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Data Acquisition & Processing Report

Type of Survey Navigable Area
Project No. OPR-K376-KR-18
Time Frame August 2018 – February 2019

LOCALITY

State Texas
General Locality Port Lavaca, TX

2018 - 2019

CHIEF OF PARTY
Andrew Orthmann

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DATE

Data Acquisition and Processing Report

OPR-K376-KR-18

Port Lavaca, TX

April 26th, 2019

Project Name:	***Port Lavaca, TX***
General Locality:	***Port Lavaca, TX***
Time frame:	***August, 2018 – February, 2019***
Sub Localities:	***F00734 – Matagorda Bay*** ***H13180 – Vicinity of Matagorda Bay Entrance*** ***H13181 – Matagorda Bay Entrance*** ***H13182 – 8 NM WSW of Entrance to Colorado River*** ***H13183 – 7 NM WSW of Pass Cavallo*** ***H13184 – 14 NM ENE of Cedar Bayou*** ***H13185 – 15 NM ESE of Cedar Bayou*** ***H13186 – 9 NM WSW of Pass Cavallo*** ***H13187 – 10 NM WSW of Entrance to Colorado River***
Vessel(s):	***R/V Bella Marie, R/V Bunny Bordelon, M/V Sea Ark***
Field Unit:	***TerraSond Limited***
Lead Hydrographer:	***Andrew Orthmann***

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A. *Equipment*

A.1. Echosounder Systems

A variety of sonars were utilized on this project. These consisted of Reson SeaBat T50 and 7125 Multibeam Echosounders (MBES) and a CV100 Single Beam Echosounder (SBES). Bottom imagery was acquired with EdgeTech 4200 Side Scan Sonar (SSS).

A.1.1. Side Scan Sonar

EdgeTech 4200 systems were used for all side scan imagery collection on this project. These systems were utilized on the vessels *R/V Bella Marie* and *R/V Bunny Bordelon*. Configuration was nearly identical between vessels, with any important differences noted below.

Figure 1 EdgeTech 4200 basic kit

This SSS system consists of a stainless steel towfish, topside processor, and interconnecting cables. EdgeTech Discover software served as the user interface and data acquisition software.

For this survey the SSS towfish was towed behind the vessels. Layback was computed using cable-out. Cable out was measured on the *R/V Bella Marie* with a Hydrographic Consultants, Ltd. Smart Cable Counter (SCC). Cable-out on the *R/V Bunny Bordelon* was measured with a Subsea Technology & Rentals (STR) T-Count Cable Counting System. Manual measurements of cable out was done when the cable counter systems had issues and were noted when applicable in the acquisition logsheet, and applied in processing.

Edgetech Discover was configured to output data via Ethernet network connection to a Windows 10 PC running Discover software, which logged the side scan data to EdgeTech JSF format files. GNSS positioning was input to Discover from the Applanix POSMV.

The system was operated in “High Speed Mode (HSM),” which utilized EdgeTech’s “MultiPulse” (MP) feature. By placing two pings in the water simultaneously, MP allows NOAA object detection requirements to be met at speeds as high as 10 knots. Despite this capability, survey speeds were limited to 8 knots or less, with survey speeds normally in the range of 6 to 6.5 knots.

The system can generate 100 kHz and 400 kHz pulses simultaneously. However, due to regulatory restrictions on frequencies less than 180 kHz, only the 400kHz frequency was utilized.

After initial setup issues on the *Bunny Bordelon*, the SSS system performed normally without any major issues. Initial setup issues consisted of intermittent connectivity and excessive dropped data packets from the start of the job until JD2018-283, when the issue was resolved by isolating the SSS system entirely from the vessel electrical systems.

The SSS system on the *Bella Marie* performed without major issues from initial deployment until JD2018-346 when it failed completely and required replacement. At this point in the survey the *Bunny Bordelon* had completed its SSS operations, so the SSS system from the *Bunny Bordelon* was transferred to the *Bella Marie* on JD2018-349, where it was used until survey completion on JD2019-038.

A minor but relatively common issue with the SSS systems was a failing electrical connection resulting intermittent or complete loss of communications with the towfish. This condition, which was obvious to the online operators, was addressed by pulling the towfish from the water, re-terminating the electrical connection, and then re-deploying to continue data collection.

When in operation, SSS performance was verified by daily confidence checks with features captured in the sonar record. Objects of 1 m and smaller were readily discernable in the side scan records and position agreement, when compared to the multibeam data, was good (generally within 5 m or better). SSS confidence checks are available in *Appendix II* of this report.

EdgeTech 4200-MP	
Sonar Operating Frequency	100 /400 kHz (400 kHz used)
Modulation	Full Spectrum Chirp frequency modulated pulse with amplitude and phase weighting
Operating Range (max)	400 kHz 150 m
Towing Speed (max safe)	12 knots
Max Towing Speed (to meet NOAA specifications)	9.6 knots in HSM* (HSM used) * Multipulse (MP)
Output Power	400 kHz 2 joules
Pulse Length	400 kHz up to 10 ms
Resolution Across Track	400 kHz: 2 cm
Resolution Along Track	400 kHz: 0.7 m @ 100 m range
Horizontal Beam Width (HSM)	400 kHz – 0.4°
Vertical Beam Width	50°
Max Operating Depth	2000 m

Table 1 – EdgeTech 4200-MP SSS technical specifications.

A.1.2. Multibeam Echosounder

A combination of Reson SeaBat MBES systems were used to collect multibeam data on this project. This consisted of T-50 and 7125 systems.

The vast majority of multibeam data on this project was acquired with T-50 MBES. The T-50 was favored because at the time of this survey it was the latest technology in Reson's SeaBat MBES series, with improvements in specifications and capabilities, which included an optional Integrated Dual Head (IDH) mode.

IDH, which featured two sonar heads tilted 30 degrees to port and starboard with simultaneous ping capability, was utilized on this project to improve coverage per linear nautical mile. IDH was successfully used on the *RV Bunny Bordelon* vessel but was unsuccessful on the *RV Bella Marie*, as described below.

The *R/V Bella Marie* utilized a T50 IDH system from JD2018-247 to JD2018-256. However, the IDH system exhibited excessive noise and artifact which was not resolved after consultation with the manufacturer. The likely cause was identified as insufficient deployment depth through the moonpool to fully clear the catamaran-style hulls on this vessel, resulting in outer beam reflections from the sonar head's 30 degree tilt. Instead of remounting the sonar heads deeper which would have put them at more risk of damage in the shallow waters of the area, the decision was made to reconfigure and operate the T50 as a standard single-head system. The system was operated as a single-head from JD2018-259 to JD2018-355, when it was demobilized at the conclusion of 2018 operations.

Due to equipment availability, a 7125 was mobilized on the *Bella Marie* and used for final infills and developments briefly, from JD2019-015 to JD2019-038.

The *R/V Bunny Bordelon* utilized a T50 IDH at all times. The IDH system on the *Bunny Bordelon* performed adequately and provided sufficient advantages towards improved swath width to continue its use for the full project.

Figure 2 Bunny Bordelon T50 IDH during mobilization.

The Reson SeaBat T50 and 7125 MBES utilized Teledyne RESON Sonar UI (User Interface) software to serve as the user interface. In the interface, power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through Teledyne RESON Sonar UI to monitor and maintain data quality. The system was configured to output bathymetric data via Ethernet network connection to the acquisition software (QPS QINSy), which logged DB (database format) files, a proprietary QPS format. The software also simultaneously wrote XTF (eXtended Triton Format) files which were utilized in processing. The system was also configured to output backscatter (multibeam "snippet") data, which was logged to the DB files with accompanying DTM files in QINSy QPD format.

MBES accuracy was checked by bar check and lead line methods on both vessels, with good results.

The T50 single-head on the *R/V Bella Marie* received a bar check on JD2018-269. Compared to the actual bar depth, real-time results were 0.000 m on average, with processed CARIS results at 0.044 m. A lead-line check JD2018-260 returned a processed result of -0.042 m on this sonar.

The 7125 single-head on the *R/V Bella Marie* received a lead line check on 2019-038 and returned a processed (CARIS) difference of -0.030m compared to the actual lead-line depth. An additional lead line check was done on JD2019-023 and returned a processed difference of 0.130 – a result higher than desired but considered acceptable given the variables of lead line checks and results that were still well within error specifications.

The T50 IDH on the *R/V Bunny Bordelon* received a bar check on JD2018-305, returning real-time results averaging 0.000 m and processed results of 0.003 m compared to the actual bar depth. A lead line was also performed, on JD2018-337, and returned a processed result averaging 0.315 m different that the lead line depth – a difference considered acceptable given the variables of the check, including current and seafloor variance.

In addition to these formal checks, all MBES systems have significant overlap which was examined in both CARIS subset mode and difference surface methodology. Agreement was determined to be within 0.08 m on average for all systems with a standard deviation of 0.16 m, showing agreement to be well within IHO Order 1a specifications. Note that the T50 IDH system on the *Bella Marie* did not receive a formal bar or lead line check but was found through these methods to also have good agreement with all other sounding data.

Refer to Section B of this report for discussion of echosounder accuracy test methodology including additional results, with depth check results available in *Appendix II*.

Reson SeaBat T50-R [and IDH T50-R] *	
Sonar Operating Frequency	190 – 420 kHz (400 used on this project)
Along Track Transmit Beamwidth	1° at 400 kHz
Across Track Receive Beamwidth	0.5° at 400 kHz
Max Ping Rate	50 p/s (10 p/s used on this project)
Pulse Length	15 [30 for IDH] to 300 µsec

Reson SeaBat T50-R [and IDH T50-R] *	
Number of Beams	10 - 512 [1024 for IDH] (512 [1024 for IDH] used this project)
Max Swath Angle	Up to 165° [220° for IDH] (150° [190° for IDH] in Equi-Distant, used this project)
Depth Range	0.5 – 300 m at 400 kHz
Depth Resolution	0.006 m
**An integrated dual head (IDH) T50-R (Rackmount) system was used on the Bunny Bordelon for the entire survey and on the Bella Marie from the start of the survey to JD2018-256. A single head T50-R system was used on the Bella Marie from JD2018-256 to JD2018-355. The specifications above are for a single-head T50-R, [IDH T50-R in square brackets]. The difference is in the combined maximum swath angle and number of beams, and the topside form-factor; other specifications are equivalent.*	

Table 2 – Reson SeaBat T50-R MBES technical specifications.

Reson SeaBat 7125 *	
Sonar Operating Frequency	200-400 kHz (400 used on this project)
Along Track Transmit Beamwidth	1° at 400 kHz
Across Track Receive Beamwidth	0.5° at 400 kHz
Max Ping Rate	50 p/s (10 p/s used on this project)
Pulse Length	30 to 300 µsec
Number of Beams	240-512 (512 used this project)
Max Swath Angle	Up to 140° Equi-Distant (140° in Equi-Distant, used this project)
Depth Range	0.5 – 150 m at 400 kHz
Depth Resolution	0.006 m
**A Reson SeaBat 7125 (Rackmount) system was used on the Bella Marie for the 2019 portion of the survey (JD2019-015 to 2019-038).*	

Table 3 – Reson SeaBat 7125 MBES technical specifications.

A.1.3. Single Beam Echosounder

One Odom Echotrac CV100 system was used on this survey, installed aboard the *M/V Sea Ark* for preliminary investigations within Matagorda Bay (F00734).

The Odom Echotrac CV100 is a digital single beam echosounder (SBES), which utilizes Odom eChart software to serve as the user interface. The CV100 was interfaced with an Airmar SMB200-3 transducer, which generates a 3 degree beam at 200 kHz.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through eChart. eChart was configured to output the bathymetric data via Ethernet network connection to acquisition software (HYPACK) running on a Windows 7 PC, which logged the raw data.

CV100s are all-digital units that do not create a paper record of bottom track quality information. Instead, this information was logged to BIN format files, which were later viewable in CARIS HIPS' single beam editor software during data processing.

Echosounder accuracy was formally checked by bar check and lead line methods. On JD2018-231, a bar check was performed that returned real-time results averaging 0.000 m difference from the actual bar check depth. Then, processed (CARIS) results were checked with lead line on JD2018-231 (0.045 m average difference), and JD2018-238 (0.001 m average difference). An additional lead line also done on JD2018-238 and yielded a processed difference of -0.070 m. Results were considered satisfactory given the variables involved in bar check and lead line collection.

Additionally, the Odom CV100 single beam data was analyzed where it overlapped with the Reson T50 multibeam data by difference surface methodology. The two data sets demonstrate good agreement, with an average difference of 0.04 m with a standard deviation of 0.22 m. More details on this comparison is available in Section B.

Echosounder accuracy test (depth check) results are available in *Appendix II* of this report.

See Table 4 for echosounder specifications.

Odom Echotrac CV100	
Firmware Version	4.09
Sonar Operating Frequency	100 – 750 kHz (200 kHz used)
Output Power	300 W RMS Max
Ping Rate	Up to 20 Hz
Resolution	0.01 m
Depth Range	0.3 – 600 m, depending on frequency and transducer

Table 4 – Odom Echotrac CV100 single beam echosounder technical specifications.

A.2. Vessels

Three vessels were utilized to acquire all hydrographic data for this project. These consisted of the *R/V Bella Marie, R/V Bunny Bordelon,* and *M/V Sea Ark*.

The *R/V Bella Marie* and *R/V Bunny Bordelon* collected all MBES and SSS data. The *Bella Marie* was outfit with three different Reson SeaBat MBES ecosounders over the course of the survey – a T50 Integrated Dual Head (IDH), T50 single-head, and a 7125. The *Bunny Bordelon* utilized a Reson SeaBat T50 IDH for its entire time on site. Both vessels utilized EdgeTech 4200 SSS systems for bottom imagery collection.

M/V Sea Ark was utilized for preliminary investigations of assigned features in Matagorda Bay (F00734). The vessel was equipped with an Odom Echotrac CV100 SBES.

A.2.1. R/V Bella Marie

The *R/V Bella Marie* is owned and operated by TerraSond and is based out of Corpus, Christi, Texas. It is a 36’ aluminum hull Armstrong Marine Catamaran with a beam of 14’ and a 2.5’ draft. This vessel was used previously on post hurricane NOAA surveys in Louisiana, Alabama, and Florida as well as a host of other work all through the US Gulf of Mexico. It is powered by twin Volvo Penta D6 engines and uses an Izuzu 13KV generator for AC electrical power.

The vessel was tasked with performing near-shore work too shallow to be surveyed effectively with the larger vessel. The vessel and its crew were based out of the community of Port O’Conner, TX, on Matagorda Bay and worked 12-hour (daylight only) operations. Raw data was transmitted over the internet daily for offsite data processing.

Figure 3 – The R/V Bella Marie dockside in Port O’Conner, TX, September 2018

The MBES was mounted on a pole that was deployed through a 3’ x 4’ moonpool custom fabricated between its two hulls. An electric winch was used to raise and lower the MBES pole through the moon pool. A hydraulic winch was installed on the back deck for towing the SSS in conjunction with a hydraulic A-frame.

For this survey, the *Bella Marie* was configured with an Applanix POSMV to provide attitude and positioning. GPS antennas were located on an antenna bar above the bridge. A submersible IMU was used with the system through JD2018-355, where it was mounted nearly coincident with the MBES transducer (see vessel offsets in Section C). From JD2019-015 to JD2019-038 a non-submersible IMU was used which required mounting forward of the MBES transducer in a dry, protected location.

The MBES transducer was mounted on a mid-ship pole that could be lowered and raised by electric winch through a moonpool between the vessels’ twin hulls, and locked into place during operations. A Valeport MiniSVS sound speed sensor was mounted on the MBES transducer mount and configured to provide real-time sound speed measurements to the MBES system. Three different MBES configurations were used on this vessel: A Reson Seabat T-50 IDH from the start of the project to JD256, a T-50 single-head from JD256-JD355. Finally, a Reson Seabat 7125 was used for 2019 operations (JD015-JD038).

Sound speed profiles were collected using an AML Minos X profiler, outfit with SV- and P- Xchange sensors, was hand deployed off the back deck of the vessel. A Valeport Swift SV was also briefly used at the end of the project for profiles.

For side scan collection, an EdgeTech 4200-MP was utilized on the *Bella Marie* for the full duration of the survey. The towfish was towed using the vessel winch and A-frame, or towed from a starboard-side davit and supported by a surface buoy if water depth was too shallow for standard towing. When towed from the A-frame, a Hydrographic Consultants, Ltd. Smart Cable Counter (SCC) block was used to measure cable out. When towed from the davit, cable out was manually measured and confirmed with a range finder to the towfish surface buoy. GNSS positioning was fed into Discover software from the POSMV and logged to JSF as the vessel position.

Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Vessel drawings showing the location of major survey equipment components are included in Section C of this report.

