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-R302-KR-22
Time Frame:	June - August 2022

LOCALITY

State(s):	Alaska
General Locality:	Nunivak Island

2022

CHIEF OF PARTY
Andrew Orthmann

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Data Acquisition and Processing Report

Terrasond
Chief of Party: Andrew Orthmann
Year: 2022
Version: 22.1
Publish Date: 2022-12-29

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' (32 m) 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 Alaskan 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 6-ton 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, 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 *Beam*: 9.1 *Max Draft*: 1.8
Most Recent Full Static Survey	*Date*: 2019-03-23 *Performed By*: TerraSond
Most Recent Full Offset Verification	*Date*: 2022-06-03 *Method*: Taped applicable offsets

Figure 1: The Qualifier 105 (Q105) vessel.

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 yearly by TerraSond on previous NOAA task orders in Alaska from 2016 through 2020. 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 up to 3km 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
	Beam	1.7
	Max Draft	0.9
Most Recent Full Static Survey	*Date*	2019-06-29
	Performed By	TerraSond

Most Recent Full Offset Verification	*Date*	2022-06-03
	Method	Taped applicable offsets

Figure 2: The ASV-CW5 in its launch system on the back deck of the Q105.

Figure 3: The ASV-CW5 working in the survey area.

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 system. This system consisted of a transmit (Tx) array, a receiver (Rx) array, 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 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 (normally 30 used on this project)
Number of Beams: 512 max at 400 kHz
Max Swath Angle: 165 degrees

Depth Range: 0.5 to 150 meters at 400kHz
Depth Resolution: 0.006 meters

Qualifty control and accuracy checks included bar checks (Q105 only), inter-vessel surface comparisons, lead-line checks (Q105 only), and crossline analysis. These are detailed later in this report.

Manufacturer	Teledyne Reson				
Model	SeaBat T50-R				
Inventory	*338192000 (MMSI)*	*Component*	Rx Array	Tx Array	Topside
		Model Number	EM 7218	TC 2181	T-50 RSP INS
		Serial Number	2318037	1618050	05752318013
		Frequency	N/A	400 kHz	N/A
		Calibration	N/A	N/A	N/A
		Accuracy Check	2022-06-05	2022-06-05	N/A
	CW76	*Component*	Rx Array	Tx Array	Topside
		Model Number	EM 7218	TC 2181	T-50 RSP INS
		Serial Number	1518012	818041	5753818010
		Frequency	N/A	400 kHz	N/A
		Calibration	N/A	N/A	N/A
		Accuracy Check	2022-06-18	2022-06-18	N/A

Figure 4: T50 mounted on hydraulic arm on the Q105.

Figure 5: T50 mounted on ASV-CW5 keel.

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 Various GNSS Tide Buoys

Two GNSS Tide Buoys were installed on the western side of Nunivak Island. Buoy 946BBBB was located just NW of Cape Mendenhall. Buoy 946AAAA was located just south of DookSook Lagoon on NW Nunivak Island. Refer to the HVCR for additional information on the GNSS tide buoy deployments.

Manufacturer	Various				
Model	GNSS Tide Buoys				
Inventory	*Component*	GNSS Reciever	GNSS Antenna	GNSS Antenna	Modem
	Model Number	Septentrio AsterRX SB	Septentrio PolaNt-X	Septentrio PolaNt-X	Iridium
	Serial Number	3041147	12422788	12695180	J1B9H0
	Calibration	N/A	N/A	N/A	N/A
	Component	GNSS Reciever	GNSS Antenna Primary	GNSS Antenna Secondary	Modem
	Model Number	Septentrio AsterRX SBi3 Pro	Septentrio PolaNt-X MF	PolaNt-X MF	Iridium
	Serial Number	5402223	15504	15531	J1B9NW
	Calibration	N/A	N/A	N/A	N/A

Figure 6: GNSS Tide Buoy (946AAAA) deployed for this project.

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

This system is branded by Teledyne Reson with a T-series IMU-20 or IMU-30 but is a repackaged Applanix POSMV Wavemaster integrated with the Reson T-50 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 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 multibeam, which simplifies connections and communications between the systems.

On the Q105, the system utilized POS software version 10.3 (firmware version 10.31 and POSView version 10.3). While on the ASV, 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.

<table>
<tr><td>Manufacturer</td><td colspan="7">Applanix</td></tr>
<tr><td>Model</td><td colspan="7">POSMV Wavemaster II</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">338192000 (MMSI)</td><td>Component</td><td>IMU</td><td>GNSS Antenna 1</td><td>GNSS Antenna 2</td><td>Rack Mount Topside</td></tr>
<tr><td>Model Number</td><td>T-Series IMU-30</td><td>AT1675-540TS</td><td>AT1675-540TS</td><td>T50 RSP INS</td></tr>
<tr><td>Serial Number</td><td>13252</td><td>13009</td><td>na</td><td>05752318013</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="4">CW76</td><td>Component</td><td>IMU</td><td>GNSS Antenna 1</td><td>GNSS Antenna 2</td><td>Rack Mount Topside</td></tr>
<tr><td>Model Number</td><td>T-Series IMU-20</td><td>AT1675-540TS</td><td>AT1675-540TS</td><td>T50 RSP INS</td></tr>
<tr><td>Serial Number</td><td>579232</td><td>13007</td><td>13013</td><td>5753818010</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

A.5.2 DGPS

A.5.2.1 Hemisphere AtlasLink Smart Antenna

Each survey vessel was outfit with a Hemisphere AtlasLink receiver to provide real-time, RTK-level GNSS corrections to the vessel POSMV to assist with navigation.

The receivers utilized the SBAS, subscription-based Atlas H10 offshore service.

However, all real-time corrections were replaced in CARIS HIPS for final deliverables through application of post-processed kinematic (PPK) SBET data generated in Applanix POSPac MMS software, as described elsewhere in this report.

