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

Data Acquisition & Processing Report

Type of Survey: Navigable Area

Project Number: S-L361-FA-19

Time Frame: October - October 2019

LOCALITY

State(s): California

General Locality: San Fransisco, CA

2019

CHIEF OF PARTY
CAPT Marc Moser, NOAA

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Data Acquisition and Processing Report

NOAA Ship Fairweather (S220)
Chief of Party: CAPT Marc Moser, NOAA
Year: 2019
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A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAAS Fairweather

Vessel Name	NOAAS Fairweather	
Hull Number	S220	
Description	NOAAS Fairweather (S220) is a 70.4 meter oceanographic research vessel owned and operated by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). It has a welded steel and ice strengthened hull for an ABS classification of #A1, #AMS.	
Dimensions	*LOA*	70.4 meters
	Beam	12.8 meters
	Max Draft	4.8 meters
Most Recent Full Static Survey	*Date*	2015-01-07
	Performed By	The IMTEC Group, Ltd.

Figure 1: NOAA Ship Fairweather S220

A.1.2 FA 2805

Vessel Name	FA 2805	
Hull Number	2805	
Description	FA 2805 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 knot (kt) cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2015-01-21
	Performed By	National Geodetic Survey, Geodetic Services Division
Most Recent Partial Offset Verification	*Date*	2019-05-22
	Method	Direct measurement from benchmarks by the field unit.

Figure 2: FA 2805

A.1.3 FA 2806

Vessel Name	FA 2806	
Hull Number	2806	
Description	FA 2806 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters

Most Recent Full Static Survey	*Date*	2015-01-21
	Performed By	National Geodetic Survey, Geodetic Services Division
Most Recent Partial Offset Verification	*Date*	2019-05-22
	Method	Direct measurement from benchmarks by the field unit.

Figure 3: FA 2806

A.1.4 FA 2807

Vessel Name	FA 2807	
Hull Number	2807	
Description	FA 2807 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2015-01-21
	Performed By	National Geodetic Survey, Geodetic Services Division
Most Recent Partial Offset Verification	*Date*	2019-05-22
	Method	Direct measurement from benchmarks by the field unit.

Figure 4: FA 2807

A.1.5 FA 2808

Vessel Name	FA 2808
Hull Number	2808
Description	FA 2808 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.
Dimensions	*LOA*: 8.6 meters *Beam*: 3.5 meters *Max Draft*: 1.1 meters

Most Recent Full Static Survey	*Date*	2015-01-21
	Performed By	National Geodetic Survey, Geodetic Services Division
Most Recent Partial Offset Verification	*Date*	2019-05-22
	Method	Direct measurement from benchmarks by the field unit.

Figure 5: FA 2808

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM 710

S220 has a hull-mounted Kongsberg EM 710 multibeam echosounder (MBES), which operates at sonar frequencies in the 70 to 100 kHz range. The maximum utilized across-track swath coverage is 140° with a published maximum depth of >2500 meters. The along track beam width configuration is ½° with a receive beam width of 1°. The system forms 400 soundings per swath with an equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range of the EM 710 is 10 to 2500 meters.

<table>
<tr><td>Manufacturer</td><td colspan="6">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="6">EM 710</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">S220</td><td>Component</td><td>HWS</td><td>Transceiver Unit (TRU)</td><td>Transmit Array</td><td>Receive Array</td></tr>
<tr><td>Model Number</td><td>MP 8300</td><td>EM 710</td><td>EM 710</td><td>EM 710</td></tr>
<tr><td>Serial Number</td><td>CZC3407GZ9</td><td>232</td><td>232</td><td>232</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>70-100 kHz</td><td>70-100 kHz</td><td>70-100 kHz</td></tr>
<tr><td>Calibration</td><td>2019-05-17</td><td>2019-05-17</td><td>2019-05-17</td><td>2019-05-17</td></tr>
<tr><td>Accuracy Check</td><td>2019-05-18</td><td>2019-05-18</td><td>2019-05-18</td><td>2019-05-18</td></tr>
</table>

Figure 6: EM 710 gondola during transducer installation

A.2.1.2 Kongsberg EM 2040

HSLs 2805, 2806, 2807, and 2808 are each equipped with a Kongsberg EM 2040 MBES. The EM 2040 is capable of operating at low frequency (200 kHz), intermediate frequency (300 kHz), and high frequency (400 kHz), with maximum swath coverage of 150°. At the common usage frequency of 300 kHz, the beam width is 1° for both TX and RX. The system forms 256 beams, with dynamic focusing employed in the near field. The system forms 400 soundings per swath with an equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range for the EM 2040 is 0.5 to 600 meters.

Manufacturer	Kongsberg					
Model	EM 2040					
Inventory	*2805*	*Component*	HWS	Processing Unit (PU)	Transmit Array	Receive Array
		Model Number	MP5810	Slim PU	EM 2040	EM 2040
		Serial Number	CZC5502TSD	40122	255	364
		Frequency		200, 300, 400 kHz	200, 300, 400 kHz	200, 300, 400 kHz
		Calibration	2019-04-04	2019-04-04	2019-04-04	2019-04-04
		Accuracy Check	2019-04-24	2019-04-24	2019-04-24	2019-04-24
	2806	*Component*	HWS	Processing Unit (PU)	Transmit Array	Receive Array
		Model Number	MP8300	Slim PU	EM 2040	EM 2040
		Serial Number	CZC3410KN0	40111	249	351
		Frequency		200, 300, 400 kHz	200, 300, 400 kHz	200, 300, 400 kHz
		Calibration	2019-04-23	2019-04-23	2019-04-23	2019-04-23
		Accuracy Check	2019-04-25	2019-04-25	2019-04-25	2019-04-25
	2807	*Component*	HWS	Processing Unit (PU)	Transmit Array	Receive Array
		Model Number	MP8300	Slim PU	EM 2040	EM 2040
		Serial Number	CZC3410KMV	40109	247	355
		Frequency		200, 300, 400 kHz	200, 300, 400 kHz	200, 300, 400 kHz
		Calibration	2019-04-04	2019-04-04	2019-04-04	2019-04-04
		Accuracy Check	2019-04-25	2019-04-25	2019-04-25	2019-04-25
	2808	*Component*	HWS	Processing Unit (PU)	Transmit Array	Receive Array
		Model Number	MP8300	Slim PU	EM 2040	EM 2040
		Serial Number	CZC3410KN0	40117	251	356
		Frequency		200, 300, 400 kHz	200, 300, 400 kHz	200, 300, 400 kHz
		Calibration	2019-04-03	2019-04-03	2019-04-03	2019-04-03
		Accuracy Check	2019-04-24	2019-04-24	2019-04-24	2019-04-24

Figure 7: EM 2040 topside processing unit

Figure 8: EM 2040 transceiver array

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

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

Field units maintain calibrated lead lines for use in occasional direct water measurements, particularly during shoreline investigation. Fairweather maintains two calibrated lead lines on board.

<table>
<tr><td>Manufacturer</td><td colspan="4">FA Personnel</td></tr>
<tr><td>Model</td><td colspan="4">Traditional</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S220</td><td>Component</td><td>Lead Line</td><td>Lead Line</td></tr>
<tr><td>Model Number</td><td>Traditional</td><td>Traditional</td></tr>
<tr><td>Serial Number</td><td>10-05-09</td><td>10-06-09</td></tr>
<tr><td>Calibration</td><td>2019-03-18</td><td>2019-03-18</td></tr>
</table>

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 320 V5

The POS MV V5 calculates position, heading, attitude, and vertical displacement (heave) of a vessel. It consists of a rack mounted POS Computer System (PCS), a bolt down IMU-200 Inertial Measurement Unit (IMU), and two GNSS antennas corresponding to GNSS receivers in the PCS.