***R/V Bella Marie* Major Survey Systems**				
Description	**Manufacturer**	**Model / Part / Dates**	**Serial Number(s)**	**Use Dates (JD)**
MBES Wet-End	Teledyne Reson	T50 IDH Transducers	1518006 (rx array port) 818042 (tx array port) 1518012 (rx array stbd) 0818041 (tx array stbd)	247 – 256 (2018)
		T50 Transducers	1518006 (rx array) 818042 (tx array)	259 – 355 (2018)
		7125 Array	3212011	015 – 038 (2019)
MBES Processors	Teledyne Reson	T50-R	TID13251	247 – 355 (2018)
		7125	18340413031	015 – 038 (2019)
SSS Towfish	EdgeTech	4200 Towfish	37874, N/A	247 – 346 (2018), 349 – 038 (2019)
SSS Processors	EdgeTech	DL-401	37705, 33911	
Sound Speed, Surface	Valeport	MiniSVS	24667	247 (2018) – 038 (2019)
Position, Motion, Heading	Applanix	POSMV Oceanmaster	N/A (integrated in T50)	247 – 355 (2018)
		IMU Type 45	TID13252	
	Applanix	AT1675-540TS	TID13254 (Primary)	
		AT1675-540TS	TID13253 (Secondary)	

***R/V Bella Marie* Major Survey Systems**

Description	Manufacturer	Model / Part / Dates	Serial Number(s)	Use Dates (JD)
	Applanix	POSMV 320 V4	2147	015 – 038 (2019)
		IMU Type 2	778	
	Trimble	Zephyr	60243133	
		Zephyr	12589892	
Sound Speed, Profiler	AML Oceanographic	Minos-X	30301	247 (2018) – 028 (2019)
		SV-Xchange	204188	
		P-Xchange	304617	
	Valeport	Swift SV	68632	029 (2019) – 038 (2019)
Cable Counter	Hydrographic Consultants	Smart Cable Counter	1658	247 (2018) – 038 (2019)
DGPS Corrections	MBX3	Receiver	0049-7483-0005	015 – 038 (2019)
		Antenna	0614-24269-0004	

Table 5 – Major survey equipment used aboard the Bella Marie.

A.2.2. M/V Bunny Bordelon

The *R/V Bunny Bordelon* is owned and operated by Bordelon Marine Services (BMS), LLC, of Houma, Louisiana. The *Bunny Bordelon* is a 150’ offshore supply vessel with a beam of 36’ and an 10-12’ draft. TerraSond commonly charters BMS vessels for hydrographic projects in the Gulf of Mexico and East Coast. The vessel is powered by twin Cummins KTA 38MO 1800 HP engines. Electrical power is provided by two 99KW Cummins 6CTAs.

This vessel was tasked with performing offshore survey work on this project, with a practical shoal limit of approximately 7-8 m water depth. Operations were conducted 24 hours per day, with crew rotations/resupplies weekly in nearby Port Aransas, TX. Raw data was transmitted over the internet via cellular connection twice daily for offsite data processing.

Figure 4 R/V Bunny Bordelon during mobilization in Houma, LA, September, 2018.

During mobilization, TerraSond installed a 20’ offshore Conex on the back deck to provide working space. A hydraulic A-frame and winch was installed aft of the Conex for towed SSS operations. The MBES was installed on an over-the-side pole mounted approximately midship on the port side, which could be raised and lowered with an electric winch.

Figure 5 R/V Bunny Bordelon back deck showing offshore Conex. MBES pole is deployed on the port side, indicated by aerial MBES cables

For this survey, the *R/V Bunny Bordelon* was configured with an Applanix POSMV to provide attitude and positioning. GPS antennas were located on top of the survey Conex. The MBES transducers were mounted to a pole mid-ship on the port side of the vessel.

Sound speed profiler systems were deployed off the aft end of the vessel during operations using a variety of deployment methods, including hand-deployed and use of a Teledyne Oceanscience RapidCAST system.

An Integrated Dual Head (IDH) T50-R (Rackmount) MBES was utilized on this vessel for the full duration of the survey. A submersible IMU was co-located with the MBES on the MBES mounting plate. Surface sound speed was measured with an AML Micro-X sensor mounted on the sonar head.

An EdgeTech 4200-MP SSS was utilized on the *Bunny Bordelon* for the full duration of the survey. GNSS positioning was fed into Discover software from the POSMV. Cable-out was measured by an STR T-Count wireless Cable Counting System.

Vessel systems performed acceptably with the exception of a poor MBES mount at the start of the project. During the initial patch test, excessive vibration or shaking became apparent in the MBES pole at speeds above about 4 knots. The effect on the data was minimized by adding additional support to the pole and minimizing survey speeds while a replacement MBES pole was fabricated. The new MBES pole was installed on JD2018-278, which resolved the issue for the remainder of the survey. Data quality collected with the shaky pole (up to and including JD2018-278) was found to be acceptable, largely due to the submersible IMU co-located with the MBES head which moved at the same frequency as the MBES head. This data exhibited above average noise, which was rejected in processing. The first data with the new pole was collected on JD2018-282.

Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Vessel drawings showing the location of major survey equipment components are included in Section C of this report.

***R/V Bunny Bordelon* Major Survey Systems**

Description	Manufacturer	Model / Part	Serial Number(s)	Use Dates (JD)
MBES Wet-End	Teledyne Reson	T50 IDH Transducers	1518006 (rx array port) 818041 (tx array port) 2108151 (rx array stbd) 818042 (tx array stbd)	269 – 349 (2018)
MBES Processor	Teledyne Reson	T50-R	3516077	
SSS Towfish	EdgeTech	4200 Towfish	N/A	
SSS Processor	EdgeTech	DL-401	33911	
Sound Speed, Surface	AML Oceanographic	Micro-X	N/A	
		SV-Xchange	10873	
Position, Motion, Heading	Applanix	POSMV Wavemaster II	8986	

***R/V Bunny Bordelon* Major Survey Systems**				
Description	**Manufacturer**	**Model / Part**	**Serial Number(s)**	**Use Dates (JD)**
		IMU Type 45	N/A	
	Applanix	AT1675-540TS Primary Antenna	6967	
		AT1675-540TS Secondary Antenna	7472	
Sound Speed, Profiler	AML Oceanographic	Minos-X	30356	299 -321 (2018)
		SV-Xchange	207183	
		P-Xchange	304553	
	Valeport	Swift SV	63780	301 – 349 (2018)
		Rapid SV 200Bar	61463	269 – 298 (2018)
Sound Speed, Profiler Deployment	Oceanscience	RapidCAST	147	301 – 349 (2018)
Cable Counter	STR	T-Count	50887-TC	269 – 349 (2018)

Table 6 – Major survey equipment used aboard the Bunny Bordelon.

A.2.3. Sea Ark

The *M/V Sea Ark* is owned and operated by TerraSond. The vessel is based out of Corpus Christi, TX, and commonly utilized on hydrographic projects in the area. The 18' aluminum vessel features a flat bottom and shallow draft (less than 2') for working in shallow waters. On this project it was powered by a 115 HP Yamaha outboard engine and utilized a 1KW Honda generator for electrical production.

For this project, the vessel was outfit with an Odom CV100 SBES echosounder for collecting bathymetric data, a Hemisphere V113 GPS Gyrocompass for real-time navigation and heading, and a Trimble 5700 L1/L2 GPS Reciever for post-processed positioning. The Odom transducer and Trimble 5700 antenna were mounted on an over-the-side mount on the port side bow while the Hemisphere was mounted on the vessel cabin. Sound speed profiles were collected with a hand deployed AML Minos X.

The vessel and crew were based out of Port O'Conner, TX and was used to collect recon data inside Matagorda Bay (F00734) prior to the arrival of the larger vessels. Assigned features inside the bay were investigated and resolved when found. When not found, the SBES system on the vessel was used to collect recon SBES data to determine feasibility of the additional survey with the *Bella Marie*.

Figure 6 – Sea Ark on trailer, with port-bow mounted SBES

Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Vessel drawings showing the location of major survey equipment components are included in Section C of this report.

***M/V Sea Ark* Major Survey Systems**				
Description	**Manufacturer**	**Model / Part**	**Serial Number(s)**	**Use Dates (JD)**
SBES	Teledyne Odom	Echotrac	003498	2018-231 to 2018-238
Position (Post Processed)	Trimble	5700	0220321784	
	Trimble	Zephyr Antenna (Primary)	12368889	
Sound Speed, Profiler	AML Oceanographic	Minos-X	30301	
		SV-Xchange	204188	
		P-Xchange	304617	
Position & Heading (Realtime)	Hemisphere	V113	AA1139-1158576-0014	

Table 7 – Major survey equipment used aboard the Sea Ark.

A.3. Speed of Sound

Various sound velocity profiler systems were utilized on the three survey vessels used on this survey.

For the *Bella Marie*, an AML Minos X profiler system, outfit with SV-Xchange and P-Xchange sensors, was hand deployed off the back deck of the vessel to collect sound speed profiles for the majority of the survey. A Valeport Swift SV was used briefly near the end of the project as well after the AML Minos X began having data access issues

The *Sea Ark* also utilized a AML Minos X profiler system, which was hand deployed.

For the *Bunny Bordelon*, three different sound velocity profiler systems were utilized. These consisted of a Valeport RapidSV, AML Minos X, and Valeport SwiftSV. Dates in use are shown in the table above that describes vessel equipment (Table 6).

The Valeport RapidSV was hand-deployed from the back deck but lost when a line broke on JD2018-298. It was temporarily replaced with a backup hand-deployed AML Minos X until JD301, which was then replaced by a Valeport SwiftSV.

Profiles or "casts" were collected as deep as possible while underway, targeting at least 80% of the surveyed water depth during each cast, and reaching 95% minimally once per day.

Sound speed casts were taken when the difference between the sound speed at the sonar head on the vessel differed from the previous cast's sound speed at the same depth by more than 2 m/s. This resulted in casts approximately every 2 hours during operations. During SBES operations on the *Sea Ark*, casts were done once to twice daily, an interval deemed sufficient for SBES collection in shallow water.

Survey line lengths were limited to 15 km or less to keep the survey vessels in the same general geographic proximity as the casts. This led to a collection of normally well-distributed casts that minimized both the distance and time between bathymetric data and applicable sound speed profiles. When depth varied significantly along a survey line, preference was given to casting in the deeper portion of the line to capture as much of the water column profile as possible.

Formal confidence checks between sound speed profiler systems were accomplished on the *Bella Marie* and the *Bunny Bordelon* by comparing the results with a simultaneous deployment of a separate calibrated probe. Four checks were completed over the course of the project and returned excellent results (see Section B), usually comparing to 0.25 m/s or better.

Refer to the CARIS HIPS SVP files submitted with the deliverables for positions, collection times, and processed profile data. Processed profile data has also been submitted to NCEI for archival and oceanographic research purposes. Raw SVP data is available with the raw data deliverables. Copies of the manufacturer's calibration reports are included in *Appendix IV* of this report.

The MBES sonar heads were also equipped with sound speed sensors to feed real-time sound speed data to the MBES systems for beam-forming purposes. These consisted of a AML Micro X sensor on the *Bunny Bordelon* and a Valeport MiniSVS on the *Bella Marie*. These sensors were not used to collect profiles, but were regularly compared to profile data at the same depth, with good results – normally comparing to 0.49 m/s or better. Results of the surface speed comparisons are available in the DRs, *Separate II*.

The instruments listed in the following table were used to collect sound speed profiles on this project.

A.3.1. Sound Speed Profilers

Project Sound Speed Profilers					
Vessel	**Sound Speed Device**	**Manufacturer**	**Serial Number(s)**	**Cal Date**	**Purpose**
Bunny Bordelon	Rapid SV	Valeport Limited	61463	4/9/2018	Primary sound speed profiler to JD2018-298
	Swift SV		63780	5/31/2018	Primary sound speed profiler JD2018-301 to 349
	AML Minos-X	AML Oceanographic	30356 (Minos-X)	N/A	Backup sound speed profiler (primary JD2018-298 to 301) and backup/comparisons
			207183 (SV-Xchange)	9/10/2018	
			304553 (P-Xchange)	4/18/2018	
Bella Marie	AML Minos-X	AML Oceanographic	30301 (Minos-X)	N/A	
			204188 (SV-Xchange)	4/10/2018	
			304617 (P-Xchange)	4/18/2018	
	Swift SV	Valeport Limited	68632	10/18/2018	Backup, then primary 2019-029 to 038
Sea Ark	AML Minos-X	AML Oceanographic	30301 (Minos-X)	N/A	Primary sound speed profiler during SBES ops
			204188 (SV-Xchange)	4/10/2018	
			304617 (P-Xchange)	4/18/2018	

Table 8 – Sound speed profilers used on this project.

A.3.2. Sound Speed Sensor Technical Specifications

AML Oceanographic Micro-X (SV- and P-Xchange)	
SV Range	1375 – 1625 m/s
SV Precision	+/- 0.006 m/s
SV Accuracy	+/- 0.025 m/s

AML Oceanographic Micro-X (SV- and P-Xchange)	
SV Resolution	0.001 m/s
P Response Time	10 ms
P Accuracy	0.05% FS
P Precision	0.03% FS
P Resolution	0.02% FS

Table 9 – AML Oceanographic SV- and P- Xchange specifications.

Valeport Rapid SV (200Bar) and Swift SVP	
SV Range	1375 – 1900 m/s
SV Accuracy	0.02 m/s
SV Resolution	0.001 m/s
Pressure Range	200 bar (RapidSV), 10 bar (Swift SVP)
Pressure Accuracy	0.05% of range
Pressure Resolution	0.001% of range

Table 10 – Valeport Rapid SV and Swift SVP specifications.

A.4. Positioning and Attitude Systems

The *Bella Marie* and *Bunny Bordelon* utilized Applanix POSMV systems as the source of vessel positioning, motion, and heading data.

The POSMV system consists of two dual-frequency GPS/GNSS antennas and an inertial measurement unit (IMU) interfaced with a topside processor. For real-time GPS position corrections, the POSMV was configured to receive Wide Area Augmentation System (WAAS) correctors provided by the Federal Aviation Administration (FAA), or USCG DGPS corrections. However, the real-time WAAS or USCG data was replaced in processing by application of post-processed kinematic (PPK) corrections to the dataset.

The POSMV also provided time synchronization for the acquisition systems. The unit output 1-PPS (pulse per second) and a ZDA data string to sync the Teledyne RESON Sonar UI software and QPS QINSy systems to UTC time, at a rate of 1 Hz.

Additionally, the POSMV was configured to continuously log raw data during survey operations. Data was logged over network to POS format (.000) files. These raw files enabled post-processing of the GPS and inertial data in Applanix POSPac MMS software to produce higher quality PPK position, motion, and heading. POS files also enabled application of delayed heave (Applanix TrueHeave) to sounding data during processing.

Finally, the POSMV was configured to output a GGA to the SSS system at 1 Hz where vessel position was logged by Edgetech Discover software during SSS operations.

Vessel positioning checks were performed on the POSMV systems and returned good results. These are available in each DR, *Separate I*.

A.4.1. RV Bella Marie

The Applanix POSMV system used aboard the *R/V Bella Marie* for the majority of the project was a POSMV OceanMaster. This was an integrated system, where the topside hardware was built into the same physical rackmount as the T-50 IDH MBES system. The system utilized Applanix AT1675-540TS GNSS antennas.

A submersible, type-45 IMU was mounted on the same physical sonar mount as the T-50 MBES—nearly co-located. This POSMV was configured to receive WAAS corrections for real-time positions using its integrated receiver. During this project, this POSMV ran firmware version SW09.29-Sep21/17.

On JD2019-015, when the *R/V Bella Marie* was remobilized after a brief shutdown period, a POSMV 320 V4 was mobilized instead. The system had similar specifications and setup, except the system utilized Trimble Zephyr (GPS-only) antennas and a Type 2, non-submersible IMU. A CSI MBX3 DGPS receiver was used to provide this POSMV with USCG RTCM DGPS corrections.

This POSMV ran firmware version SW03.42-May28/07.

No major issues were experienced with these systems. Some unresolved minor vertical busts were experienced with positioning from the 320 V4 as described later in this document, but were within specifications.

POSMV OceanMaster and 320 V4 specifications are shown in the table below.

POSMV OceanMaster and 320 V4		
DGPS Positioning	Positioning Accuracy	0.5 – 2 m (Realtime) 0.1 m (PPP)
	Roll, Pitch Accuracy	0.02 degrees
Heave Accuracy		Real-time Heave: 5 cm or 5% TrueHeave: 2 cm or 2% (whichever is greater) for periods of 20 seconds or less
Heading Accuracy		0.02 degrees (1 sigma, 2 m baseline)

Table 11 – Applanix POSMV OceanMaster and 320 V4 technical specifications.

A.4.2. Bunny Bordelon

The Applanix POSMV system used aboard the *Bunny Bordelon* was a POSMV Wavemaster II. A submersible, type 45 IMU was mounted directly on the MBES sonar mount, nearly co-located. Applanix AT1675-540TS GNSS antennas were mounted on top of the survey Conex on the vessel's back deck. WAAS corrections were utilized for real-time positioning using the system's integrated receiver.

During this project, the POSMV Wavemaster II ran firmware version SW09.13-Mar03/17.

The system performed well overall, with one item of note: Tx power settings on the T-50 IDH MBES greater than about 2/3 full would cause the Wavemaster to reset, apparently due to interference. Applanix and Reson were consulted without resolution. This was addressed during operations by maintaining MBES Tx powers less than 2/3 full, which was acceptable to maintain a full swath in the relatively shallow waters of this survey area.

On JD2018-296 at approximately 14:06 the IMU cable failed on the system at the IMU end due to chaffing. The cable was replaced on JD2018-297.