Manufacturer	Hemisphere		
Model	AtlasLink Smart Antenna		
Inventory	*338192000 (MMSI)*	*Component*	AtlasLink
		Model Number	Smart Antenna
		Serial Number	B1920-03697-01-220
		Calibration	N/A
	CW76	*Component*	AtlasLink
		Model Number	Smart Antenna
		Serial Number	B1920-03697-01-206
		Calibration	N/A

A.5.3 GPS

Additional GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

A.5.5 Other Positioning and Attitude Equipment

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 was not equipped with a moving vessel profiler.

<table>
<tr><td>Manufacturer</td><td colspan="4">Teledyne Oceanscience</td></tr>
<tr><td>Model</td><td colspan="4">RapidCast</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">338192000 (MMSI)</td><td>Component</td><td>Sound Speed Deployment Winch</td><td>Control Box</td></tr>
<tr><td>Model Number</td><td>RapidCast</td><td>RapidCast</td></tr>
<tr><td>Serial Number</td><td>147</td><td>154</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td></tr>
</table>

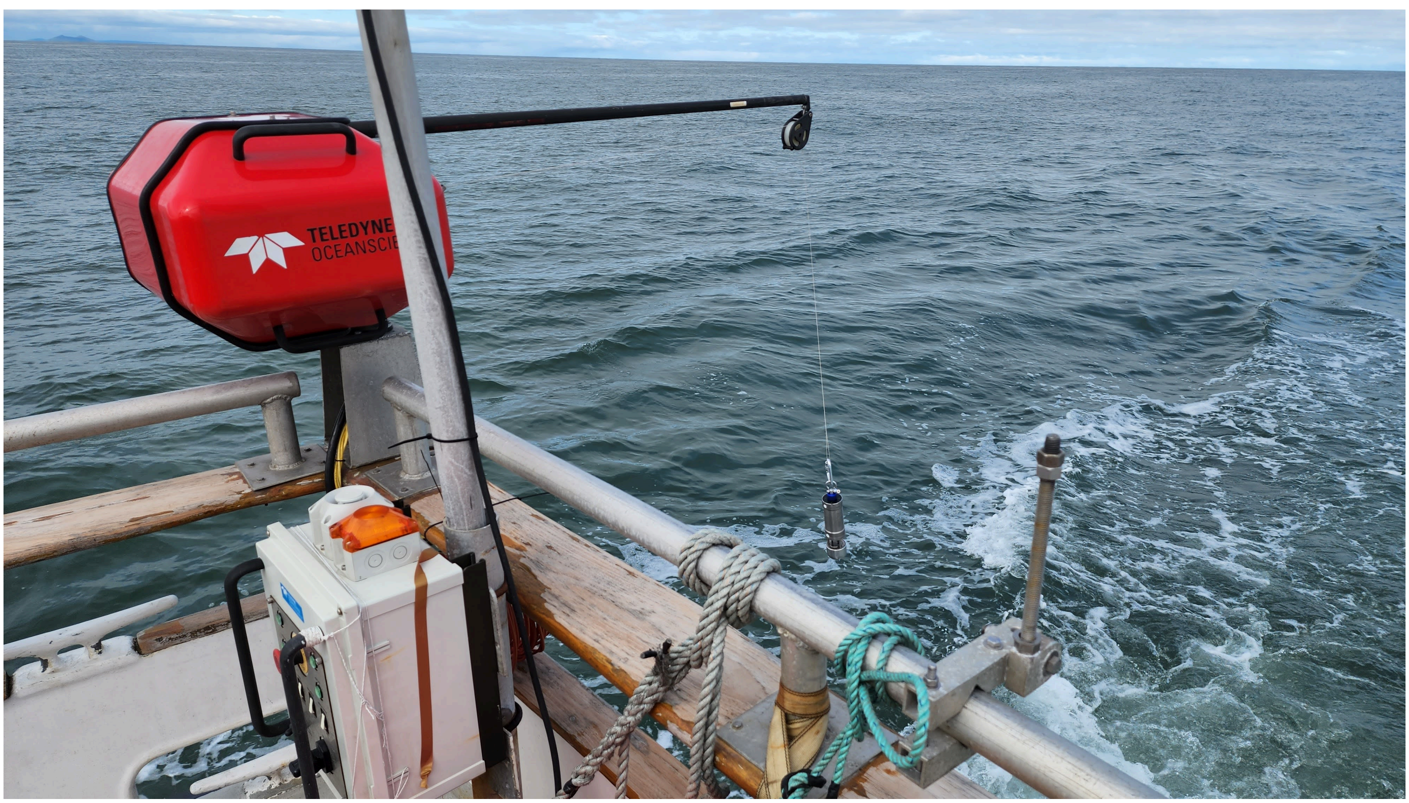

Figure 7: RapidCast system recovering the Valeport SWiFT sound speed profiler on the back deck of the Q105.

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 Valeport SWiFT SVP

A Valeport SWiFT SVP was used on the Q105 as the primary sound speed sensor. Two sensors were utilized over the course of the project.

The SWiFT is designed to be used with the RapidCast deployment system and features a GPS sensor for profile positioning. It has a maximum depth rating of 100 m, which was sufficient for this project.

The ASV was not equipped to deploy SVP sensors. Profiles acquired with the Q105 were used to correct ASV data, which was possible because the ASV worked in close range to the Q105, usually 2 km or less.

On rare occasion where the ASV was out of range of the Q105 (only during Mekoryuk survey of H13589) , a skiff accompanied the ASV and collected profiles with the SWiFT sensor nearby by hand.

For quality control, the sensors were compared against each other during a side by side test on JD179 and had a mean difference of 0.136 m with a standard deviation of 0.006 m. Results are available with the project DRs.