Manufacturer	Applanix					
Model	POS MV 320 V5					
Inventory	*2805*	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	LN200	GA830	GA830
		Serial Number	8198	294	9961	9962
		Calibration	2019-03-28	2019-03-28	2019-03-28	2019-03-28
	2806	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	LN200	GA830	GA830
		Serial Number	8197	991	9963	9964
		Calibration	2019-04-04	2019-04-04	2019-04-04	2019-04-04
	2807	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	LN200	GA830	GA830
		Serial Number	8195	37	9965	9966
		Calibration	2019-04-04	2019-04-04	2019-04-04	2019-04-04
	2808	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	LN200	GA830	GA830
		Serial Number	8196	324	9967	9968
		Calibration	2019-03-27	2019-03-27	2019-03-27	2019-04-15
	S220	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	LN200	GA830	GA830
		Serial Number	8194	292	9959	9960
		Calibration	2019-05-17	2019-05-17	2019-05-17	2019-05-17

Figure 9: POS MV 320 V5 System

A.5.2 DGPS

A.5.2.1 Hemisphere MBX-4

S220 and its HSLs each have differential GPS beacon receivers. FA personnel tune these receivers to the closest available U.S. Coast Guard (USCG) beacon transmitters with reliable signals. The GPS correctors feed to the Applanix POS-MVs to produce real time differentially corrected positions.

Manufacturer	Hemisphere			
Model	MBX-4			
Inventory	*2805*	*Component*	DGPS Receiver	DGPS Antenna
		Model Number	MBX-4	MA40
		Serial Number	0927-9567-0001	0927-9488-0046
		Calibration	N/A	N/A
	2806	*Component*	DGPS Receiver	DGPS Antenna
		Model Number	MBX-4	MA40
		Serial Number	0923-9416-0007	0919-9231-0193
		Calibration	N/A	N/A
	2807	*Component*	DGPS Receiver	DGPS Antenna
		Model Number	MBX-4	MA40
		Serial Number	0923-9416-0005	0919-9231-0191
		Calibration	N/A	N/A
	2808	*Component*	DGPS Receiver	DGPS Antenna
		Model Number	MBX-4	MA40
		Serial Number	N/A	0924-9488-0040
		Calibration	N/A	N/A
	S220	*Component*	DGPS Receiver	DGPS Antenna
		Model Number	MBX-3	MGL3
		Serial Number	0324-11969-0002	0328-12352-0002
		Calibration	N/A	N/A

Figure 10: MBX-4 DGPS

A.5.3 GPS

GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

A.5.4.1 Laser Tech TruPulse 200

The TruPulse laser rangefinders are used to measure the static draft of S220, as well as to take range and bearing measurements to

Manufacturer	Laser Tech			
Model	TruPulse 200			
Inventory	*S220*	*Component*	Laser Range Finder	Laser Range Finder
		Model Number	TruPulse 200 Laser Rangefinder	TruPulse 200 Laser Rangefinder
		Serial Number	LR 041156	LR 041169
		Calibration	2019-03-22	2019-03-22

Figure 11: TruPulse 200 Laser Rangefinder

A.5.5 Other Positioning and Attitude Equipment

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

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 AML Oceanographic MVP 200

The MVP 200 is a self-contained system capable of sampling water column profiles to depths of 200 meters from a vessel moving at up to 12 kts, achieving deeper depths at slower speeds. During towed operation, the MVP 200 can be controlled by computer without the requirement for personnel on deck. The system consists of a single sensor free fall fish, an integrated winch and hydraulic power unit, a towing boom, and a remotely located computer controller with a user interface. Fairweather's MVP fish is equipped with an AML Oceanographic Micro-CTD sensor capable of acquiring conductivity, temperature, and depth (CTD) profiles to determine the speed of sound and absorption in the water column, primarily to correct bathymetry data acquired with the EM 710 MBES.

<table>
<tr><td>Manufacturer</td><td colspan="3">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="3">MVP 200</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S220</td><td>Component</td><td>CTD Sensor</td></tr>
<tr><td>Model Number</td><td>Micro-CTD</td></tr>
<tr><td>Serial Number</td><td>8817</td></tr>
<tr><td>Calibration</td><td>2018-05-28</td></tr>
</table>