POSMV Wavemaster II		
DGPS Positioning	Positioning Accuracy	0.5 – 2 m (Realtime) 0.1 m (PPP)
	Roll, Pitch Accuracy	0.03 degrees
Heave Accuracy		Real-time Heave: 5 cm or 5% TrueHeave: 2 cm or 2% (whichever is greater) for periods of 20 seconds or less
Heading Accuracy		0.03 degrees (1 sigma, 2 m baseline)

Table 12 – Applanix Wavemaster II Technical Specifications

A.5. Sea Ark

The *Sea Ark* utilized a Hemisphere V113 GPS Compass for real-time positioning. The V113 provided WAAS-based real-time DGPS positioning, as well has heading data.

The vessel was also outfit with a T5700 dual-frequency GPS system. The T5700 was configured to continuously log dual-frequency GPS data to compact flash card at 10 Hz, which was later post-processed to provide final positioning and heave data.

Trimble 5700		
Code Differential GPS Positioning	Horizontal Positioning Accuracy	± 0.25 m + 1 ppm RMS
	Vertical Positioning Accuracy	± 0.50 m + 1 ppm RMS
Kinematic Surveying	Horizontal Positioning Accuracy	± 10 mm + 1 ppm RMS
	Vertical Positioning Accuracy	± 20 mm + 1 ppm RMS

Table 138 – Trimble 5700 technical specifications.

Hemisphere Vector V113		
SBAS (WAAS) Positioning	Horizontal Positioning Accuracy	0.3 m
	Vertical Positioning Accuracy	0.6 m
Motion and Heading	Heading	0.3°
	Pitch / Roll	1 °
	Heave	0.3 m

Table 14 – Hemisphere Vector V113 technical specifications.

A.6. Dynamic Draft Corrections

Speed-based dynamic draft correctors were determined using PPK GPS methods using squat settlement tests. Corrections were determined for a range that covered normal survey speeds. Note that as an ERS survey, these corrections were generally not applied.

See Section B of this report for processing methodology and Section C for results.

A.7. GPS Base Stations

No GPS base stations were installed for this project. Real-time positioning utilized WAAS or USCG DGPS, as described previously, while post-processed positioning utilized Trimble PP-RTX.

A.7.1. NWLON Tide Stations

This was an ERS survey using VDATUM. NWLON stations were not utilized except for QC or for corrections for a small number of lines. These are rare and noted where applicable in the appropriate DR.

A.7.2. Subordinate Tide Stations

Subordinate tide stations were not installed.

A.8. Software Used

Multiple software packages were used for acquisition and processing purposes on this project. All were executed on Intel-based quad-core PCs running Microsoft Windows 7 or Windows 10.

A.8.1. Acquisition Software

Acquisition software was setup nearly identically across survey vessels. The major software packages used on this project are summarized below.

- QPS QINSy hydrographic data acquisition software was used for navigation and to log the bathymetric, positioning, and attitude data to DB (and XTF) format files.
- Teledyne RESON Sonar UI served as the interface with the Reson SeaBat multibeam system, allowing the system to be tuned and operated.
- Trimble Configuration Toolbox was used, as necessary, to configure common options in the T5700 receivers.
- POSMV POSView was used as the interface with the POSMV. The software was used to log raw POS data as well as configure and monitor the POSMV system.
- TerraLog, an in-house software package, was used to keep digital logsheets during *Sea Ark* operations.

- Oceanscience RapidCAST Interface software was used in conjunction with Valeport RapidSVLog software to control the RapidCAST deployment system and configure/download profiles from the Valeport sound speed sensor.
- HYPACK 2017 was utilized on the *Sea Ark* for recon operations with SBES. Like QPS QINSy, it provided navigation for the vessel as it maneuvered to assigned feature locations and logged SBES data when needed.
- Odom eChart served as the interface with the Odom Echotrac CV100 echosounder on the *Sea Ark* during SBES operations. It also displayed the digital bottom track and waveform to assist with proper bottom tracking.

Software Name	Version	Year	Primary Function
QPS QINSy	8.18.1 (Build 2018.03.27.1)	2018	Acquire MBES data and provide vessel navigation
Teledyne RESON Sonar UI	4.0.0.0 (7kCenter 6.3.0.7)	2017	Interface with Reson MBES
Oceanscience RapidCAST Interface	1.5.1	2016	Interface with RapidCAST system
Valeport RapidSVLog	0400/7158/B1 27/03/2013	2013	Interface with Valeport probe
Trimble Configuration Toolbox	6.9.0.2	2010	Interface with Trimble 5700 receiver
Applanix POSView	5.03		Interface with POSMV 320 V4 (*Bella Marie)*
	9.21		Interface with POSMV (*Bunny Bordelon Wavemaster, Bella Marie OceanMaster*)
TerraLog	1.2.0.1	2014	Record keeping, *Sea Ark*
AML SeaCast	4.4.0		Interface with AML Minos X
Edgetech Discover 4200 MP	38.0.1.107	2018	Edgetech 4200 SSS interface and logging
HYPACK	17.0.26.0	2017	*Sea Ark* acquisition (SBES, navigation)
Odom eChart	1.4.0	2010	Interface software for the Odom CV100 on the *Sea Ark*

Table 15 – Software used for data acquisition.

A.8.2. Processing and Reporting Software

A summary of the primary software used to complete planning, processing, and reporting tasks follows:

- CARIS HIPS and SIPS was used as the primary MBES processing system. CARIS HIPS was used to apply all necessary corrections to soundings including corrections for motion, sound speed and tide. CARIS HIPS was used to clean and review all soundings and to generate the final BASE surfaces and generate S-57 deliverables.
- ESRI ArcGIS was used for line planning pre-plots during survey operations to assist with tracking of work completed, generation of progress sketches, and during reporting for chartlet creation and other documentation.
- Applanix POSPac MMS was used for post-processed kinematic (PPK) processing of POSMV data.
- TerraLog, an in-house multi-purpose software package, was used to process sound speed profiles and keep track of processing work completed on lines, drafts, depth checks, PPK files, and others.
- Chesapeake SonarWiz was used for processing SSS data, including application of offsets, layback computation, contact review, and outputting final SSS products
- NOAA's in-house utility Pydro was also used for data checks purposes on surfaces and feature files as well as production of the final XML DRs.

Program Name	Version	Date	Primary Function
CARIS HIPS and SIPS	10.3.3	2017	Process multibeam data and compile S-57 deliverables
ESRI ArcGIS ArcMap	10.2.1	2013	Produce chartlets for reports and track survey progress
Applanix POSPac MMS	8.3	2018	Post-processing of POSMV data
Microsoft Office	365	2018	Logsheets, reports, and various processing tasks
TerraLog	2014	2014	Keeping notes, reporting, process SVP casts, and produce PDF logsheets
Ultimate Underway Converter	2016	2016	Auto-convert Valeport Rapid SV files to MVP format prior to processing
Chesapeake SonarWiz 7	7.02.003	2018	SSS processing and review
Trimble Business Center	5.0		Post-process *Sea Ark* GPS data

Table 16 – Software used for processing and reporting.

A.9. Bottom Samples

A Van Veen grab sampler was used to collect bottom samples.

At locations assigned by NOAA via the Project Reference File (PRF), the grab sampler was dropped to the bottom from the survey vessel to collect a sample. Once aboard, the sample was examined and its S-57 (SBDARE object) attributes noted along with time and position in a logsheet. Samples were not retained, but photos were taken for most. Description, attributes, and photos are available with the S-57 deliverables.

Refer to Section B for more information on bottom sampling methodology.

A.10. Feature Investigations

Features assigned via the Composite Source File (CSF) were investigated.

Most assigned were located in Matagorda Bay (F00734). These were initially investigated with the *Sea Ark* vessel, and fixed and photographed when found.

If not found, the *Sea Ark* performed a recon survey with its SBES system to determine if water depths were sufficient to survey with MBES/SSS and the *Bella Marie,* which later performed a 200% SSS with MBES search within the assigned search radii.

B. *Quality Control*

B.1. 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.

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.

B.2. Data Collection

B.2.1. General Acquisition Systems Configuration

Bella Marie and *Bunny Bordelon* acquisition systems were configured similarly.

Both vessels utilized two primary Intel-based Windows 7 or Windows 10 PCs for acquiring data. One PC was devoted to the MBES system, and ran QPS QINSy and the Reson MBES Sonar UI software, as well as Applanix POSView for logging POSMV data. The second PC was devoted to the SSS and ran Edgetech Discover SSS acquisition software.

The *Sea Ark* was configured with a relatively simple setup consisting of a Windows 7 laptop running HYPACK to provide navigation to assigned features and log SBES data (RAW and BIN format) as required.

B.2.2. Navigation and Bathymetric Collection

QPS QINSy data acquisition software was used to log all MBES data and to provide general navigation for survey line tracking on the *Bella Marie* and *Bunny Bordelon* vessels. 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. The DTM was displayed as 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 assigned 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.

HYPACK also provided nearly identical functionality during *Sea Ark* operations.

B.2.3. Data Coverage and Density – MBES and SSS

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

Requirements called for either Complete Coverage or Object Detection Coverage (sheet-dependent) within the assigned survey areas, with the NALL as the inshore limit.

The NALL for this survey was generally the 3.5 m water depth limit, though in some areas safety of navigation pushed the NALL further offshore. These are discussed in the appropriate DR.

Work in Complete Coverage areas was done to either “Option A: Complete Coverage Multibeam” or “Option B: 100% side scan sonar coverage with concurrent multibeam” standards.

Likewise, work in Object Detection Coverage areas was done to either “Option A: Object Detection Multibeam Coverage” or “Option B: 200% side scan sonar coverage with concurrent multibeam” standards.

For each coverage type, a mix of the two options for each coverage type was used to meet the coverage requirements. The choice of which “Option” to utilize was made on the fly in the field and largely depended on the status of the SSS system as well as the necessity and suitability of SSS operations at that time. For example, “Option A” would often be utilized when the SSS system had issues or weather conditions degraded SSS data quality too much. Or, in other cases – especially holiday infills – small gaps in the existing SSS coverage could be filled with MBES without requiring additional SSS collection.

Prior to the project commencement, a line plan designed to meet these requirements was developed. Pre-plot lines were generated that filled the survey area regions at a spacing of 5 meters. During operations, the appropriate pre-plot line was selected and ran, with spacing adjusted as necessary to meet coverage requirements.

When “Option A” was utilized, line spacing was set by selecting an appropriate pre-plot line that allowed substantial overlap of the MBES system outer beams.

When “Option B” was utilized, line spacing was based on the SSS swath width instead, allowing for about 30% overlap of SSS data for Complete Coverage areas and at least 100% overlap of SSS data for Object Detection areas.

Sonar swath width for both MBES and SSS was adjusted by the field crew based on data quality, with the intent to maintain as wide a swath as possible while still meeting specifications.

SSS swath width was adjusted by changing the sonar range scale. To maintain a towfish altitude of 8% to 20% of the current range scale while accounting for vessel draft and the desire to maintain approximately 30% SSS overlap for Complete Coverage areas and at least 100% SSS overlap for Object Detection areas, a table of planned SSS range to depth was developed. These were largely adhered to during operations, with adjustments to range based on data quality at the time.

Min Depth (m)	Max Depth (m)	SSS Range Scale	Line Spacing*
3.5	4.0	25.0	40.0
4.0	5.0	25.0	40.0
5.0	6.0	35.0	55.0
6.0	7.0	35.0	55.0
7.0	8.0	50.0	80.0
8.0	9.0	50.0	80.0
9.0	10.0	75.0	120.0
10.0	11.0	75.0	120.0
11.0	12.0	100.0	160.0
12.0	13.0	100.0	160.0
13.0	14.0	100.0	160.0
14.0	15.0	100.0	160.0
15+		100.0	160.0
* Line spacing reduced by ½ for 200% SSS areas			

Table 17 – SSS Range Scale by Depth

Coverage was monitored relative to the assigned survey area boundaries and planned lines in real-time in the QPS QINSy acquisition software. When running lines, the vessel navigated the line as closely as possible. Care was taken during run-ins and run-outs to collect data to at least the survey boundaries.

Data density requirements were met by utilizing adequate ping rates to address along-track density, generating maximum sounder beams to improve across-track density, and providing overlap between adjacent lines. Ping rates were capped at a relatively high rate (10/second for all *Bella Marie* areas and *Bunny Bordelon* Object Detection areas, 5/second on all other *Bunny Bordelon* areas) while vessel speeds were moderated (less than 8 knots, but usually 6 to 6.5 knots, and less in shallow water) to control pings-per-meter on the seafloor. Across-track density for MBES was maximized by utilizing the "best coverage" beam modes, which generated 512 equi-distant soundings per ping on the single-head T50 and 7125 MBES and 1024 on the T50 IDH, which was the maximum capability of the MBES systems used. This combination of ping rate and beam mode caused the system to generate between 5120 and 10240 soundings per second and—at the speeds used—meet density specifications. Overlap between adjacent lines also improved data density, especially in cases where erroneous data required rejection.

On the Edgetech 4200 SSS systems, the “multi-pulse” feature was used at all times. This allowed the sonar to have two pings in the water simultaneously, doubling along-track data density compared to single-ping systems and allowing it to meet object detection requirements at the speeds used on this survey.

MBES coverage and density were checked during 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.

SSS coverage and density was confirmed in Chesapeake SonarWiz. Following application of offsets, layback computations, and gain corrections, the imagery was examined line-by-line for data quality and gaps. Imagery quality deemed insufficient to discern 1 m objects on the seafloor was rejected and reran with either SSS or MBES. Quality was documented through daily confidence checks, available in *Appendix II*.

Since both Option A and Option B types were acceptable coverage methods, a wholistic approach was used for final coverage checks and determination. All areas were reviewed in CARIS HIPS with MBES surfaces overlaid on SSS GeoTIFs output from Chesapeake SonarWiz to ensure at least one of the coverage types were achieved. Holidays were identified and rerun whenever possible, favoring MBES-only for infills on smaller gaps and SSS for larger gaps.

Note that SBES data collection completed with the *Sea Ark* was not assigned under the task order and was largely completed for recon purposes. Data quality is sufficient for charting but it does not adhere to specific set-line spacing or coverage and density standards.

B.2.4. MBES Backscatter

MBES backscatter was collected continuously during MBES operations. Presence of backscatter records in the raw MBES files was confirmed by periodic random checks through processing in Fledermaus Geocoder Toolbox (FMGT).

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

XTF files on this project do not contain backscatter records; these were intentionally configured to contain bathymetric sounding data only to limit XTF file size.

B.2.5. Draft Measurements

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, usually when alongside a dock. Measurements were also taken whenever the potential to significantly change the draft was experienced, such as after fueling or adjustments in ballast.

With the vessel at rest, a metal measuring tape was used to measure the distance from a measure-down point on the vessel gunwale to the waterline. The measurement was taken on both sides of the vessel on the *Bella Marie*, and then averaged to calculate the value at the vessel center reference point (CRP). On the *Bunny Bordelon* and *Sea Ark* vessels, the measurement was taken only on the port side next to the MBES mount where the CRP was also located.

The relationship between the measure-down point and CRP had been previously determined by vessel survey, allowing computation of the CRP to waterline offset for application in processing.

Draft values were logged with the time of acquisition and checked to ensure they fell within the normal range for the survey vessel. Questionable values were discarded. Values with high-confidence were entered into the CARIS HIPS Vessel Files (HVF) by processing (included with the survey deliverables) and then applied to all soundings. Static draft measurements are available in the survey logsheets, included with the DRs.

B.2.6. Sound Speed Measurements

Sound speed casts were taken from the survey vessels using a combination of sensors, described earlier in this report. These consisted of AML Minos X, Valeport RapidSV, and Valeport Swift SVP sensors. These sensors were all internal-logging units which were configured prior to deployment and downloaded following recovery.

On the *Bella Marie* and *Sea Ark*, and until JD2018-301 on the *Bunny Bordelon*, deployment was achieved by lowering the sensors on a line, by hand, through the water column to capture the profile. Starting on JD2018-301 the *Bunny Bordelon* utilized an Oceanscience Rapidcast system for underway deployments.

Sound speed casts were completed approximately every 2 hours. The sound speed sensor on the sonar head 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.

Line lengths were limited (generally 15 km or less) before completing a line turn to keep the survey vessels in the same general geographic proximity as the casts. This led to a collection of fairly well distributed casts that minimized both the distance and time between bathymetric data and applicable sound speed profiles. When depth varied significantly along a survey line, preference was given to casting in the deeper portion of the line to obtain as much of the water column profile as possible.

Position and time were noted in an acquisition log for all sound speed profiles for later processing.

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

To check data quality, profile results from independent sound speed sensors logged simultaneously were compared to each other. The comparison methodology is described in more detail later in this report. Comparison results are available in the DRs, *Separate II*.

B.2.7. Logsheets

Logsheets were kept on all vessels to track all significant survey events.

The following common events, with their time and position when applicable, were recorded by the survey crew:

- Generic line information including line name
- Sonar settings, RPM data, vessel speeds
- Generic POS file information including approximate start and stop times
- SSS Cable In / Cable Out
- Static draft measurements
- Sound speed cast events
- Sea and wind state, especially when adversely affecting operations
- Crew names and shift changes
- Calibration results and confidence checks
- Comments on any unusual observations or issues

In processing, logsheets were kept to record common processing tasks. These included:

- Common CARIS HIPS processes including conversion, SVP correction, tide correction, SBET and TrueHeave application, TPU computation, merge, cleaning, and general processing comments
- Common Chesapeake SonarWiz processes including conversion, bottom tracking, gain correction, sheave offsets, layback correction, and general processing comments. Picked contacts in the side scan data and correlation to the MBES surface were also recorded.
- POS file processing including base station selection and processing methods
- SVP file processing

Following processing and application of final corrections, logsheets were exported to PDF. Acquisition, processing, and other applicable logs are available in the DRs, *Separate I: Acquisition & Processing Logs*.