Manufacturer	Valeport			
Model	SWiFT SVP			
Inventory	*338192000 (MMSI)*	*Component*	Sound Speed Profiler	Sound Speed Profiler
		Model Number	SWiFT SVP	SWiFT SVP
		Serial Number	68631	63780
		Calibration	2022-02-23	2022-02-24

A.6.4 TSG Sensors

A.6.4.1 AML Oceanographic Micro-X with SV-Xchange Surface Speed Sensor

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 an SV-Xchange sensor tip.

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 -0.076m/s with a standard deviation of 0.419 m/s.

Results are available with each project DR.

<table>
<tr><td>Manufacturer</td><td colspan="4">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="4">Micro-X with SV-Xchange Surface Speed Sensor</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">338192000 (MMSI)</td><td>Component</td><td>Surface Sound Speed Sensor - Housing</td><td>Surface Sound Speed Sensor - Sensor Tip</td></tr>
<tr><td>Model Number</td><td>Micro-X</td><td>SV-Xchange</td></tr>
<tr><td>Serial Number</td><td>10873</td><td>207266</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-02-16</td></tr>
<tr><td rowspan="4">CW76</td><td>Component</td><td>Surface Sound Speed Sensor - Housing</td><td>Surface Sound Speed Sensor - Sensor Tip</td></tr>
<tr><td>Model Number</td><td>Micro-X</td><td>SV-Xchange</td></tr>
<tr><td>Serial Number</td><td>11175</td><td>207548</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2022-02-16</td></tr>
</table>

A.6.5 Other Sound Speed Equipment

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

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
QPS	QINSy	9.4.6.781, Build 2022.04.16.1	Acquisition
Teledyne Reson	Reson Sonar UI (7k Control Center)	5,0,0,11 (7kCenter: 6,3,0,19)	Acquisition
L3Harris-ASV	ASView	2022	Acquisition
Valeport	Valeport Connect	1.0.7.0	Acquisition
Teledyne Oceanscience	RapidCAST Interface	1.3.2.22	Acquisition
Applanix	POSView	10.3 (Q105), 10.2 (ASV)	Acquisition
NOAA CSDL/UNH/CCOM	Sound Speed Manager	2022.1.0	Acquisition and Processing
NOAA	Pydro	19.4 (Field), 22.1 (Office)	Processing
Teledyne CARIS	HIPS & SIPS	11.4.8 and 11.4.9 (Field), 11.4.15 (Office)	Processing
Applanix	POSPac	8.7.7908.20821	Processing
QPS	FMGT	7.10.1 (Field), 7.10.2 (Office)	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Wildco 3-1728-G40

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

Samples were acquired at locations assigned in the PRF. In addition, samples were assigned in the Project Instructions that did not have corresponding locations specified in the PRF. For these, the field crew chose locations that were both geographically distributed and broadly representative of areas identified in the backscatter records.

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 both vessels, the IMU was mounted on standard manufacturer-provided T-50 MBES single-head brackets.

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 03, 2022 on both vessels.

Offsets 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.

Offsets from the CRP up to the static draft (measure-down) point-or point from where draft measurements would be made were also measured directly by tape. On the Q105, this point was on the rail directly above the MBES head. Similarly, on the ASV, this point was on the upper edge of the hull in-line with the MBES mounting bracket.

Offsets 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 Q105 and the T-50 on the ASV were 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.

Refer to Appendix III for vessel offset survey records.

B.1.1.1 Vessel Offset Correctors

<table>
<tr><td>Vessel</td><td colspan="4">338192000 (MMSI)</td></tr>
<tr><td>Echosounder</td><td colspan="4">Teledyne Reson Reson T-50 RSP INS</td></tr>
<tr><td>Date</td><td colspan="4">2022-06-15</td></tr>
<tr><td rowspan="14">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.091 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.167 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y2</td><td>0.279 meters</td><td>0.010 meters</td></tr>
<tr><td>z2</td><td>0.214 meters</td><td>0.010 meters</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.091 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.167 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>0.000 meters</td><td>0.010 meters</td></tr>
<tr><td>y2</td><td>0.279 meters</td><td>0.010 meters</td></tr>
<tr><td>z2</td><td>0.214 meters</td><td>0.010 meters</td></tr>
<tr><td>Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
</table>

Vessel	CW76			
Echosounder	Teledyne Reson Reson T-50 RSP INS			
Date	2022-06-15			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.000 meters	0.010 meters
		y	0.091 meters	0.010 meters
		z	0.167 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.279 meters	0.010 meters
		z2	0.214 meters	0.010 meters
	Nav to Transducer	*x*	0.000 meters	0.010 meters
		y	0.091 meters	0.010 meters
		z	0.167 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.279 meters	0.010 meters
		z2	0.214 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.

Initial waterline measurements are noted below. Subsequent waterline measurements obtained on the vessels were similar, within 0.10 m of the initial values or less. All waterline measurements are available in the CARIS HVF for each vessel, and static draft logsheets are available with the project DRs.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
338192000 (MMSI)	2022-06-15	0.030 meters	-1.935 meters	0.020 meters
CW76	2022-06-18	0.010 meters	-0.638 meters	0.020 meters

B.2.2 Dynamic Draft

As an ERS survey, effects of dynamic draft are accounted for in the GNSS corrections. Therefore dynamic draft correctors were not derived or applied for this survey.

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 both vessels following mobilization in Homer, Alaska on JD158. Another patch test was completed on JD230, near the end of the project, to compare against the initial values. The final patch test returned the same values as the initial patch test, indicating there was excellent alignment stability throughout the entire project.

Industry-standard patch test procedures--summarized below--were used to determine latency, pitch, roll, and yaw correctors.

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.

Patch test data received standard corrections and processing prior to examination in CARIS HIPS prior to determining the calibration values.

Note that zero (0) values were obtained for all patch test results for pitch, roll, and yaw. This was confirmed on two separate patch tests, on JD158 following mobilization, and near the end of the project while on site on JD230. This was not unexpected as the IMU and MBES were mounted on manufacturer brackets which provided precise alignment between the IMU and MBES systems.

