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-R385-KR-20
Time Frame:	June - September 2020

LOCALITY

State(s):	Alaska
General Locality:	Norton Sound, Alaska

2020

CHIEF OF PARTY
Thomas Morino

LIBRARY & ARCHIVES

Date:

Table of Contents

List of Figures

Data Acquisition and Processing Report

Terrasond
Chief of Party: Thomas Morino
Year: 2020
Version: 19.4
Publish Date: 2020-11-30

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 Qualifier 105 (Q105)

Vessel Name	Qualifier 105 (Q105)	
Hull Number	338192000 (MMSI)	
Description	The Q105 is a 105' aluminum-hulled vessel that is owned and operated by Support Vessels of Alaska (SVA). It is home-ported in Homer, Alaska and has been chartered by TerraSond every year since 2013 to complete NOAA task orders as well as other projects along the Alaska coast. The Q105 carries a USCG COI (200-mile offshore). It is powered by three Detroit D-60 diesel engines and has a 4,000 nautical mile endurance. Features include a 6ton deck crane, A-frame, davit, survey skiff, and hydraulic over-the-side MBES arm. On this project, the Q105 surveyed as the primary survey platform, housing all staff and operating on a 24/7 schedule. It was used to collect MBES data including sound speed profiles, deploy offshore tide gauges, collect bottom samples, and deploy/ operate the ASV-CW5 vessel. Preliminary (field) data processing was also completed aboard the vessel.	
Dimensions	*LOA*	32 meters
	Beam	9.1 meters
	Max Draft	1.8 meters
Most Recent Full Static Survey	*Date*	2019-03-23
	Performed By	TerraSond
Most Recent Full Offset Verification	*Date*	2020-06-21
	Method	Taped applicable offsets

Figure 1: The Qualifier 105 (RV) outside of Sand Point, Alaska, 2017

A.1.2 ASV-CW5 (ASV)

Vessel Name	ASV-CW5 (ASV)	
Hull Number	CW76	
Description	The 18' (5.5 m) aluminum-hulled vessel ASV-CW5 (C-Worker 5 model), owned and operated by L3Harris ASV, was used to acquire MBES data on this project. The vessel has been used by TerraSond on NOAA task orders in Alaska each year since 2016. The unmanned vessel is propelled by a single 57 HP Yanmar diesel engine. Once deployed from the larger vessel it was operated in an "unmanned-but-monitored" mode, at ranges of up to 3 km from the larger vessel. It collected MBES data on lines parallel to the Q105 and also surveyed the shallower portions of the survey areas. The vessel worked a 24/7 schedule with an endurance of approximately 4-5 days between refueling.	
Dimensions	*LOA*	5.5 meters
	Beam	1.7 meters
	Max Draft	0.9 meters
Most Recent Full Static Survey	*Date*	2019-06-29
	Performed By	TerraSond

Most Recent Full Offset Verification	*Date*	2020-06-21
	Method	Taped applicable offsets

Figure 2: ASV-CW5 south of Nunivak Island, Alaska. July, 2019

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Teledyne Reson SeaBat T50-R

The Teledyne Reson SeaBat T50-R was used on both the Q105 and ASV-CW5 for multibeam echosounder (MBES) data collection. The T50 platform offers a wide variety of configuration options. Two were utilized on this project: The first, mounted on the Q105, was the SeaBat T50-R integrated dual head (IDH) system. This system consisted of two transmit (Tx) arrays, two receive (Rx) arrays, and one topside rackmount processor. On this vessel the wet end components were mounted on a hydraulic arm on the vessel's port side, approximately midship. The IDH configuration utilizes two T50-R sonar units tilted 30 degrees outward to improve swath coverage at shallow depths. The system was capable and configured to simultaneously ping from both sonar heads in order improve along-track data density.

The second system, consisting of a transmit (Tx) array, receive (Rx) array, and a topside rackmount processor, was used on the ASV-CW5. On this vessel wet-end components were hull-mounted on the vessel's keel, approximately midship. Specifications of the T50-R MBES are as follows:

Sonar Operating Frequency: 200 or 400 kHz (400 used on this project)
Along-track Beamwidth: 1 degree at 400 kHz
Across-track Receiver Beamwidth: 0.5 degrees at 400 kHz
Max Ping Rate: 50 pings/s (normally 10 pings/s used on this project)
Pulse Length: 30 to 300 microseconds (300 used on Q105, 30-60 on ASV)
Number of Beams: 512 max at 400 kHz (1024 for IDH system)
Max Swath Angle: 165 degrees (220 degrees for IDH)
Depth Range: 0.5 to 150 meters at 400kHz
Depth Resolution: 0.006 meters

Accuracy checks on the T50-R IDH are as follows:

1. A bar check: A formal bar check was completed on JD 175 and yielded good results. Mean echosounder agreement (with vessel offsets applied) to the actual bar depth was 0.045 m for processed data and 0.038 for real time data.

2. Echosounder comparisons: The T50 systems on each echosounder were compared weekly to each other. Results were good, with the vessels always comparing to 0.08 m or better.

3. Crossline comparisons: For each survey sheet, crossline soundings were compared to surfaces created from the mainscheme data. Results were excellent, with at least 95% of crossline soundings comparing to the mainscheme within IHO Order 1a.

4. Three lead lines were performed, one on JD 186 and two on JD 261 that returned differences of MBES nadir depth of 0.115 m, 0.038 and 0.045 m, respectfully. Results were deemed acceptable given the variances associated with lead line checks.

Depth checks including bar check and echosounder comparisons are available in Appendix V. Crossline results are available in each project DR.

<table>
<tr><td><i>Manufacturer</i></td><td>Teledyne Reson</td></tr>
<tr><td><i>Model</i></td><td>SeaBat T50-R</td></tr>
<tr><td><i>Inventory</i></td><td>
<table>
<tr><td><i>338192000 (MMSI)</i></td><td>
<table>
<tr><td><i>Component</i></td><td>Topside</td><td>Port Tx Array</td><td>Port Rx Array</td><td>Starboard Tx Array</td><td>Starboard Rx Array</td></tr>
<tr><td><i>Model Number</i></td><td>T50 RSP INS</td><td>TC 2181</td><td>EM 7218</td><td>TC 2181</td><td>EM 7218</td></tr>
<tr><td><i>Serial Number</i></td><td>5753319021</td><td>1019055</td><td>2919051</td><td>2519024</td><td>2919039</td></tr>
<tr><td><i>Frequency</i></td><td>N/A</td><td>400 kHz</td><td>N/A</td><td>400 kHz</td><td>N/A</td></tr>
<tr><td><i>Calibration</i></td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td><i>Accuracy Check</i></td><td>N/A</td><td>2020-06-23</td><td>2020-06-23</td><td>2020-06-23</td><td>2020-06-23</td></tr>
</table>
</td></tr>
<tr><td><i>CW76</i></td><td>
<table>
<tr><td><i>Component</i></td><td>Topside</td><td>Rx Array</td><td>Tx Array</td></tr>
<tr><td><i>Model Number</i></td><td>T-50 RSP</td><td>EM 7218</td><td>TC 2181</td></tr>
<tr><td><i>Serial Number</i></td><td>3516077</td><td>274117</td><td>4912145</td></tr>
<tr><td><i>Frequency</i></td><td>N/A</td><td>N/A</td><td>400kHz</td></tr>
<tr><td><i>Calibration</i></td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td><i>Accuracy Check</i></td><td>N/A</td><td>2020-06-23</td><td>2020-06-23</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

Figure 3: Teledyne Reson SeaBat T50-R IDH configuration mounted on Q105's hydraulic arm.

Figure 4: Teledyne Reson SeaBat T50-R single head configuration mounted on the ASV-CW5. Note submersible IMU mounted directly on T-50 Mount.

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

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

A.4.3.1 St. Michaels ERTDM Validation Station (9999770) RBR solo³ D, Solinist Barologger

Water level measurement gauge at St. Michaels

<table>
<tr><td><i>Manufacturer</i></td><td>St. Michaels ERTDM Validation Station (9999770)</td></tr>
<tr><td><i>Model</i></td><td>RBR solo³ D, Solinist Barologger</td></tr>
<tr><td><i>Inventory</i></td><td>
<table>
<tr><td><i>Component</i></td><td>Tide Gauge</td><td>Barometer</td></tr>
<tr><td><i>Model Number</i></td><td>RBRsolo³ D</td><td>LT Barologger</td></tr>
<tr><td><i>Serial Number</i></td><td>K195203</td><td>2118942</td></tr>
<tr><td><i>Calibration</i></td><td>2020-05-28</td><td>2020-02-28</td></tr>
</table>
</td></tr>
</table>

A.4.3.2 Koyuk Tide Station (9469031) WaterLOG H-350, RBR solo³ D, Solinist Barologger, Septentrio PolaRx5, Septentrio Sepchoke, WaterLOG H-335

Water Level Measurement Gauge located at Koyuk

<table>
<tr><td><i>Manufacturer</i></td><td>Koyuk Tide Station (9469031)</td></tr>
<tr><td><i>Model</i></td><td>WaterLOG H-350, RBR solo³ D, Solinist Barologger, Septentrio PolaRx5, Septentrio Sepchoke, WaterLOG H-335</td></tr>
<tr><td><i>Inventory</i></td><td>
<table>
<tr><td><i>Component</i></td><td>Tide Gauge</td><td>Tide Gauge</td><td>Tide Gauge</td><td>Barometer</td><td>GOES Radio</td><td>GNSS Reciever</td><td>GNSS Antenna</td><td>Bubbler</td></tr>
<tr><td><i>Model Number</i></td><td>H-350 XL</td><td>RBRsolo³ D</td><td>RBRsolo³ D</td><td>Solinist Barologger 3001</td><td>H-222DASE</td><td>PolaRx5</td><td>SEPCHOKE_B3E6</td><td>H-335</td></tr>
<tr><td><i>Serial Number</i></td><td>1643</td><td>204937</td><td>204936</td><td>0012118936</td><td>1543</td><td>3048292</td><td>5614</td><td>2880</td></tr>
<tr><td><i>Calibration</i></td><td>2020-03-24</td><td>2020-06-22</td><td>2020-06-22</td><td>2020-02-28</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>
</td></tr>
</table>

A.4.3.3 Stebbins Tide Station (9468151) WaterLOG H-350, RBR solo³ D, WaterLOG H-223, WaterLOG H-355, Barologger Edge, NexSens CB-450, Septentrio PolaNt-x MF, Septentrio AsteRx-SB

Water Level Measurement Gauge and GNSS Tide buoy located at Stebbins

Manufacturer	Stebbins Tide Station (9468151)					
Model	WaterLOG H-350, RBR solo³ D, WaterLOG H-223, WaterLOG H-355, Barologger Edge, NexSens CB-450, Septentrio PolaNt-x MF, Septentrio AsteRx-SB					
Inventory	*Component*	Tide Gauge	Tide Gauge	Bubbler	Barometer	N/A
	Model Number	H-350	RBRsolo³ D	H-355	Barologger Edge	N/A
	Serial Number	1616	201622	1800	0012118659	N/A
	Calibration	2020-03-24	2020-04-09	N/A	2020-02-28	N/A
	Component	GNSS Receiver	Datalogger	GNSS Antenna	Data Buoy	Modem
	Model Number	AsteRx-SB	CR-300	PolaNt-x	CB-450	Iridium
	Serial Number	5101174	11125	15504	J1B9NW	J1B9NW
	Calibration	N/A	N/A	N/A	N/A	N/A

A.4.3.4 Eastern and Western Norton Sound GNSS Tide Buoy NexSens CB-450, Septentrio PolaNt-x MF, Septentrio AsteRx-SB, Iridium Modem

One GNSS Tide Buoy collected data for two 30 day intervals at two different locations in Norton Sound. Same buoy and instruments used for the two locations.

Manufacturer	Eastern and Western Norton Sound GNSS Tide Buoy					
Model	NexSens CB-450, Septentrio PolaNt-x MF, Septentrio AsteRx-SB, Iridium Modem					
Inventory	*Component*	GNSS Receiver	GNSS Antenna	Data Buoy	Modem	Datalogger
	Model Number	AsteRx-SB	PolaNt-x	CB-450	Iriduim	CR-300
	Serial Number	5101175	15531	J1B9H0	J1B9H0	20249
	Calibration	N/A	N/A	N/A	N/A	2021-01-09

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 POSMV Wavemaster II

The primary components are two GNSS antennas, a IP68-rated (submersible) inertial measurement unit (IMU), and a topside processor. On the ASV, the POSMV IMU was co-located with the MBES sonar as closely as possible and the GNSS antennas were mounted in locations that gave a clear view of the sky.

On the ASV, the POSMV utilized POS software version 9.0 (firmware version 9.03 and POSView version 9.02)

Calibrations consisted of an initial GAMS (GPS-azimuth measurement subsystem) calibration and alignment with the MBES frame of reference via standard patch test methodology.

Manufacturer	Applanix					
Model	POSMV Wavemaster II					
Inventory	*CW76*	*Component*	IMU	GNSS Antenna 1	GNSS Antenna 2	POS Computer System (PCS) Topside
		Model Number	Type 45	AT1675-540TS	AT1675-540TS	POS MV V5
		Serial Number	4581	18499	18498	11463
		Calibration	N/A	N/A	N/A	N/A

A.5.1.2 Applanix POSMV Oceanmaster

This system is branded by Teledyne Reson with a T-series IMU-30 but is a repackaged Applanix POSMV Oceanmaster integrated with the Reson T-50 dual-head system.

The primary components are two GNSS antennas, a IP68-rated (submersible) inertial measurement unit (IMU), and a topside processor. The IMU was co-located with the dual head MBES sonars as closely as possible and the GNSS antennas were mounted in locations that gave a clear view of the sky. The INS system is built into the same rack-mount sonar processor topside as the dual head multibeam, which simplifies and streamlines connections and communications between the systems.

On the Q105, the system utilized POS software version 10.2 (firmware version 10.21 and POSView version 10.2).

Calibrations consisted of an initial GAMS (GPS-azimuth measurement subsystem) calibration and alignment with the MBES frame of reference via standard patch test methodology.

Manufacturer	Applanix					
Model	POSMV Oceanmaster					
Inventory	*Q105*	*Component*	IMU	GNSS Antenna 1	GNSS Antenna 2	Rack Mount Topside
		Model Number	T-Series IMU-30	AT1675-540TS	AT1675-540TS	T50 RSP INS
		Serial Number	1010763	17707	17643	5753319021
		Calibration	N/A	N/A	N/A	N/A

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

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

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 Teledyne Oceanscience RapidCast

A Teledyne Oceanscience RapidCast system was used on the Q105 to deploy a sound speed profiler while underway during survey operations.

The system utilized RapidCast Interface Software V1.5.1 for configuring and controlling the system.

The ASV-CW5 was not equipped with a sound speed profiling system.

<table>
<tr><td><i>Manufacturer</i></td><td colspan="3">Teledyne Oceanscience</td></tr>
<tr><td><i>Model</i></td><td colspan="3">RapidCast</td></tr>
<tr><td rowspan="4"><i>Inventory</i></td><td rowspan="4"><i>Qualifier 105</i></td><td><i>Component</i></td><td>Sound Speed Deployment Winch</td></tr>
<tr><td><i>Model Number</i></td><td>RapidCast</td></tr>
<tr><td><i>Serial Number</i></td><td>147</td></tr>
<tr><td><i>Calibration</i></td><td>N/A</td></tr>
</table>

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 Valeport RapidPro SVT Soud Speed Profiler

A Valeport rapidPro SVT was used on the Q105 as the primary system to collect sound speed profiles on this project up to JD 227.