B.2.8. Bottom Samples

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.

Both the *Bunny Bordelon* and *Bella Marie* acquired bottom samples. To collect the samples, the vessel 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, 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 most assigned locations, with exceptions noted in the applicable DR and encoded with a “NATSUR” as “Unknown”.

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

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

Bottom sample results are available in the S-57 FFF (Final Feature File) submitted with the survey deliverables. Sample photos are included in the “multimedia” directory. Bottom samples were encoded at the actual position of acquisition, which may differ slightly from the assigned locations.

B.2.9. File Naming and Initial 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.

The following table lists raw data files commonly created in acquisition and transferred to data processing.

Raw File Naming Conventions		
Type	**Description**	**Example / Format**
DB, XTF, QPD, JSF	MBES Mainscheme and Crossline Data from QPS QINSy SSS Mainscheme	**1165-Bunny-224-C1-345-0002 (.DB, .XTF, .QPD, .JSF)** [Index]-[Vessel]-[JD]-[Area]-[Line]-[FileSequence#]. Area denotes sheet and block, line usually includes a type designation (XL, Infill, etc.).
	MBES Patch Test or Depth Check from QPS QINSy	**0764-Q105-225-Yaw (.DB, .XTF)** [Index]-[Vessel]-[JD]-[Purpose]_-_[FileSequence#], where purpose is calibration type such as "yaw"
SVP	Text File from Valeport SV	**2017-07-16-14-13-24 (.TXT)** [Year]-[Month]-[Day]-[Hour]-[Minute]-[Second]
	Converted Version of Valeport SV file	**2017-07-16-14-13-24_MVPFormat (.RAW)** [Year]-[Month]-[Day]-[Hour]-[Minute]-[Second]_
	CARIS SVP format exported from AML or Valeport sensors	**2018-339-0040-BB (.SVP)** [Year]-[JD]-[Time]-Vessel
T01	Trimble 5700 Binary File (navigation / base)	**00562340 (.T01)** [ReceiverSN][StartJD][FileSequence#]
POS	Raw Positioning Data (.000 file) from POSMV POSView	**2016-183-1245-Q105 (.000)** [Year]-[JD]-[Start time HHMM]-[Vessel]

Table 18 – Common raw data files and their naming convention on this project.

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

During data collection, the raw data files were logged to a local hard drive in a logical directory structure (based on file type and Julian day) on the acquisition PCs.

On the *Bella Marie* and the *Sea Ark*, at the completion of each survey day acquired data was copied to an external hard drive and brought to a laptop on a land-based internet connection where it was zipped and posted to a Microsoft Onedrive account.

On the *Bunny Bordelon*, data was similarly transferred but twice per day (after each survey shift) and via a cellular LTE internet connection.

DB, XTF, QPD, and JSF files were automatically split by the acquisition software (QINSy and Discover) to keep file sizes manageable. This was done when a DB file reached about 1.2 GB in size and a JSF file reached about 600 MB. When the size limit was reached, the software would automatically begin writing a new file with the same name but adding a file sequence number to the filename. This results in many lines in CARIS and SonarWiz having two or more segments / files per line.

Each day, processing personnel in Palmer, Alaska would retrieve the compressed data from the Onedrive accounts. Data was decompressed and checked against the acquisition logsheets to ensure all files were included in the transfer. Then the data was filed in the appropriate location on the office server and included in the automated backup systems. The data was then taken through the processing workflows. Despite acquisition in Texas and processing in Alaska, data was generally processed within 24 hours of collection with this method, and feedback provided on quality to the acquisition crews.

B.3. Bathymetric (MBES) Data Processing

Bathymetric data was processed in preliminary and final phases.

Preliminary processing, which was usually completed within 24 hours of acquisition to provide timely feedback to the field crews, consisted primarily of:

- Conversion into CARIS
- Processing of POSMV data in POSPac
- Processing of SVP casts
- Application of SBET data and GPSTides computation
- Preliminary TPU Computation
- Swath filtering
- Swath editing
- Preliminary CUBE surface generation

Final processing occurred following completion of field acquisition. This consisted primarily of:

- Review all offsets and corrections
- Review completeness of dataset
- Re-SVP, Re-Merge, Re-TPU with final correctors
- Subset review and editing
- Compile S-57 deliverables, reports, and other deliverables

Processing logs were kept and are available with each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. 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 timestamping, use of the ship ping header for navigation, and gyro data from attitude packets. No soundings were rejected during conversion.

Sea Ark SBES data was imported using the “Hypack RAW,HSX” converter. 1500 m/s was used as the sound velocity to match the setting used in the Odom eChart software in acquisition, an important step so that depths could be reconverted to travel times enabling SV correction in CARIS to be applied correctly.

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

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

B.3.2. Dual-Head HIPS Vessel Files

The CARIS HVFs (HIPS Vessel Files) for all MBES configurations for this project are setup as dual-head configurations, even when the systems weren’t actually configured as a dual-head. This was done per CARIS’ technical bulletin “HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data”. Per the bulletin, this was necessary because QINSy was configured to log “new” style (Reson 7027) bathymetric records.

Note that in this configuration vessel offsets (other than minor patch test corrections) 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. For single-heads (T50 singlehead and 7125) separate Tx and Rx offsets are entered under SVP1 and SVP2 in the HVFs, respectively. For the actual dual-head configurations a common center on the dual-head bracket is used for the SVP1 and SVP2 offsets, with a 30 degree rotation entered for each sonar head.

B.3.3. 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.

Acquisition logs containing the draft measurements are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.4. Load Delayed Heave

All POSMVs were configured to record Delayed Heave (also known as Applanix “TrueHeave”) to a POS file. Delayed Heave provides improved heave corrections over real-time heave, especially at the start of lines where the real-time heave filter may not have had adequate time to filter new sea-state conditions after a line turn to compute a zero-reference point. POS files were logged continually during survey operations, with rare exceptions.

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 rates (25 Hz).

Along with the Delayed Heave data, Delayed Heave RMS error records were also imported during this process so that final TPU values would reflect actual computations of RMS error for heave by the POSMV over the fixed values specified in the HVF.

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) where lines do not have a POS file (and hence Delayed Heave coverage), CARIS defaulted to utilizing the real-time heave corrections.

In CARIS HIPS, options to apply Delayed Heave were utilized during both Sound Velocity Correction and Merge.

Note that *Sea Ark* was not equipped with a POSMV and therefore did not have delayed heave applied.

B.3.5. Load Attitude / Navigation Data

On this project, positioning and attitude data was processed using post-processed kinematic (PPK) methodology. The PPK process (described later in this report) produced smoothed best estimate of trajectory (SBET) files, which contain an 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, and all available records were imported (navigation, gyro, pitch, roll, and GPS height). 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.

Through this process, each line's original, real-time attitude and navigation records were superseded in CARIS HIPS by the records in the SBET files. However, using post-processed pitch, roll, and gyro was found to introduce some roll misalignment issues in the *Bunny Bordelon* data that resembled an incorrect roll calibration offset. This was resolved by re-loading pitch, roll, and gyro data only from the POS files into all *Bunny Bordelon* data.

Therefore, final *Bella Marie* data contains all post-processed records, while *Bunny Bordelon* data contains post-processed navigation and GPS altitude records only.

Note that the *Sea Ark* was not equipped with a POSMV. However, the T5700 L1/L2 GPS receiver data logged during operations was post-processed using standard kinematic GPS techniques in Trimble Business Center to produce a PPK file in text format that was subsequently loaded into *Sea Ark* lines using CARIS' Generic Data Parser utility, replacing the real-time navigation and altitude records. These post-processed files are included with the survey deliverables.

B.3.6. Dynamic Draft Corrections

Dynamic draft corrections were determined for this project using squat-settlement tests.

Speed-based corrections were computed for all survey vessels. These corrections were generally not applied directly to the data because as an ERS survey all vessel vertical motions are measured and compensated for through application of GPS heights.

Section C of this report summarizes the dynamic draft results.

B.3.7. Sound Speed Corrections

Sound speed profiles (also known as "SV casts") were processed by appending the SVP cast results to the master CARIS SVP file for the sheet for which the cast applied. The timestamp and position from the acquisition logs was checked for reasonableness and appended to the cast header. Only the down- or up- cast was utilized. Typically, this was the down-cast due to noise on the up-cast from bottom strikes. The cast was then examined in CARIS HIPS SVP editor for spikes, which were rejected.

Each line was corrected for sound speed using CARIS HIPS "Sound Velocity Correct using CARIS Algorithm" utility. To prevent the use of sound speed profiles that were too old or distant relative to the bathymetric data, "Nearest in Distance Within Time" was used for the profile selection method. For the time constraint, 4 hours was used for the vast majority of survey lines. 12 hours was used for the *Sea Ark*, which performed only SBES collection.

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). This option was not applicable to the *Sea Ark*, which did not have delayed heave records or a surface speed sensor.

B.3.8. Total Propagated Uncertainty

CARIS HIPS was used to compute total propagated uncertainty (TPU). The CARIS HIPS TPU calculation 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). The following table describes the TPU values entered in the HVF. Note that all values entered are at 1-sigma, per CARIS guidance, while CARIS reports TPU at 2-sigma.

HVF TPU Entries

HVF TPU Entry	*Sea Ark*	*Bella Marie*	*Bunny Bordelon*	Source
Sonar Type	Teledyne Odom Echotrac CV	Teledyne RESON SeaBat T50P (400 kHz 512 Beams)		Entry in HVF for Transducer1 (sonar model). Uses the sonar parameters from the CARIS device models .XML file to model sonar error based on manufacturer-provided estimates
Motion Gyro	0.30°	0.02°		CARIS TPU values for Applanix POSMV 320 (2 m baseline), manufacturer heading accuracy for Hemisphere V111/V113 for *Sea Ark*
Heave	N/A	5% for Heave % Amplitude, 0.05m for Heave (m)		CARIS TPU values for Applanix POSMV 320. *Sea Ark* did not have a Heave sensor.
Roll and Pitch	N/A	0.02°		CARIS TPU values for Applanix POSMV 320. *Sea Ark* did not have a Roll/Pitch sensor.
Position Nav	0.1 m			PPK position processing results report RMS errors that were better than 0.10 m on average
Timing – (all systems)	0.01 sec.			Estimated overall synchronization error
Offset X	0.02 m	0.01 m	0.01 m	Accuracy estimate of the X offset measurement of the transducer acoustic center relative to the vessel CRP
Offset Y			0.025 m	Same as above
Offset Z			0.069 m	Variance of bar check results
Vessel Speed	1 m/s			Estimated average max current experienced in survey area
Loading	0.01 m	0.018 m	0.074 m	Standard deviation of the difference between subsequent static draft measurements
Draft	0.02 m			Estimated accuracy of static draft measurements
Delta Draft	0.01 m			Overall estimated uncertainty of squat-settlement test results
MRU Align StdDev Gyro	1°	0.1°		Estimated yaw – sonar alignment accuracy

HVF TPU Entries

HVF TPU Entry	*Sea Ark*	*Bella Marie*	*Bunny Bordelon*	Source
MRU Align StdDev Gyro, Roll/Pitch	N/A	0.02°		Estimated accuracy of patch test value for roll/pitch.
MRU to Trans and Nav to Trans Offsets	IMU to Transducer X, Y, Z offset			Offsets are from the CRP/measurement computation point to the transducer(s)

Table 19 – HVF TPU values used.

Other TPU computation parameters:

- **Tide error uncertainty**: During final TPU computation, a static tide error value of 0.104 m was used. This corresponds to the uncertainty value provided by NOAA for the VDATUM separation grid applied to the soundings for tidal corrections.
- **Real-time Error Estimates:** Real-time error estimates were loaded into most survey lines collected with the *Bella Marie* and *Bunny Bordelon*. This consisted of Delayed Heave RMS error loaded from POS files during the Import Delayed Heave process, and Navigation/Gyro/Pitch/Roll/GPSHeight RMS loaded from SMRMSG files that were created concurrently with PPK/SBET processing.

  Real-time error values for Gyro/Pitch/Roll were loaded and applied for the *Bella Marie* but not the *Bunny Bordelon*, which used fixed vessel error estimates for these records. This was because the *Bella Marie's* Gyro/Pitch/Roll corrections were loaded from SBETs while the *Bunny Bordelon's* were real-time.

  Note that this means the static error estimates for these specific sensors in the HVF were ignored by HIPS during TPU computation for most survey lines. The associated static error estimate in the HVF was used by CARIS HIPS as a backup for when the real-time error data was not available.

  Real-time errors were not available for the sonar or tide sensors.
- **Sound speed error**: For estimated sound speed error, a value of 2 m/s was entered. This corresponded to the surface change in sound speed which would require an additional sound speed profile to be collected.

Other TPU Settings

TPU Setting	*Sea Ark*	*Bella Marie*	*Bunny Bordelon*	Description
Sound Speed - Measured	2 m/s			Approximate maximum variance in surface sound speed experienced before additional sound speed profiles would be acquired during acquisition

Other TPU Settings				
TPU Setting	***Sea Ark***	***Bella Marie***	***Bunny Bordelon***	**Description**
Sound Speed - Surface	N/A	0.025 m/s		Manufacturer-specified accuracy of the surface sound-speed probes. The *Sea Ark* did not have a surface sensor.
Tide (Measured)	0.104 m			NOAA provided uncertainty value for the VDATUM grid applied for final tide corrections. A zero uncertainty value was entered for “Zoning” since zones were N/A
Uncertainty Source:				Caused HIPS to use the real-time estimates of error loaded into survey lines whenever available, falling back to the static HVF values when real-time errors were not available. The *Bella Marie* utilized realtime gyro/pitch/roll errors (from SMRMSG files) because these records were loaded from SBET files.
Position	Vessel (all)	Realtime		
Sonar		Vessel		
Heading (Gyro)		Realtime	Vessel	
Pitch		Realtime	Vessel	
Roll		Realtime	Vessel	
Vertical		Delayed Heave		
Tide	Static			

Table 20 – Other TPU computation settings.

B.3.9. Post-Processed Kinematic (PPK) Navigation and Attitude

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

PPK processing for this project for the *Bella Marie* and *Bunny Bordelon* vessels 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) as well as real-time attitude data (gyro, pitch, and roll) with the post-processed version. The process also produced SMRMSG files, which contained root mean square (RMS) error estimates, for the post-processed solution at 1 Hz, that were loaded and used for dynamic (real-time) TPU estimates, as described previously in this report.

To process POS files to produce an SBET, a POSPac MMS project was first established based on a pre-defined 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 Trimble PP-RTX functionality was utilized for POSPac processing. PP-RTX is a subscription-based service available within POSPac, based on Trimble CenterPoint RTX, that utilizes Precise Point Positioning (PPP) to post-process data without the use of base stations. Advertised accuracies are 0.1 m RMS Horizontal and 0.2 m RMS vertical. However, on this project, reported RMS errors were generally better than advertised – usually at the 0.05 to 0.1 m level vertically.

Applanix Smart Base (ASB) mode was also utilized but only as an independent comparison against the PP-RTX results.

Following selection of PP-RTX and automatic download of applicable ephemeris and base station data, 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. QC reports in PDF format, that show performance metrics, were then created for each POSPac project and are available with the project HVCR.

Lastly, SBETs were exported from POSPac. The option to produce "Custom Smoothed BET" was used to produce an SBET in the NAD83 (2011) reference frame at 50 Hz. This made it so that all final positions were NAD83 (2011) per the 2018 HSSD.

The flow chart shown below is a generalized overview of the POSPac workflow used on this project.

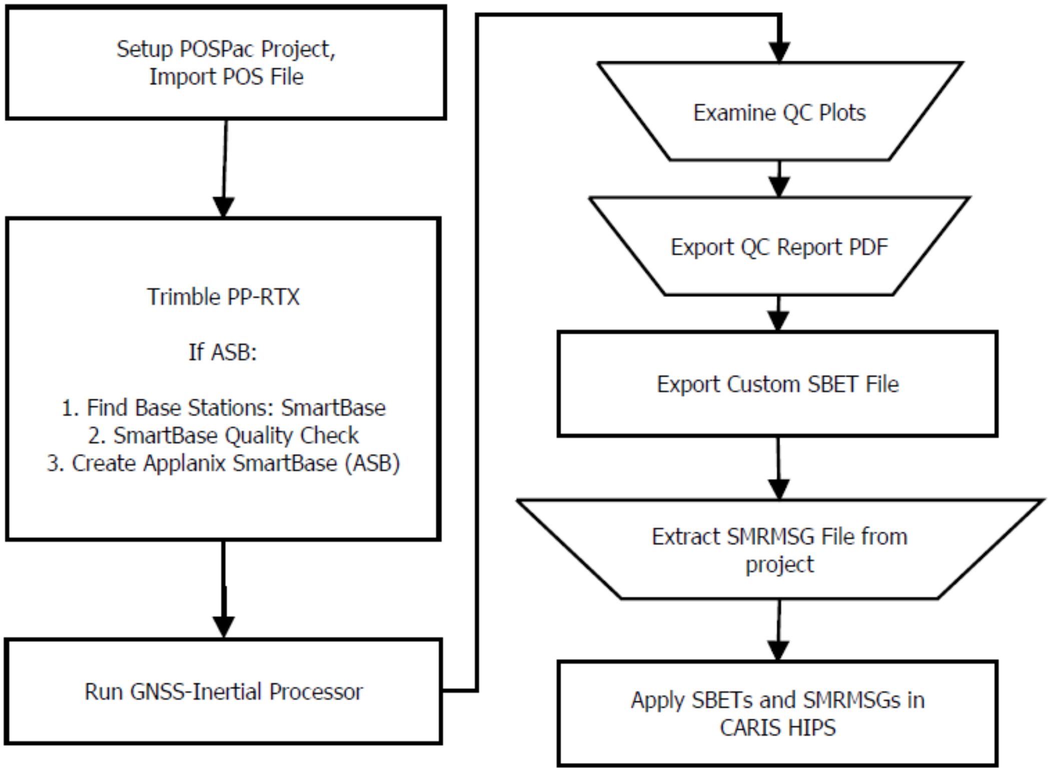


Figure 7 – Flow chart overview of POSPac workflow used on this project.