Accuracy checks on the T50-R systems included:

1. A bar check: A formal bar check was completed on JD156 on the Q105 and yielded good results. Mean echosounder agreement (with vessel offsets applied) to the actual bar depth was -0.020 m for processed data and 0.017 for real time data.

2. Echosounder comparisons: The T50 systems on each vessel were compared weekly to each other. Results were good, with the vessels always having a mean difference that was at most 0.07 m, but usually 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. Four lead lines were performed and compared against Q105 MBES data, on JD 156, JD 201, JD217, JD230 that returned differences of MBES nadir depth of -0.04 m, 0.13 m, 0.52 m, and 0.13 m respectfully. Results were deemed acceptable given the environmental variables 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.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td colspan="3">338192000 (MMSI)</td></tr>
<tr><td>Echosounder</td><td colspan="3">Teledyne Reson Reson T-50 RSP INS</td></tr>
<tr><td>Date</td><td colspan="3">2022-06-07</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Pitch</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>CW76</td></tr>
<tr><td>Echosounder</td><td>Teledyne Reson Reson T-50 RSP INS</td></tr>
<tr><td>Date</td><td>2022-06-07</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
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<tr><td>Yaw</td><td>0.000 degrees</td><td>0.000 degrees</td></tr>
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<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
</table>
</td></tr>
</table>

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Q105 and ASV acquisition systems were configured nearly identically.

Both vessels utilized Intel-based Windows 10 PCs for acquiring data. 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. Since both the POSMV and Reson systems share the same topside on the Q105, there is only one network connection between the Windows PC and integrated rack mount topside.

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. For the both vessels, connections between the POSMV and Reson systems are integrated internally in one rack mount topside.

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 primarily done to “Set Line Spacing” (“Option A: Multibeam Sonar Set Line Spacing without Concurrent Side Scan Sonar Coverage”), as described in the HSSD. MBES backscatter was also acquired during all MBES data acquisition. Line spacing generally ranged from 120 to 480 meters.

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. In addition, lines were oriented to be oblique to the expected position of depth contours per the Project Instructions. Line plans were periodically modified on the fly as necessary, usually by the addition of splits to develop shoals, charted soundings shoaler than adjacent survey data, and investigation areas, as well as 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 2 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 5 to 7 knots, and much 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 T50 sonars, generating up to 512 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. 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 (if applicable) 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.

During conversion, ITRF2008 was selected as the geographic datum to match the output reference system of the AtlasLink RTK positioning source. Note that all real-time positions are ITRF2008, but final positions are all NAD83(2011) due to the application of NAD83(2011) SBETs to all survey lines.

CARIS HIPS created a directory structure organized by project (area) and line. 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 the T50 systems were a single head. Per the bulletin, this was necessary because QINSy was configured to log "new" style (Reson 7027) bathymetric records, and XTFs were set to contain "raw" Reson records instead of "QPS" 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.

Import Auxiliary 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. Attitude data, also available in the SBET, was NOT loaded. 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.

Additionally, "Import Auxiliary Data" was used to load Delayed Heave from POSMV (POS) files to all lines. Only Delayed Heave and Delayed Heave RMS error was loaded from POS files. Note that on occasion, usually due to a crash of the PC running POSView, a POS file would not be able to be applied to a line segment. In these cases real-time heave was used in all HIPS processes. These cases are itemized where the occurred in the appropriate DRs.

Dynamic Draft Corrections

Separate dynamic draft corrections were not required for this project as it was an Ellipsoid Referenced Survey (ERS).

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 on some nearshore traces where it was desirable to keep the shoalest beams closest to shore. This filtering 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, to 55 degrees from nadir.

Georeference Process

The “Georeference” process was run on all lines in CARIS HIPS.

During this process, the following corrections were made.

1. Sound Velocity Correction was enabled. The appropriate SVP file for the vessel and area was selected. The option to use nearest in distance in time 2 hours was used for final corrections.

2. TPU computation was enabled. "GPS Sounding Datum" error was set to 0.130 m per the stated error for the ERTDM model in the Project Instructions. Measured sound velocity error was set to a value that was determined by area and vessel. Surface sound velocity error was set to 0.025 per AML specifications for the surface sound speed sensors. All error sources were set to "Vessel" to use the estimated errors in the HVF, except for "Tide" which was set to use "Static" error.

3. GPS Vertical Adjustment (GPS Tide) was enabled. The NOAA-provided CSAR separation surface was selected as the model file, using the band name "NAD83_MLLW". The coordinate reference system was set to NAD83(2011) to match the SBET processing system. Dynamic Heave source was set to "Delayed Heave", except in rare cases (itemized in the DRs) where Delayed Heave was not available and Real-Time heave was selected instead. The waterline source was set to "Vessel".

Multibeam Swath Editing

Initial cleaning of multibeam data was done in the field using CARIS HIPS Swath Editor. Obvious fliers and erroneous data were manually 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.

Two methods were primarily 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.

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

Any line files requiring alternate SBET or height processing methodology are described in the applicable DR.