Figure 12: MVP 200 system

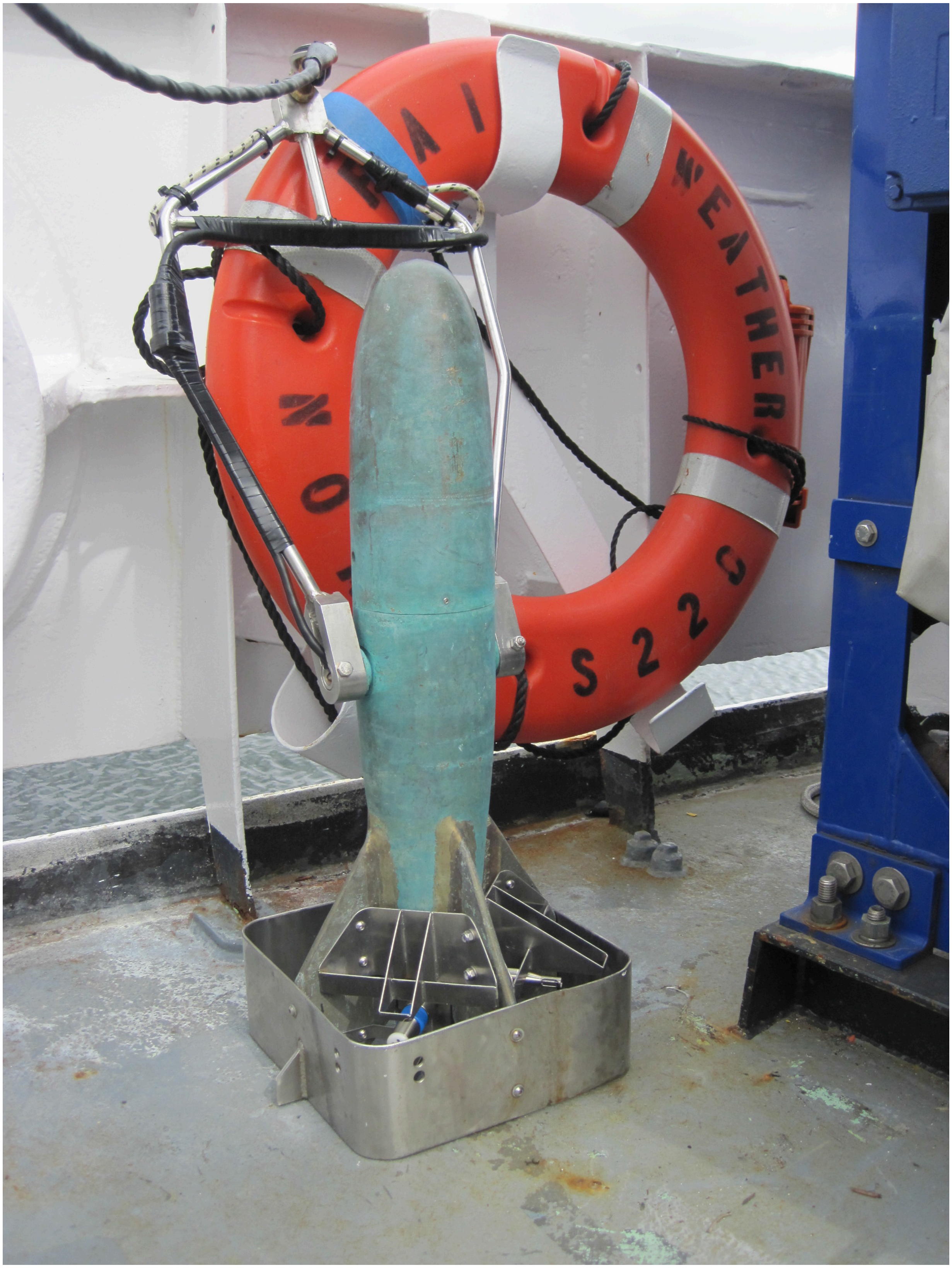

Figure 13: Single sensor free fall fish

A.6.2 CTD Profilers

A.6.2.1 Sea-Bird Electronics SBE CTD

Fairweather is equipped with one SBE 19plus and four SBE 19plusV2 SeaCAT sound speed profilers used to acquire conductivity, temperature, and depth (CTD) data throughout the water column. The titanium-cased SBE 19plus has a pressure sensor rated to 3,500 m, while the four SBE 19plusV2 have pressure sensors rated to 600 m. All SeaCAT sound speed profilers were calibrated by the manufacturer during the 2018-2019 winter repair period. The survey department performs quality checks and comparison casts on any instruments suspect of being out of calibration.

Manufacturer	Sea-Bird Electronics	
Model	SBE CTD	
Inventory	*Component*	CTD
	Model Number	SBE 19plus
	Serial Number	4585
	Calibration	2019-02-20
	Component	CTD
	Model Number	SBE 19plusV2
	Serial Number	7370
	Calibration	2019-02-24
	Component	CTD
	Model Number	SBE 19plusV2
	Serial Number	6122
	Calibration	2019-03-01
	Component	CTD
	Model Number	SBE 19plusV2
	Serial Number	6121
	Calibration	2019-02-24
	Component	CTD
	Model Number	SBE 19plusV2
	Serial Number	7634
	Calibration	2019-02-19

Figure 14: SBE 19plusV2

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne RESON SVP-71

The SVP-71 is a direct-reading sound speed probe with a 125mm sound transmission path. The unit's housing composition is hard, anodized, sea water resistant aluminum. This sensor is mounted in close proximity to the multibeam transceiver on each HSL, providing real-time surface sound speed values for refraction corrections.

<table>
<tr><td>Manufacturer</td><td colspan="3">Teledyne RESON</td></tr>
<tr><td>Model</td><td colspan="3">SVP-71</td></tr>
<tr><td rowspan="16">Inventory</td><td rowspan="4">2805</td><td>Component</td><td>Surface Sound Speed Sensor</td></tr>
<tr><td>Model Number</td><td>SVP-71</td></tr>
<tr><td>Serial Number</td><td>1713034</td></tr>
<tr><td>Calibration</td><td>2015-01-26</td></tr>
<tr><td rowspan="4">2806</td><td>Component</td><td>Surface Sound Speed Sensor</td></tr>
<tr><td>Model Number</td><td>SVP-71</td></tr>
<tr><td>Serial Number</td><td>1213046</td></tr>
<tr><td>Calibration</td><td>2015-01-26</td></tr>
<tr><td rowspan="4">2807</td><td>Component</td><td>Surface Sound Speed Sensor</td></tr>
<tr><td>Model Number</td><td>SVP-71</td></tr>
<tr><td>Serial Number</td><td>1213047</td></tr>
<tr><td>Calibration</td><td>2015-01-26</td></tr>
<tr><td rowspan="4">2808</td><td>Component</td><td>Surface Sound Speed Sensor</td></tr>
<tr><td>Model Number</td><td>SVP-71</td></tr>
<tr><td>Serial Number</td><td>3511352</td></tr>
<tr><td>Calibration</td><td>2015-01-26</td></tr>
</table>

A.6.3.2 Teledyne RESON SVP-70

The SVP-70 is a direct-reading sound speed probe with a 125mm sound transmission path. The unit's housing is composed of robust titanium, which reduces marine growth on these continually submerged sensors. S220 has two sensors in close proximity to the ship's multibeam transducer.

<table>
<tr><td>Manufacturer</td><td colspan="4">Teledyne RESON</td></tr>
<tr><td>Model</td><td colspan="4">SVP-70</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S220</td><td>Component</td><td>Surface Sound Speed Sensor</td><td>Surface Sound Speed Sensor</td></tr>
<tr><td>Model Number</td><td>SVP-70</td><td>SVP-70</td></tr>
<tr><td>Serial Number</td><td>0614171</td><td>0614172</td></tr>
<tr><td>Calibration</td><td>2019-04-01</td><td>2019-03-29</td></tr>
</table>

A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Teledyne CARIS	HIPS and SIPS	11.1.3	Processing
Teledyne CARIS	BASE Editor	4.4.0	Processing
Applanix	MV POSView	9.91	Acquisition
Applanix	POSPac MMS	8.3.3	Processing
HYPACK, Inc.	HYPACK 2018	2018	Acquisition
Quality Positioning Services BV (QPS)	Fledermaus Geocoder Toolbox	7.7	Processing
Kongsberg Maritime AS	Seafloor Information System (SIS)	4.3.2	Acquisition
NOAA Hydrographic Systems and Technology Branch (HSTB)	Pydro Explorer	19.4	Acquisition and Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

The reference point for all positioning, attitude, and sonar systems maintained by Fairweather is co-located at the phase center of the sonar transmitter and rotated to the face of the transducer for the EM 2040 installations on the HSLs and the EM 710 installed on S220. A single reference point simplifies downstream processing and eliminates errors due to incorrect offset application in CARIS HIPS. This was achieved for position and attitude by entering the surveyed translational and rotational offsets of the IMU and GNSS antennae for each platform into the respective POS configuration. Thus the position and attitude reported by the POS, including heave and delayed heave, are valid at the transmit array. Furthermore, this reference point is the center of rotation in POS for the purposes of applying the heave filter, as the reference to center of rotation field is zero.

Rotational and translational offsets for the EM 710 system on Fairweather were determined by IMTEC Group during drydock in 2014, and a reference frame was delivered which centered on the EM 710 transmit array and aligned with the array in heading, pitch, and roll. This allows for direct entry of these values since they were already in the desired reference frame. For the HSL EM 2040 systems, offsets were derived from a combination of the 2010 NGS survey of control points permanently installed on the launch hull and engineering drawings of the sonar mount rather than being directly surveyed. Due to the relatively short baselines between HSL systems, this is not expected to introduce significant error.

Transducer and navigation offsets and alignments were entered in SIS according to the EM 710 or EM 2040 transmitter reference frame. The translational and angular offsets of the receiver array (labeled “RX Transducer”) relative to the transmit array were entered into SIS. Since the transmit array is at the reference point and was aligned with the reference frame by definition, the translational and angular offsets of the transmit array (labeled “TX Transducer”) are all zero. Since the reference point of the POS was configured to be located at and aligned with the transmit array centered frame, the offsets for the position and attitude data from the POS are also zero in SIS. With this approach, any residual misalignment between the EM 710 or EM 2040 and the IMU discovered in a patch test (see Section B.3.1) was added to the IMU alignment with respect to the reference frame in the POS configuration, maintaining the transmit array as aligned with the reference frame.