The sensor, which was designed to be used with the Oceanscience RapidCast deployment system, features a relatively fast measurement rate (32 Hz) to adequately sample sound speed through the water column when dropping at rates of up to 5 meters per second.

Valeport Connect software (version 1.0.7.0) was used to interface with and download data from the sensor.

<table>
<tr><td><i>Manufacturer</i></td><td colspan="3">Valeport</td></tr>
<tr><td><i>Model</i></td><td colspan="3">RapidPro SVT Soud Speed Profiler</td></tr>
<tr><td rowspan="4"><i>Inventory</i></td><td rowspan="4"><i>Qualifier 105</i></td><td><i>Component</i></td><td>Sound Speed Profiler</td></tr>
<tr><td><i>Model Number</i></td><td>RapidPro SVT</td></tr>
<tr><td><i>Serial Number</i></td><td>71026</td></tr>
<tr><td><i>Calibration</i></td><td>2020-05-05</td></tr>
</table>

A.6.3.2 Valeport SWiFT SVP

A Valeport SWiFT SVP was used on the Q105 as a backup to the RapidPro probe on this project until JD 227, when it then became the primary sound speed sensor.

The SWiFT is also designed to be used with the RapidCast deployment system and features a 32 Hz measurement rate, but is lighter and smaller than the RapidPro, making it ideal for shallow water casts.

Valeport Connect software (version 1.0.7.0) was used to interface with and download data from the sensor.

Manufacturer	Valeport		
Model	SWiFT SVP		
Inventory	*Qualifier 105*	*Component*	Sound Speed Profiler
		Model Number	SWiFT SVP
		Serial Number	68632
		Calibration	2020-06-05

A.6.4 TSG Sensors

A.6.4.1 AML Oceanographic Micro-X

Both vessels utilized AML Oceanographic sound speed sensors to measure sound speed at the multibeam sonar heads (surface sound speed sensors). This data stream was interfaced directly with the Reson MBES system to provide sound speed for beam-forming purposes.

Each sensor consisted of an AML Micro-X housing with a SV-XChange sensor tip. In these systems, the sensor tip (not the housing) carries the calibration.

As a QC check, during each sound speed profile cast the value reported by the surface speed sensor aboard the Q105 was noted in the acquisition log for comparison with the sound speed profile's value at the same depth. These compared well, with the mean difference of 0.117 m/s with a standard deviation of 1.151 m/s. Results are available with each project DR.

Manufacturer	AML Oceanographic			
Model	Micro-X			
Inventory	*Qualifier 105*	*Component*	Surface sound Speed Sensor - Housing	Surface Sound Speed Sensor - Sensor
		Model Number	Micro-X	SV-XChange
		Serial Number	11980	203398
		Calibration	N/A	2020-03-26
	ASV-CW5	*Component*	Surface sound Speed Sensor - Housing	Surface Sound Speed Sensor - Sensor
		Model Number	Micro-X	SV-XChange
		Serial Number	11175	203266
		Calibration	N/A	2020-03-26

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*
QPS	Qinsy	9.2.0	Acquisition
Teledyne Reson	7k Sonar UI	5.0.0.12	Acquisition
Teledyne Oceanscience	RapidCAST Interface	1.5.1	Acquisition
Valeport	Connect	1.0.7.0	Acquisition
L3Harris-ASV	ASView	2020	Acquisition
DJI	Pilot	1.9.0	Acquisition
Applanix	POSView	9.0.2 (ASV), 10.2 (Q105)	Acquisition
NOAA/UNH/CCOM	Sound Speed Manager	2019.2.6	Processing
Applanix	POSPac	8.4 SP2	Processing
Teledyne CARIS	HIPS & SIPS	10.4.21	Processing
NOAA	Pydro	19.4	Processing
Agisoft	PhotoScan Professional	1.6.5	Processing
QPS	Fledermaus FMGT	7.9.3	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Wildco Standard Ponar

A Wildco Standard Ponar, a Van Veen style grab sampler, was used to acquire all bottom samples.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

For this project, the top-center of the IMUs served as the Central Reference Point (CRP) on each vessel.

The IMU was co-located as closely as possible with the sonar heads. On the Q105 this resulted in the IMU being mounted directly on the standard integrated dual head MBES bracket, and on the ASV the IMU was mounted on a standard T-50 MBES bracket with an adapter plate to match the IMU's bolt pattern.

The co-location of the CRP and MBES sonars greatly reduced the complexity of the vessel surveys, which were completed with measuring tape methods on June 21, 2020 on both vessels.

Offset from the CRP down to the MBES was measured directly by tape to a physical point on the sonar, from where the manufacturer-provided acoustic center offsets provided in the system user manuals were applied.

Offset from the CRP up to the static draft (measure-down) point--or point from where draft measurements would be made--was also measured directly by tape.

Offset from the CRP up to the POSMV antennas were also directly measured by tape on the ASV. On the Q105, which had a large IMU lever arm, a value derived by laser scanner in March 2019 was used initially but refined following mobilization using calibrated installation lever arms derived from Applanix POSPac software.

Note that per CARIS Technical Bulletin "HIPS and SIPS Technical Note Sound Velocity Correction for Teledyne Reson 7k Data", the HVF files for the T-50 MBES system on the ASV was configured as dual-head with separate Rx and Tx array offsets even though they were physically single-head systems. The offsets for the separate Rx and Tx acoustic centers were derived from the user manuals for the systems. For the true dual-head configuration on the Q105, a common center on the dual head bracket is used for the offsets to the transducer.

Refer to Appendix III for vessel offset survey results.

B.1.1.1 Vessel Offset Correctors

Vessel	Qualifier 105			
Echosounder	Teledyne Reson T-50 IDH			
Date	2020-06-21			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.000 meters	0.010 meters
		y	0.091 meters	0.010 meters
		z	0.233 meters	0.020 meters
		x2	0.000 meters	0.010 meters
		y2	0.091 meters	0.010 meters
		z2	0.233 meters	0.020 meters
	Nav to Transducer	*x*	0.000 meters	0.010 meters
		y	0.091 meters	0.010 meters
		z	0.233 meters	0.020 meters
		x2	0.000 meters	0.010 meters
		y2	0.091 meters	0.010 meters
		z2	0.233 meters	0.020 meters
	Transducer Roll	*Roll*	30.000 degrees	
		Roll2	-30.000 degrees	

Vessel	CW76			
Echosounder	Teledyne Reson T-50			
Date	2020-06-21			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.000 meters	0.010 meters
		y	0.110 meters	0.010 meters
		z	0.187 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.302 meters	0.010 meters
		z2	0.234 meters	0.010 meters
	Nav to Transducer	*x*	0.000 meters	0.010 meters
		y	0.110 meters	0.010 meters
		z	0.187 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.302 meters	0.010 meters
		z2	0.234 meters	0.010 meters
	Transducer Roll	*Roll*	0.000 degrees	

B.1.2 Layback

Layback calculations are not applicable to this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

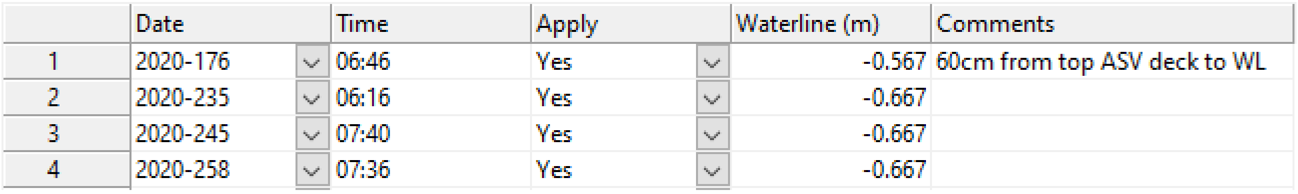
Vessel static draft (waterline) measurements were taken to correct for the depth of the vessel’s sonars below the water level. Draft was measured when sea conditions were calm enough to obtain a high confidence value. Measurements were also taken whenever the potential to significantly change the draft was experienced, such as after fueling or adjustments in ballast.

On the Q105, a static draft ("measure-down") was recorded in the following manner: With the vessel at rest, a calibrated (corrected/checked by tape) plastic pole was used to measure the distance from a designated measure-down (MD) point to the water. The MD point was located on the vessel rail/gunwale directly above the CRP on the vessel's port side, midship.

On the ASV-CW5, the static draft was recorded in the following manner: Draft markings on the vessel's starboard side were visually examined when the vessel was alongside the Q105, and the value at their intersection with the water was noted. The draft marks represented the vertical distance from the MD point, which was the vessel's deck directly above the CRP.

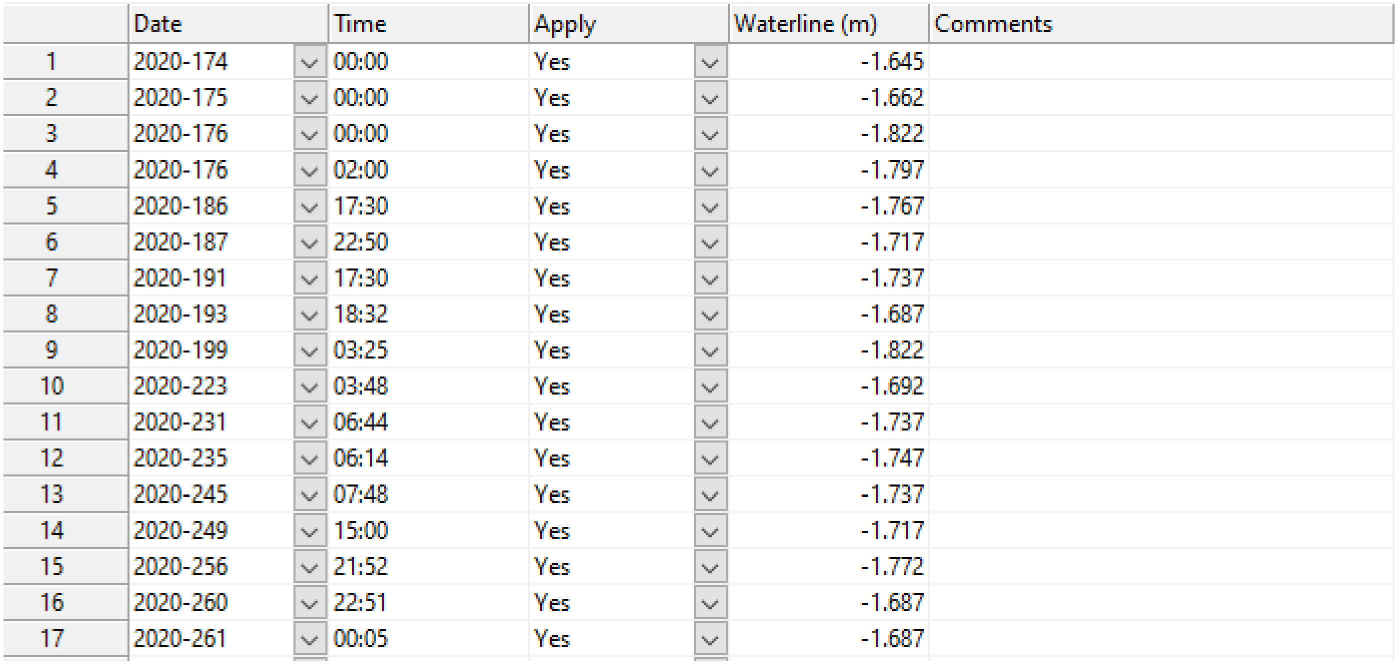
For each vessel, the CRP to waterline correction value was computed by subtracting the above measurement from the known offset between the CRP and MD point. The resulting value was entered as a waterline offset in the CARIS HVF file. This value was always negative in this configuration since the CRP on both vessels was under the water level.

Note only initial corrections are shown below for each vessel due to the inability to include all values in the XML DAPR. However, the following images show all the waterline correction values entered into the CARIS HVF files for each vessel.



	Date	Time	Apply	Waterline (m)	Comments
1	2020-176	06:46	Yes	-0.567	60cm from top ASV deck to WL
2	2020-235	06:16	Yes	-0.667	
3	2020-245	07:40	Yes	-0.667	
4	2020-258	07:36	Yes	-0.667	

Figure 5: CARIS HVF Waterlines from Static Draft Measurements - ASV-CW5



	Date	Time	Apply	Waterline (m)	Comments
1	2020-174	00:00	Yes	-1.645	
2	2020-175	00:00	Yes	-1.662	
3	2020-176	00:00	Yes	-1.822	
4	2020-176	02:00	Yes	-1.797	
5	2020-186	17:30	Yes	-1.767	
6	2020-187	22:50	Yes	-1.717	
7	2020-191	17:30	Yes	-1.737	
8	2020-193	18:32	Yes	-1.687	
9	2020-199	03:25	Yes	-1.822	
10	2020-223	03:48	Yes	-1.692	
11	2020-231	06:44	Yes	-1.737	
12	2020-235	06:14	Yes	-1.747	
13	2020-245	07:48	Yes	-1.737	
14	2020-249	15:00	Yes	-1.717	
15	2020-256	21:52	Yes	-1.772	
16	2020-260	22:51	Yes	-1.687	
17	2020-261	00:05	Yes	-1.687	

Figure 6: CARIS HVF Waterlines from Static Draft Measurements - Q105

B.2.1.1 Static Draft Correctors

Vessel		Qualifier 105	ASV-CW5
Date		2021-06-22	2021-06-24
Loading		0.067 meters	0.020 meters
Static Draft	*Measurement*	-1.645 meters	-0.567 meters
	Uncertainty	0.01 meters	0.02 meters

B.2.2 Dynamic Draft

Dynamic Draft was measured using Squat-Settlement test methodology. However, the results were not directly applied to the data since as an ERS survey the effects of dynamic draft are already accounted for in the vertical positioning of the vessel CRP.

NOTE: A squat settlement test was completed on both vessels on JD260 for this 2020 project. However, the test was not processed because the results are not applied to the data. The following text refers to the 2019 squat settlement tests completed for both vessels, which were outfit nearly identifically as 2020.

Corrections for dynamic draft were determined for each vessel by means of a squat settlement test. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal vessel speeds experienced while surveying. The values were checked against results obtained on the same vessels in prior years, with results comparing well--usually to 0.03 m or better.

The tests were competed on JD230 (2019). During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to a POS file. A survey line was run in each direction at incrementing engine RPM/ speed. Between each line set, as well as at the start and end of the test, a “static” was collected whereby the vessel would sit with engines in idle and log for a minimum of 2 minutes. The survey crew would note the time and speed of each event.

The POS file was post-processed in Applanix POSPac software to produce the PPK positioning data, which was exported to text and brought into Excel. Using the event notes, the positioning data was separated and grouped according to RPM/speed range and static. Each range was averaged to remove heave and motion. A polynomial equation was computed that best fit the static periods and then used to remove the tide component from each altitude. The residual result was the difference from static or dynamic draft. Finally, the results were averaged for each direction to eliminate any affect from the current, wind or other factors.

Four RPM/speed values were tested on the Q105, while six were tested on the ASV-CW5. These were interpolated to 0.1 meter/seconds to develop a smooth dynamic draft corrector chart, shown in the following images.

Figure 7: Graph of dynamic draft results (from 2019 tests).

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

Patch tests were conducted on both vessels to establish latency, pitch, roll, and yaw alignment values between the POSMV and the MBES systems. Patch tests were completed on site on JD176/JD177, and again near the end of the project on JD253 to reconfirm the initial values.