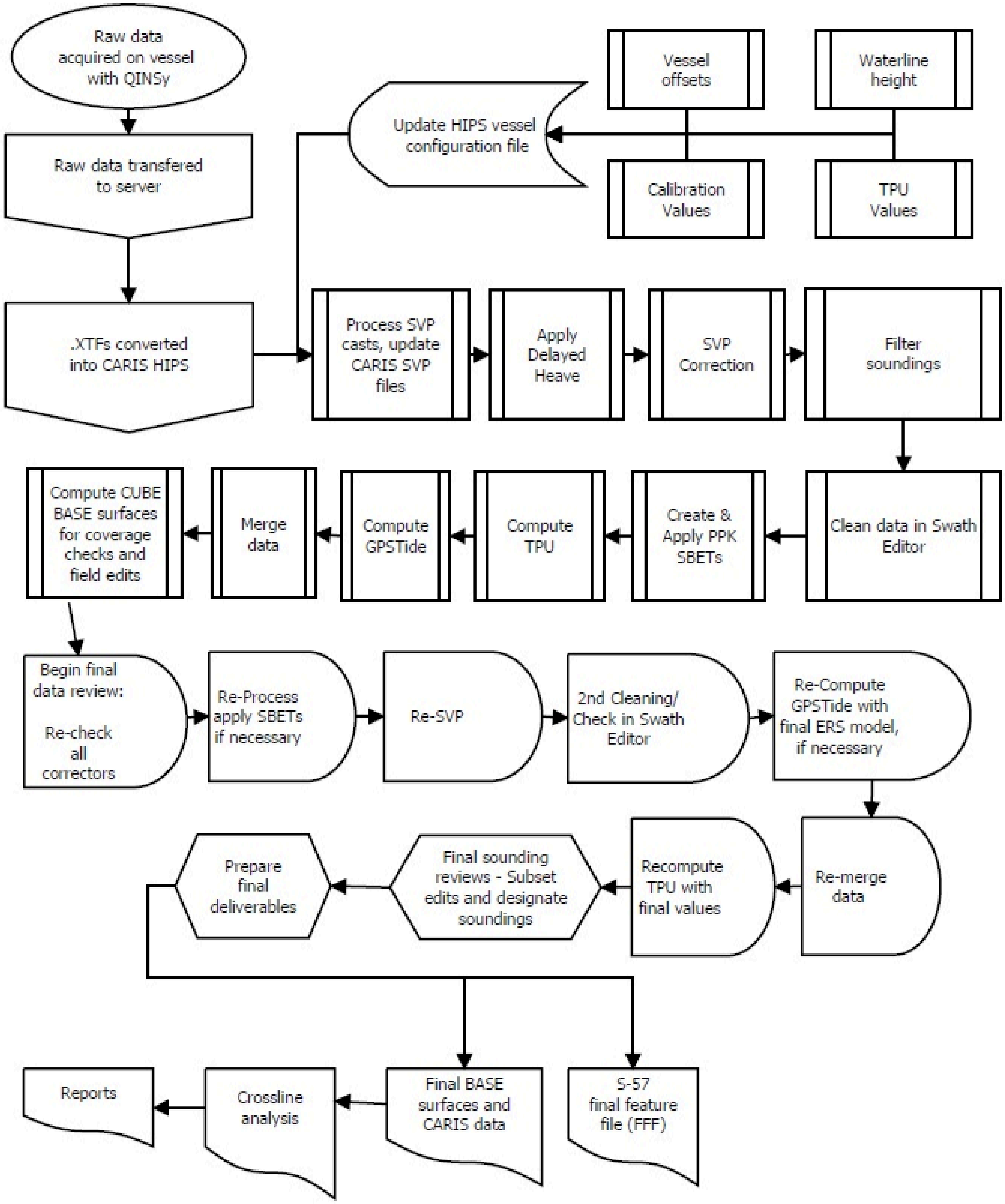

Figure 8: High level processing flow diagram.

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 11.4.15 in CSAR format and represent the seafloor at the time of survey with depths relative to chart datum (MLLW).

Resolutions of the CSAR surfaces were created in accordance with the 2022 HSSD based on coverage type and depth. Coverage types required on this survey were “Set Line Spacing” (Option A).

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 (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. 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, XTF, 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.

Changes to the MBES settings were minimized when surveying to a few pre-set groups to simplify processing. Both vessels maintained substantially similar, if not identical, sonar settings to eliminate relative shifts between their respective backscatter datasets. This was simplified by the fact both vessels utilized the same MBES sonars (Reson T50s) and were operated at the same frequency (400 kHz).

A calibration was run on a sample line within sheet F00847 in order to determine if an offset was needed to compensate for differences between the backscatter collected by the systems on the Q105 and the ASV. Additionally, the calibration was used to create beam pattern correction files for use in FMGT processing. The calibration line was run multiple times by each vessel, twice (opposing directions) for each group of MBES settings utilized during data collection on the project. A bottom sample was then collected and documented for ground truthing purposes.

Data collected for the calibration as well as the beam patter correction file are provided with the "Calibration" survey deliverables.

Data Processing Methods and Procedures

Initial data processing was carried out aboard the Q105. Final data processing and reporting was completed in the office following the completion of field operations. Data was processed in accordance with standard TerraSond processing procedures – customized as necessary – for this survey.

Following transfer from the acquisition computers, MBES backscatter data was paired (using DB-QPD pairing in FMGT), imported, processed, and filtered. The backscatter was then used to create mosaics which were briefly examined for coverage and quality determination. If infills were required, the processor would note the issue in the log and inform the data acquisition team.

After the conclusion of data acquisition in the field the MBES backscatter was reprocessed in the office using XTF-CARIS HDCS pairings (discussed in more detail below).

Importing MBES Backscatter into FMGT

QPS's FMGT software was the primary software used for backscatter processing for this project. When importing backscatter data FMGT pairs a backscatter source with a digital terrain model (DTM) to create the GSF file that will be used for processing. It should be noted that once the GSF is created, FMGT no longer needs to reference the original source and DTM files. The FMGT project was configured to be in the NAD83 (2011) UTM Zone 3N datum.

Prior to importing and pairing files, settings configuration files were created for each MBES system and setting group to reflect the differences in the MBES settings during data collection. Each setting file was configured to apply FMGT's backscatter corrections, apply the beam pattern correction file, and retain ARA data for later analysis (and possible use in seafloor classification). The beam angle limits were set to -65 & 65 degrees while in the field. For processing in the office angle limits of -75 & 75 degrees were used to include the entirety of the swath collected by the Reson T50 MBES. An absorption value of 110 dB/km was used as it matches the configuration for the Reson T50 in salt water when realtime absorption values are not collected.