Entries in the CARIS HVF account for the offset between the transmit and receive arrays for the EM 710 and EM 2040 systems, entered under the SVP 2 section so processing of raw range-angle data is correct after sound speed profile corrections are applied. All other vessel offset values have been set to zero and apply to “No” to avoid double-correction. Offsets to the IMU and primary GNSS antenna are also entered under the TPU section, but this is only used for estimates of uncertainty and not positioning of soundings.

B.1.1.1 Vessel Offset Correctors

<table>
<tr><td>Vessel</td><td colspan="4">FA_2805_EM2040</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td colspan="4">2017-03-31</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.195 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.148 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.534 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.110 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.048 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.518 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.877 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.954 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.712 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.572 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.854 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.696 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="4">FA_2806_EM2040</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td colspan="4">2017-03-31</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.205 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.134 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.532 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.100 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.034 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.516 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.842 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.966 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.697 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.537 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.866 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.681 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="4">FA_2807_EM2040</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td colspan="4">2017-03-31</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.207 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.130 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.540 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.098 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.030 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.523 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.992 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.941 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.691 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.688 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.841 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.674 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

Vessel	FA_2808_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2017-03-31			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.205 meters	0.006 meters
		y	0.140 meters	0.006 meters
		z	0.534 meters	0.006 meters
		x2	-0.100 meters	N/A
		y2	0.040 meters	N/A
		z2	0.518 meters	N/A
	Nav to Transducer	*x*	0.886 meters	0.006 meters
		y	0.977 meters	0.006 meters
		z	3.698 meters	0.006 meters
		x2	0.582 meters	N/A
		y2	0.877 meters	N/A
		z2	3.682 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	FA_S220_EM710			
Echosounder	Kongsberg Simrad EM710			
Date	2015-02-06			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.728 meters	0.002 meters
		y	8.427 meters	0.002 meters
		z	4.677 meters	0.002 meters
		x2	1.838 meters	N/A
		y2	7.204 meters	N/A
		z2	4.675 meters	N/A
	Nav to Transducer	*x*	1.728 meters	0.002 meters
		y	8.427 meters	0.002 meters
		z	4.677 meters	0.002 meters
		x2	1.838 meters	N/A
		y2	7.204 meters	N/A
		z2	4.675 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

No towed arrays were utilized for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

The static drafts (Waterline Height in the HVF) for HSLs 2805, 2806, 2807, and 2808 are calculated based on steel tape and plumb bob measurements of the distance from benchmarks on the port and starboard quarter of the vessel to the waterline. These measurements were combined with the offset from these benchmarks to the sonar transducer to determine the waterline relative to the reference frame.

Measurements were conducted in April of 2019 in Seattle, WA. The values and calculations for static draft of the HSLs are listed in the respective Waterline Measurement spreadsheets included within this report.

Static draft for Fairweather is determined by using a laser rangefinder to measure the vertical distance to the water from benchmarks on the port and starboard E-Deck breezeway below the bridge wings. The measurements are translated to the transmitter reference frame using surveyed offsets to the benchmarks. The loading condition of the ship, particularly fuel and launches, has a more significant influence on static draft than for the launches. To compensate for static draft changes, static draft values are measured on S220 after any changes in fuel levels, and at the start of survey operations for each leg throughout the season. These measurements are taken while the vessel is at anchor or hove to.

For both the S220 and HSL sonar systems, static draft corrector values are entered in the Kongsberg SIS Installation Parameters window. In addition, waterline values are entered in the CARIS HVF. For S220, only the HVF is updated with the measurements taken throughout the field season, as this will override the SIS waterline during processing. The waterline value in CARIS will only be used during Sound Speed Correction. The Apply switch is set to “No” to avoid double application of the waterline value during HIPS merge.

B.2.1.1 Static Draft Correctors

Vessel		FA_2805_EM2040	FA_2806_EM2040	FA_2807_EM2040	FA_2808_EM2040	FA_S220_EM710
Date		2019-04-11	2019-04-11	2019-04-11	2019-04-11	2019-05-20
Loading		0.018000 meters	0.018000 meters	0.018000 meters	0.018000 meters	0.116000 meters
Static Draft	*Measurement*	-0.641000 meters	-0.630000 meters	-0.641000 meters	-0.625000 meters	-4.660000 meters
	Uncertainty	0.014000 meters	0.011000 meters	0.010000 meters	0.014000 meters	0.128000 meters

B.2.2 Dynamic Draft

Dynamic draft data were acquired for all HSLs in April of 2019 in Lake Washington, WA. The method employed calculates the vessel's ellipsoid height change while transiting at different speeds in a straight line. The ellipsoid heights were determined using a Post Processed Kinematic (PPK) trajectory for each vessel through processing the recorded POS MV data with RTX correctors in Applanix POSPac MMS software. A third order polynomial curve was fit to the speed versus ellipsoid height data using a least squares fit through a script implemented in the POSPac AutoQC tool.

Since all launches are of essentially identical construction, a historical average for all launches using data from 2016-2019 was used to populate the CARIS HVF in order to reduce uncertainty introduced by wave action noise. Outlier vessel measurements with multiple delta draft values more than two standard deviations from the mean were removed from the average. The standard deviation of the residuals was used to determine the associated uncertainty in the measurement.

For S220, the 2016 polynomial curve was used to derive the table used in the CARIS HVF as this value has historically remained consistent, and the 2016 data were collected in an environment free from currents and swell.

B.2.2.1 Dynamic Draft Correctors

<table>
<tr><td>Vessel</td><td colspan="2">FA_280x_EM2040</td><td colspan="2">FA_S220_EM710</td></tr>
<tr><td>Date</td><td colspan="2">2019-04-11</td><td colspan="2">2016-05-02</td></tr>
<tr><td rowspan="16">Dynamic Draft</td><td>Speed (m/s)</td><td>Draft (m)</td><td>Speed (m/s)</td><td>Draft (m)</td></tr>
<tr><td>0.00</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>0.50</td><td>0.00</td><td>1.50</td><td>0.01</td></tr>
<tr><td>1.00</td><td>0.01</td><td>2.00</td><td>0.03</td></tr>
<tr><td>1.50</td><td>0.03</td><td>2.50</td><td>0.06</td></tr>
<tr><td>2.00</td><td>0.04</td><td>3.00</td><td>0.08</td></tr>
<tr><td>2.50</td><td>0.05</td><td>3.50</td><td>0.11</td></tr>
<tr><td>3.00</td><td>0.06</td><td>4.00</td><td>0.14</td></tr>
<tr><td>3.50</td><td>0.06</td><td>4.50</td><td>0.17</td></tr>
<tr><td>4.00</td><td>0.05</td><td>5.00</td><td>0.20</td></tr>
<tr><td>4.50</td><td>0.03</td><td>5.50</td><td>0.23</td></tr>
<tr><td>5.00</td><td>0.00</td><td>6.00</td><td>0.25</td></tr>
<tr><td>5.50</td><td>-0.03</td><td>6.50</td><td>0.27</td></tr>
<tr><td>6.00</td><td>-0.08</td><td></td><td></td></tr>
<tr><td>6.50</td><td>-0.13</td><td></td><td></td></tr>
<tr><td>7.00</td><td>-0.17</td><td></td><td></td></tr>
<tr><td rowspan="2">Uncertainty</td><td>Vessel Speed (m/s)</td><td>Delta Draft (m)</td><td>Vessel Speed (m/s)</td><td>Delta Draft (m)</td></tr>
<tr><td>0.03</td><td>0.03</td><td>0.03</td><td>0.10</td></tr>
</table>

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Patch test data were collected in Seattle, WA along a slope with two parallel lines surveyed in both directions for determination of pitch and yaw correctors. An additional line was surveyed in a flat area in reciprocal directions for determination of the roll corrector.