Industry-standard patch test procedures--summarized below--were used to determine latency, pitch, roll, and yaw correctors for the single head T-50 on the ASV.

To determine latency, a survey line was run twice – in the same direction – at low and high speeds over the feature. The data was examined in CARIS HIPS Calibration mode. Any horizontal offset of the features indicated latency between the positioning and sounding systems. A correction (in seconds) that improved the match-up was determined and entered into the HVF.

Note that the timing correction (if any) was entered into the HVF for the Transducer1 sensor instead of the navigation sensor, which resulted in the correction being applied to all positioning and attitude data (not just navigation). This was desirable because latency, determined with the POSMV, is system-wide and affects all output data. The sign of the value found also needed to be reversed since the correction was being added to the Transducer1 sonar times, instead of the navigation sensor. For this project, latency was indiscernible in the patch test data for both vessels and no correction was necessary.

To determine pitch offset, a third line was run back over the feature at low speed in the same direction as the first line. The first and third lines were examined for feature alignment. Any remaining horizontal offsets of bottom features in this line set, following latency correction, indicated the pitch offset between the attitude and sounding systems. The value that best compensated for the pitch misalignment was entered into the HVF.

Yaw offset was then determined following the corrections for latency and pitch. Survey lines run in opposite directions with outer beams overlapping the feature were examined. Any remaining horizontal offset of corresponding beams indicated a yaw offset between the sounder and motion sensor reference frames. A value that improved match-up was determined and entered into the HVF.

Roll offset was then determined. The same survey line run twice over flat bottom topography, in opposite directions, was examined. Any vertical offset of outer beams indicated a roll offset between the sounder and motion sensor reference frames. A value that brought the data into alignment was determined and entered into the HVF.

The dual-head systems utilized on the Q105 received a similar patch test, with the only exception that each sonar head was aligned separately in calibration mode to determine its own corrector.

Patch test data received standard corrections and processing prior to examination in CARIS HIPS prior to determining the calibration values. Note that the Q105 IDH and IMU were mounted on a manufacturer bracket which minimized patch test calibration values, with some values returning 0 correction.

The results of the JD253 (end of project) patch test were the same as the initial patch test completed following mobilization on JD176/JD177 for the Q105, revealing no discernible change in the patch test alignment values over the course of the project.

However, there were significant differences between the ASVs two patch tests, most noticeable in the roll value. By systematically comparing data with significant ASV overlap day-by-day over the project, it was determined an unknown event likely occurred JD215, resulting in a change in patch test values (with roll corrector changing from 0.138 degrees prior to JD215 and 0.250 degrees after, and yaw corrector changing from -0.100 to 0.400 degrees). This event was not noticed during field operations and there was no apparent damage to equipment that would be indicative of a bottom or log strike. Both offshore and nearshore surveys were being conducted with the ASV on JD215, so it is possible that the sonar or vessel made contact with driftwood, which was very common during the survey. JD253 patch test values are back-dated to JD215 in the HVF to address the issue.

B.3.1.1 System Alignment Correctors

Vessel	Qualifier 105		
Echosounder	Teledyne Reson T-50 IDH		
Date	2020-06-24		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	0.00 degrees	0.01 degrees
	Roll	0.06 degrees	0.01 degrees
	Yaw	0.00 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds
Date	2020-06-24		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	0.00 degrees	0.01 degrees
	Roll	0.06 degrees	0.01 degrees
	Yaw	0.00 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds

Date	2020-09-09		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	0.00 degrees	0.01 degrees
	Roll	0.06 degrees	0.01 degrees
	Yaw	0.00 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds
Date	2020-09-09		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	0.00 degrees	0.01 degrees
	Roll	0.06 degrees	0.01 degrees
	Yaw	0.00 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds

Vessel	ASV-CW5		
Echosounder	Teledyne Reson T-50		
Date	2020-06-24		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	-0.10 degrees	0.01 degrees
	Roll	0.138 degrees	0.01 degrees
	Yaw	-0.10 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds

Date	2020-09-09		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.01 seconds
	Navigation Time Correction	0.00 seconds	0.01 seconds
	Pitch	-0.10 degrees	0.01 degrees
	Roll	0.25 degrees	0.01 degrees
	Yaw	0.40 degrees	0.01 degrees
	Pitch Time Correction	0.00 seconds	0.01 seconds
	Roll Time Correction	0.00 seconds	0.01 seconds
	Yaw Time Correction	0.00 seconds	0.01 seconds
	Heave Time Correction	0.00 seconds	0.01 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

General Acquisition Systems Configuration

Q105 and ASV-CW5 acquisition systems were configured nearly identically.

Both vessels utilized Intel-based Windows 10 PCs for acquiring data. On the Q105, two PCs were used: One PC devoted to note-taking, monitoring deck cameras, and acquiring POSMV data running Applanix POSView, with the other PC to acquire multibeam data using QPS QINSy and Teledyne RESON Sonar UI software. On the more space-limited ASV-CW5, one PC was used for all data acquisition.

QPS QINSy data acquisition software was used to log all bathymetric data and to provide general navigation for survey line tracking. QPS QINSy was configured with inputs that included positioning and attitude data from the POSMV via network, bathymetric and backscatter data from the Reson SeaBat MBES via network, and 1-PPS timing over coax cable with 1 Hz ZDA timing string via serial cable from the POSMV.

Teledyne Reson Sonar UI software was used to monitor, configure, and tune the MBES systems. Inputs into the software included surface sound speed via serial cable and a 1-PPS timing over coax cable with 1 Hz ZDA timing string via serial cable from the POSMV.

ASV-CW5 Operations

Operations on the unmanned ASV-CW5 vessel were semi-autonomous, whereby the vessel would be directed to follow pre-defined survey lines without human intervention. However, the vessel was still monitored constantly, with two technicians dedicated to it at all times: One technician was responsible for monitoring and directing the vessel's operations, the other for monitoring and controlling the survey systems.

Obstacle avoidance, including avoidance of other vessels, depended on constant monitoring and frequent intervention by the remote vessel operator. Tools for this purpose included a streaming camera view from ASV, on-board radar, AIS system, and a forward-looking sonar. The MBES system was relied upon for water depth under the vessel. In addition, the bridge crew on the Q105 would monitor the area in front of the ASV for potential interactions, informing the ASV crew and communicating with other vessels as necessary.

The ASV-CW5 worked in a normal range of 5 km or less of the Q105. This facilitated visual monitoring and radio link strength for streaming of vessel and survey system data. The proximity also made it possible to perform all sound speed profile casts from the Q105, for which the ASV-CW5 was not configured to collect.

Since the survey PC aboard the ASV-CW5 was not directly accessible, its display was continuously streamed via wireless network to the Q105 using a remote desktop connection. This allowed the survey technician to monitor and control the systems in a manner similar to the conventional setup aboard the Q105. Raw files (XTF, DB, QPD, and POSMV) were logged locally on the ASV survey computer, which made data logging immune to radio dropouts.

Transfer of a survey line's associated raw data files (XTF, DB, and QPD) from the ASV-CW5 to the Q105 commenced soon after the collection of each line was completed. POSMV files were also transferred across the link whenever logging was stopped, approximately every 12 hours. Radio bandwidth was usually sufficient to transfer data as fast as new data was being acquired. This made it possible to process the data soon after acquisition without the need to wait to physically download it, which allowed potential issues to be detected relatively quickly. Occasionally, in shallow water with high MBES ping rates, the rate of data transfer could fall behind the rate of data acquisition, creating a backlog of un-transferred raw data aboard the ASV. When this occurred, the survey crew prioritized transfer of file types to only those necessary for immediate processing (XTF), and queued DB and POSMV files for later transfer—either by radio or USB hard drive when the ASV was physically accessible.

Although the ASV-CW5 could autonomously follow pre-defined (and relatively straight) survey lines, the current generation of technology used on this project did not have the capability to autonomously navigate based on water depth. Therefore, in nearshore shallow/complex areas where straight survey lines were not possible, constant intervention by the remote operator was necessary, with the ASV effectively operating as a remote-controlled vessel. In the data records, straight tracklines (offshore, generally deeper water) were collected in autonomous mode, while sinuous and/or nearshore tracklines were collected in remote-controlled mode.

QPS QINSy Navigation and MBES Collection

The software features many quality assurance tools, which were taken advantage of during this survey.

Using the raw echosounder depth data, the acquisition software generated a real-time digital terrain model (DTM) during data logging that was tide and draft corrected. The DTM was displayed as a layer in a plan-view layer. The vessel position was plotted on top of the DTM, along with other common data types including shape files containing survey lines and boundaries, nautical charts, waypoints, and shoreline features as necessary. Note that the DTM was only used as a field quality assurance tool and was not used during subsequent data processing. Tide and offset corrections applied to the DTM and other real-time displays had no effect on the raw data logged and later imported into CARIS HIPS. Final tide and offset corrections were applied in CARIS HIPS.

In addition to the DTM and standard navigation information, QINSy was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real-time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These included alarms for loss of time sync and critical data streams from the POSMV and Reson sonars.

Data Coverage and Density

Effort was made to ensure coverage and density requirements described in the HSSD were met.

Work was done to “Set Line Spacing” (“Option A: Multibeam Sonar Set Line Spacing without Concurrent Side Scan Sonar Coverage”), or Complete Coverage standards, as described in the HSSD depending on the survey sheet. MBES backscatter was also acquired during all MBES data acquisition. Per the project Work Instructions, line spacing was assigned at 240, or 320 meters in Set Spacing sheets.

A line plan, with lines at the required spacing by area, was developed prior to commencement of operations. Line plans with multiple orientations were made to provide options, with the orientation most suitable to weather conditions or bottom topography was utilized during operations. Line plans were periodically modified on the fly as necessary, usually by the addition of splits to develop shoals and investigation areas, or addition of diagonal crosslines.

Coverage was monitored relative to the line plans as well as the assigned survey area boundaries in realtime in the QPS QINSy acquisition software. When running lines, each vessel navigated the line as closely as possible while surveying, with the Q105 generally able to maintain average off-track errors of 5 m or less, and the ASV-CW5 1 m or less. Care was taken during run-ins and run-outs to collect data at least to the survey boundaries.

Data density requirements were met through close attention to vessel speed, ping rates, and use of best possible across-track beam density. Ping rate was capped at a relatively high rate (10 pings / second) while vessel speeds were moderated (less than 8 knots, but usually 6 to 6.5 knots, and less in shallow water) to control pings-per-meter on the seafloor. Across-track density for MBES was maximized by utilizing the “best coverage” beam mode on the T-50 sonars, generating up to 512 (single head) or 1024 (dual head) beams spaced equidistant across the swath for every ping, which was the maximum capability of the MBES systems. This combination of ping rate and beam mode allowed the systems to generate up to 5,120 soundings per second (10,240 on the dual head, which was enabled to ping from both sonar heads simultaneously). At the speeds used on this project exceed density specifications for the required grid resolutions were greatly exceeded for the majority of grid cells.

Coverage and density were confirmed by processing in CARIS HIPS. Following application of preliminary correctors, filters, and manual cleaning, CUBE BASE surfaces, at the required resolutions, were generated and examined for coverage and density. When identified, holidays or other gaps were re-run unless deemed unsafe due to water depth or other conditions.

Data Processing Methods and Procedures

Initial data processing was carried out in the field aboard the Q105. Final data processing and reporting was completed in the office following the completion of field operations.

Following transfer from the acquisition, raw bathymetric data was converted, cleaned, and preliminary tide and GPS corrections were applied in accordance with standard TerraSond processing procedures-customized as necessary--for this survey. This was accomplished in near real-time, immediately after each line was acquired, providing relatively rapid coverage and quality determination.

Following the completion of field operations, final data processing was completed at TerraSond's Palmer, Alaska office. This included a comprehensive review of all collected data for completeness and accuracy of corrections, application of final tides and TPU, final cleaning and surface review, compilation of reports, S-57 deliverables, and generation of final products.

Checks and data corrections applied by data processors for MBES data were recorded to a log sheet in Microsoft Excel. Logsheets were then output to PDF format and are available with each project DR.

Conversion into CARIS HIPS and the HIPS Vessel File

CARIS HIPS was the primary software used for bathymetric processing for this project. The XTF (extended Triton Format) files written by QINSy were imported into CARIS HIPS using the “Triton XTF” conversion wizard. Import options selected during conversion included importing coordinates as geographic, automatic time stamping, use of the ship ping header for navigation, and gyro data from attitude packets. No soundings were rejected during conversion.

During conversion, raw data was converted under the appropriate HVF (HIPS Vessel File) corresponding to the vessel that acquired the bathymetric data. The HVF contains time-based, vessel-specific static vessel offsets, configurations, and error estimates that are utilized by CARIS HIPS during various processes including SVP, TPU computation, and Merge.

CARIS HIPS created a directory structure organized by project (area), vessel, and Julian day. Sensors were parsed from the input raw data files, allowing them to be reviewed and edited separately from each other.

HIPS Vessel Files (HVF) - Dual Head Configuration

The CARIS HVFs (HIPS Vessel Files) for this project were setup in a dual-head configuration to ensure proper application of offsets and sound speed correction. This was done per CARIS' technical bulletin

“HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data” even though only the T-50 system on the ASV was a single head. Per the bulletin, this was necessary because QINSy was configured to log “new” style (Reson 7027) bathymetric records.

Note that in this configuration vessel offsets appear only under the SVP1 and SVP2 sensors in the HVF, not under the Transducer 1 and Transducer 2 sensors as they might for other sonar configurations. Angular corrections derived from the patch tests are still included under Transducer 1 (but not the non-existent Transducer 2).

Waterline

To correct for the depth of the transducer, the HVF for each vessel was updated with a new waterline value prior to processing. The static draft, or computed distance from the vessel CRP to the water level with the vessel at rest (computed as described previously in this report), was entered as a waterline correction in the CARIS HVF. Values were occasionally pre-dated in the HVF when necessary.

Static draft measurements were logged in an Excel logsheet, which was exported to PDF and is available with each DR.

Load Attitude / Navigation Data

On this project, positioning and attitude data was processed using post-processed kinematic (PPK) methodology. The PPK process (described later in this report) produced smoothed best estimate of trajectory (SBET) files, which contain a significantly improved navigation and attitude solution over the real-time.

SBETs were loaded into lines using CARIS HIPS “Import Auxiliary Data” utility. During the loading process, the option to import “Applanix SBET” was selected. Navigation and GPS Height records were imported. Data rate was set to ‘0’ to use the data at the default rate within the SBET, which on this project was produced at 50 Hz. Gaps were allowed in order to show as holidays for rerun.

Through this process, each line’s original, real-time navigation and GPS Height records were superseded in CARIS HIPS by the records in the SBET files.

Dynamic Draft Corrections

Dynamic draft corrections were determined for this project using squat-settlement tests, but were not applied to the data.

As an Ellipsoid Referenced Survey (ERS) project, vertical changes in vessel displacement were captured in the GPS data for the vessels and are therefore corrected for without the need to apply separate Dynamic Draft Corrections. The HVF files therefore do not contain Dynamic Draft Correction tables.

Multibeam Swath Filtering

Prior to manual review and cleaning, all multibeam data was filtered using CARIS HIPS “HIPS Data Filters > Apply > Bathymetry” function.

All soundings were filtered based on Reson MBES quality flags and angle from nadir. Soundings flagged as 0, 1, and 2 were “rejected” automatically in filtering, which left only high quality (3, being both co-linear and bright) soundings. Beams greater than 65 degrees from nadir were also rejected, except in Complete Coverage areas where a beam angle filter was generally not used. This removed a large amount of water column noise and reduced the amount of manual editing necessary.