In the field QPS database files (.db) were used as the backscatter source, while the realtime DTM from QINSy was used (.QPD). In FMGT these files were paired together by matching exact file names, and the appropriate settings file was applied. As the Db and QPD files were already in the appropriate datum from QPS QINSy, NAD83 (2011) UTM Zone 3N was read from the imported files and used as the source datum. FMGT would then import the files and create the GSF files for each pair of backscatter source and DTM files.

After field data collection was completed and MBES bathymetry processing was complete in CARIS HIPs the backscatter was reprocessed to reflect the final bathymetry. This was done by utilizing XTF (extended Triton format) files from QINSy as the backscatter source and CARIS HDCS data (the processed bathymetry) was used for the digital terrain model. The process for pairing the XTF files and HDCS data was similar to the process used in the field. However, copies of the XTF files had to be renamed to match the trackline names from the HDCS (" – " to "_--_") so as the filenames needed to match exactly. In addition, prior to starting the import process, a copy of the CARIS project was converted from NAD83 (2011) UTM Zone 3N to WGS84. This was done as the raw data in the XTFs was in WGS84/ITRF2008 and FMGT assumes the paired source and DTM files are in the same datum. After the files were paired and the appropriate settings and datum were selected, FMGT then imported the files and created the GSF files for processing.

It should be noted FMGT only allows one settings file to be selected during each import, so files were imported chronologically in groupings of files with the same sonar settings.

Backscatter Processing and Mosaic Creation

Following the creation of the GSF file from the paired backscatter sources and DTM files, the mosaic pixel size settings (effectively surface resolution) were adjusted to be 2 meters to meet specifications in the project instructions. FMGT automatically calculated and adjusted the statistic layer to be 40 meters. Due to the size of the sheet mosaic tiles were created for the extents of the FMGT project to keep the required mosaic memory reasonable. These tiles were sized at 2500 x 2500 units (a unit is equal to the mosaic pixel size). The mosaic process was then started from the manual processing tab in FMGT. FMGT then processed the data for coverage, applied adjustments and correctors, filtered the data, and rendered the mosaic. As the statistic and ARA product layers are not required deliverables they were not created. However, the data for their creation is present in the GSFs.

Coverage QC and Geo TIFF Export

Following the creation of the backscatter mosaic the mosaic was examined by the processor for coverage gaps and issues. In the office the mosaic was then used to export a “Merged Floating Point” Geo Tiff as per requirements.

Calibration and Creation of the Beam Pattern Correction File

For the calibration mentioned in the data acquisition section DB and QPD file pairs were used for the creation of the GSF files in FMGT. These files were then processed as described above for each file, however the “rebuild all” option was used so that the ARA and Statistic layers would also be created. No beam pattern correction file was applied.

Upon visual examination of the resultant mosaics, it was determined that no offset between the Q105 and ASV was required to bring their backscatter results into alignment. This was expected as both vessels utilized near identical Reson T50R MBE systems and maintained similar to identical sonar settings during acquisition.

In order to create beam pattern correction files for each system and settings group, the edit segment tool was used to select the calibration area. The Beam pattern correction tool was then opened for the selected segment. The collected bottom sample was then used to classify the seafloor and generate beam pattern corrections. This was done for each settings group with both vessels. The results were then saved as beam pattern correction files. It should be noted that the correction for each vessel and settings group were the same. This was somewhat expected as the MBES systems used on each vessel were nearly identical Reson T50R MBE systems. As a result, only the Q105-P220-G10PL30-A110-S30 beam pattern correction file was used during processing. The beam pattern correction files generated by this calibration are available alongside the raw data collected during the calibration.

Note regarding XTF-HDCS pairing and FMGT mosaic artifacts:

An issue was noted early during field processing of MBES backscatter data that significant noise and motion artifact was present when utilizing paired XTFs and CARIS HDCS data during the import and GSF creation stage in QPS FMGT. However, the artifact was not present, or at least significantly reduced, when DB – QPD files were used for GSF creation, indicating the issue was with the XTF-CARIS HDCS pairing instead of the backscatter data itself.

The issue was brought to the attention of QPS technical support, and it was eventually determined to be an error in FMGT v7.10.1 (which was the latest version available at the time of the field work) resulting in mismatches within XTF-HDCS pairs during the import and creation of the GSFs from the raw data. For this reason, backscatter coverage checks in the field utilized DB-QPD pairing in FMGT because it did not exhibit significant noise or other artifact. However, DB-QPD pairing is not linked to the final (cleaned) processed bathymetry.

QPS subsequently released FMGT 7.10.2 to address the issue. All final backscatter products (GSFs and mosaics) were then generated in 7.10.2 for this project. This version appeared to mitigate much of the original issue. However, artifact that appears motion-related is still present sporadically in products created with this version when using CARIS HDCS pairing. This artifact is apparent during periods when the vessels were experiencing above normal motion, and especially on the ASV-CW5 vessel's data due to its small size and excessive motion relative to the larger vessel.

This was also brought to QPS support's attention and the feedback at the time of data submission is that there may still be issues with XTF-HDCS pairing but they are working on solutions that should be available in an upcoming FMGT version. It should be noted for any future backscatter processing that DB-QPD pairing appears to generate a better backscatter product than XTF-HDCS pairing with this data set (when using the FMGT version available at the time of data submission). However, final GSFs and mosaics were provided using XTF-HDCS pairing per requirements for backscatter data to be based on the final (cleaned) bathymetric data. All file types (DB, QPD, XTF, GSF) are provided with the survey deliverables.

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

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

The POSMV positioning systems on both vessels were configured to receive Atlas H-10 correctors using Hemisphere SmartLink antennas. Atlas H-10 correctors allowed the POSMVs to operate in RTK mode, assisting with real-time vessel positioning -- especially corrected depth determination.