Data were converted in CARIS HIPS using an HVF file with heave, pitch, roll, and timing values set to zero. Delayed heave, SBETs, SBET RMS, the most recent dynamic draft, sound speed correctors, and GPS tides via a VDATUM separation model were applied and the data were georeferenced before cleaning via Subset Editor. Bias values were determined in the following order; pitch, roll, yaw. A minimum of five individual testers determined alignment test biases in CARIS. Additionally, a reviewer examined these results for outlier elimination, after which the remaining results were averaged. The averaged values were entered as opposite sign rotations into the POS MV angular offsets in “IMU Frame w.r.t. Ref Frame" within the Lever Arms & Mounting Angles setup. The values for roll, pitch, and yaw correctors were entered as X, Y, and Z, respectively. These rotations are therefore applied to all raw orientation data output from the POS.

An additional examination of the correlation between a bathymetric roll artifact and the motion time series is used to solve for timing errors that are difficult to detect in the traditional patch test methodology. From these results, a constant timing delay is applied to all motion data in Kongsberg SIS. A value of 7 milliseconds is used for all HSLs and 14 milliseconds for S220.

The values listed below are those entered into the POS MV, as the alignment values in the HVF are all set to zero.

B.3.1.1 System Alignment Correctors

Vessel	FA_2805_EM2040		
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode		
Date	2019-04-04		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.001 seconds
	Navigation Time Correction	0.000 seconds	0.001 seconds
	Pitch	-0.248 degrees	-0.010 degrees
	Roll	0.031 degrees	-0.010 degrees
	Yaw	0.302 degrees	0.120 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	FA_2806_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2019-04-23

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.657 degrees	-0.010 degrees
Roll	0.021 degrees	-0.010 degrees
Yaw	-0.736 degrees	0.120 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	FA_2807_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2019-04-04

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.098 degrees	-0.010 degrees
Roll	0.178 degrees	-0.010 degrees
Yaw	-1.011 degrees	0.120 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	FA_2808_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2019-04-03

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.500 degrees	-0.010 degrees
Roll	0.049 degrees	-0.010 degrees
Yaw	-0.370 degrees	0.120 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	FA_S220_EM710
Echosounder	Kongsberg Simrad EM710
Date	2019-05-18

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.000 degrees	0.040 degrees
Roll	0.080 degrees	0.040 degrees
Yaw	0.090 degrees	0.060 degrees
Pitch Time Correction	0.000 seconds	0.005 seconds
Roll Time Correction	0.000 seconds	0.005 seconds
Yaw Time Correction	0.000 seconds	0.005 seconds
Heave Time Correction	0.000 seconds	0.005 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Acquisition methods employed are determined based on consideration of sonar system specifications, seafloor topography, water depth, and the capabilities of the acquisition platforms. They are also dictated by the coverage method specified in the Project Instructions for a survey area. For the Kongsberg EM 710 and EM 2040, all multibeam data were acquired in the .all format within the SIS (Seafloor Information System) software. Data were monitored in 2D, 3D, and backscatter imagery real-time display windows. A survey template defined the storage location of raw and gridded (survey) data, and the file naming convention for mainscheme (Filename_M.all) and crossline (Filename_X.all) data. During acquisition, the hydrographers often adjusted parameters of the Kongsberg systems to improve data quality. The following are parameters that are commonly adjusted: the port and starboard beam angle, the force depth fields, ping mode, and yaw stabilization. Settings and specialized filters are found in the Runtime Parameters tear off window within SIS.

During both launch and ship acquisition, mainscheme MBES lines are generally run parallel to depth contours with appropriate overlap to ensure the data density requirements for the proper finalized CUBE surfaces are met. For discrete item developments, 200 percent coverage is acquired to ensure least-depth determination by multibeam near-nadir beams. For complete coverage surveys, the HYPACK HYSWEEP realtime coverage display is used in lieu of pre-planned line files. Hysweep displays the acquired multibeam swath during acquisition and is monitored to ensure overlap and full bottom coverage.

For areas where shoreline verification is not conducted before multibeam acquisition and hazards are suspected to exist, extra caution is taken by “half stepping” shoreward when operating near shore. Half stepping is executed by driving along the edge of real time coverage to prevent the survey vessel from working in un-surveyed waters. Survey launch crews in the field survey to the Navigable Area Limit Line (NALL) line as defined by section 1.3.2 of the HSSD.

Seafloor backscatter data were acquired for all lines during the 2019 field season, logged in the .all files. The Kongsberg EM 710 system has an internal file, BsCorr, used to correct for beam pattern effects to equalize backscatter returns between swaths, sectors, and modes. A default file is populated at the factory, however a modified BsCorr file was provided by HSTB following the sonar acceptance to optimize the quality of the backscatter data. This HSTB version was used for all backscatter acquisition for the EM 710.

Navigation and motion data are acquired and monitored in POSView and logged to a POS MV file with a .### extension, starting with .000. Data are logged on a USB flash drive inserted into the PCS and automatically split into 12 MB files. Various position and heading accuracies, as well as satellite constellations, are monitored real-time both in POSView and in Hypack Hysweep to ensure the collection of quality data. It is standard procedure not to log the POS/MV data through UTC midnight on Saturdays. At this time the GPS seconds of the week reset.

Data Processing Methods and Procedures

Following daily acquisition, all data are loaded to an external hard drive connected to the launch acquisition computer. This drive contains a standard file structure created by Charlene, an automated data transfer and batch processing software developed by HSTB and distributed within the PydroXL software suite.

Initial processing is typically completed the same day as acquisition, and employs Charlene to transfer the external hard drive data to the S220 network and process it to a daily QC product, which is typically a bathymetric surface with data from that acquisition platform. Charlene automates the following tasks between raw data collection and the final daily product:

1. Perform verification of raw data
2. Build a deliverable directory structure
3. Transfer and verify raw data
4. Convert the Kongsberg .all file to CARIS HIPS HDCS format
5. Apply delayed heave from the POS files
6. Generate and apply SBET and SBET RMS files
7. Apply sound speed correctors
8. Apply a GPS Tide via a separation model (VDATUM or ERTDM)
9. Compute the Total Propagated Uncertainty
10. Generate a CARIS CSAR bathymetric surface from the data

Once Charlene has completed, night processors inspect the data in CARIS HIPS to ensure all correctors have been properly applied, and that the final products reflect observed conditions to the standards set by the relevant OCS guidance. Bathymetric surfaces are reviewed to ensure that all data quality problems are identified and resolved if possible, and all submerged features are accurately represented.

C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

The field unit’s final deliverable bathymetric surface is a variable resolution (VR) Combined Uncertainty and Bathymetric Estimator (CUBE) surface for complete coverage surveys, and a four meter single resolution CUBE surface for set line spacing surveys. The CUBE surface’s resolution, depth range, and parameters follow HSSD section 5.2.2. The bathymetric surfaces are generated following the application of all correctors highlighted above in Section C.1.1.