During final review, some lines exhibiting SVP error received additional beam filtering, set to 55 or 60 degrees.

Merge

The “Merge” process was run on all lines in CARIS HIPS. During this process, “GPS” was selected as the tide source to ensure the “GPSTide” record computed previously was used for tidal correction, and the Heave Source was set to “Delayed” to utilize the “Delayed Heave” records loaded previously.

Multibeam Swath Editing

Initial cleaning of multibeam data was done in the field using CARIS HIPS Swath Editor.

Following application of filters and other correctors, soundings were examined for spikes, fliers, or other abnormalities, and obviously erroneous soundings (fliers) were rejected.

Cleaning status was tracked in the processing section of an Excel logsheet, included with each DR.

GPS Height Busts

Although the majority of overlapping multibeam data showed good vertical agreement (to 0.10 m or better), vertical separation or busts of 0.20 m or greater are observed occasionally in the dataset. When these were found to approach or exceed HSSD specifications (generally 0.5 m) they were addressed by repairing in processing.

Three methods were used to address these:

1) If possible, bad altitudes apparent in the GPS Height record in CARIS attitude editor were rejected "with interpolation". This was only possible where bad GPS Height records were fully bracketed by good GPS Height records, i.e. not possible if at the start or end of a line file.

2) If it was not possible to fix through GPS Height interpolation, alternate SBETs were loaded and the results observed. Final processing used ASB SBETs (see POSPac discussion), though in rare cases PPRTX SBETs provided better results on problem lines.

3) In a few cases where the above options did not work, CARIS GDP was used. In this method, GPS Heights were extracted to text file from lines that fully bracketed the problem heights. Then the last "good" height was used to replace all bad heights in the file, creating a flatlined height. Next, the modified height file was loaded to the affected line through CARIS GDP, replacing the existing GPS Height records. Finally the flatlined height was rejected with interp in CARIS HIPS attitude editor.

Any line files requiring alternate SBETs or application of GDP heights are itemized in the appropriate DR.

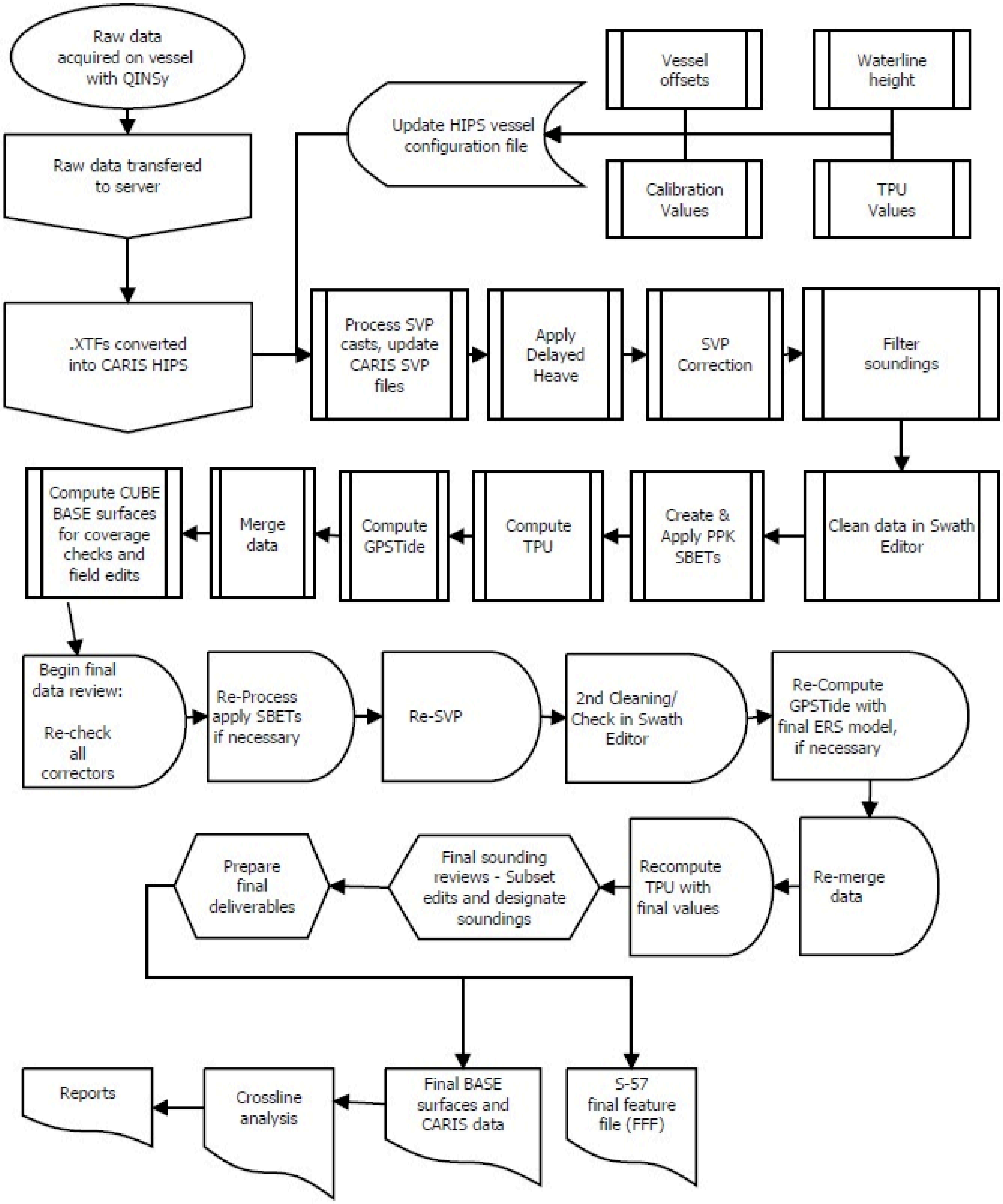


Figure 8: Processing flow diagram.

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 final depth information for this survey is submitted as a collection of surfaces gridded from the sounding data. Surfaces were generated in CARIS HIPS 10.4.21 in CSAR format, and represent the seafloor at the time of survey with depths relative to chart datum (MLLW).

Resolutions of the BASE surfaces were created in accordance with the 2019 HSSD based on coverage type and depth. Coverage types required on this survey were “Set Line Spacing” (Option A, Section 5.2.2.4 in the 2019 HSSD) and "Complete Coverage" (Option A, Section 5.2.2.3 in the 2019 HSSD).

As all depths were less than 80 m, only 4 m resolution surfaces were created for final deliverables in Set Line Spacing areas. Within Complete Coverage areas (and feature investigations within Set Line Spacing area), 1 m resolution surfaces were created for final deliverables.

C.1.4.2 Depth Derivation

Surface filters, sounding suppression parameters, and data decimation parameters were not used to derive depths. Beam and quality filters were run on the data and are discussed previously.

C.1.4.3 Surface Computation Algorithm

CUBE (Combined Uncertainty and Bathymetric Estimator) was used as the gridding algorithm for all surfaces. Per NOAA/CCOM definition, CUBE is "an error-model based, direct DTM generator that estimates the depth plus a confidence interval directly on each node point of a bathymetric grid."

NOAA standard CUBE parameters for 1 m and 4 m resolution surfaces were utilized. This included a 0.71 m and 2.83 m limit on the capture distance of soundings contributing to each grid node, which corresponds to the resolution (1 and 4 meters, respectively) divided by the square root of 2.

During surface computation, “Density and Locale” was chosen as the “disambiguity” method. “Order 1a” was selected as the IHO S-44 Order type.

Each surface was “finalized” in CARIS HIPS prior to submittal. During this process, final uncertainty was determined using the “Greater of the Two” (Uncertainty or Std. Dev. at 95% C.I.) option. Maximum and minimum depth cutoffs were entered based on the HSSD requirements for the resolution (0 to 80 m for both

1 m and 4 m resolution surfaces on this project). The option to apply designated soundings was selected, which forced the final surfaces to honor these soundings where applicable.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

MBES backscatter was collected continuously during MBES operations.

DB and QPD ("DTM result") files, which are compatible with QPS Fledermaus Geocoder Toolbox (FMGT), are provided with the survey deliverables to allow backscatter processing. Basic beam quality filters (reject flags 0, 1 and 2) were applied to the QPD files in QINSy in real-time.

Note that XTF files on this project do not contain backscatter records; these were intentionally configured to contain bathymetric sounding data-only in order to reduce file sizes from redundant recording of backscatter data to both DB and XTF files.

Data Processing Methods and Procedures

During field operations, the presence and quality of backscatter records in the raw MBES files was confirmed by periodic random checks through processing in FMGT.

Following completion of field acquisition, backscatter was processed and mosaics were generated in FMGT at 1 meter resolution. The mosaics (GeoTIFF format) are provided with the processed survey deliverables.

DB and QPD Files were imported into FMGT, which automatically pairs the files based on the name. FMGT extracts the backscatter data stored in the DB and the bathymetry DTM in the QPD, then creates a merged GSF file inside the project that is used in backscatter processing.

The MBES backscatter intensity is dependent on the sonar operation settings (Power, Pulse Length, Gain, Absorption, Spreading) used at the time of acquisition. When different sonar operation settings are used, it causes a shift in the decibel intensity of the acquired data. To account for this in FMGT, several "settings parameter" configurations were created for each sonar type and for each combination of sonar operating settings. DB and QPD files were imported and assigned the appropriate "settings parameter" as tracked in the survey acquisition log, and a preliminary mosaic at 1 meter resolution was generated. The most frequently used "settings parameter" (i.e. the sonar operation settings used for the majority of the survey) was selected as a reference (0 decibel offset). Using the intensity differences between lines visible in the preliminary mosaic, all other "settings parameter" configurations were assigned a static decibel offset to match the intensity of the reference. This brought the files for all vessels and all sonar operation settings onto the same intensity level. A 1 meter mosaic was then re-created and exported as a greyscale geotiff.

Note that backscatter processing and mosaic generation was not a requirement of this survey. The mosaics may therefore have flaws or holidays which could be addressed through further processing. However, they are of sufficient quality to show the relative changes in seafloor type.

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

Data Acquisition Methods and Procedures

The POSMV positioning systems on both vessels were configured to recieve FAA WAAS DGPS corrections via their internal WAAS receiver.

In all cases, DGPS corections were replaced with post-processed positions in NAD83 (2011)

Data Processing Methods and Procedures

All positions were post-processed in Applanix POSPac software, which is described in more detail in the Vessel Positioning section of this report.

Note that CARIS projects have their project geodetic settings set to "NA83" (NAD83), not NAD83(2011). This was done because in the versions of CARIS used on this project (10.4) a NAD83(2011) option was unavailable for the navigation sensor in the CARIS HVF. Only "NA83" is available for the navigation sensor. Using "NA83" for both the navigation sensor as well as in the project settings ensures HIPS does not perform a conversion on the imported SBET positions, which are already NAD83(2011), and also ensures final data and surfaces are indeed in the desired NAD83(2011) system.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

Two tertiary tide stations were installed for this project, as well as three ERTDM validation sites. Three stations were near the communities of Stebbins, Koyuk, and St. Michael. A combinations of bubblers, non-vented pressure sensors, GNSS Tide Buoys, and GNSS-R systems were used to measure water levels at the different sites. Vented and nonvented sensors were attached to rebar and driven into seafloor or riverbed. The GNSS Tide buoys were moored in place using a danforth anchor. The water levels for each station were tied to a global reference frame via differential levels and GNSS observations. The equipment was calibrated by the manufacturer prior to deployment. Pre and post-deployment tests were also performed on the equipment to monitor for sensor drift.

However, no project tide data was used to correct project echo soundings. The ERTDM provided by NOAA for this purpose was used instead.

Refer to the HVCR and its accompanying appendices for additional detail.

Data Processing Methods and Procedures

Final tides were completed using ERS (Ellipsoid-Referenced Survey) techniques. NAD83(2011) ellipsoid based altitudes, loaded from PPK SBET files, were reduced to MLLW in CARIS HIPS using the Compute GPSTide routine in conjunction with the NAD83 to MLLW separation model provided by NOAA for this purpose.

Data from the pressure sensors were converted from PSI to meters by correcting for water density and gravity. The non-vented pressure sensors were also corrected for barometric pressure. Water levels from the GNSS Tide Buoy were resolved using baseline processing. The stability of each water level sensor was assessed by either differential levels or differences between simultaneous water level readings. Tidal datums for each location were computed using a control station and at least one calendar month of data.

A total water level error estimate was assigned to each water level record using the methodology outlined in the "COOPS Policy for Management and Dissemination of External Source Water Level Data Revised December 2015".

Ellipsoidally Referenced Zoned Tides (ERZT) (as well as conventional discrete tide zones) were also computed for this project but were used for comparison purposes only.

PPK and ComputeGPS tide procedures are described elsewhere in this report. Refer to the project HVCR for additional information on tide correction methodology as well as comparison results.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Positioning and Attitude Data

Positioning and attitude data was computed during acquisition with Applanix POSMV systems. This data included horizontal position, vertical position, and attitude data consisting of heave, pitch, roll, and heading (gyro).

The POSMV systems were configured to output positioning and attitude data in real-time to the QPS QINSy acquisition software at a rate of 50 Hz. The real-time positions were written to DB and XTF file by QINSy for later import into CARIS HIPS during processing.

Raw POSMV data was also logged at a rate of 50 Hz to POS (.000) file continuously during data acquisition operations, with a new file created approximately every 12 hours. All data packets necessary for Delayed Heave and Applanix POSPac post-processing were included in the records. Care was taken to ensure the POS files were logged for at least two minutes before and after applicable survey lines to allow for the application of Delayed Heave as well as post-processed solutions from Applanix POSPac.

Note real-time positioning data (horizontal and vertical) was superseded with application of post-processed positioning, as described below.

Data Processing Methods and Procedures

Apply Delayed Heave

In processing, CARIS HIPS’ “Import Auxiliary Data” utility was utilized to load lines with the "Delayed Heave" record. Delayed Heave was imported at the default data rate (25 Hz) from POS (.000) files logged during acquisition. Along with the Delayed Heave data, Delayed Heave RMS error records were also imported during this process.

Delayed Heave records were then utilized by CARIS HIPS over real-time heave for final heave correction. In rare cases (noted in the applicable DRs) some lines did not receive application of Delayed Heave because of POS file issues, typically caused by occasional software crashes that prematurely ended the POS file logging prior to reaching the 2-minute logging requirement after survey lines. In these cases the lines utilized realtime heave instead.

In CARIS HIPS, options to apply Delayed Heave were utilized during both Sound Velocity Correction and Merge. The option to apply Delayed Heave was also used on the vast majority of survey lines during the Compute GPSTide process, with exceptions noted in the applicable DRs.

Post-Processed Kinematic (PPK) Navigation and Attitude

Final position and attitude data for this project were post-processed.

The project was not located within a region of USCG DGPS coverage. As described elsewhere in this report, SBAS corrections (FAA WAAS) corrections were used for real-time positioning but were replaced in final processing with PPK positions.

PPK processing for this project utilized Applanix POSPac MMS software. POSPac produced SBET format .OUT files, which were loaded into all lines during processing. This superseded real-time navigation (position and GPS height). Note that SBET files also contain post-processed roll, pitch, and gyro (heading) records but these were normally not applied in processing.