As a backup, the POSMVs would operate using their integrated WAAS receivers if Atlas H-10 was not available.

Most lines therefore used Atlas H-10 for real-time corrections, but were occasionally (in whole or part) WAAS. All realtime corrections were ITRF.

However, in all cases, H-10 (or WAAS) corrections were replaced with post-processed positions in NAD83(2011) from post-processed SBET files.

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.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

Two GNSS tide buoys were installed for this project.

However, no data from the tide buoys 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 Georeference (Compute GPSTide) routine in conjunction with the NAD83 to MLLW separation model provided by NOAA for this purpose.

PPK and ComputeGPS tide procedures are described elsewhere in this report.

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 Georeferencing. 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, Atlas H10 corrections (GNSS) corrections were the primary source 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 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. Advantages of PPRTX are primarily that no base stations are needed, and processing can be completed quickly, usually within 1 hour of completion of file logging.

Following completion of operations and availability of precise ephemeris and nearby CORS station data, some POSMV data was reprocessed in POSPac using Applanix Smart Base (ASB) methodology. This was possible because the survey area was encompassed in a network of regional CORS sites. ASB was used to troubleshoot lines that exhibited vertical busts when using PP-RTX, and in most cases improved their vertical agreement. Individual lines that utilized ASB instead of PP-RTX are itemized in the appropriate DRs.

The PP-RTX and ASB methods were compared to each other during Vessel Position Confidence checks. Results were good, with agreement always within horizontal and vertical specifications, but usually to 0.30 m or better. 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 50Hz. This made it so that all final positions were NAD83 (2011) per the 2022 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 (in Georeference)

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).

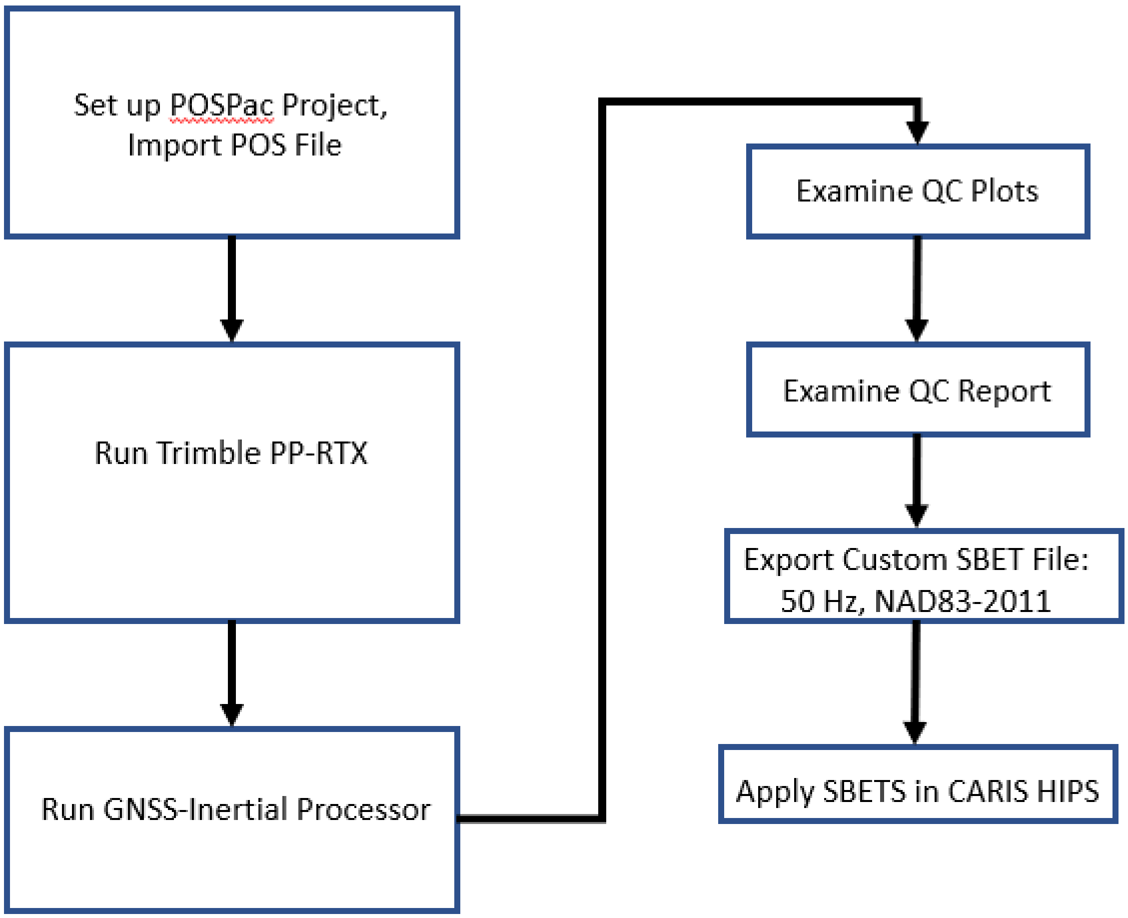

Figure 9: Generalized POSPac processing procedure.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Sound speed profiles (casts) were taken from the Q105 using an Oceanscience RapidCAST system, which utilized a Valeport SWiFT sensor. 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. These files were transferred via Bluetooth connection from the SWiFT to a PC running Valeport Connect software after each cast.

Sound speed casts were completed approximately every 2 hours when possible. 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.

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.

The ASV was not configured to collect sound speed profiles, however it did collect surface sound speed.

Data Processing Methods and Procedures

Sound speed profiles (casts) were normally processed in HydroOffice Sound Speed Manager.

Each VP2 file 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, 2 hours was used. Exceptions, if any, are noted in the applicable DR.