SBET .OUT and SMRMSG .OUT files were then applied in CARIS HIPS to lines using the Import Auxiliary Data process. All .OUT files that were applied to the data are included with the survey deliverables, as well as the POSPac QC Report PDFs.

Navigation and GPS height records from SBETs were applied to *Bella Marie* and *Bunny Bordelon* lines. SBET gyro/pitch/roll values were applied to both vessels as well but appeared to introduce some roll misalignments in the *Bunny Bordelon* data. Therefore

Bunny Bordelon lines were re-loaded with real-time (non SBET) gyro/pitch/roll from POS files.

Note that while SBETs were produced in NAD83 (2011), CARIS HIPS project geodetics were intentionally set to NAD83 without the 2011 epoch designation. This was done because of a known issue in CARIS HIPS 10.3.3, whereby if the project were set to an epoch of 2011 the software may perform a potentially detrimental (albeit minor) conversion on the navigation which is already on the 2011 epoch. This would happen because only "NA83" is available (without a 2011 epoch designation) as the applicable datum under the navigation sensor in the HVF. If a CARIS project is set to NAD83 (2011) but assumes the NAD83 (2011) navigation is standard NAD83 due to the "NA83" setting in the HVF, the unwanted conversion would be triggered.

Sea Ark GPS data was post-processed as well. *Sea Ark* GPS data logged with a T5700 GPS receiver was processed in Trimble Business Center (TBC), which utilized the nearby CORS station at Port Lavaca (TXPV). The solution data was output on NAD83(2011) in text file format, containing NAD83(2011) position and GPS altitude for the vessel CRP. This was loaded into *Sea Ark* SBES lines using CARIS' Generic Data Parser utility.

B.3.10. Compute GPSTide

Following loading of PPK altitude data in final processing, 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 VDATUM) separation model were used so that the GPSTide record reflects the elevation of the vessel waterline above MLLW.

For *Bella Marie* data from JD2019-015 to JD2019-038, when the vessel was utilizing a POSMV with an IMU offset from the vessel CoG and CRP, the options to apply "Antenna Offset" and "MRU Remote Heave" were also utilized to minimize remote heave effects. However, some residual remote heave artifact on the order of 0.10 to 0.20 m remained and could not be resolved.

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.

B.3.11. Load Tide

For a very small number of lines, conventional tides needed to be applied due to poor results from the GPS records. These are itemized in the applicable DR. In these rare cases verified tides from either the Port O'Conner (8773701) or Matagorda Bay Entrance (8773767) NWLON stations were downloaded and applied with CARIS HIPS' "Load Tide" utility. Merge (described below) was ran using "Observed/Predicted" tides instead of "GPS" to apply the gauge-measured water levels.

B.3.1. Merge

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

B.3.2. 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. Soundings flagged as 0, 1, and 2 were “rejected” automatically in filtering. Only high quality (3, being both co-linear and bright) soundings passed. This removed a large amount of water column noise.

Beam-based filters were also selectively run to remove outer beam soundings in some configurations. Crosslines, when applicable, were filtered to remove soundings greater than 55° from nadir to ensure that only good near-nadir crossline data was used for crossline comparisons. Some lines with excessive sound velocity error also received outer beam filters to remove soundings that were outside of specifications.

B.3.3. Multibeam Editing

Initial field cleaning of multibeam data was done 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 the MBES processing logsheet, along with the processors’ comments or notes, if any.

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

In CARIS HIPS, CUBE surfaces were first generated based on the depth resolution standards and CUBE parameters conforming to the 2017 Hydrographic Surveys Specifications and Deliverables (HSSD). The CUBE surfaces were “finalized” using depth ranges for resolution specified in the HSSD. Surfaces were then loaded as a reference layer and examined in subset mode simultaneous with the contributing soundings. Only the CUBE surface appropriate for the depth and coverage type being examined was loaded (0.5, 1 m, and 2 m surfaces).

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), which meets TVU specifications. However, during editing, reviewers erred on the side of rejecting erroneous soundings even when they did not adversely affect the surface.

When changes in the seafloor over the course of operations from sediment transport caused mismatches in swath depth the bottom was generally not rejected, even if it exceeded specifications. These rare circumstances are itemized in the applicable DRs.

On occasion, designated soundings were flagged on the shoalest point of features not well modeled by the CUBE surface during subset editing, or to ensure the least depth of developed features was honored.

For editing consistency, the data was reviewed in subset with set visualization parameters. Data was examined looking along-track through the data, which is standard practice for examining bathymetry in subset. The subset view slice length was constrained to approximately 10-20 lines, and slice width was constrained to about 25-50 m, based on ruggedness of the seafloor being examined. Vertical exaggeration in the subset window was manually set so the vertical scale graticule displayed in increments of 0.50 m. Subset tiles were used to track editing progress, with care taken to ensure all data was examined. Issues such as busts or artifact that exceeded specifications were noted and addressed. Final BASE Surfaces

The final depth information for this survey is submitted as a collection of surfaces gridded from the sounding data. Surfaces were generated in CARIS HIPS 10.3.3 in CSAR format, and represent the seafloor at the time of survey, relative to chart datum (MLLW).

Resolutions of the BASE surfaces were created in accordance with the HSSD based on coverage type and depth. Resolutions ranged from 0.5 m for Object Detection areas, to 1m and 2 m for Complete Coverage areas. BASE surfaces for the SBES data was created at 4 m resolution.

For all surfaces, “CUBE” was selected as the gridding algorithm. “Density and Locale” was chosen as the “disambiguity” method and NOAA CUBE parameters appropriate to the resolution were selected. The CUBE parameters (XML format) are included with the CARIS HIPS digital data deliverables. “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 that resolution. Designated soundings were applied, which forced the final surfaces to honor these soundings where applicable.

B.3.4. Final Feature Files

A final feature S-57 file (FFF) (and supporting files) was submitted in conjunction with each survey. The FFF contains information on objects not represented in the depth grid, including bottom samples, features, and metadata. Each feature object includes the mandatory S-57 attributes (including NOAA extended attributes) that may be useful for chart compilation. The FFF was created in CARIS HIPS 10.3.3 by importing all applicable features and assigning mandatory attributes as necessary.

“CARIS Support Files V5.7” were used as NOAA extended attributes, which added custom NOAA attributes to the standard S-57 library. V5.7 was most recent version provided by NOAA (June 2018) at the time of field operations for this survey. During feature attribution, effort was taken to ensure required attributes described in the HSSD were applied.

B.3.5. Crossline Analysis

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 2 m resolution in the same manner as the final surfaces, but with the important distinction that the QC BASE surface excluded crosslines to not bias the QC report results.

Differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings with differences from the BASE surface falling within IHO Order 1. When at least 95% of the soundings exceed IHO Order 1, the crossline was considered to "pass," but when less than 95% of the soundings compare within IHO Order 1, the crossline was considered to "fail." A 5% (or less) failure rate was considered acceptable since this approach compares soundings to a surface, instead of a surface to a surface. Note that although IHO Order 2 standards are acceptable for depths greater than 100 m, Order 1 parameters were used for all depths for simplicity.

Overall, there was excellent agreement between crosslines and mainscheme on this project, with the vast majority of crosslines comparing to mainscheme well within IHO Order 1.

Note that individual crosslines often have two or more files (or segments) in CARIS due to the automatic file splitting feature in the acquisition software (QPS QINSy). For each individual crossline, all applicable segments were selected and ran through the QC report process so that the QC report would reflect the line as a whole instead of its individual sections.

Crosslines received additional filtering above normal filtering for mainscheme so as to remove erroneous outer beams and help assure good crossline nadir depths were used for the comparisons. The filter setting used for crosslines was 55°.

A discussion concerning the methodology of crossline selection, as well as a summary of results for each sheet, is available in the project DRs. The crossline reports are included in the DRs, *Separate II.*

B.3.6. Bathymetric Processing Flow Diagram

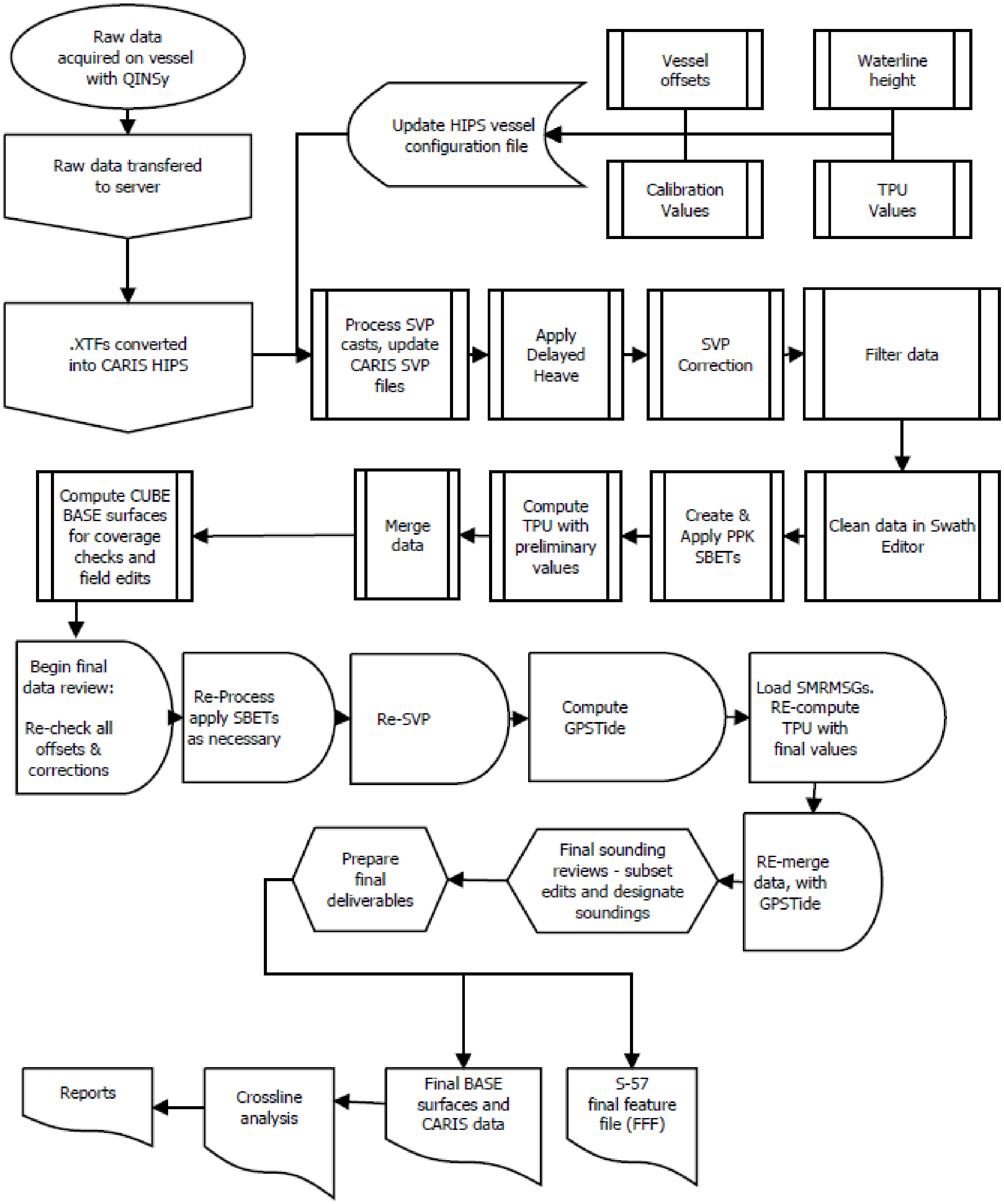


Figure 8 – Generalized flow chart of processing steps used on this project.

B.3.1. SBES Data

Only a small amount of SBES data was acquired for this project. This was acquired aboard the vessel *Sea Ark* for sheet F00734 during recon operations.

However, this data passed through a workflow substantially similar to the MBES data, with the exception that RAW and BIN files logged by HYPACK were used instead of XTF files, initial cleaning was done in CARIS Singlebeam Editor instead of Swath Editor, and sounding filters were not applied. Delayed heave was not applicable to this data. Instead of SBETs, text files containing post-processed navigation and GPS heights were loaded using CARIS Generic Data Parser. Real-time errors were not available for TPU computation, so static (HVF-based) error estimates were utilized instead.

B.3.1. Sea Ark Feature Investigations

The *Sea Ark's* primary purpose was investigating assigned features inside Matagorda Bay (F00734) and collecting recon data prior to the arrival of the MBES/SSS-equipped vessel, the *Bella Marie*.

The *Sea Ark* operated with the following general parameters:

- Navigate, if possible, to the position of each assigned feature. Visually search within the assigned search radius shown in the PRF.
- If a feature was found at or above the surface and matched the feature type (i.e. a post found near an assigned post feature) a position was taken as close as possible to the feature as well as a photo and the feature was considered resolved.
- If no obvious feature was found, SBES recon lines were collected to search for the feature and determine the depth in the area. If still not resolved with SBES and found to be deeper than 3.5 m, the area was earmarked to receive Object Detection search and was addressed later with the *Bella Marie* with SSS and MBES.
- If the object was not found and the area was shoaler than 3.5 m and therefore too shallow for Object Detection (MBES/SSS) coverage, the object was considered as unresolvable and would be recommended to be retained during S-57 processing.
- In a few cases where the feature was not found and the water was too shallow for Object Detection survey, UAS (Unmanned Aerial System) was used to fly over and photograph the surrounding area in an attempt to resolve the feature. When applicable, these are discussed under the appropriate feature in the FFF with photos from the UAS attached.

B.4. Side Scan Sonar Processing

Side scan data was processed in Chesapeake SonarWiz 7 processing software. SonarWiz is a comprehensive side scan processing package that includes the capability to apply all necessary data adjustments while also providing useful data visualization tools to assist with contact selection. SonarWiz is also equipped with various data review and quality control tools and preserves the full data quality of the side scan time series without unnecessary downsampling.

Data that was logged in raw EdgeTech JSF format by Discover software was imported directly into SonarWiz to begin processing. Only high frequency (400kHz) data was acquired and processed.

Work completed in SonarWiz was tracked line-by-line in a SSS processing log, which are included in *Separate I* of the DRs.

B.4.1. SSS Navigation Editor

Navigation data was reviewed in the SonarWiz Navigation Editor utility, which is similar in form and functionality to CARIS HIPS' Navigation Editor. Manual edits (rejection of erroneous navigation) were rare and done only when necessary. The figure below shows an example screen grab from Navigation Editor.

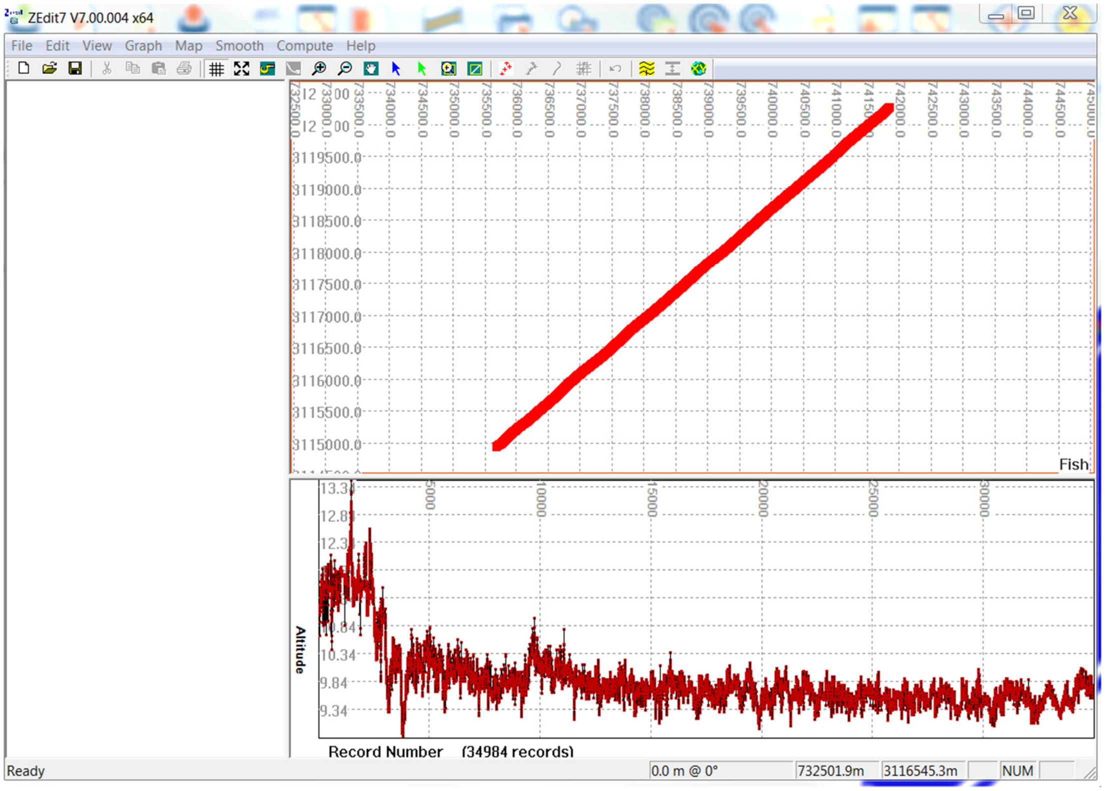


Figure 9 – SonarWiz 7 Navigation Editor utility interface.