C.1.4.2 Depth Derivation

Multibeam data were reviewed and analyzed in CARIS HIPS Subset Editor, utilizing the generated CUBE surfaces for directed data editing to reject data that led to fliers in the surface. The surfaces were also used to demonstrate coverage and to check for errors due to tides, sound speed, attitude, and timing.

Vessel heading, attitude, and navigation data were reviewed in HIPS Navigation Editor and Attitude Editor if deemed necessary upon review of surfaces. Where necessary, data spikes (fliers) or gaps in heading, attitude, or navigation data were manually rejected or interpolated for small periods of time. Any editing of this nature is outlined in the Descriptive Report for the particular survey.

Hydrographers may designate soundings if the bathymetric surface fails to represent navigationally significant depths and features. Designated soundings are selected following the criteria in section 5.2.1.2.3 of the HSSD.

C.1.4.3 Surface Computation Algorithm

All VR surfaces are generated via the Ranges estimation method within CARIS HIPS and SIPS. This algorithm grids data based on the resolution requirements for each depth range, adhering to the specifications in the HSSD. The following options are selected for the Ranges Estimation Method:

- Range/Resolution File: NOAA_DepthRanges_ObjectDetection.txt (for object detection surveys) or NOAA_DepthRanges_CompleteCoverage.txt (for complete coverage surveys)

- Range Estimation Method: Percentile

- Input Band: Depth

- Output Vertical Coordinate System: Unknown

- Keep Partial Bins: Checked

- Maximum Grid Size: 64

- Minimum Grid Size: 4

The population method utilized for the generation of the Ranges surfaces was CUBE. The following options were selected for the generation of each surface:

- Disambiguation Method: Density and Locale

- IHO Order: S44 Order 1a

- Display Bias: Highest

- CUBE Configuration: NOAA_VR

The CUBE Configuration utilized comes from the CUBE_Parameters_NOAA_2019.xml file included within the Caris_Support_Files_2019v0. This file contains the parameters necessary to create CUBE surfaces meeting the requirements as stated in the HSSD.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

The Kongsberg EM 710 and EM 2040 systems log backscatter to the .all file concurrently with all multibeam data. The HIC monitors the “Seabed Image” tear-off to ensure adequate backscatter imagery is obtained during survey acquisition. The HIC also documents all Kongsberg system frequency changes to aid in file segregation prior to backscatter processing.

Data Processing Methods and Procedures

Backscatter data are processed with the Fledermaus Geocoder Toolkit (FMGT) software using the subsequent steps:

- A new project was created for each frequency used by each vessel within the sheet. For example, if Launch 2806 acquired data in 200 kHz and 300 kHz, two separate projects must be created.

- The vessel pulse mode correction parameters of each frequency for each vessel were set to create a smoother appearance of the imagery between mosaics created for each project within the sheet. These parameters were based on an analysis performed by HSTB of data collected over a calibration line during HSRR. This allowed for the generation of single-frequency mosaics across platforms.

- Lines were imported into FMGT, combining the .all files with the HDCS files created in CARIS, resulting in the generation of GSF files.

- A mosaic in floating point GeoTIFF format was created for each project from the imported GSF files. The backscatter mosaic’s minimum resolution depends on the acquisition frequency, using the equation provided in HTD 2018-3. The minimum resolutions for all systems utilized by the field unit were as follows: 6 meters for 100 kHz, 3 meters for 200 kHz, 2 meters for 300 kHz, and 1.5 meters for 400 kHz.

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

C.3 Horizontal and Vertical Control

C.3.1 Horizontal Control

C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

C.3.1.2 DGPS Data

DGPS data was not acquired.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Vessel attitude is measured by the Applanix POS MV and recorded in both SIS .all files (for real-time correctors) and POS MV .000 files (for delayed heave data). The POS MV continuously logs data to a USB drive throughout the survey day. A five minute buffer period of POS MV data is acquired preceding and following any sonar data acquisition to permit proper initialization of filters for delayed heave and PPK solutions.

Data Processing Methods and Procedures

Attitude correctors applied after initial CARIS HIPS conversion use the raw POS MV attitude data recorded in the Kongsberg data files (.all). The .000 delayed heave file logged by the POS MV is separately loaded into HIPS, replacing the real-time heave values recorded in the raw data.

This .000 file is then post processed in Applanix POSPac to generate a Smoothed Best Estimate of Trajectory (SBET), adjusting the integrated positioning and inertial measurements with Trimble CenterPoint Real-Time Extended (RTX) differential correctors. Trimble RTX uses a network of globally distributed high-performance GNSS receivers that generate the precise orbit, clock, and observation biases for any location on Earth, eliminating the need to establish local reference stations. Post processed RTX corrections are available an hour after data acquisition. The SBET file is exported from WGS84 to NAD83, and then run through the POSPac AutoQC tool in Pydro to evaluate the quality of the ERS vessel positioning. Any short-term unresolvable errors in the GNSS height and uncertainty time series data are manually replaced with an interpolated signal derived from differential heave, dynamic draft, and water level data. Once this quality assessment has been completed, the SBET and corresponding RMS uncertainty file containing the recomputed vessel navigation and ellipsoidal height are applied to the data in CARIS HIPS.

Once SBETs have been applied to the data a GPS vertical adjustment is computed in CARIS HIPS, utilizing an Ellipsoidally Referenced Tidal Datum Model (ERTDM) supplied by HSTB to reduce the data from the ellipse to MLLW. The data are then reviewed for consistency, ensuring that no vertical offsets due to artifacts in the SBET or improper application exist.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

HSL sound speed profiles are captured with the SeaBird Electronics SBE19plusV2 CTD. All HSLs have small swing-arm davits with 24-volt electric winches for deploying and recovering the CTD profilers. Sound speed profiles are collected while the launch is at rest.

For acquisition with S220, sound speed profiles are taken with the AML MVP200 and the Lockheed Martin XBT. The Moving Vessel Profiler (MVP) is an automated winch system that deploys a fish containing a CTD sensor. The fish is typically towed behind the survey vessel in a “docked” position that is marked by messengers attached to the tow cable. Ideally, at survey speeds the fish is towed just above the depth of the sonar transducers. The deployment depth is selected by specifying a distance off the bottom (typically 10 meters). Once at the depth limit, the winch free fall is automatically stopped and the drag forces on the fish cause it to rise toward the surface due to the ship's forward motion. The cable slack is then pulled in by the winch to the docked position.

In the event of a particularly deep survey area or when there are risks to towing the MVP fish, the MVP fish can be manually deployed while the ship is stationary using the hand-operated control box located on the winch. This method ensures that the maximum possible depth is obtained since the cable is deployed vertically. If necessary, the deep end of such a stationary cast can be added to the end of shallower casts obtained while the ship is underway.

The Expendable Bathythermograph (XBT) can be deployed using the LM-3A hand launcher interfaced with a MK21 Oceanographic Data Acquisition System by a 100' cable. Changes in water temperature are recorded by changes in the resistance of the thermistor as the XBT falls through th water.