To process POS files to produce an SBET, a POSPac MMS project was first established based on a predefined template with project-specific settings. Project-specific settings consisted of custom SBET output using a decimated data rate of 50 Hz (from the default 200 Hz) and output datum of NAD83 (2011). One project was set up for each POS file, and the POS file was imported into the project. The correct antenna type (AT1675-540TS) was selected.

Trimble PP-RTX methodology was used for initial (field) POSPac processing. PP-RTX is a subscription-based service available within POSPac, that utilizes nearby publicly available GNSS base stations to post-process data. Advertised accuracies are 0.1 m RMS Horizontal and 0.2 m RMS vertical.

Following completion of operations and availability of precise ephemeris and nearby CORS station data, all POSMV data was reprocessed in POSPac using Applanix Smart Base (ASB) methodology. This was possible because the survey area was fully encompassed in a network of regional CORS sites, and facilitated by nearby stations at St. Michael and Unalakleet. ASB resulted in generally better positioning results and was used for all final data, except in rare occassions where PP-RTX was used.

The PP-RTX and ASB methods were compared during Vessel Position Confidence checks, with good results. Refer to Data Quality Management section of this report.

Following PP-RTK (or ASB in final processing) generation, the POSPac Inertial processor function was run.

After completion of the inertial processor, QC plots of RMS error and vessel altitude were examined for spikes and other anomalies. The real-time position was compared visually to the post-processed position in the POSPac MMS plan view window as a check for gross positioning error.

Finally, Smooth Best Estimate of Trajectory (SBET) files were exported from POSPac. The option to produce “Custom Smoothed BET” was used to produce an SBET in the NAD83 (2011) reference frame at 50 Hz. This made it so that all final positions were NAD83 (2011) per the 2020 HSSD.

Load Navigation Data (SBETs)

SBETs were loaded into lines using CARIS HIPS “Import Auxiliary Data” utility. During the loading process, the option to import “Applanix SBET” was selected, and the option to import only "Navigation" and "GPS Height" were selected. Data rate was set to ‘0’ to use the data at the default rate within the SBETs, which on this project were produced at 50 Hz. The option to allow partial coverage of SBETs to lines was also used, which resulted in coverage gaps from missing SBET data (if applicable) during coverage review and subsequent rerun of the affected lines or sections of lines while still in the field.

Through this process, each line’s original, real-time horizontal and vertical positions were superseded in CARIS HIPS by the records in the SBET files.

Compute GPSTide

Following loading of PPK altitude data from the SBET files, CARIS HIPS’ “Compute GPSTide” function was run on all lines. This created a GPSTide record within each survey line. Options to apply dynamic heave, vessel waterline, and the NOAA-provided ellipsoid separation model were used so that the GPSTide record reflects the elevation of the vessel waterline above MLLW.

Note that “Delayed Heave” was used as the heave source since the vast majority of lines were loaded with this record. Rare lines without Delayed Heave used real-time heave during this computation instead. These cases are noted in the applicable DR(s).

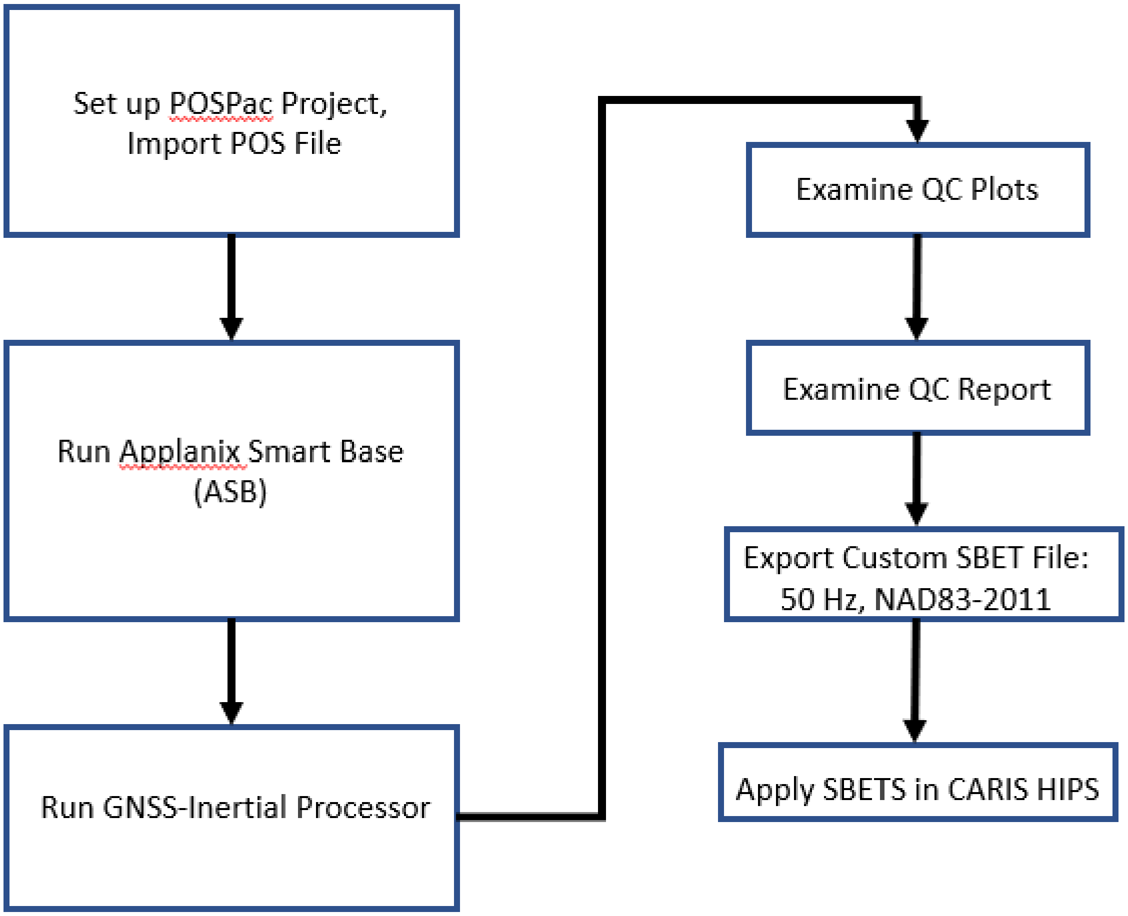


Figure 9: Generalized POSPac processing Workflow

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Sound speed casts were taken from the Q105 using an Oceanscience RapidCAST system, which utilized a Valeport rapidPro SVT or Swift sensor. Note the ASV-CW5 was not equipped to acquire SV profiles: All ASV MBES data was corrected using the profiles acquired aboard the Q105. This was possible because the unmanned vessel always worked within radio range of the Q105, which was approximately 5 km or less. There were specific shallow bays or areas where the ASV had to operate farther than 5km away from the Q105 using a secondary radio system, but was never greater than 9 km away. At these times the Q105 was not collecting data so casts could generally be taken more frequently. Comparisons from the ASV sonar head could also be taken against SV profile during acquisition, which were generally in agreement even at greater distances.

During the cast, sensor depth is estimated by the RapidCAST software based on the manufacturer's algorithm utilizing line tension measured at the winch, free-fall time, and other factors. Survey personnel set a desired target depth and the system would typically achieve the target depth with a margin of error of +/- 5% to 10%. Due to the margin of error on the system's estimates of the probe depth, conservative target depths were entered into the system to avoid striking bottom. This resulted in profiles that were at least 80% of the water depth, but not extending completely to the seafloor. However, effort was made to ensure at least one cast per 24 hours (or more) extended to 95% of the water depth.

Sound speed profiles in their raw format were logged as ".vp2" (Valeport Connect) format. In addition to depth and sound speed, VP2 files contained various metadata including UTC timestamp and geographic position generated from the Valeport sensor's GPS.

Sound speed casts were completed approximately every 2 hours. The sound speed sensor on the sonar head (surface sound speed) was also monitored continuously and compared automatically in QINSy software to the prior sound speed profile. When the software indicated a 2 m/s or greater differential, another cast was performed.

Additionally, line lengths were limited (generally 20 km or less). This led to a collection of well distributed casts that minimized both the distance and time between bathymetric data and applicable sound speed profiles. When depth varied significantly along a survey line, preference was given to casting in the deeper portion of the line to obtain as much of the water column profile as possible.

Sound speed profiles were applied in CARIS HIPS using the methodology by nearest in distance, with a time interval equal to 2 hours. Exceptions were rare and are described in the applicable DR.

Data Processing Methods and Procedures

Sound speed profiles (also known as "SV casts") were processed in HydroOffice Sound Speed Manager.

Each VP2 files logged in acquisition was imported into Sound Speed Manager (SSM). SSM presented a graph of depth versus sound speed, which was examined for spikes (fliers) and to confirm that the desired cast depth was achieved. The VP2 was edited when necessary to remove fliers, and then exported to CARIS ".SVP" format and amended to the master CARIS SVP files by survey area prior to sound speed correction. The profile data was also exported to the acquisition software (QPS QINSy) in order to allow QINSy to alert the acquisition crew if sound speed had changed by greater than 2 m/s between casts.

In CARIS HIPS, each line was corrected for sound speed using CARIS HIPS "Sound Velocity Correct using CARIS Algorithm" utility. The CARIS-format .SVP file corresponding to the survey area was selected. To prevent the use of sound speed profiles that were too old or distant relative to the bathymetric data, "Nearest in Distance Within Time" was used for the profile selection method. For the time constraint, 4 hours was used.

In addition to the profile selection method, options applied during sound velocity correction were; setting heave source to “Delayed” (to apply Delayed Heave records loaded earlier), and including the option to “Use Surface Sound Speed” (if available).

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed data was acquired using AML Oceanographic Micro-X sensors mounted on the MBES sonar heads. These were configured to continuously feed sound speed data directly to the MBES systems for internal beam forming purposes.

The surface sound speed value updated in real-time in the Reson 7k Sonar UI interface software. The software was set to alarm upon loss of sound speed data, and during data collection, the value was checked for reasonableness regularly by the survey crew. The acquisition software, QPS QINSy, was also set to alert the acquisition crew if there was significant change (greater than 2 m/s) in the surface sound speed value relative to the previous sound speed profile.

In addition, a formal check was carried out whenever a sound speed profile was collected, which was approximately every 2 hours during data collection. During this check, the surface sound speed value shown in the Reson 7k Sonar UI was noted in the Acquisition Log and then compared to the sound speed profile value at the same depth as the sensor (approximately 2 meters on the Q105).

Results of the surface sound speed checks are available with the project DRs.

Data Processing Methods and Procedures

Surface sound speed data was not processed. It was utilized in acquisition only, for internal beam forming purposes by the Reson T-50 and T-50 IDH systems.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

CARIS HIPS was used to compute total propagated uncertainty (TPU) for all soundings as well as uncertainty for the final grids.

The CARIS HIPS TPU computation assigned a horizontal and vertical error estimate to each sounding based on the combined error of all contributing components. These error components include uncertainty associated with navigation, gyro (heading), heave, tide, latency, sensor offsets, and individual sonar model characteristics. Stored in the HVF, these error sources were obtained from manufacturer specifications, determined during the vessel survey (sensor offsets), or while running operational tests (patch test, squat settlement). Note that all values are entered at 1-sigma, per CARIS guidance, while CARIS reports TPU at 2sigma. HVF entries and their justification are shown below.

Sonar Type: Teledyne RESON SeaBat T50P (400kHz 512 beams)

Motion Gyro: 0.020 degrees CARIS TPU values for Applanix POSMV 320 (2 m baseline)

Heave: 5% of Heave Amplitude or 0.05m, whichever is greater -- CARIS TPU values for Applanix POSMV 320

Roll and Pitch: 0.02 degrees -- CARIS TPU values for Applanix 320, non-RTK

Position Nav: 0.1 m -- PPK position processing results report RMS errors that were better than 0.10 m on average

Timing (all systems) 0.010 seconds -- estimated overall synchronization error using 1-PPS

Offset X and Y: 0.01 m -- estimated measurement error from vessel survey for X and Y

Offset Z: 0.01 m on the ASV-CW5, 0.02 m on the Q105 -- estimated measurement error for Z on the ASV-CW5, standard deviation of bar-check results on the Q105

Vessel speed: 1 m/s -- estimated maximum speed of water currents experienced during survey operations

Loading: 0.025 m on the ASV-CW5, 0.067 m on the Q105 -- mean difference between subsequent static draft measurements

Draft: 0.020 m on the ASV-CW5, 0.01 on the Q105 -- estimated accuracy of the visually observed static draft measurements

Delta Draft: 0.01 m -- estimated uncertainty of squat settlement results

MRU Align StdDev Gyro and Roll/Pitch -- 0.01 degrees, overall accuracy estimate of patch test results for gyro, pitch, and roll

The TPU computation also incorporated error estimates for tide which were entered at the time of TPU computation. Tidal error was entered as 0.135 (at 1-sigma) based on the 0.27 m (2-sigma) value provided for the ERTDM model in the project Work Instructions document.

Sound speed error (measured) differed by sheet and ranged from 0.54 to 2.259 m/s. This was determined by determining the standard deviation of the difference between subsequent casts taken in each survey sheet. The actual value of the analysis or 1 m/s -- whichever was higher -- was entered into CARIS HIPS during TPU computation. The value used for each sheet is noted in the applicable DR.

Sound speed error (instrument) was entered as the manufacture's provided value for the surface sound speed sensor on each vessel as 0.025 m/s.

Final CUBE surfaces include an "Uncertainty" layer that shows the estimated uncertainty for the depth value of each cell. Surfaces were finalized in CARIS HIPS with the "Uncertainty Source" selected as "Greater of the two values", which ensured final uncertainty values for the surfaces were the larger of either surface uncertainty or standard deviation (at 2-sigma).

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		Qualifier 105	ASV-CW5
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees
Navigation Sensor		0.10 meters	0.10 meters

C.6.2.2 Real-Time Uncertainty

Real-time uncertainty was not applied.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

A small number of features were offshore of the NALL and investigated with Complete MBES techniques within their assigned search radius, in accordance with the 2019 HSSD.

However, the vast majority of shoreline features were inshore of the NALL and were therefore investigated with limited shoreline verification techniques. On this project limited shoreline verification was undertaken using Unmanned Aerial Systems (UAS). DJI Phantom 4 Professional (P4P) units were used.

Use of UAS to investigate assigned features instead of from a surface vessel (skiff) improved safety while simultaneously allowing a more accurate, comprehensive, and quantitative shoreline dataset to be acquired. The skiff-based approach, which has inherent safety concerns, relies heavily on visually estimated heights for features as well as estimated positions since most features cannot be approached directly. In addition, inspection of the coastline by skiff can miss potentially hazardous uncharted or new features just at or under the water surface that are clearly visible from the air.

To investigate features with UAS, “missions” of approximately 1 to 2 nautical miles of coastline were first pre-defined. Missions routes were best-fit to intersect assigned features, with consideration for photo coverage and overlap. Altitudes were set to 400' or less and speeds were limited to allow at least three high-resolution (20 megapixel) geotagged photos to be taken on each feature and adjacent seafloor.

When conditions were favorable for shoreline verification (low tide, good visibility, and winds of 20 knots or less), the missions were carried out. With the Q105 in the general proximity of the features requiring investigation, the UAS was launched from the top deck (or in some cases from the Q105 skiff or nearby shore) and sent on the pre-defined mission. Camera angle was usually set to a straight-down (nadir) orientation, and the UAS was set to automatically take high-resolution (typically 20 megapixel), geo-tagged JPG images every 2 seconds. Images were saved to an on board SD card for later processing.