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 QC and internal beam forming purposes by the Reson T50 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 (under "Georeference" in CARIS HIPS 11) 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 a 2sigma. HVF entries and their justification are shown below.

Sonar Type: Teledyne RESON SeaBat T50R (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, Y, and Z: 0.01 m -- estimated measurement error from vessel survey

Vessel speed: 1 m/s Q105, 1 m/s ASV -- estimated maximum average speed of water currents experienced during survey operations

Loading: 0.03 m Q105, 0.01 m ASV -- mean difference between subsequent static draft measurements

Draft: 0.010 Q105, 0.020 m ASV -- estimated accuracy of the visually observed static draft measurements

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 "GPS Sounding Datum" which were entered at the time of TPU computation. Tidal error was entered as 0.13 based on the value provided for the ERTDM model in the Project Instructions.

Sound speed error (measured) differed by sheet and ranged from 0.9 to 2.2 m/s. This was computed 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 manufacturer'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		338192000 (MMSI)	CW76
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

Shoreline and feature data collection was incidental on this project. Most assigned features were inshore of the NALL. A small number were offshore of the NALL and were investigated with Complete MBES coverage within a 200 m disproval radius specified in the Project Instructions.

Data Processing Methods and Procedures

MBES data for feature investigations was processed with the same methodology as mainscheme data, with the exception that products were created at 1 m resolution to prove Complete MBES was achieved.

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.

Additional sample locations were selected based on geographic dispersion and backscatter mosaics indication of seafloor change.

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.

Some assigned bottom sample locations were inside the NALL or otherwise too shallow to approach safely 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.

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” (even though their nature as volcanic or not is unknown) 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.

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. Log sheets are available with the project DRs.

Following review and application of final correctors in the office, 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. The surfaces were examined for fliers, holidays, and artifact such as vertical busts or motion error, and examined in HIPS subset mode where possible issues were noted.

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.

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 2022 HSSD. In survey areas where complete coverage was required (only for feature disprovals on this survey), holiday requirements were followed based on "Complete Coverage Multibeam, Option A", referencing Section 5.2.2.3 of the 2022 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 on mainscheme lines 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 v3.8.8 "Grid QA v6" 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 Order1, 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. 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 some occasions a recon or 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 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 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 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. Each comparison resulted in a mean difference between the two vessels ranging from 0.02 to 0.07 m, with the Q105 showing slightly shoaler in most comparisons than the ASV.

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.

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 to a secondary server 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 hand offs 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. The number of files associated with each line was noted in the logsheet as well. 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.

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 on both the Q105 and ASV.

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.

Note that 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' = H13589
Sheet 'B' = H13590
Sheet 'C' = H13591
Sheet 'D' = H13592
Sheet 'E' = H13593
Sheet 'T' = F00847

Logs were exported to PDF 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 JD156 (6/05/22) during sea trials following mobilization. A prior bar check had been conducted earlier on JD156 however it was repeated later closer to a peak tide.

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 4.275 to 9.275 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 -0.020 m on average with a standard deviation of 0.013 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 0.017 m on average with a standard deviation of 0.010 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 on the Q105 to check for gross error in the absolute accuracy for the echosounder and processing systems. The check was done on JD156, JD201, JD217, and JD230, while anchored near Homer, Bethel, Nash Harbor, and Cape Mendenhall.

Note other lead line checks were attempted on multiple occasions during the project but were often compromised by weather or current and were therefore rejected.

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 test returned differences of MBES nadir depth of -0.040 m, 0.130 m, 0.52 m, and 0.130 m respectfully.

Results were considered acceptable as a gross error check given the variables inherent in a lead line check. 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 another independent sound speed profiler. All 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 JD179. The check was completed while on anchor near Bethel, Alaska. The two project Valeport SWiFT sensors were used in the check. The check extended to a depth of about 5 meters.

All sensors compared to each other within 0.136 m/s on average, with a standard deviation of 0.006 m/s.

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 differences agreeing within horizontal and vertical positioning specifications, but usually to 0.3 m 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

D.2.1 Coverage Assessment

MBES backscatter imagery was visually examined in the field after preliminary processing and mosaics were created from QINSy database (DB) and Digital Terrain Model (QPD) files. The mosaics were then reviewed for coverage and quality to determine the need for re-runs and infills.

A similar procedure was done on the final bathymetry-referenced backscatter produced by pairing backscatter data form XTF files with CARIS HDCS data in the office after bathymetry processing was complete.

Coverage assessment QC was performed on the backscatter data after bathymetry coverage QC was performed. Geotiffs of the backscatter mosaics were exported from FMGT and imported into CARIS where they were layered with the MBES bathymetry surfaces produced during bathymetry processing in CARIS. The layers were then visually examined to determine if there were any gaps in imagery coverage.

D.2.2 Contact Selection Methodology

MBES Backscatter contact selection was not required for this project.

E. Approval Sheet

As Chief of Party, field operations for this hydrographic survey were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports.

All field sheets, this Data Acquisition and Processing Report, and all accompanying records and data are approved. All records are forwarded for final review and processing to the Processing Branch.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Hydrographic Survey Project Instructions, and Statement of Work. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies,if any, noted in Descriptive Reports.

Approver Name	Approver Title	Date	Signature
Andrew Orthmann	TerraSond Charting Program Manager	12/29/2022	Andrew Orthmann Digitally signed by Andrew Orthmann Date: 2022.12.29 13:11:11 -09'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	OPR-R302-KR-22_DAPR_Appendices.pdf
Sound Speed Sensor Calibration	OPR-R302-KR-22_DAPR_Appendices.pdf
Vessel Offset	OPR-R302-KR-22_DAPR_Appendices.pdf
Position and Attitude Sensor Calibration	OPR-R302-KR-22_DAPR_Appendices.pdf
Echosounder Confidence Check	OPR-R302-KR-22_DAPR_Appendices.pdf
Echosounder Acceptance Trial Results	N/A