B.4.2. SSS Bottom Tracking

All SSS data was bottom tracked in SonarWiz. Bottom tracking eliminates the irrelevant water column data from the record to enable correction for slant range and application of gains. Utilizing the real time bottom tracking from Discover software was the preferred method. Whenever real time tracking did not accurately define the intersection of the water column and the seafloor, tracking was redone in SonarWiz using "Auto bottom tracking", whereby SonarWiz automatically detected the intersection based on user-entered blanking, duration, and threshold settings.

When automatic bottom tracking was used, the blanking, duration, and threshold values were set to create the best possible match to the bottom in order to minimize manual correction. These values varied greatly line-by-line. Specific bottom tracking settings used for each line are specified in the SSS processing logs, which are included in *Separate I* of the DRs. After auto bottom tracking was completed, the results were reviewed and manually edited in instances where automatic bottom tracking did not pick the correct bottom.

Next, an offset of 0.80 meters was made to the bottom tracking. This shifted the bottom track result outward from nadir horizontally by 0.80 m on each channel, effectively removing the small portion of the seafloor at nadir where side scan data is of poorest quality. Additionally, the near-nadir area was fully ensonified by the multibeam sonar system. Therefore, removing near-nadir SSS data reduced the 'zipper' effect in the data without compromising data coverage or object detection capabilities.

B.4.3. Slant Range Correction

All lines were slant range corrected with a sound velocity of 1500 m/s in SonarWiz. During this standard automated process common to all SSS processing software, sonar data was repositioned across-track to compensate for the compression of data in the near-sonar region.

B.4.4. Gain Correction

Different methods of gain correction were utilized for the SSS data acquired from each vessel.

For the *Bella Marie*, Automatic Gain Control (AGC) was utilized. AGC signal processing corrects for differences in the amplitude of a reflected signal due to the angle of incidence and the propagation distance. AGC has the effect of normalizing the across-track gradient banding (high to low intensity moving outwards from nadir) in the imagery. This gain method produced a higher quality mosaic with a balanced intensity (brightness) for each line and between adjacent lines.

For the *Bunny Bordelon* data, Empirical Gain Normalization (EGN) was utilized because AGC produced a poorly balanced brightness between adjacent lines. Unlike AGC, which applied gain on a file-by-file basis, EGN sums and averages all the sonar amplitudes for the entire dataset. It does this by creating an EGN Table where the x-axis is range and the y-axis is altitude, effectively creating a beam pattern for the specific sonar and the specific settings utilized in acquisition. This table is then applied to each amplitude sample in a file.

One EGN table per survey sheet created a mosaic with balanced brightness within each line and between adjacent lines for most of the data. Exceptions to this occurred in H13182 and H13187, where separate EGN tables were needed for groups of lines offset in brightness. Using a separate EGN table normalized the brightness of the outlier group of lines to match the rest of the mosaic.

The specific lines that utilized a separate EGN table are identified in the applicable DRs and SSS processing logs included in *Separate I* of the DRs.

Some *Bunny Bordelon* SSS lines in H13186 utilized AGC instead of ENG due to multiple lines each having a unique brightness offset from the rest of the mosaic. Unlike EGN, AGC corrections are computed on a file-by-file basis, allowing for individual brightness adjustment of outlier lines.

The specific lines that utilized AGC application are identified in the DR for H13186, and in the SSS processing logs included in *Separate I* of the DRs.

A destripe filter was applied to lines within each project on an as needed basis. This process uses a filter averaging over 100 pings in order to remove across-track striping artifacts caused by motion of the towfish. Use of this filter significantly improved the quality of the SSS mosaics where striping was present.

B.4.5. Tow Point Offset

SonarWiz was used to compute the position of the towfish. During this process, SonarWiz utilized the known tow point offset from vessel CRP to the tow point (the XYZ sheave) and the layback (cable out from the tow point). Vessel course made good (CMG) was used as the towfish heading source.

For the *Bella Marie,* the sheave offset changed throughout the survey. From JD 248 to 301, the sheave was the block of the davit on the starboard side of the vessel. For JD 302 to 319, the sheave was a tie-off point on the back deck. For JD 320 in 2018 to JD035 in 2019, the sheave offset was the top of the cable counter block on the vessel A-frame. Changes in the towpoint were made in attempts to address wake or other vessel-induced artifact in the SSS imagery.

For the *Bunny Bordelon,* the sheave offset remained the top of the cable counter block on the vessel A-frame for the entire duration of the survey.

The sheave offset utilized for each line is specified in the SSS processing logs, which are included in *Separate I* of the DRs.

Julian Days	Sheave Location	X (+Starboard) m	Y (+Forward) m	Z (+Up) m
JD 248-301	*Bella Marie* starboard davit	3.239	-2.816	2.440
JD 302-319	*Bella Marie* off back deck	0.000	-5.55	1.30
JD 320-035 (2019)	*Bella Marie* cable counter A-Frame	0.000	-6.200	3.180
JD 290-346	*Bunny Bordelon* cable counter A-Frame	6.513	-19.750	5.000

Table 21 – Sheave Offsets (Towpoint) summary, Bella Marie

B.4.6. Layback & Cable Out Offset

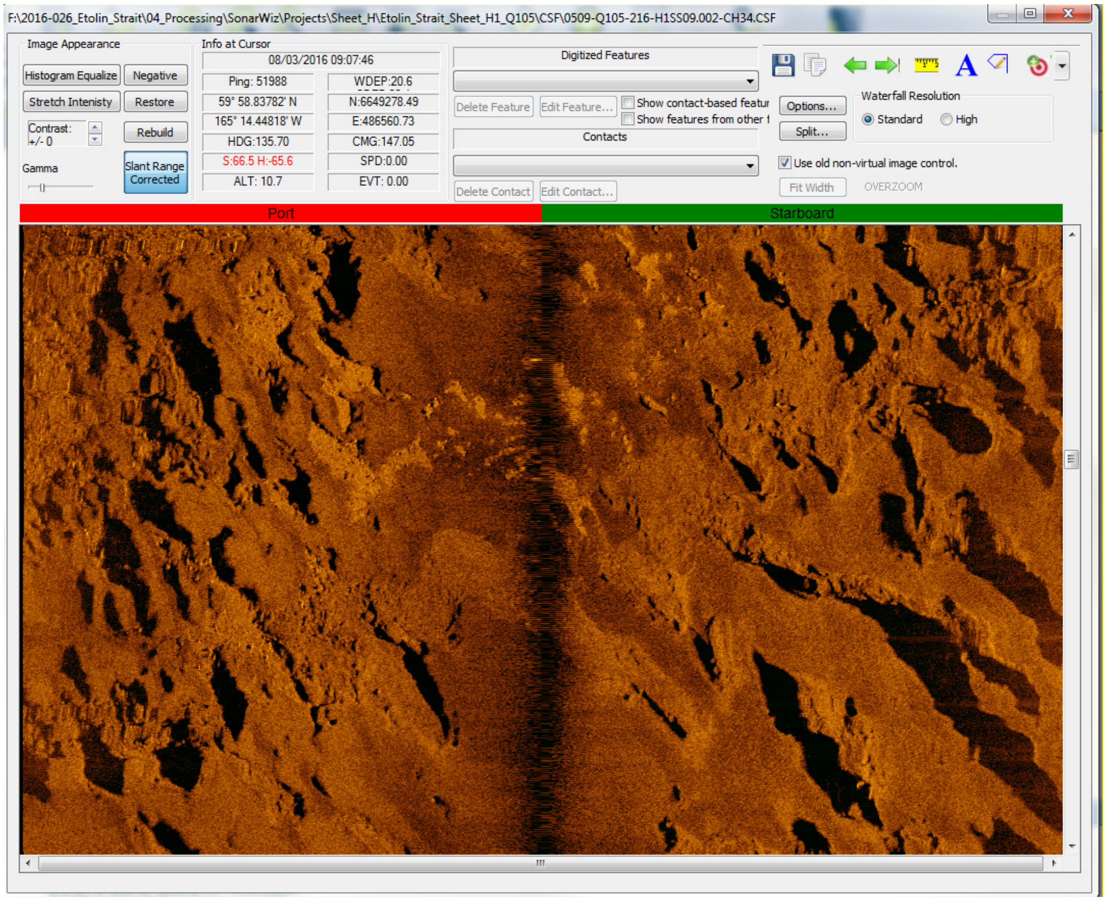
Layback was applied as a percentage of the cable out. SonarWiz was set to use 95% of the specified cable out value to account for cable catenary. When possible, cable out was recorded directly to JSF file. The side scan acquisition software (Discover) was interfaced with the serial output from the cable counter and subsequently logged cable out (at a rate of 1 Hz) directly into the raw JSF files, which carried over into SonarWiz. Exceptions to this occurred throughout the project when cable out was either not properly input into Discover, in which case the cable out was manually set in SonarWiz. Exceptions also occurred when the cable out value was known to be inaccurate, in which case an offset was applied to the cable out in the file.

The side scan processing logs in *Separate I* of the DRs detail which lines have manually set cable out and which have cable out logged in the JSF.

During contact correlation with the MBES data, some lines were rubber-sheeted to the MBES via an offset to the cable out value. This was done by applying an offset to the cable out for that file. These lines are specified in the SSS processing logs, which are included in *Separate I* of the DRs.

B.4.7. Data Review and Contact Selection

Following application of corrections, all lines were reviewed for data quality and contact selection. The SonarWiz Digitizing View allows detailed examination of individual lines in which the user can switch on/off slant range correction to view the water column if desired, which is similar to CARIS SIPS side scan editor.



F:\2016-026_Etolin_Strait\04_Processing\SonarWiz\Projects\Sheet_H\Etolin_Strait_Sheet_H1_Q105\CSF\0509-Q105-216-H1SS09.002-CH34.CSF

Info at Cursor
08/03/2016 09:07:46
Ping: 51988
WDEP:20.6
59° 58.83782' N
N:6649278.49
165° 14.44818' W
E:486560.73
HDG:135.70
CMG:147.05
S:66.5 H:-65.6
SPD:0.00
ALT: 10.7
EVT: 0.00

Contrast: +/- 0

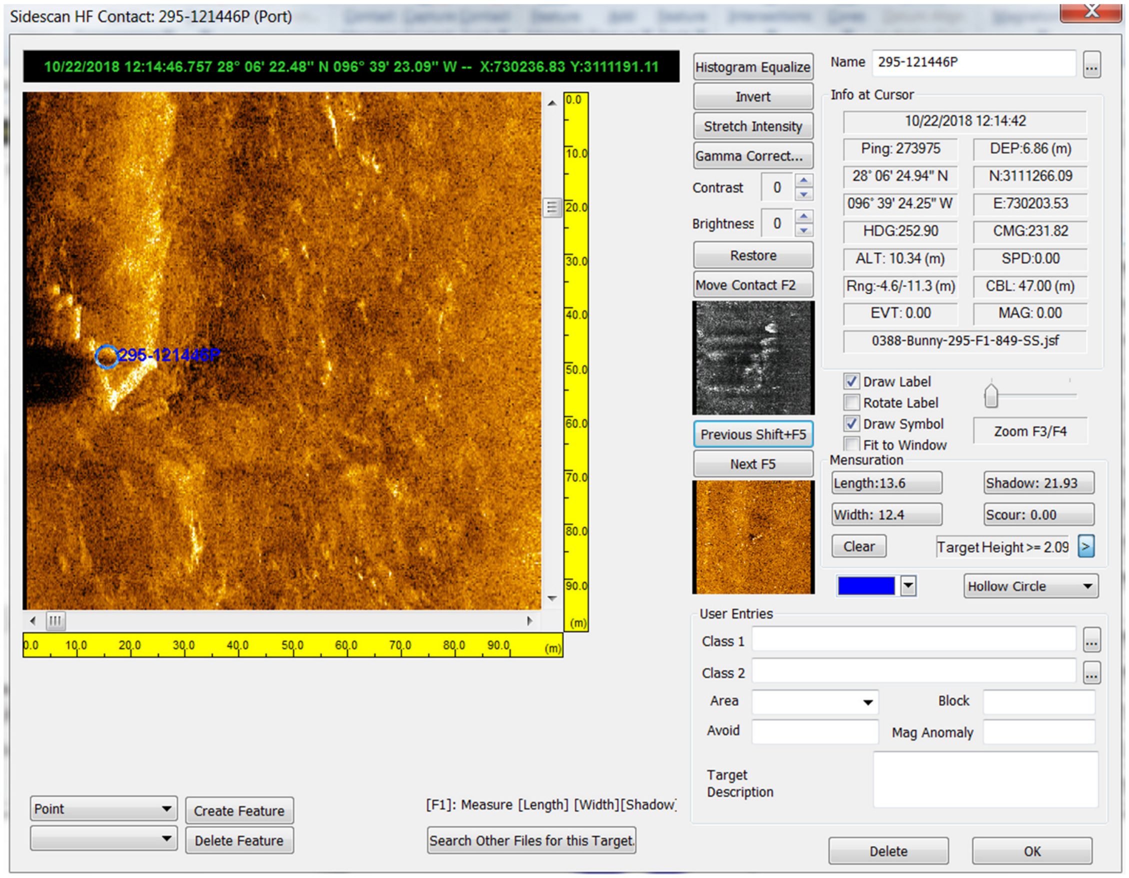
☐ Show contact-based featur
☐ Show features from other f
☑ Use old non-virtual image control.

Waterfall Resolution
● Standard ○ High

Figure 10 – SonarWiz Digitizing View.

Possible contacts were flagged and measured for height in the SonarWiz contact editor. In the contact editor, shadow length was measured to provide an estimate of object height above the seafloor. Contacts were flagged for further examination and possible development with MBES, especially if their estimated height exceeded 1 m.

When picking contacts, SonarWiz exported a JPG image with the contact name for each contact. These images are available in the S57 multimedia folder.



Sidescan HF Contact: 295-121446P (Port)

10/22/2018 12:14:46.757 28° 06' 22.48" N 096° 39' 23.09" W -- X:730236.83 Y:3111191.11

Name: 295-121446P

Info at Cursor
10/22/2018 12:14:42
Ping: 273975
DEP:6.86 (m)
28° 06' 24.94" N
N:3111266.09
096° 39' 24.25" W
E:730203.53
HDG:252.90
CMG:231.82
ALT: 10.34 (m)
SPD:0.00
Rng:-4.6/-11.3 (m)
CBL: 47.00 (m)
EVT: 0.00
MAG: 0.00
0388-Bunny-295-F1-849-SS.jsf

Contrast: 0
Brightness: 0

☑ Draw Label
☐ Rotate Label
☑ Draw Symbol
☐ Fit to Window

Mensuration
Length:13.6
Shadow: 21.93
Width: 12.4
Scour: 0.00
Target Height >= 2.09

Hollow Circle

User Entries
Class 1
Class 2
Area
Block
Avoid
Mag Anomaly
Target Description

Point

[F1]: Measure [Length] [Width][Shadow]

Figure 11 – SonarWiz Contact Editor.

B.4.8. *SSS Final Review for Coverage and Contacts*

All lines were reviewed for contacts at least twice. Lines were first reviewed quickly after acquisition, usually within 24 hours of collection. Then, to ensure possible contacts were not missed, all lines were reviewed at least one additional time prior to departing the field.

B.4.9. *Contact Development*

Significant contacts (generally those with estimated heights of 1 m or greater above the seafloor) flagged for development were checked against multibeam coverage. In many cases the contact was determined to have received adequate multibeam coverage during mainscheme collection without requiring an additional survey line over the contact. When this was not the case, dedicated survey lines were run to develop the contact further with MBES. In some cases where there were multiple contacts, it was more time efficient to develop the area fully with MBES to the applicable coverage standards.

B.4.10. *Mosaic and Coverage Report Generation*

Two methods were used to confirm the coverage requirement for the survey was met.

In the field, SonarWiz was utilized to provide coverage reports. Coverage reports output a geo-referenced image with color codes for coverage. Green indicated areas that have 200% (or greater) coverage and red indicated areas that had 100% coverage. Areas not meeting the 100% coverage requirement according to the SonarWiz coverage reports were addressed in the field by collecting additional data until coverage was confirmed. An example of the SonarWiz coverage report is shown in the following figure.