Except for launch and recover from the Q105, the vast majority of UAS missions were executed autonomously. This allowed for consistent altitude, speed control, and positioning along the pre-defined route. Care was taken to time missions for good weather and visibility as well as low tide (usually 0.5 m or less).

Data Processing Methods and Procedures

SfM Processing in Agisoft Photoscan

The UAS data acquisition process generated thousands of overlapping images of the assigned feature areas and surrounding shoreline. Instead of analyzing images individually, Structure from Motion (SfM) methodology was utilized to create ortho-rectified photomosaics and digital elevation models (DEMs) over assigned features. For this purpose, Agisoft PhotoScan software was utilized. Final products from PhotoScan were high resolution photo-mosaics and DEMs for correlation with assigned features and identification of new (uncharted) features.

SfM is a technique of photogrammetry that allows 3D modeling from 2D image sequences. Using multiple photos of features, SfM utilizes changes in perspective to determine positional relationships between matching features and models them in 3D. On this project, care was taken to ensure at least three photos were acquired of each feature in order to provide sufficient data for good SfM results.

Each UAS mission was imported into PhotoScan as a separate photoset project. Images taken during “transit” of the UAS over open water were rejected. Remaining images were run through an automated process of photo alignment and aero-triangulation, wherein photos were matched and merged with adjacent photos based on geotags and common features identified in overlapping photos. Photos were sometimes auto-rejected by PhotoScan when insufficient tie points with adjacent photos were computed, which was common with open water crossings or during searches for submerged features.

Initial field processing in PhotoScan was done immediately after each mission to ensure coverage and data quality. During this initial processing, PhotoScan was run with reduced quality settings to rapidly verify integrity of acquired data. Processing was separated into ‘chunks’ that represented UAS missions. Since SfM processing can be time intensive, lower quality settings for aero triangulation and point cloud generation were used to compile a scene for the mission within a suitable timeframe (usually within the available tide window). Preliminary orthophotomosaics (as georeferenced TIF images) were then output and compared to assigned features to ensure coverage.

Secondary field processing involved reprocessing missions to generate densified point clouds. The point clouds were then manually reviewed to verify a 3D height could be measured on features of interest. From the dense point clouds, DEMs and ortho- photomosaics were batch processed for each mission.

In final office processing following availability of final tides, tide corrections were applied in PhotoScan to bring point cloud data to MLLW. A tide value was first computed for each mission, based on the average time of acquisition of the mission using zone-corrected tide data from the project tide station at Stebbins.

Next, vertical control points were created along the recognizable water line. The tide value was then used to shift the entire mission’s point cloud and associated DEMs to MLLW for height determination.

Final products from SfM processing were ortho-rectified photo-mosaics (orthophotomosaics) at a resolution of approximately 0.035 m and DEMs at a resolution of approximately 0.105 m. Both ortho-photomosaics and DEMs were output as GeoTIF images projected into NAD83, UTM Zone 3N. These images are included with the survey deliverables for each sheet. Note that DEM and orthomosaic accuracy is best along the shoreline (correlating with feature positions) and degrades on the edges of the images as well as over water.

Refer to the included table for a list of missions, the tide correction used to place the DEM on MLLW, associated filenames, and processing comments.

Feature Correlation and FFF Encoding in CARIS HIPS

Correlation between assigned and observed features were done in CARIS HIPS. All applicable data sets were overlaid in CARIS HIPS for this process, consisting primarily of the project CSF (including assigned features), multibeam surfaces, as well as the SfM-derived orthomosaic and DEM GeoTIFs. NOAA extended attributes (V2020.3) were used for attribution.

Each assigned feature was inspected for accuracy and attributed with applicable S-57 attributes.

Features were considered as “verified” if the actual feature could be identified within the search radius assigned in the PRF. Most features could be identified within the radius. However, per guidance in the “New/Delete vs Update” section (7.5.2) of the HSSD, the better positions obtained by this survey frequently required position updates for features. The increased accuracy as well as high level of detail available with the low-altitude aerial imagery led to extensive re-digitization of assigned features. For this reason, many assigned features were noted in the FFF to be verified but incorrectly positioned, with a recommendation of “delete”, to be replaced by an associated “new” feature defined nearby in the FFF.

Common scenarios and important parameters used when correlating assigned features with observed features were:

* Few features were found within 10 m of the assigned position, leading to the creation of a large number of new features

* The MHW value used for islet determination used was 0.741 m, as determined at the nearby project tide station at Stebbins. Refer to tidal documentation with the HVCR for more information on datum computations.

* Many assigned "rock" features were found to be islets due to heights of at least 0.10 m above MHW

* In a few cases the area of an "islet" above MHW exceeded 1 m at survey scale, requiring the creation of area objects instead of point objects

* Water clarity was not good in this area in general, with the seafloor generally not visible more than 1-2 m depth. For this reason a number of assigned features inshore of the NALL could not be located and are recommended to be retained as charted in the FFF

* Many assigned rocks or islets were found to actually be more complex areas of ledges or reefs, and were encoding appropriately as new features

* Heights of features were determined from the DEM in most cases. All DEMs are referenced to MLLW. Heights that are estimated from raw images are noted where applicable.

Although the area of assigned features were generally all overflown during the missions, in some cases they did not appear in the associated photomosaic because they would not mosaic, either due to lack of shoreline for SfM to successfully tie images together, or because the object was partially or fully submerged. When features were not clearly identified in the mosaics, the raw images from the missions were examined for any sign of a feature. In a few cases the feature was identified in a raw photo and the geotag of the photo used to position the feature, with a height estimated from the image. These cases are noted where applicable in the FFF.

For reference, features in the FFF have additional information added to assist during review. Where applicable, these are:

* Mission numbers are added to the feature "remarks" field. For example, "New ledge extending from MHW M1006" means the feature was investigated during Mission 1006 and the orthomosaic(s) and DEM(s) files associated with 1006 should be referenced for the determination.

* The tide value for the time of the mission imagery is entered into the "Tidal adjustment" field for each new feature that includes a height. For example, a tidal adjustment of -0.014 means the mission was completed at a -0.014 m tide, and this tide value was used at the water-shore interface for DEM adjustment to MLLW.

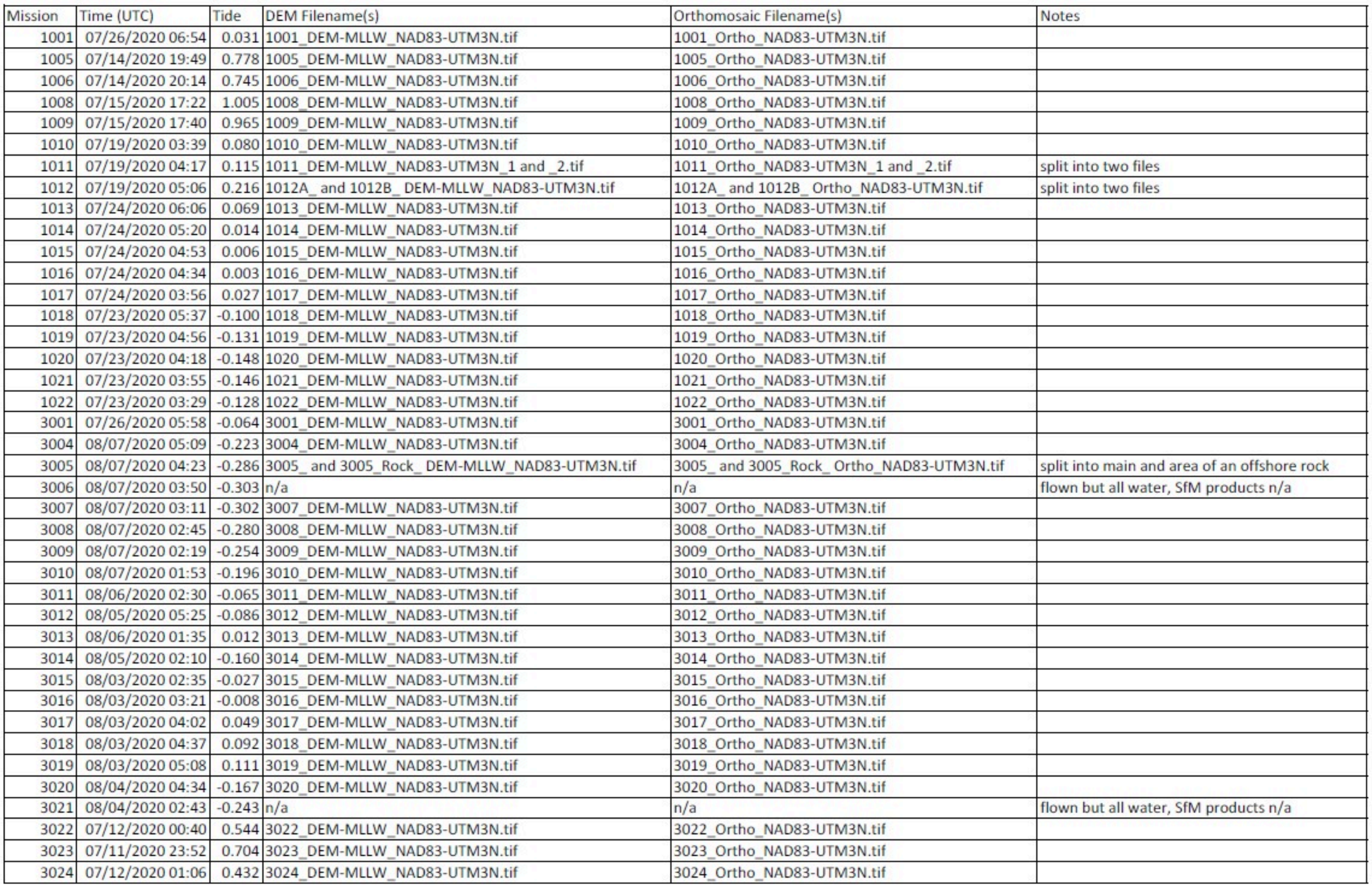
* The observed depth (at time of observation) of the feature was entered into the "Observed Depth" field. For example, a value of -0.5 m means the feature stands 0.5 m above water level in the imagery.

* Estimated positional accuracy of orthomosaic is 2 meters horizontally. Estimated vertical accuracy of DEM of 0.10 m.

Orthomosaics and DEM GeoTIF images are included with the survey deliverables for each sheet. All are projected as NAD83, UTM 3 North. GeoTIF images are named for the associated mission, and split when necessary to address issues with processing individual sections. GeoTIF DEMs are referenced to MLLW and open as CSAR surfaces with associated height data in CARIS HIPS.

Raw aerial images are included with the survey deliverables as well, organized by mission in the raw data (preprocess) directory.

Refer to the image below for a list of UAS missions and their locations.



Mission	Time (UTC)	Tide	DEM Filename(s)	Orthomosaic Filename(s)	Notes
1001	07/26/2020 06:54	0.031	1001_DEM-MLLW_NAD83-UTM3N.tif	1001_Ortho_NAD83-UTM3N.tif	
1005	07/14/2020 19:49	0.778	1005_DEM-MLLW_NAD83-UTM3N.tif	1005_Ortho_NAD83-UTM3N.tif	
1006	07/14/2020 20:14	0.745	1006_DEM-MLLW_NAD83-UTM3N.tif	1006_Ortho_NAD83-UTM3N.tif	
1008	07/15/2020 17:22	1.005	1008_DEM-MLLW_NAD83-UTM3N.tif	1008_Ortho_NAD83-UTM3N.tif	
1009	07/15/2020 17:40	0.965	1009_DEM-MLLW_NAD83-UTM3N.tif	1009_Ortho_NAD83-UTM3N.tif	
1010	07/19/2020 03:39	0.080	1010_DEM-MLLW_NAD83-UTM3N.tif	1010_Ortho_NAD83-UTM3N.tif	
1011	07/19/2020 04:17	0.115	1011_DEM-MLLW_NAD83-UTM3N_1 and _2.tif	1011_Ortho_NAD83-UTM3N_1 and _2.tif	split into two files
1012	07/19/2020 05:06	0.216	1012A_ and 1012B_ DEM-MLLW_NAD83-UTM3N.tif	1012A_ and 1012B_ Ortho_NAD83-UTM3N.tif	split into two files
1013	07/24/2020 06:06	0.069	1013_DEM-MLLW_NAD83-UTM3N.tif	1013_Ortho_NAD83-UTM3N.tif	
1014	07/24/2020 05:20	0.014	1014_DEM-MLLW_NAD83-UTM3N.tif	1014_Ortho_NAD83-UTM3N.tif	
1015	07/24/2020 04:53	0.006	1015_DEM-MLLW_NAD83-UTM3N.tif	1015_Ortho_NAD83-UTM3N.tif	
1016	07/24/2020 04:34	0.003	1016_DEM-MLLW_NAD83-UTM3N.tif	1016_Ortho_NAD83-UTM3N.tif	
1017	07/24/2020 03:56	0.027	1017_DEM-MLLW_NAD83-UTM3N.tif	1017_Ortho_NAD83-UTM3N.tif	
1018	07/23/2020 05:37	-0.100	1018_DEM-MLLW_NAD83-UTM3N.tif	1018_Ortho_NAD83-UTM3N.tif	
1019	07/23/2020 04:56	-0.131	1019_DEM-MLLW_NAD83-UTM3N.tif	1019_Ortho_NAD83-UTM3N.tif	
1020	07/23/2020 04:18	-0.148	1020_DEM-MLLW_NAD83-UTM3N.tif	1020_Ortho_NAD83-UTM3N.tif	
1021	07/23/2020 03:55	-0.146	1021_DEM-MLLW_NAD83-UTM3N.tif	1021_Ortho_NAD83-UTM3N.tif	
1022	07/23/2020 03:29	-0.128	1022_DEM-MLLW_NAD83-UTM3N.tif	1022_Ortho_NAD83-UTM3N.tif	
3001	07/26/2020 05:58	-0.064	3001_DEM-MLLW_NAD83-UTM3N.tif	3001_Ortho_NAD83-UTM3N.tif	
3004	08/07/2020 05:09	-0.223	3004_DEM-MLLW_NAD83-UTM3N.tif	3004_Ortho_NAD83-UTM3N.tif	
3005	08/07/2020 04:23	-0.286	3005_ and 3005_Rock_ DEM-MLLW_NAD83-UTM3N.tif	3005_ and 3005_Rock_ Ortho_NAD83-UTM3N.tif	split into main and area of an offshore rock
3006	08/07/2020 03:50	-0.303	n/a	n/a	flown but all water, SfM products n/a
3007	08/07/2020 03:11	-0.302	3007_DEM-MLLW_NAD83-UTM3N.tif	3007_Ortho_NAD83-UTM3N.tif	
3008	08/07/2020 02:45	-0.280	3008_DEM-MLLW_NAD83-UTM3N.tif	3008_Ortho_NAD83-UTM3N.tif	
3009	08/07/2020 02:19	-0.254	3009_DEM-MLLW_NAD83-UTM3N.tif	3009_Ortho_NAD83-UTM3N.tif	
3010	08/07/2020 01:53	-0.196	3010_DEM-MLLW_NAD83-UTM3N.tif	3010_Ortho_NAD83-UTM3N.tif	
3011	08/06/2020 02:30	-0.065	3011_DEM-MLLW_NAD83-UTM3N.tif	3011_Ortho_NAD83-UTM3N.tif	
3012	08/05/2020 05:25	-0.086	3012_DEM-MLLW_NAD83-UTM3N.tif	3012_Ortho_NAD83-UTM3N.tif	
3013	08/06/2020 01:35	0.012	3013_DEM-MLLW_NAD83-UTM3N.tif	3013_Ortho_NAD83-UTM3N.tif	
3014	08/05/2020 02:10	-0.160	3014_DEM-MLLW_NAD83-UTM3N.tif	3014_Ortho_NAD83-UTM3N.tif	
3015	08/03/2020 02:35	-0.027	3015_DEM-MLLW_NAD83-UTM3N.tif	3015_Ortho_NAD83-UTM3N.tif	
3016	08/03/2020 03:21	-0.008	3016_DEM-MLLW_NAD83-UTM3N.tif	3016_Ortho_NAD83-UTM3N.tif	
3017	08/03/2020 04:02	0.049	3017_DEM-MLLW_NAD83-UTM3N.tif	3017_Ortho_NAD83-UTM3N.tif	
3018	08/03/2020 04:37	0.092	3018_DEM-MLLW_NAD83-UTM3N.tif	3018_Ortho_NAD83-UTM3N.tif	
3019	08/03/2020 05:08	0.111	3019_DEM-MLLW_NAD83-UTM3N.tif	3019_Ortho_NAD83-UTM3N.tif	
3020	08/04/2020 04:34	-0.167	3020_DEM-MLLW_NAD83-UTM3N.tif	3020_Ortho_NAD83-UTM3N.tif	
3021	08/04/2020 02:43	-0.243	n/a	n/a	flown but all water, SfM products n/a
3022	07/12/2020 00:40	0.544	3022_DEM-MLLW_NAD83-UTM3N.tif	3022_Ortho_NAD83-UTM3N.tif	
3023	07/11/2020 23:52	0.704	3023_DEM-MLLW_NAD83-UTM3N.tif	3023_Ortho_NAD83-UTM3N.tif	
3024	07/12/2020 01:06	0.432	3024_DEM-MLLW_NAD83-UTM3N.tif	3024_Ortho_NAD83-UTM3N.tif	

Figure 10: List of UAS missions by mission number, time of collection, tide at time of collection, and DEM / mosaic filenames.