Sound speed casts are taken at least once every four hours during multibeam survey operations in accordance with section 5.2.3.3 of the HSSD. All platforms collect sound speed casts according to observed variations in the water column and any changes in survey location that would influence sound speed differences in excess of the accepted 2 m/s range. Changes are monitored through the real-time surface sound speed view in Sound Speed Manager (SSM) and the data view in SIS. SSM provides a geographic view of changes in surface sound speed which assists in the targeting of casts for zoning water masses. The CastTime algorithm is also employed in SSM to guide cast frequency. In SIS, the user is warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

Data Processing Methods and Procedures

Sound speed cast processing is performed via the HydrOffice Sound Speed Manager (SSM) application. HSL casts are downloaded from the CTD and converted from their raw binary sensor measurements (.hex) to standard units (.cnv) using a manufacturer supplied calibration file (.xmlcon). These files are then smoothed using 1 meter cosine averaged depth bins and saved to the SSM database. The smoothing eliminates errors near the surface resulting from wave action and engine cooling water outflow. S220 casts are loaded over the network from the MVP computer as .m1 files to gain the highest resolution available. Since these profiles start deeper, they are less prone to erroneous values and are therefore manually checked for outlier values in the SSM interface. Once the profiles have been loaded and filtered or inspected, they are transmitted by SSM over the network to the Kongsberg HWS for application in SIS. SSM confirms reception, or the hydrographer may inspect the updated file name in the “Runtime Parameters” tear-off upon network errors.

At least one cast is compared daily to the SVP 71 surface sound speed sensors on the HSLs to verify their accuracy in lieu of annual SVP 71 calibration. The results of the daily SSP sensor comparisons are logged in the Microsoft Excel acquisition log to track instrument health. Deviations from this procedure are outlined in the Descriptive Report for the affected survey.

Data collection for the XBT system is controlled by the MK21 software and the buffered I/O stores all the data until it can be read by the operating system. Every data point is time stamped by an independent clock on the MK21 to ensure no data is lost of skipped. The MK21 is controlled by either a laptop or desktop PC computer via USB. The operator uses the computer to select the type of probe to be launched along with other parameters to be stored such as date, time, and latitude/longitude (by manual input or NMEA string). The computer performs system diagnostics and prelaunch tests and then indicates the probe is ready for launch. The computer then receives probe data during the descent and displays and stores the information. The XBT data is easily translated to an ASCII text (.edf file) that Sound Speed Manager can process into CARIS SVP format files. Since the XBT data itself contains no salinity data, Sound Speed Manager creates CARIS SVP files using the depth-temperature data from the XBT augmented with salinity data from the World Ocean Atlas.

All sound speed casts saved to the SSM database are exported into a .svp file that is readable in CARIS HIPS. Casts are progressively concatenated per sheet, including all casts taken within the sheet limits. This concatenated file is applied to all HDCS data using the “Nearest in distance within time” algorithm, using the time interval suggested by the Hydrographer in Charge during acquisition. This time interval is generally four hours, but may be reduced if necessitated by environmental conditions.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

S220 measures surface sound speed values with a SVP 70 probe, while all HSLs use SVP 71 probes. The SVP probes supply the MBES with real-time values, which applies a median filter and corrects for the flat-faced transducer's refraction. During acquisition, the HIC adjusts this filter's length to capture variability while suppressing bubble sweep-down errors. HICs monitor the surface sound speed for a > 2 m/s change, which requires a new cast using the methods described in C.5.1.

Data Processing Methods and Procedures

Surface sound speed data are not post-processed.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

The final uncertainty for soundings is calculated within CARIS HIPS using the Compute TPU tool. CARIS HIPS computes the TPU based on the vessel's static and dynamic measurements, project specific tidal referencing, ERS positioning, and sound speed values. The TPU section of the HVF captures fixed estimates of uncertainty. Uncertainty values for the multibeam and positioning systems are compiled from manufacturer specification sheets for each sensor, and from those set forth in Section 4.2.3.8 of the 2014 FPM. CARIS HIPS also applies a sonar device model for uncertainty values associated with the sounding detections.

Tidal uncertainty is captured in the TCARI grid supplied with the project. Sound speed uncertainty is estimated based on cast frequency and distribution, with a typical value of 2 m/s employed unless otherwise specified in the DR. Real-time sonar uncertainties are provided via EM 2040 or EM 710 MBES data, and positioning errors are provided via the Applanix Delayed Heave RMS. Following post-processing of the real-time vessel motion, recomputed uncertainties of navigation and ellipsoidal height are applied in CARIS HIPS via a Smoothed Best Estimate of Trajectory (SBET) RMS file generated in Applanix POSPac.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		FA_2805_EM2040	FA_2806_EM2040	FA_2807_EM2040	FA_2808_EM2040	FA_S220_EM710
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		0.50 meters	0.50 meters	0.50 meters	0.50 meters	0.50 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
All Platforms	Real-time sonar uncertainties are provided via EM2040 or EM710 MBES data, and positioning errors via Applanix Delayed Heave RMS.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

The composite source file (CSF) in S-57/.000 format provided with the Project Instructions is the primary source for shoreline feature verification. The original project file is imported into CARIS BASE Editor, converted to a .hob file, clipped to the sheet limits for the specific survey, and named H#####_Feature_File.hob to be utilized during field verification. Additionally, all bottom samples to be investigated are provided to the field in the project reference file (PRF). All hob files are re-exported to S-57/.000 format for data submission.

Fairweather personnel conduct limited shoreline verification during periods when the tide is less than 0.5m above Mean Lower-Low Water (MLLW) as directed by section 3.5.5.3 of the FPM. Detached positions (DPs) are acquired and edits to the daily field feature files are recorded on boat sheets. An inshore limit buffer line, defined by the distance seaward from the Mean High Water (MHW) line at the scale of the largest chart in the area, is provided with the Project Instructions. This inshore limit buffer line is used in the shoreline acquisition software and on the boat sheet as a reference, and is utilized as described in section 1.1.2 of the HSSD. The NALL is determined in the field as the farthest offshore of one of the following; the MHW inshore limit buffer specified above, the 3.5-meter depth contour, or the inshore limit of safe navigation as defined by the HSSD. All shoreline features from the CSF seaward of the NALL are verified (including an update to depth and/or position as necessary) or disproved during operations. Features inshore of the NALL are not addressed, and features of an ambiguous nature include remarks for further clarification.

Specifically assigned features may be investigated that are inshore of the NALL in accordance with the associated instructions for a given project area.

Detached positions (DPs) acquired during shoreline verification indicate new features, revisions to source features, or source features not found in the field. They are recorded as targets in HYPACK and on boat sheets.

Data Processing Methods and Procedures

During shoreline verification, field detached positions (DP) are acquired as HYPACK .tgt files. Tidal corrections for new/updated heights on features are applied in PydroXL via the Shoreline Attribution Machine (SHAM) program within Charlene. This program takes the observed time (obstim) and observed depth (obsdept) attributes from the Final Feature File that are populated following field investigation and uses the TCARI grid or ERTDM separation model to perform a tidal correction.

New features and any updates to the composite source shoreline, such as ledges or reefs, are acquired or digitized with S-57 attribution and compiled from the field daily files into the H#####_FFF.hob. Updates to source shoreline features primarily include a change in depth/height, position, or S-57 classification. If the position of a feature changes, the existing feature is deleted and a new feature created in the new location. Any changes to depth/height or S-57 classification are done so as an update to the S-57 object with the inclusion of NOAA's object attributes.

The SORIND and SORDAT S-57 attribute fields for new features or modified source features are updated to reflect the information for the associated survey number and date (US,US,graph,H#####). All new or modified features are S-57 attributed as applicable and descriptively attributed as New or Update respectively. All unmodified source features retain their original SORIND and SORDAT values. Assigned features that are addressed but not updated are descriptively attributed as Retain and unaddressed assigned features are attributed as Not Addressed. Short descriptive comments taken from the boat sheets or DP forms are listed under the Remarks field.