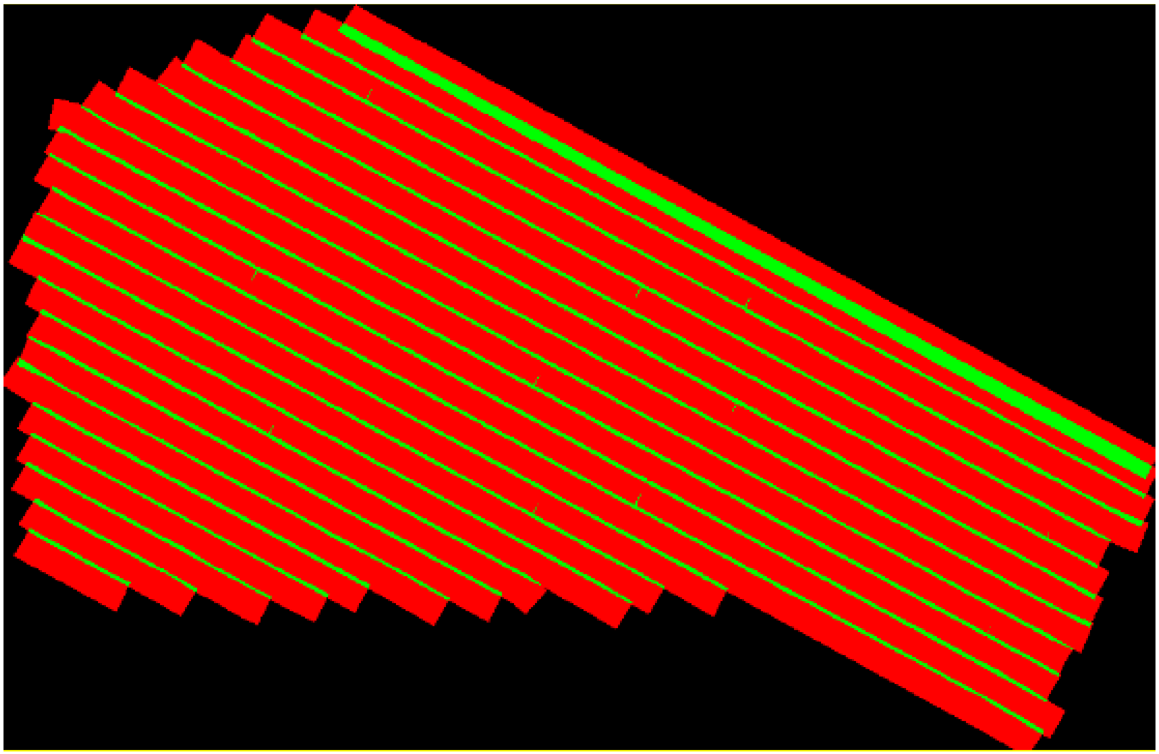


Figure12 – Example of SonarWiz Coverage Report; green indicates 200% (or greater) coverage and red indicates 100% coverage.

To further demonstrate coverage requirements were met, 100% coverage greyscale GeoTif images were exported from SonarWiz at 1 meter resolution and examined.

In many cases holidays in the SSS coverage were filled with MBES-only data, without concurrent SSS. This leaves apparent holidays in the SSS coverages, but when viewed in conjunction with the MBES data these areas were fully surveyed.

The 100% coverage GeoTifs are provided with the survey deliverables.

B.4.11. Side Scan Sonar Contact Correlation and S-57 Presentation

After the application of SSS corrections and processing, SSS contacts were exported from SonarWiz to S-57 format. These were then imported into CARIS HIPS as CSYMB objects with required attribution. Contacts were then correlated with the MBES and overlapping SSS data.

During this process, MBES and overlapping SSS data was examined in the vicinity of the SSS contact position. The correlation with nearby features, or lack thereof, was analyzed and the results noted in the “remrks” attribute of the S-57 feature. If a feature was verified by MBES and found to be significant, it was designated when it met HSSD designation criteria.

Insignificant contacts (less than 1 m height) were only incidentally correlated with the multibeam data. These were analyzed in some cases to demonstrate the ability of the SSS system to discern smaller objects. Contacts that were determined to be noise in the SSS data, such as vessel wake or fishballs, were deleted.

During contact correlation with the MBES data, some lines were rubber-sheeted to the MBES via an offset to the cable out value. This was done by applying an offset to the cable out for that file. These lines are specified in the SSS processing logs, which are included in *Separate I* of the DRs. In these cases, the contact position was updated and the S-57 features were then re-exported from SonarWiz.

SSS contacts (including significant and insignificant) were attributed as “CSYMB” objects and are available for review in the SSS contact feature file, with contact images in the accompanying Multimedia folder.

B.4.12. SSS Processed Data – SonarWiz Projects

Final SSS lines were submitted in a format readable by SonarWiz 7 software. The SonarWiz utility “Project Mover” was used to create compressed files that can be imported back into SonarWiz with the same utility, restoring correct directory structure and file hierarchy for review.

B.4.13. SSS Processing Flow Diagram

The following is an overview of the SSS processing flow used on this project.

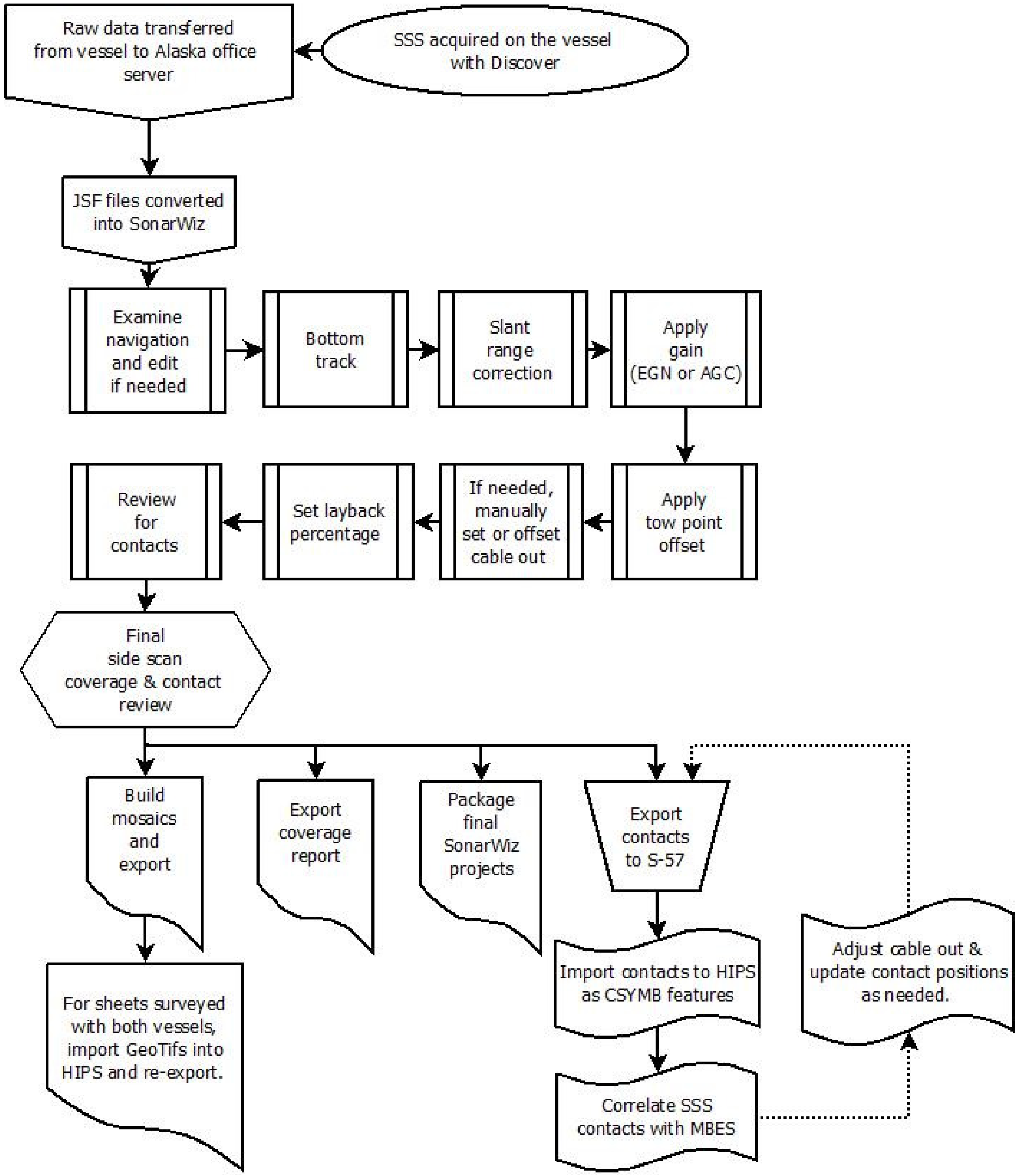


Figure 13 – Flow chart showing the side scan sonar processing workflow.

B.5. Feature Investigation Processing

A Composite Source S-57 File (CSF) was provided with the project instructions that included "Assigned" features for investigation (Acronym "asgnmt", name "Assignment flag", Value="Assigned"). Assigned features were extracted from the CSF and investigated, as described earlier in this report.

Correlation between assigned and observed features were done in CARIS HIPS. All applicable data sets were overlaid in CARIS HIPS for this process, consisting primarily of the project CSF (including assigned features), multibeam surfaces, SSS contacts, as well as field notes and photos from the *Sea Ark* investigations. NOAA extended attributes V5.7 was used for attribution.

Each assigned feature was inspected for and attributed with applicable S-57 attributes to describe the investigation results and provide charting recommendations.

If the surveyed position of a feature was found to be within 5 m of the assigned feature location, an updated position was deemed unnecessary and the assigned feature was attributed with any findings.

However, if a better position was obtained for the feature by whatever means (fix, SSS/MBES coverage, or UAS imagery) a new S-57 feature was digitized at the better position.

Most features were fully addressed in this survey. However, some had a assigned position inshore of the NALL and could not be addressed in the field – these are recommended in the FFF to be retained.

B.6. Confidence Checks

In addition to the crossline comparisons and daily QC efforts utilized during acquisition and processing described previously in this report, formal confidence checks were also completed throughout the survey.

The table below summarizes the formal confidence checks. Planned intervals (for example, the weekly SVP comparison) were not always achieved on schedule due to weather or operational concerns. However, planned confidence checks were accomplished as soon as possible when conditions allowed.

Confidence Check	Purpose	Planned Frequency
Depth Check: Bar Check	Check depth accuracy Determine and refine Z offsets	At least once per project per vessel
Depth Check: Lead Line	Check depth accuracy	At least once per project per vessel
Echosounder Depth Comparison (Multiple Vessels)	Overall check of consistency of survey systems between independent vessels	Formally compare overlap as convenient
SVP Surface Sensor Check	Ensure MBES surface speed sensor is producing good values	Daily
SVP Comparison	Check SVP profilers for consistency	Once per project
Base Station Position Check	Ensure stable and repeatable base station position	N/A this project

Confidence Check	Purpose	Planned Frequency
Vessel Position Confidence Check – Alternate Base Station	Check for accurate and consistent vessel positioning regardless of base station used (PPRTX vs ASB)	Weekly
Staff Shots	Check of tide gauge stability	N/A for this project
SSS Confidence Check	Confirm SSS contact detection capabilities	Daily during SSS operations
Tide Float	GPS water surface height comparison versus tide gauge data	Once per project per NWLON gauge – see HVCR

Table 22 – Summary of formal confidence checks.

B.6.1. Bar Checks

A bar check was completed once during the project on all three vessels. The bar check results were used to determine and refine sonar Z offsets, and to check the relative accuracy of the echosounder and processing systems.

Bar checks were accomplished when dockside with calm sea conditions.

To perform the bar check, a rectangular steel grate was hung by cable from the vessel's gunwale. The cable was marked at an interval of 0.5 m from the bar and measured carefully by tape. A sound speed profile was collected, and static draft was measured.

With QINSy logging (or HYPACK for the *Sea Ark*) and the sonar tuned to track the bar instead of the bottom, the bar was lowered in 0.5 m increments directly below the transducer while bar depth and time were noted in the log. The bar was lowered as deep as possible. Generally, the sonars needed at least 0.5 m below the transducer to track the bar, with max depth constrained by the seafloor or environmental conditions such as excessive current pushing the bar out of the sonar's ability to track it.

The bar depth was read relative to the waterline for later comparison to the CARIS HIPS results.

Bar checks were processed in CARIS HIPS. The heave data record was removed, and the 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. Real-time values from the sonar UI (with offsets applied) were also examined. Note that real-time results usually returned better results because the real-time values were used to determine the transducer acoustic center to CRP offset, while the processed results introduced most of the corrections usually applied by CARIS in processing. Results, summarized below, were good on all vessels.

- *Sea Ark*: Completed on JD2018-231. Processed values N/A, but real-time difference (bar versus sonar depth with offsets applied) averaged 0.000 m (standard deviation of 0.013 m). Checked while dockside, bar depths 1.31 to 2.81 m.

- *Bella Marie*: Completed on JD2018-269. Real-time values compared to 0.000 m on average (with a standard deviation of 0.004 m), while processed values compared to 0.044 m on average (with a standard deviation of 0.008 m). Checked while dockside, bar depths 2.784 to 3.819 m.
- *Bunny Bordelon:* Completed on JD2018-305. Real-time values compared to 0.000 m on average (with a standard deviation of 0.069 m) while processed values compared to 0.003 m on average (with a standard deviation of 0.022 m). Completed while dockside, some current during test but crosstrack distance was noted and this was corrected for in processing. Depths ranged from 5.955 to 7.416 m.

Bar check logs (processing and sonar depth check logsheet) are available with the echosounder accuracy test results, in *Appendix II* of this report.

B.6.2. Lead Line Check

A lead line check was completed periodically on all vessels to check for gross error in the absolute accuracy for the echosounder and processing systems. The *Sea Ark* received three of these checks, the *Bella Marie* received five, and the *Bunny Bordelon* received two.

The check was accomplished by lowering a measuring tape outfit with a 3 lb. weight to the seafloor and noting the waterline level on the tape. This was done as close as possible to the echosounder mount location to help minimize the effect of any seafloor slope.

The real-time or raw sonar depth (from the sonar UI at nadir) was noted and compared to the lead line depth, with corrections for static draft and vessel offsets applied.

To check the accuracy of processed results when all offsets and corrections were applied, XTF files were also logged during the check. Sound speed casts were taken as well as draft measurements. These were applied as normal in CARIS, and the depth extracted and compared against the known (Lead Line) depth.

Results are summarized in the following table.

Julian Day	**Actual (Lead Line) Depth**	**Real-time: LL versus Offset Corrected Raw Sonar Depth**		**Processed: LL versus CARIS Processed Depth**	
		Sonar UI Depth (with Offsets Applied)	Difference	Result	Difference
Sea Ark					
2018-231	2.34 m	2.245 m	0.095 m	2.295 m	0.045 m
2018-238	2.00 m	1.955 m	0.045 m	1.999 m	0.001 m
2018-238	5.930 m	5.585 m	0.345 m	6.000 m	-0.070 m
Bella Marie					
2018-260	2.578 m	2.618 m	-0.040 m	2.620 m	-0.042 m
2019-023	2.290 m	2.409 m	-0.119 m	2.400 m	-0.110 m
2019-023	2.260 m	2.409 m	-0.149 m	2.410 m	-0.150 m

Julian Day	**Actual (Lead Line) Depth**	**Real-time: LL versus Offset Corrected Raw Sonar Depth**		**Processed: LL versus CARIS Processed Depth**	
		Sonar UI Depth (with Offsets Applied)	Difference	Result	Difference
2019-038	2.362 m	2.402 m	-0.040 m	2.392 m	-0.030 m
2019-038	2.350 m	2.402 m	-0.052 m	2.381 m	-0.031 m
Bunny Bordelon					
2018-337	7.940 m	7.650 m	0.290 m	7.650 m	0.290
2018-337	7.990 m	7.643 m	0.347 m	7.650 m	0.340 m

Table 23 – Q105 Lead Line check results summary

Tests were generally good, though tests undertaken with more current or irregular bottom returned worst results. For example, the *Bunny Bordelon* tests on JD2018-337 returned differences of up to 0.347 m, but this was likely due to the irregular bottom as well as current pulling the lead line away from directly under nadir during the test – the bar check on this vessel returned very good results (processed results to 0.003 m).

Given the variables of lead line checks, results were deemed acceptable.

Sonar depth check logsheets, which includes the lead line results, are available in *Appendix II* of this report.