Figure 11: Mission locations shown on Google Earth in the vicinity of Stuart Island.

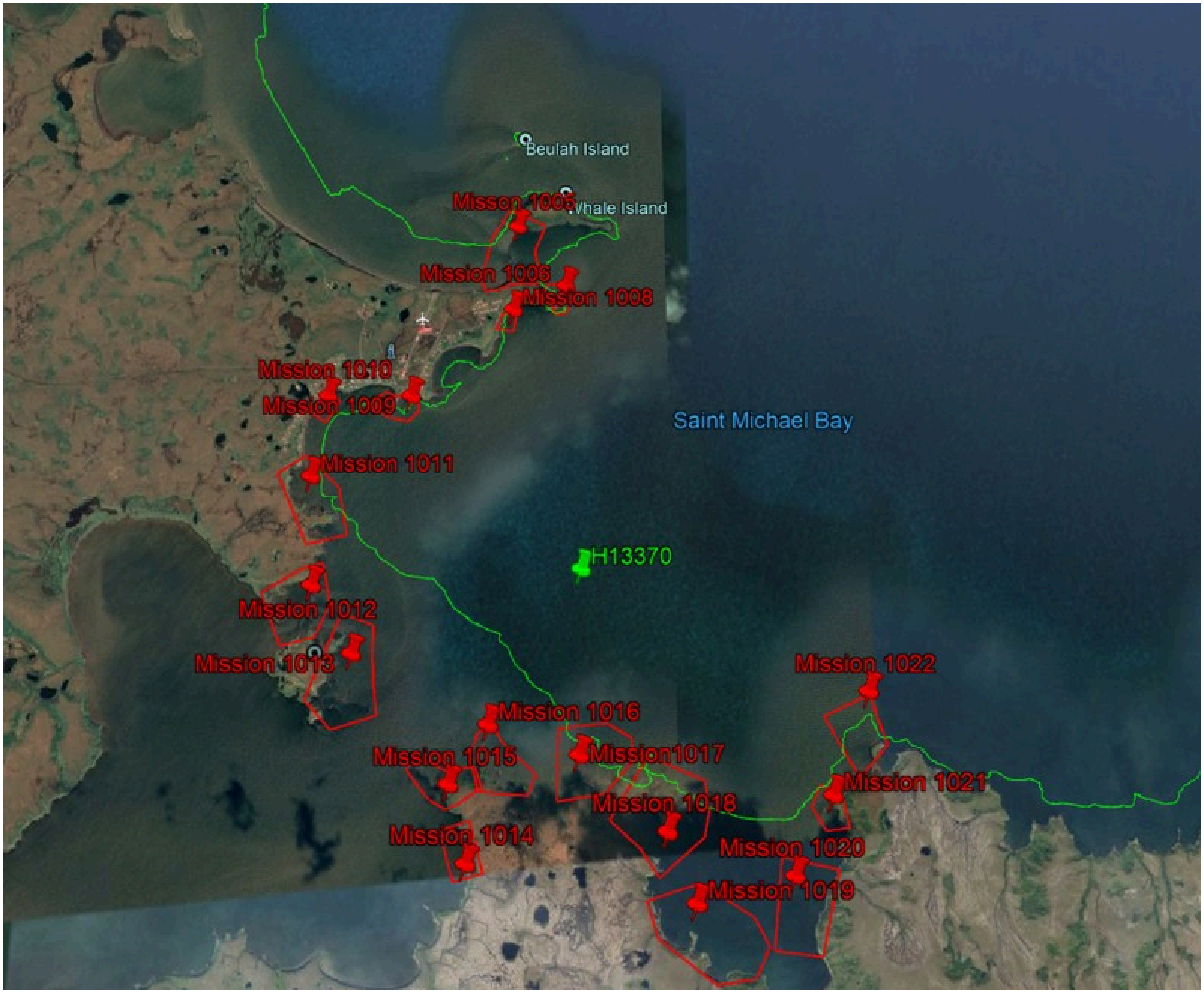


Figure 12: Mission locations shown on Google Earth in the vicinity of St. Michael Bay.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

Locations for bottom samples were assigned by NOAA via the S-57 format Project Reference File (PRF). Assigned locations were given a name for reference, imported, and displayed in the acquisition software.

To collect the samples, the Q105 would navigate as close as possible to each assigned location. With the vessel at full stop, the survey crew on the back deck would set a spring-loaded Van Veen grab sampler and lower it quickly to the seafloor. A GPS position fix was taken when the sampler was noted to touch bottom. Back on the surface, the sampler was opened, and the contents analyzed to determine its “SBDARE” (Seabed Area) S-57 attributes including “NATSUR” (nature of surface), “NATQUA” (qualifying terms), and “COLOUR”. Time of acquisition was noted, and a photo was taken of each sample. Following analysis, the sample was discarded overboard.

If no sample was obtained, the vessel was repositioned if it had moved more than 100 m from the planned location, and another attempt made. Attempts at collecting a bottom sample would be made at least three times. If no sample was obtained after three attempts, the vessel would move on. An attempt was only considered valid if the grab sampler had returned to the surface in the closed state. For this project, samples were successfully obtained at the vast majority of assigned locations, with exceptions noted in the applicable DR, and encoded with a “NATSUR” as “Unknown” in the FFF.

Many bottom sample locations were too shallow to approach with the Q105, and the ASV-CW5 was not equipped for bottom sampling. Therefore multiple bottom sample locations had to be moved to more navigable waters. When this occurred a sample was taken as close as practical in order to achieve the same overall quantity of samples, without crowding other nearby sample sites. A handful of locations were not approachable by either vessel and inside the NALL -- these were relocated in the same manner.

During analysis, sample particle dimensions were not actually measured. Instead, careful estimations were done visually and by touch. Samples determined in the field to have particle sizes smaller than sand (silt and/or clay) were encoded with “NATSUR” as “mud” and “NATQUA” as “soft” when encoding S-57 attributes, though field comments may retain the original determination of silt or clay. Similarly, samples determined in the field to be pebbles or gravel (“NATSUR”) with field determinations for “NATQUA” as course, medium, or fine were encoded with “volcanic” for “NATQUA” to conform with allowable NATSUR/NATQUA combinations in the HydrOffice QC Tools manual.

If multiple constituents were present in the sample, only the three most prevalent were noted. Constituents were encoded in order of most predominant first.

Field results were recorded in a Bottom Sample logsheet, which is included with the project DRs.

Data Processing Methods and Procedures

Bottom samples were encoded into the Final Feature File (FFF) for each sheet in CARIS HIPS.

In CARIS, an SBDARE S-57 point object was created for each bottom sample. The object position was encoded to be the actual position of the sample as noted in the Bottom Sample Logsheet. Applicable information was entered for Nature of Surface, Nature of Surface - Qualifying Terms, Color, Source Date, Source Indication, Description, and Recommendations. Notes from the acquisition log were kept in the Remarks field.

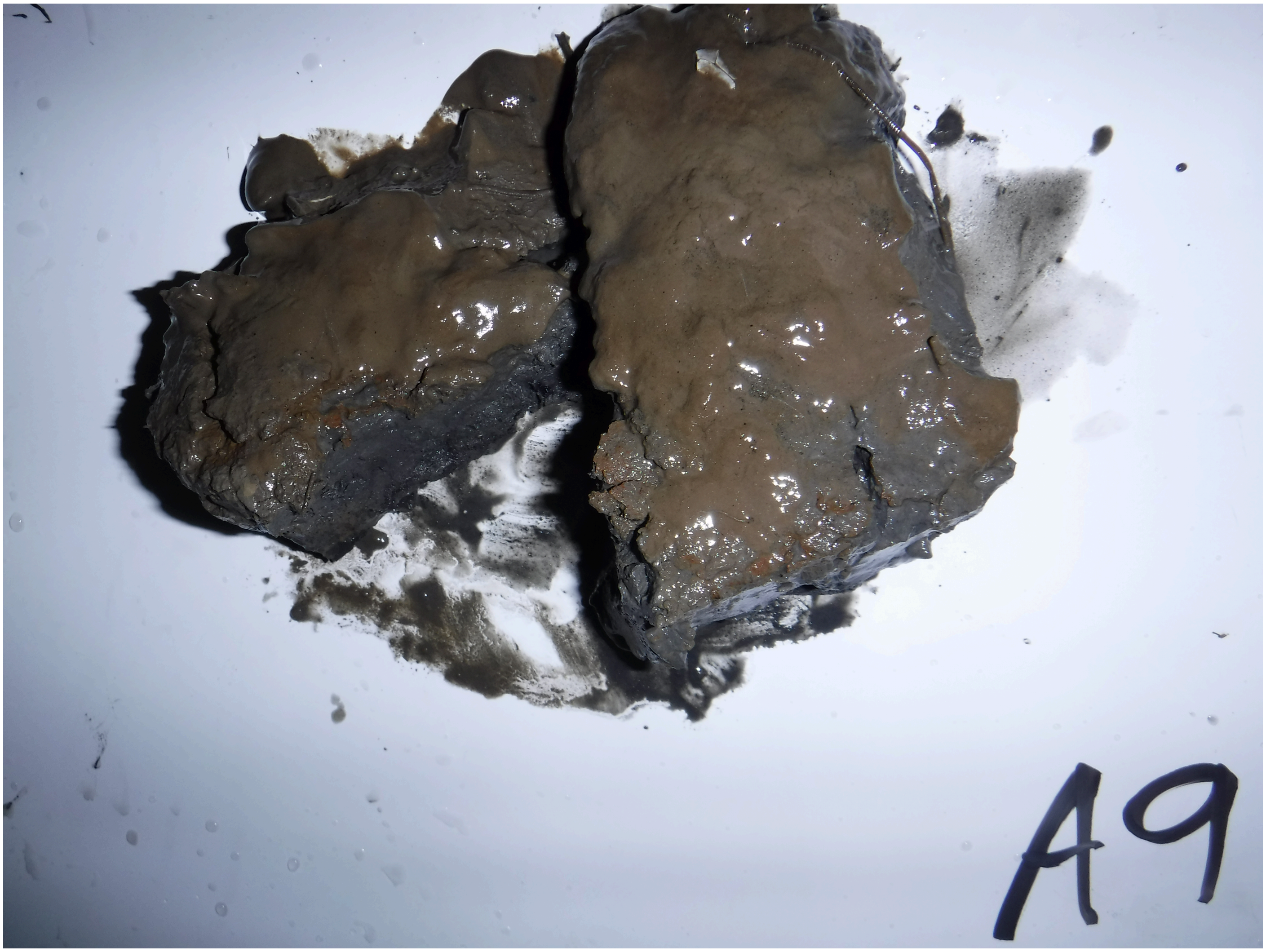


Figure 13: Example bottom sample from this project

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Initial field cleaning of multibeam data was done in the field using CARIS HIPS Swath Editor. Following application of filters, soundings were examined for spikes, fliers, or other abnormalities, and obviously erroneous soundings (fliers) were rejected. Cleaning status was tracked in a processing log along with processing comments or notes, if any. Logsheets are available with the project DRs.

Following application of final correctors including final tides, an examination of soundings was completed in CARIS HIPS Subset Editor, in context of bathymetric surfaces generated using the CUBE (Combined Uncertainty and Bathymetric Estimator) algorithm.

In CARIS HIPS, CUBE surfaces were first generated based on the depth resolution standards and CUBE parameters conforming to the 2019 HSSD. The CUBE surfaces were "finalized" using depth ranges for resolution specified in the HSSD. Surfaces were then loaded as a reference layer and examined in subset mode simultaneous with the contributing soundings. Only the CUBE surface appropriate for the depth and coverage type being examined was loaded.

To prevent unnecessary and excess rejection of soundings, requirements in the HSSD were adhered to during the subset editing process. Specifically, only soundings that caused the CUBE surface to error from the obvious seafloor position by an amount greater than the allowable TVU (total vertical uncertainty) at that depth were rejected. It is important to note that this surface-focused approach leaves noisy 'accepted' soundings that can exceed the TVU allowance, however, the final deliverable is the surface (not the soundings) and meets TVU specifications.

For editing consistency, the data was reviewed in subset with set visualization parameters. Data was examined looking along-track through the data, which is standard practice for examining bathymetry in subset. The subset view slice length was limited to approximately 10-15 lines, and slice width was constrained to about 25-50 m, based on ruggedness of the seafloor being examined. Vertical exaggeration in the subset window was manually set so the vertical scale graticule displayed in increments of 0.50 m, which approximated allowable TVU and served as a reference to the reviewer. Subset tiles were used to track editing progress, with care taken to ensure all data was examined.

D.1.2 Designated Sounding Selection

On occasion, designated soundings were flagged on the shoalest point of features not well modeled by the CUBE surface during subset editing. As specified in the HSSD, the shoalest sounding on a feature was designated only when the difference between the CUBE surface and reliable shoaler sounding(s) was more than 1 m as well as at least the maximum allowable TVU at that depth. Additionally, if a sounding on a feature was within 2 mm at survey scale (80 meters for most of the project's surveys) of a shoaler part of the surface (or a shoaler designated sounding), it was not designated.

D.1.3 Holiday Identification

Requirements for holidays in for "Set Line Spacing, Option A" were followed under this survey, referencing Section 5.2.2.4 of the 2019 HSSD. In survey areas where complete coverage was required, holiday requirements were followed based on "Complete Coverage Multibeam, Option A", referencing Section 5.2.2.3 of the 2019 HSSD.

Following application of preliminary correctors, filtering, and the first pass of manual edits in CARIS Swath Editor, 4 m resolution CUBE surfaces were generated and systematically examined for holidays in Set Spacing areas. 1 m resolution surfaces were generated for holidays in Complete Coverage areas.

