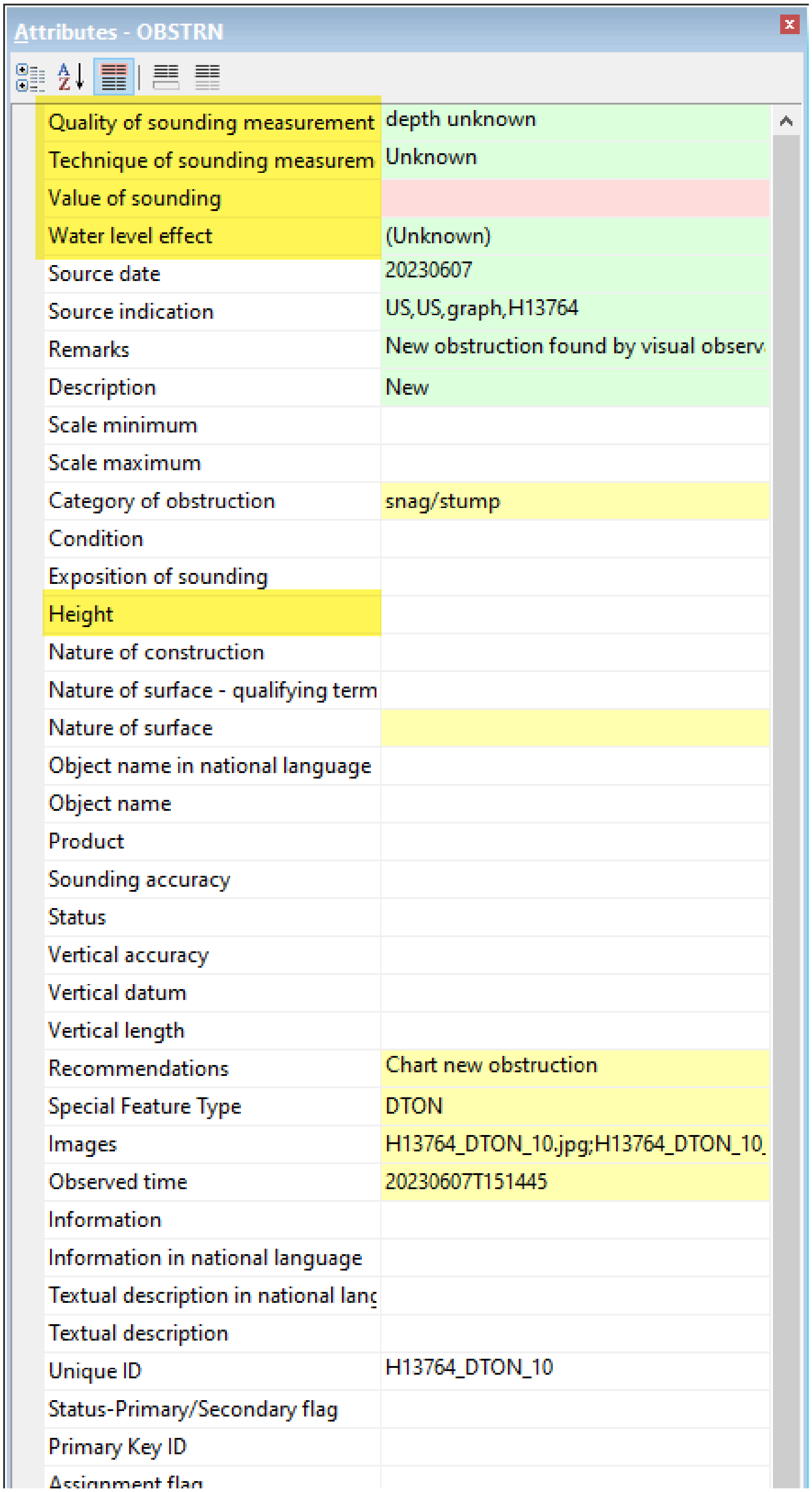

Figure 40: NOAA HSD OPS Approved Attribution for Above Water Features

C.8 Bottom Sample Data

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

Predetermined bottom sample locations within each sheet were provided in the Project Reference File (PRF) prior to the start of field work. Each sample was collected successfully aboard R/V Benthos and R/V Chinook using a Wildco petite ponar grab sampler. To reduce error, streamline the workflow, and QC the bottom samples from collection to delivery in the FFF, Geodynamics utilized another ArcGIS Survey 123 mobile data collection application. The application's schema was designed to facilitate collection and storage of well-organized and accurate field notes. Hydrographers recorded sample locations as well as name and NATSUR / NATQUA attributes through a series of guided questions using predefined selections that eliminated erroneous descriptions and guaranteed completeness and accuracy as per the HSSD. GPS tagged photos for each sample were acquired and associated with the corresponding sample when stored in the PMA, where the Lead Hydrographer and Data Processing Manager reviewed each sample in near real-time.

Figure 41: ArcPro and the utilization of Survey 123 for Bottom Samples

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

Bottom sample data and GPS-tagged photos stored in the PMA were transferred to a CARIS .hob file for processing and QA. All bottom samples can be found in the FFF.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Direct editing of MBES soundings were performed in CARIS to clean spurious and erroneous data that adversely affected the final surface and depth determination of features. In addition to visual assessment and cleaning from the bathymetric surface, many derivative layers computed from the bathymetric surface and sounding data were used to guide data cleaning, assess quality, and illustrate adherence to the HSSD. Node standard deviation, standard deviation, uncertainty, hypothesis count, and hypothesis strength were surface layers commonly used in data cleaning and quality assessments. In addition to a visual inspection, all CUBE surfaces were analyzed using HydrOffice QC Tools Flier Finder tool to assure data does not contain fliers (anomalous data as defined by QC Tools flier finding algorithms #2-5). The tool was run with the standard presets and results were used to guide data editing, as well as manually adjusting the forced height.