For significant features that deserve additional discussion, the Hydrographer may include a recommendation to the cartographer in the Recommendations field, along with the notes and investigation methods provided in the Remarks field. Features that are disproved or that do not adequately portray the shoreline are descriptively attributed as Delete in the H#####_FFF.hob layer. Features with the attribution of Delete retain their original SORIND and SORDAT values and include a recommendation from the Hydrographer along with an informative remark.

Images are named in accordance with the convention set forth in HTD 2018-5. They are included with the survey data and stored in the Multimedia folder with the deliverables. References to the images are comma delimited and listed with the file extension in the "Images" attribute for the specific feature.

The H#####_FFF.hob along with CARIS HIPS BASE surface(s) are reviewed to compare MBES coverage and features simultaneously. The current NOAA object catalog is used for all CARIS software for processing and the version is documented in the individual Descriptive Reports, along with any deviations in shoreline processing from those listed above. The final shoreline deliverable is an S-57 (*.000) file included with the processed data.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

HSD-OPS recommends bottom sample sites in the project reference file (PRF). The field unit examines these proposed sample sites and potentially eliminates some based on the actual depths found during survey operations (if deeper than 80 m), or supplements them with good anchorage positions located by the ship. Bottom sample locations may also be adjusted by the field unit to investigate areas of interest as determined through analysis of the backscatter data in an effort to ground truth returns of different intensities.

Field units acquire bottom samples with the image grab sampler, as described in Section A.8.1. This method utilizes a GoPro camera and lights to capture sea floor imagery. After starting the video recording, the sampler is lowered rapidly to the bottom until the line goes slack, then lifted slowly to approximately 0.5 m above the seafloor. This elevation is maintained for a few seconds to capture the environment before retrieving the sampler to the surface. The physical sample from the Petite Ponar grab is set on the deck for visual and textural analysis. A picture is taken of the sample on deck. The physical sample analysis further verifies the sediment type for S57 attribution classification, with the most prevalent bottom type listed first. Attribution is recorded in the field on a bottom sample form and may also be entered into a CARIS feature layer. The sample site's "Nature of Surface" (NATSUR) is characterized as “unknown” upon the field unit’s failure to obtain a sample after three attempts. Field units discard samples after completing analysis.

Data Processing Methods and Procedures

All bottom samples are entered or imported into the Final Feature File as Seabed Area (SBDARE) point features and attributed to match the recorded characteristics. A minimum of three images are selected from each GoPro video to satisfy the requirements as described in HTD 2018-4. Sheet managers link the sample images to the corresponding S-57 SBDARE attributed feature within the Final Feature File.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Preliminary data cleaning is performed daily during night processing following acquisition, addressing the most blatant fliers and blowouts. Cleaning is primarily done in Subset Editor, rejecting data that cause fliers in the CUBE grid. Following this gross cleaning, Flier Finder, part of the QC Tools package of HydrOffice, is used to assist the search for spurious soundings. Flier Finder is run iteratively until all remaining flagged fliers are deemed to be valid aspects of the steep slopes and dynamic nature of the seafloor. Additionally, the uncertainty, hypothesis count, hypothesis strength, and node standard deviation child layers of the surface in CARIS HIPS are utilized to identify potential problem areas.

D.1.2 Designated Sounding Selection

In depths less than 20 meters in areas of navigational significance where the bathymetric surface does not adequately depict the depth for the given area, a designated sounding may be selected. Designated soundings are selected in accordance with section 5.2.1.2.3 of the HSSD. Detailed designated sounding searches in Subset Editor are only performed in regions expected to contain variation not captured in the standard grid, or when searching for known features. Generation of higher resolution grids than required for the depth range may be used to guide the search for designated soundings.

D.1.3 Holiday Identification

Pydro's "Holiday Finder" tool scans the CUBE surfaces for any empty grid nodes that are surrounded by populated nodes, and flags holidays dependent on the criteria set by the coverage requirements. All flags are then visually inspected to determine the validity of each holiday, and all confirmed holidays are addressed either by acquiring additional data over the gaps, or explaining the cause and likelihood of hazards within each gap.

D.1.4 Uncertainty Assessment

Pydro’s “Grid QA v.5” function verifies that all surfaces meet HSSD’s uncertainty specifications. This tool plots node percentage histograms, which demonstrate surface compliance with the uncertainty standards set forth in the HSSD.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

As a quality control measure, approximately 4% (for complete coverage surveys) or 8% (for set line spacing surveys) of the linear nautical mile total of mainscheme multibeam lines are run on each survey as crosslines. Crosslines are run in accordance with Section 5.2.4.2 of the HSSD. Following acquisition, a surface containing strictly data from mainscheme lines and a surface containing strictly data from crosslines are generated and analyzed with the Compare Grids tool in Pydro. This tool analyzes the difference between the two grids and outputs a difference surface between the depths, as well as a second surface that contains the fraction of NOAA allowable error represented by that depth difference for each node. Additionally, statistics/ distribution summary plots of the difference surface and the fraction of allowable error are generated to provide easily interpretable analyses of the differences between the surfaces.

D.1.5.2 Junctions

Survey managers perform junction analyses between the current survey and all adjacent contemporary surveys. To ensure proper overlap between surveys, approximately one bathymetric swath of overlap is acquired at each junction. Surface based and statistical analysis of the junctions is performed through the Compare Grids tool as described in D.1.5.1.

D.1.5.3 Platform to Platform

Agreement and continuity of data collected between platforms is visually investigated by the survey manager to ensure consistency and highlight any potential biases in the data. To aid in the determination of potential biases, the depth child layer of the surfaces is inspected with an increased vertical exaggeration, generally between five and ten times greater.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Processed backscatter mosaics are inspected in CARIS HIPS to ensure that no data were omitted during processing, and that no errors occurred in mosaic generation.

D.2.2 Contact Selection Methodology

Not applicable.

E. Approval Sheet

As Chief of Party, I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies noted herein.

Approver Name	Approver Title	Date	Signature
CAPT Marc Moser, NOAA	Chief of Party	07/22/2020	MOSER.MARC.STANTON.1163193902 MOSER.MARC.STANTON.1163193902 2020.07.22 11:25:16 -07'00'
LT Marybeth Head, NOAA	Operations Officer	07/22/2020	HEAD.MARYBETH.1474026490 Digitally signed by HEAD.MARYBETH.1474026490 Date: 2020.07.22 09:08:20 -07'00'
HCST Alissa Johnson	Chief Survey Technician	07/22/2020	Alissa Johnson Digitally signed by Alissa Johnson Date: 2020.07.22 09:01:43 -07'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	280x_Wiring_Diagram.pdf S220 Wiring Diagram.pdf
Sound Speed Sensor Calibration	Sound_Speed_Sensor_Calibration_Reports.pdf
Vessel Offset	Launch_Offset_Verification_2019.pdf Static_Draft_Measurements_2019.pdf Dynamic_Draft_Table_2019.pdf
Position and Attitude Sensor Calibration	2805_POS_GAMS_Report_2019.pdf 2806_POS_GAMS_Report_2019.pdf 2807_POS_GAMS_Report_2019.pdf 2808_POS_GAMS_Report_2019.pdf S220_POS_GAMS_Report_2019.pdf
Echosounder Confidence Check	2019_PatchTests.pdf HSRR_2019_Reference_Surfaces.pdf
Echosounder Acceptance Trial Results	N/A