Holidays were considered to be along-track gaps of at least 12 m in Set spacing coverage. This corresponded to the requirement that no holidays may span more than 3 nodes along-track in depths less than 20 m. When identified these holidays were recollected in the field if depths were greater than NALL and it was safe to do so.

Holidays in Complete Coverage areas had to meet the requirement of being equal to or greater than a square with the side length equal to the coarsest resolution for that depth. For this project 1 m resolution between 0 and 20 m depth covered all of the Complete Coverage survey areas. Therefore, holidays defined as a data gap equal to a 3 m by 3 m square or larger. When identified these holidays were recollected in the field if depths were greater than NALL and it was safe to do so.

D.1.4 Uncertainty Assessment

Uncertainty of final grids was assessed through use of QCTools v3.2.17 "Grid QA v5" utility. For each grid cell in the final surfaces, the utility examined the uncertainty value and determined if it fell within allowable TVU for the depth. It then presented statistics that included the percentage of grid cells with allowable TVU as well as the minimum and maximum values for uncertainty found. Areas of higher than allowable uncertainty, if any, were examined in CARIS HIPS. Results are available with each project DR.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Crossline to Mainscheme comparisons did not utilize difference surface methodology. Instead, crossline soundings were compared to a surface that consisted only of mainscheme lines. The crossline analysis was conducted using CARIS HIPS “Line QC report” routine. Each crossline was selected and run through the process, which calculated the depth difference between each accepted crossline sounding and a “QC BASE” surface created from the mainscheme data. The QC BASE surface was created as a CUBE surface at 4 m resolution in the same manner as the final surfaces, but with the important distinction that the QC BASE surface excluded crosslines to not bias the QC report results. Differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings with differences from the BASE surface falling within IHO Order 1. When at least 95% of the soundings exceed IHO Order 1, the crossline was considered to “pass,” but when less than 95% of the soundings compare within IHO Order 1, the crossline was considered to “fail.” A 5% (or less) failure rate was considered acceptable since this approach compares soundings to a surface (instead of a surface to a surface), allowing for the possibility of noisy crossline soundings that adversely affect the QC results while not necessarily affecting the final surfaces. Results were placed into Excel spreadsheets, amended with applicable line names and surface resolutions, and exported to PDF reports. One report was made and named for each crossline. Results of crossline comparison and the reports are available with each project DR. Note that crosslines can be any line that transects mainscheme data. They were usually intentionally ran as crosslines and as a result have "XL" in their filename in the survey records. However, on many occasions a recon or even a line originally intended as mainscheme was determined to be a good crossline due to significant numbers of crossings, and was selected in processing for crossline comparison purposes. These "crosslines" may not have "XL" in their filename, but all lines used as crosslines are itemized by name in each DR.

D.1.5.2 Junctions

Junction comparison was completed using difference surface methodology. Pydro's "Compare Grids" utility (v19.4) was utilized to complete the comparison. For each Current survey, overlapping final surfaces for junctioning surveys (both Current and Prior) were selected and ran through the utility. For each intersecting grid cell, the utility computed the difference between the depth values and then determined if the difference fell within the allowable TVU for the depth, and presented the results in graphical format. Junction results are available with each DR.

D.1.5.3 Platform to Platform

Echosounder Depth Comparison (Multi-Vessel)

MBES data collected with the ASV-CW5 was compared to MBES data collected with the Q105 using difference surface methodology in the same manner described above for Junction comparisons.
These echosounder depth comparisons were completed regularly during the project, normally at least one per week. During these checks, overlapping data from each vessel that was collected as close in time as possible (in some cases minutes apart) was selected and examined. This allowed for a direct comparison of results obtained by independent survey platforms for the same seafloor while minimizing the potentially confounding temporal factors of tide or bottom change.

In addition to differencing the results in the "Compare Grids" utility, the overlap was examined in CARIS Subset mode.

Results: The vessels compared well to each other. Mean differences for tests ranged from 0.13 m to -0.01, with the Q105 showing slightly shoaler than the ASV in general.

Results were summarized in a "Echosounder Depth Comparison" logsheet, which is available in Appendix V, as well as with the Project DRs.

D.1.6 Other Validation Procedures

Traceability and Integrity Overview

The traceability and integrity of the echosounder data, position, and other supporting data was maintained as it was moved from the collection phase through processing. Consistency in file naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

CARIS HIPS and SIPS was used for bathymetric data processing tasks on this project. CARIS HIPS was designed to ensure that all edits, adjustments and computations performed with the data followed a specific order and were saved separately from the raw data to maintain the integrity of the original data. CARIS HIPS also maintains a running log of all processes that were run on each survey line.

Quality control checks were performed throughout the survey on all survey equipment and survey results. The following sections outline the quality control efforts used throughout this project in the context of the procedures used, from acquisition through processing and reporting.

D.1.7 Other Validation Procedures

File Handling

A file naming convention was established prior to survey commencement for all raw files created in acquisition. Files were named in a consistent manner with attributes that identified the originating vessel, survey sheet, and Julian day. The file naming convention assisted with data management and quality control in processing. Data was more easily filed in its correct location in the directory structure and more readily located later when needed. The file naming system was also designed to reduce the chance of duplicate file names in the project.

Files that were logged over Julian day rollovers were named (and filed) for the day in which logging began. This convention was adhered to even if most of the file was logged in the “new” day.

During data collection, the raw data files were logged to a local hard drive in a logical directory structure (based on file type and Julian day) on the acquisition PCs. On the Q105, after logging of each file was complete it was copied to a network share on the vessel server that was available to the processors. Data processors then moved the files to their permanent storage location on the server, where the data was backed up and processing began.

ASV-CW5 data was transferred over a radio link after each line, or on rare occasion transferred to the Q105 server via USB drives whenever the unmanned vessel was back aboard. Deletion of files on the acquisition PCs was done only when necessary and only following confirmation of successful transfer to the Q105 vessel file server as well as backup to secondary USB hard drives.

At the end of the project following vessel demobilization, the vessel file server containing all project data was moved to TerraSond’s Palmer, Alaska office and integrated into the office IT system, where automated backups were configured, and processing and reporting continued.

D.1.8 Other Validation Procedures

Logsheets

Logs were kept during survey operations by the survey crew during both acquisition and processing. On this project, logs were kept in Excel format with all times and dates in UTC.

A log entry was made for all important files and events that occurred during survey data acquisition operations, especially those with the potential to impact data quality. In addition to communicating metadata useful to data processing, acquisition logsheets tracked the existence of files to data processing personnel to help ensure files were not missed. Processing logsheets were used to track the progress of the various processes utilized during data processing and helped with handoffs between various processing personnel. Logsheets also serve as the survey records for archival purposes.

The logsheets kept during acquisition included:

MBES Acquisition Logsheet: This captured information pertaining to the online acquisition of MBES data, and included the file name, survey area, date, start and end times, vessel speed and heading, general sonar settings such as power and gain, and any comments on abnormal situations or observations such as the influence of adverse weather on data quality and equipment or software issues. Note that while only one entry was made in the logsheet for each survey line, a survey line may consist of multiple files or segments due to QPS QINSy's automatic splitting of files as they increased in size. Separate sheets were kept for each vessel.

SVP Logsheet: Information captured included the filename of the cast, date, time, applicable survey area(s), geographic position, approximate depth of the profile, as well as comments (if any). In addition, the sound speed as measured by the MBES surface sensor at the time of the cast was noted and compared to the value obtained from the cast at the same depth, which served as reality check on both the surface sound speed sensor and SVP profiler sensor. This was kept for the Q105 only since the ASV-CW5 did not collect SVP profiles.

Event Log: Events of general importance were recorded in the Event Log. This included items such as weather conditions and crew change-outs (shift-changes), and events that document chronological gaps in the survey records such as launch and recovery of the ASV-CW5, weather downtime, tide gauge deployments, and transit to/from port for resupplies.

Hourly Logsheet: Survey status of vessels kept here with regards to Transit, Survey, or Down Time. Categories broken down further to help track hourly operations.

POS Acquisition Logsheet: This tracked the name of the POS file, start and end times, and any comments or observations. Separate sheets were kept for each vessel.

Vessel Draft Logsheet: This sheet recorded the static draft ("measure-down") value obtained by the survey crew along with its date, time, and any comments including the quality of the observation.

Depth Check Logsheet: This sheet recorded the results of any lead lines or bar checks. As described elsewhere in this report, these checks were completed only on the Q105.

Logsheets kept during processing included:

MBES Processing Logsheet: For each survey line, this logsheet tracked the progress of processing in CARIS HIPS, including application of corrections and status of manual editing. Steps tracked included conversion, SVP correction, filtering, application of Delayed Heave and SBET, Compute GPSTide, TPU, and Merge. The status of two reviews in HIPS Swath Editor was also logged. Processing comments were kept for any abnormal situations encountered. The initials of the survey staff member completing the process or task was also kept.

POS Processing Logsheet: For each POS (POSMV) file, this logsheet tracked POSPac processing completed and any notes or observations.

Times entered into logsheets were manually entered and may differ slightly from corresponding times within the digital files.

Shorthand letter identifiers for the various survey sheets were commonly used throughout the logsheets (as well as the associated raw and processed files). These were as follows:

Sheet 'A' = H13370
Sheet 'B' = H13371
Sheet 'C' = H13372
Sheet 'D' = H13373
Sheet 'E' = H13374
Sheet 'F' = H13375

Logs were exported to PFD format and included with the applicable DRs for reference.

D.1.9 Other Validation Procedures

Bar Checks

A bar check was used to determine and refine sonar Z offsets, and to check the relative accuracy of the echosounder and processing systems. This was completed on the Q105 on JD176 (6/24/20) during sea trials. The ASV-CW5 did not receive a bar check due to the difficulty involved with this check on the unmanned vessel – MBES data was compared directly to Q105 data instead (see multi-vessel echosounder comparisons below).

To perform the bar check, a rectangular steel grate was hung by cable from the vessel’s gunwale directly above the MBES sonar on the vessel's port side. The cable was marked at an interval of 1.0 m from the bar, determined by measuring tape. A sound speed profile was collected, and static draft (gunwale to the waterline) was measured.

With QINSy logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered in 1.0 m increments directly below the transducer while bar depth and time were noted in the depth check logsheet. Bar check depths ranged from 2.24 to 6.25 m and were limited by the ability to track the bar and the depth under the vessel while on anchor.

The bar depth was read relative to the gunwale, and later corrected to the waterline using the static draft measurement for comparison to the processed results.

Bar checks were processed in CARIS HIPS. The heave data record was removed, MBES data was sound speed corrected using the associated profile, and waterline measurement (static draft) applied. Depth of the bar relative to the waterline was extracted from HIPS in swath editor and compared to the actual bar depth at that time.

Processed bar depths (CARIS results) compared to actual bar depths to 0.045 m on average with a standard deviation of 0.012 m. The computed acoustic center Z value, which used the observed nadir value from the

MBES corrected for known vessel offsets to the measure-down point, compared to 0.008 m on average with a standard deviation of 0.015 m.

Results were considered excellent given the variables of a bar check. The bar check processing logsheet in Appendix V of this report.

D.1.10 Other Validation Procedures

Lead Lines

A lead line check was completed twice on the Q105 to check for gross error in the absolute accuracy for the echosounder and processing systems. The check was done on JD186 while tied up dockside in Nome, Alaska and again on JD234 while on anchor near Stebbins, AK.

The check was accomplished by lowering a measuring tape outfit with a 3 lb. weight to the seafloor from the static draft measure-down point and noting the value. The real-time (or raw) sonar depth at nadir was simultaneously noted. The two measurements were corrected to the water level using the established vessel offsets and the static draft measurement and compared.

The JD186 test returned a difference of 0.115 m (lead line shoal of seafloor).

The JD234 test was completed under better conditions with relatively flat seafloor and little current. Two consecutive checks were done, the first returning a difference from the MBES of 0.038 m, lead line shoal of seafloor, and the second returning a difference of 0.023 m, lead line deeper than seafloor.

Results of all tests were considered acceptable given the variables inherent in a lead line check, with the JD234 tests yielding excellent results. The lead line logsheet is available in Appendix V of this report.

D.1.11 Other Validation Procedures

SVP Comparisons

An SVP comparison was used to check the accuracy and consistency of the sound velocity profiler data. In the test, data from the primary sound speed profiler was compared to two other independent, recently calibrated sound speed profilers. All three profilers were lowered simultaneously to the seafloor, with the probes taped together so that the sensors were located as close as possible to each other. Results were then compared in Excel by graphical examination and computation of mean difference and standard deviation.

On this project, one formal confidence check was completed in this manner on JD175. The check was completed while tied up in Homer, Alaska. Two Valeport rapidPro SVT profilers (SN 71026 and 71027) and one Valeport Swift (SN 68632) were used in the check. The check extended to a depth of about 7.9 meters and returned a mean difference of 0.238 m/s with a standard deviation of 0.36 m/s.

Overall, the Swift had a higher sound velocity than the other two RapidPros, on average it's velocity was 0.34 m/s faster than the RapidPros. The two RapidPros only differed from each other by 0.044 m/s.

The second RapidPro (SN 71027) was not used during the project as it was lost overboard during sea trials after the SVP comparison had been completed.

As described earlier in this report, formal comparisons were also undertaken at each SVP cast between the surface sound speed sensor on the Q105 and the profile.

The SVP Comparisons were exported to PDF format and are available with the project DRs.

D.1.12 Other Validation Procedures

Vessel Positioning Confidence Checks

As discussed elsewhere in this report, POSMV data was post-processed in Applanix POSPac MMS using Applanix SmartBase (ASB) methodology. As check on ASB positioning to ensure vessel positioning was consistent regardless of processing method used, and as an overall accuracy check of vessel positioning, vessel position confidence checks were accomplished by processing with an alternative POSPac processing method and comparing to the primary method. These checks were accomplished on a weekly basis.

To complete the check for each vessel, a random POS file was selected from each week and processed with both PP-RTX and ASB methodology. The two independent post-processed solutions were differenced in POSPac MMS's "Navdif" utility. A difference plot was produced, which was recorded on a vessel positioning confidence form along with the comparison parameters and observations.

Results were good, with average differences agreeing to 0.2 m vertically and 0.1 m horizontally, (or better), demonstrating consistent results regardless of the processing method used.

The vessel positioning confidence checks were exported to PDF format and are available with the project DRs.

D.2 Imagery data Integrity and Quality Management

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

E. Approval Sheet

All operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy.

This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the Statement of Work and Project Work Instructions.

Approver Name	Approver Title	Date	Signature
Thomas Morino	Lead Hydrographer	01/12/2021	Thomas Morino Digitally signed by Thomas Morino Date: 2021.01.12 16:39:54 -09'00'
Andrew Orthmann, C.H.	Charting Program Manager	01/12/2021	Andrew Orthmann Digitally signed by Andrew Orthmann Date: 2021.01.12 16:40:19 -09'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	OPR-R385-KR-20_DAPR_Appendices.pdf
Sound Speed Sensor Calibration	OPR-R385-KR-20_DAPR_Appendices.pdf
Vessel Offset	OPR-R385-KR-20_DAPR_Appendices.pdf
Position and Attitude Sensor Calibration	OPR-R385-KR-20_DAPR_Appendices.pdf
Echosounder Confidence Check	OPR-R385-KR-20_DAPR_Appendices.pdf
Echosounder Acceptance Trial Results	N/A