For SBES data, the Uncertainty surface was reviewed manually in CARIS. In addition to a thorough visual inspection of the surface, the surface child layers were manipulated (depth, shoal, standard deviation, shoal-deep) to flag potential fliers and help the hydrographer spot any anomalies. Filtering the surface to only show nodes with a standard deviation higher than 0.6m proved useful in identifying soundings that were sharply pulling the surface. Additionally, creating a surface by calculating the difference between the deep-shoal layers, and filtering to a 0.45m threshold, flagged many nodes within the surface that could potentially be out of specification. These flagged nodes were investigated in CARIS Subset Editor and if any soundings were questionable, the echogram was reviewed in Hypack’s Single Beam Editor (64-Bit). The majority of the flagged nodes were revealed to be steep slopes and objects that gave a strong return in the echogram. Erroneous soundings that were identified were removed in Hypack and the HS2x file was then re-brought into CARIS. The surfaces were then regenerated.

D.1.2 Designated Sounding Selection

Designated sounding selection followed specifications in the HSSD. The CARIS Subset Editor was utilized to view soundings and the surface in 2D and 3D. Erroneous sounding data were cleaned, and a least depth was designated when necessary. Routinely and before surface finalization, the critical soundings layer in CARIS, which contains designated soundings, was regenerated for QA/QC purposes.

D.1.3 Holiday Identification

For MBES data, all CUBE surfaces were analyzed using HydrOffice QC Tools Holiday Finder to determine if the surface contained holidays, as described in section 5.2.2.3 Option B of the HSSD. The tool scanned the CUBE surfaces to identify any holidays and generated an S-57 file to represent the locations of holidays. Another method of holiday evaluation for MBES data was to visually examine the CUBE surfaces to identify holidays. The hydrographer would often alter the surface display (color ranges, symbology, shading) to help aid in identifying coverage gaps. It should be noted that since mainscheme MBES was with concurrent SSS, visual observation was often the best tool for identifying holidays.

Identification of holidays for SBES data was done manually. The hydrographer would scan through the Uncertainty surface created in CARIS and look for any unnecessary gaps acrosstrack in the SBES surface.

Holidays in the SSS data were based off visual observation as well as using the Pydro survey outline tool. SSS nadir gap coverage with MBES was assessed through visual observation. SSS nadir gap coverage with SBES was visually assessed and gaps were permissible (see PIs).

During survey operations, holidays were compiled into a shapefile line plan and loaded into Hypack on each vessel for recovery. ArcPro was an essential tool to keep track of recoveries per sheet and per sensor. The recoveries were classified by sensor and recovery type.

D.1.4 Uncertainty Assessment

All finalized CUBE and Uncertainty surfaces were analyzed using the HydrOffice QC Tools Grid QA tool to assure at least 95% of the surface grid nodes meet TVU specifications. Results of the Grid QA tool are illustrated in a graphical representation of the surface uncertainty statistics.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Crosslines were evaluated in CARIS HIPS with a detailed visual inspection followed by a thorough statistical analysis. Again, a CUBE surface was made for all MBES data while an Uncertainty surface was made for all SBES data. To conduct the statistical analysis, two surfaces were made: one containing strictly mainscheme bathymetric data and the other containing strictly crossline data. The mainscheme and crossline surfaces were analyzed using the Compare Grids tool in Pydro Explorer, which generated a difference surface and associated statistics. All crossline analyses conducted with the SBES Uncertainty surface used the Shoal layer for comparisons. In addition to the direct statistics from the surface differencing, the tool computed the proportion of allowable TVU consumed by the mainscheme-to-crossline differences per surface node.

D.1.5.2 Junctions

As specified in the PI, no junction analyses were required between OPR-F330-KR-22 and previous surveys in the area. Junction analysis was conducted between all adjoining sheets of OPR-F330-KR-22. The Pydro Compare Grids tool was utilized to generate statistical reports of the surface difference, and the results were included or referenced in each DR. For any sheets which had a junction overlap with both SBES and MBES data, separate junctions analysis were conducted with each respective bathymetric surface. Any junction with SBES data utilized shoal layer values of the submitted CARIS SBES Uncertainty surface while MBES data utilized the CUBE surface depth layer. Additional inspection of junctions were performed using the 2D and 3D views in Subset Editor.

D.1.5.3 Platform to Platform

Vessel to vessel confidence checks were acquired to assess confidence between each survey vessel and their respective survey systems. Confidence checks were assessed in CARIS by evaluating the agreement of sounding data as well as assessing statistics derived from vessel to vessel surface differences. Results of confidence tests can be found in DAPR Appendix V.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Coverage was assessed in accordance with HSSD 2022, the PI, and subsequent guidance from the NOAA HSD OPS. Side scan towfish altitude data was examined for conformance with the adjusted requirements (reference Section C.2.2) by filtering navigation data exported from SonarWiz, by allowable towfish altitude. These navigational files were then brought into ArcPro and recoveries placed appropriately in areas that did not meet specification. In certain scenarios, significant altitude deviations were addressed through trimming the SSS tiff in SonarWiz based on a range (distance) to meet the minimum altitude requirement (in post-processing). This was an approved method to address SSS altitude exceedances given the shallow nature of this project (see project correspondence). The trimmed tiffs were then placed in the mosaic and assessed for conformance to coverage requirements, and if coverage gaps were created from the trimmed .TIFs, additional MBES or SSS was acquired.

Any sections of the SSS imagery that were of a degraded quality due to environmental influences and could prevent the detection of an object 1m x 1m x 1m were identified and reacquired when adequate underlap/overlap from other data did not exist. The persistent impact of environmental influences (fish balls, thermoclines etc) in the project area proved a significant challenge in evaluating whether the full coverage requirement was met, as discussed throughout this project with NOAA HSD OPS. Specific challenges for each survey area are documented in each sheet's DR.

Some methods to ensure full coverage were as follows: On a daily processing level, within Sonarwiz projects, areas without sufficient overlap/underlap of negative environmental influences were identified. Next, the CSFs from daily SonarWiz projects were imported by DPLs to a master project where overlap/underlap was analyzed using the swipe tool. This was sheetwide inter-vessel inspection. Additionally, another sheetwide method to evaluate coverage used was in ArcPro. In ArcPro, Raster Mosaic Datasets were created from the 0.25m individual line .TIFs. These Raster Mosaic Datasets allow the hydrographer to quickly "re-layer" between overlapping images and quickly identify whether areas with environmental influences were adequately covered by another SSS TIF from adjacent line or recovery line. Shapefiles from each of these reviews were compiled in ArcPro and when the overlap in lines of SSS imagery or nearby MBES were insufficient to address any environmental influences present, either SSS or MBES recovery lines were drawn. Recovery lines were rapidly evaluated post-acquisition to assess whether resulting coverage adequately met the 100% complete coverage requirements. The recoveries were given a pass/fail and additional recoveries were frequent. These were all being maintained in an ArcPro environment by the SSS DPL, Data Processing Managers, and the Lead Hydrographer.

It should be noted an extensive amount of field and office effort was made to ensure adequate coverage and feature detection. However, it should be noted that given the distribution and abundance of obstructive environmental influences, the high volume of recoveries and limitations of mosaicking, the final mosaics are not free of environmental/biological artifacts. See section C.2.2 for more details on SSS processing as well as project correspondence with respect to environmental influences encountered and the final mosaics.

D.2.2 Contact Selection Methodology

The SSS contact heights were calculated through shadow length measurement and slant range correction. All SSS imagery received an initial review by two hydrographers, and potential contacts that showed a calculated contact height above the seafloor of at least 85% of the minimum height required by the HSSD 6.1.3.3 were identified for further development with MBES. For example: in depths of water less than or equal to 20m, contacts were picked that had computed target heights rising ~0.85m above the seafloor. The implementation of contact selection criteria, which was slightly broader than those defined in the 2022 HSSD, was meant to account for any human error in the measurement of shadow length from the processed SSS imagery. Any notable seafloor objects were additionally selected at the hydrographer's discretion. All contacts that were initially selected received a final evaluation by the Geodynamics SSS DPL or Data Processing Manager/Lead Hydrographer, and every contact that met the selection criteria for contact development was then retained. Each object in the SSS Contact file was exported as an S-57 file with the attributions listed in HSSD 6.1.3.4. Some contacts were unable to be developed with MBES (unsafe to do so). These are addressed appropriately in the SSS contact file as well as the FFF. Charted ATONs identified as contacts contain remarks clarifying the contact’s association.

Again, as mentioned earlier in this document, the abundance of dense, feature rich areas (e.g., stump fields, clusters of fish stakes) required special guidance for addressing SSS contacts. The re-scheme chart scale (1:10,000) and 8mm radius at the re-scheme chart scale were used to address SSS contacts in those scenarios described above. This allowed for the development of only the largest contact in a single area (80m radii buffer together) and replaced to the need to develop and provide each individual contact (often 100's of contact per area feature). Occasionally the largest contact/feature per established area was unsafe to develop. These were treated as foul areas. Please reference Section C.7 as well as project correspondence for more information.

E. Approval Sheet

This report and the accompanying data deliverable are respectfully submitted.

As Chief of Party, field operations contributing to the accomplishment of Surveys H13755, H13758, H13760, H13761, H13762, H13763, and H13764 were conducted under my direct supervision, with frequent personal checks of progress and adequacy. This report and accompanying data deliverable have been closely reviewed and are considered complete and adequate as per the OPR-F330-KR-22 Project Instructions and Statement of Work. Any related deviations outside of those documents approved by NOAA HSD OPS are documented in project correspondence.

The survey data meets or exceeds requirements as set forth in the Hydrographic Surveys Specifications and Deliverables 2022, Project Instructions (February 14, 2023), and Statement of Work (OPR-F330-KR-22). Any related deviations outside of those documents approved by NOAA HSD OPS are documented in project correspondence. These data are adequate to supersede charted data in their common areas.

Approver Name	Approver Title	Date	Signature
Nicholas Damm, CH	Chief of Party	03/17/2024	Nicholas Damm Digitally signed by Nicholas Damm Date: 2024.03.17 17:22:15 -04'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	I_Vessel_Wiring_Diagrams.pdf
Sound Speed Sensor Calibration	II_Sound_Speed_Sensor_Calibration_Reports.pdf
Vessel Offset	III_Vessel_Offset_Reports.pdf
Position and Attitude Sensor Calibration	IV_Position_Attitude_Sensor_Calibration_Reports.pdf
Echosounder Confidence Check	V_Echo_Sounder_Confidence_Check_Reports.pdf
Echosounder Acceptance Trial Results	N/A