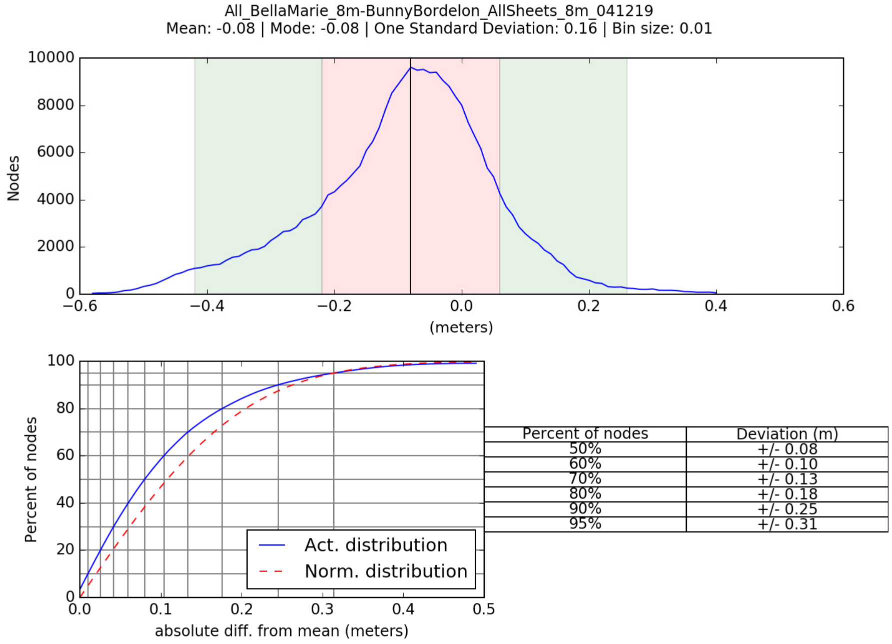
B.6.3. Echosounder Depth Comparison (Multi-Vessel)

Substantial overlap was intentionally achieved between the survey vessels whenever possible in order provide a check on each other. The *Bella Maire* overlapped with the *Bunny Bordelon*, while the *Sea Ark* overlapped with the *Bella Marie.* Because of their respective survey areas, the *Sea Ark* did not overlap with the *Bunny Bordelon*.

Overlap was examined in CARIS subset mode and found to agree within IHO Order 1a specifications, though usually to 0.1 m or better.

The data from the vessels was also examined quantitatively by difference surface methodology. 8 m CUBE surfaces were created for all bathymetric data from each vessel and differenced from an 8 m CUBE surface from the overlapping vessel(s) in Pydro's "Compare Grids" utility.

Bella Marie* versus *Bunny Bordelon: The mean difference between these vessels' bathymetric data is -0.08 m (*Bella Marie* shoaler*)* with a standard deviation of 0.16 m. Over 99.5% of grid cells agree to within IHO Order 1a.



Percent of nodes	Deviation (m)
50%	+/- 0.08
60%	+/- 0.10
70%	+/- 0.13
80%	+/- 0.18
90%	+/- 0.25
95%	+/- 0.31

Figure 14 – Bella Marie versus Bunny Bordelon depth differences

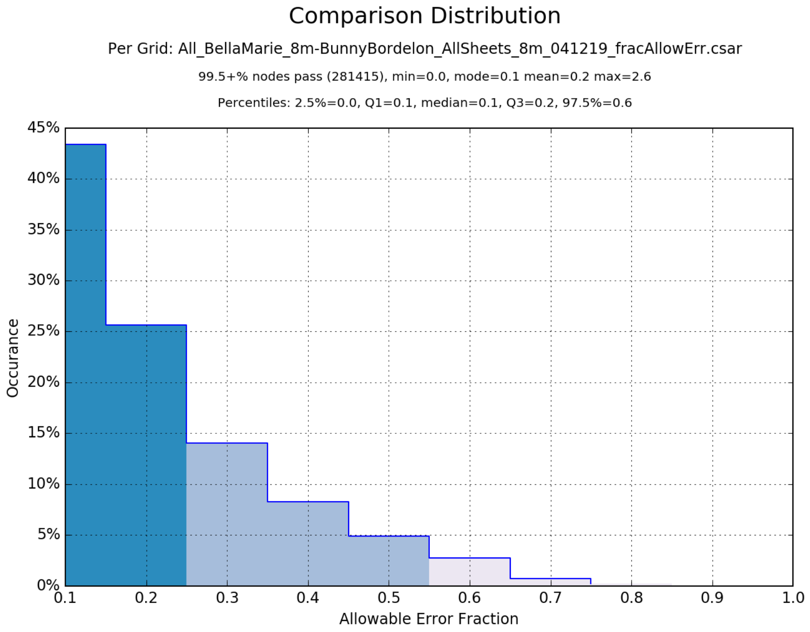
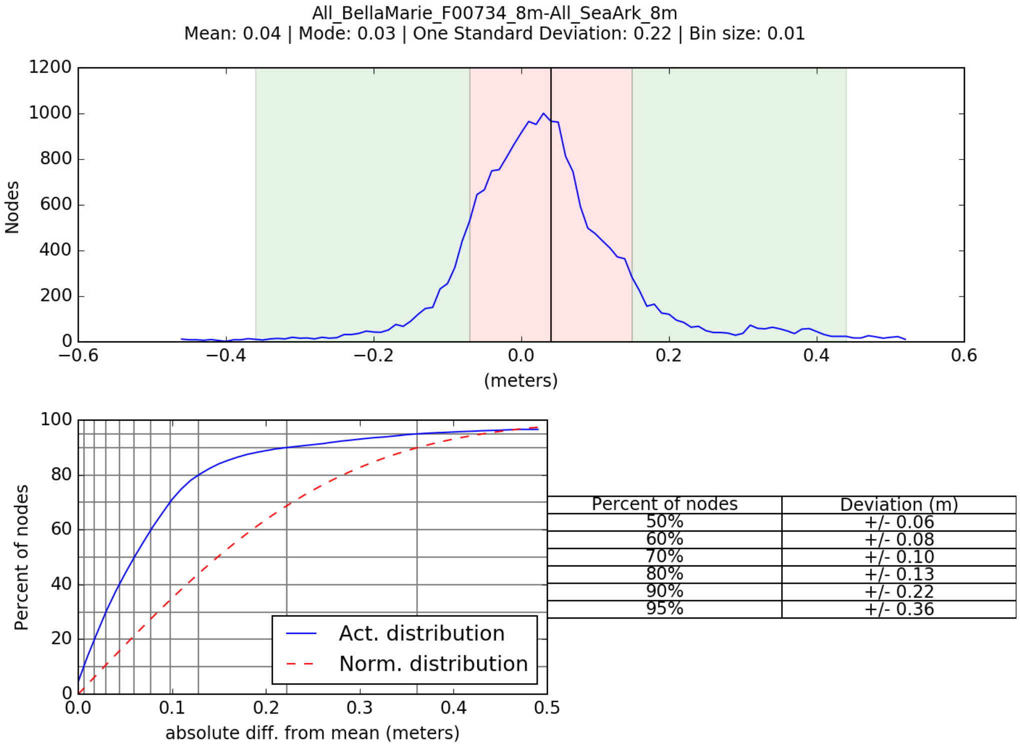


Figure 15 Bella Marie versus Bunny Bordelon depth difference comparison distribution.

***Bella Marie* versus *Sea Ark*:** The mean difference between these vessels' bathymetric data is 0.04 m (*Bella Marie* deeper*)* with a standard deviation of 0.22 m. 98% of grid cells agree to within IHO Order 1a. For the 2% that do not agree in IHO Order 1a, they appear to be steep channel slopes where the SBES system from the *Sea Ark* shows increased difference from the *Bella Marie* MBES system when spread across an 8 m grid cell.



Percent of nodes	Deviation (m)
50%	+/- 0.06
60%	+/- 0.08
70%	+/- 0.10
80%	+/- 0.13
90%	+/- 0.22
95%	+/- 0.36

Figure 16 – Bella Marie versus Sea Ark depth differences

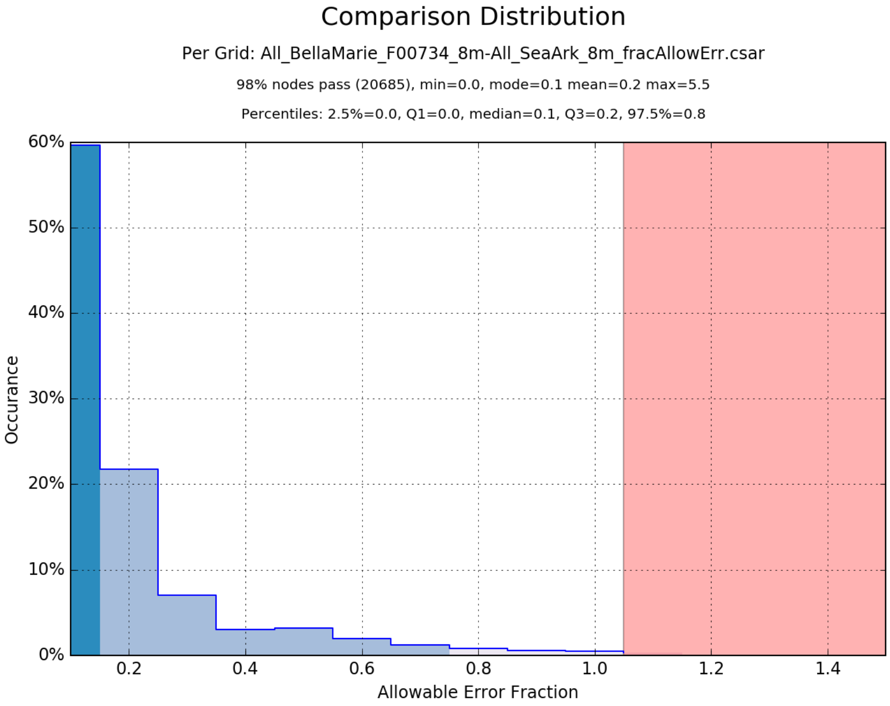


Figure 17 Bella Marie versus Sea Ark depth difference comparison distribution.

Overall, agreement is good between the vessels with the vast majority of overlapping data comparing to well within IHO Order 1a. Good agreement between the vessels – each with completely independent sonar and positioning systems – helps demonstrate the lack of significant systematic biases.

B.6.4. SVP Comparisons

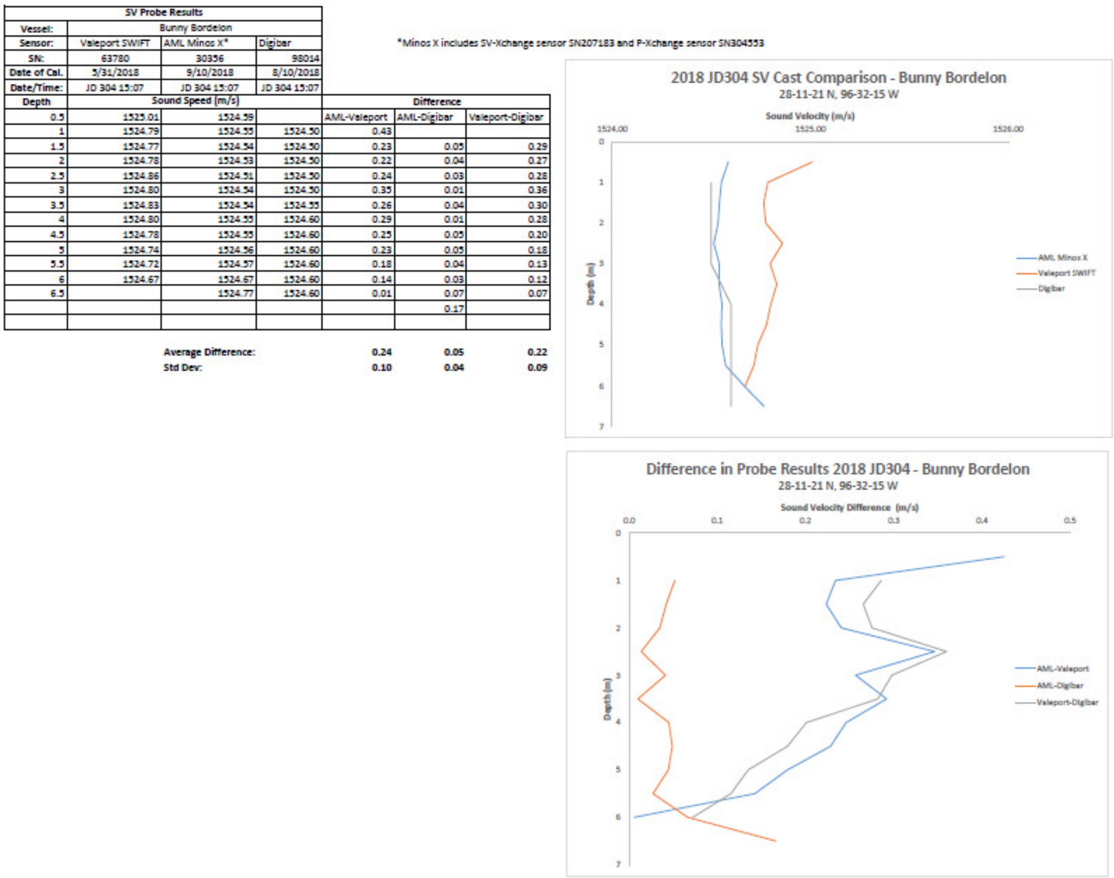
All SVPs received formal comparisons to check the accuracy and consistency of sound velocity profiler data. In the test, data from the primary sound speed profiler was compared to one other independent, recently calibrated sound speed profiler. Both profilers were lowered to the seafloor—simultaneously when possible or very close in time when not—and the measurements compared to each other in an SVP comparison form.

Four comparisons were completed.

- Two AML Minos-X sensors (with SV- and P- Xchange sensors) were compared on JD2018-245. The sensors compared to 1.0 m/s on average, with a standard deviation of 0.11 m/s. This result was slightly higher than preferred but likely due to a 6 minute separation in time between the profiles.
- Three sensors were compared on JD2018-304: A Valeport SWIFT, AML Minos-X (wth SV- and P- Xchange sensors), and a Odom Digibar profiler. Agreement was very good, within 0.24 m/s on average, with a standard deviation of 0.10 m/s.
- A Valeport SWIFT was compared to a AML Minos-X (with SV- and P- Xchange sensors) on JD2018-337. Results were very good, with the difference averaging 0.17 m/s with a standard deviation of 0.01 m/s.
- A Valeport SWIFT was compared to a AML Minos-X (with SV- and P- Xchange sensors) on JD2019-038. Results were very good, with the difference averaging 0.14 m/s with a standard deviation of 0.05 m/s.

Note the Valeport RapidSV used at the beginning of *Bunny Bordelon* operations did not receive an SVP comparison because it was lost at sea on JD2018-298. However, it was compared regularly to the sound speed sensor on the *Bunny Bordelon*'s MBES head and compared well (see next section).

SVP Comparisons are available with each DR in *Separate II*. An example is shown below.



SV Probe Results						
Vessel:	Bunny Bordelon					
Sensor:	Valeport SWIFT	AML Minos X*	Digibar			
SN:	63780	30356	98014			
Date of Cal.	5/31/2018	9/10/2018	8/10/2018			
Date/Time:	JD 304 15:07	JD 304 15:07	JD 304 15:07			
Depth	**Sound Speed (m/s)**			**Difference**		
0.5	1525.01	1524.59		AML-Valeport	AML-Digibar	Valeport-Digibar
1	1524.79	1524.55	1524.50	0.43		
1.5	1524.77	1524.54	1524.50	0.23	0.05	0.29
2	1524.78	1524.53	1524.50	0.22	0.04	0.27
2.5	1524.86	1524.51	1524.50	0.24	0.03	0.28
3	1524.80	1524.54	1524.50	0.35	0.01	0.36
3.5	1524.83	1524.54	1524.55	0.26	0.04	0.30
4	1524.80	1524.55	1524.60	0.29	0.01	0.28
4.5	1524.78	1524.55	1524.60	0.25	0.05	0.20
5	1524.74	1524.56	1524.60	0.23	0.05	0.18
5.5	1524.72	1524.57	1524.60	0.18	0.04	0.13
6	1524.67	1524.67	1524.60	0.14	0.03	0.12
6.5		1524.77	1524.60	0.01	0.07	0.07
					0.17	
		Average Difference:		**0.24**	**0.05**	**0.22**
		Std Dev:		**0.10**	**0.04**	**0.09**

*Minos X includes SV-Xchange sensor SN207183 and P-Xchange sensor SN304553

2018 JD304 SV Cast Comparison - Bunny Bordelon
28-11-21 N, 96-32-15 W

Difference in Probe Results 2018 JD304 - Bunny Bordelon
28-11-21 N, 96-32-15 W

Figure 18 – Example of SVP confidence check (comparison results).

B.6.1. SVP Surface Sensor Checks

Each MBES system used on this project was equipped with a surface sound speed sensor mounted at or on the MBES sonar head. This sensor was interfaced to feed real-time sound speed data to the MBES system for beam forming purposes.

An AML Micro-X (with SV- Xchange sensor) was used on the *Bunny Bordelon* while a Valeport MiniSVS was used on the *Bella Marie*.

During collection of sound speed profiles, the surface sensor sound speed reading was noted and checked against the profile data at the same depth. This served as regular gross error check on both the surface sensor as well as the sound speed profiler.

Results were very good overall. No major anomalies were encountered. The sensors used on the *Bunny Bordelon* compared at 0.49 m/s on average with a standard deviation of 0.68 m/s. The sensors compared on the *Bella Marie* compared at 0.14 m/s on average with a standard deviation of 0.79 m/s. No checks were done on the *Sea Ark* since this vessel did not have a surface sound speed sensor.

SVP Surface Sensor Check results are available with each DR in *Separate II*. A summary of the results is shown below.

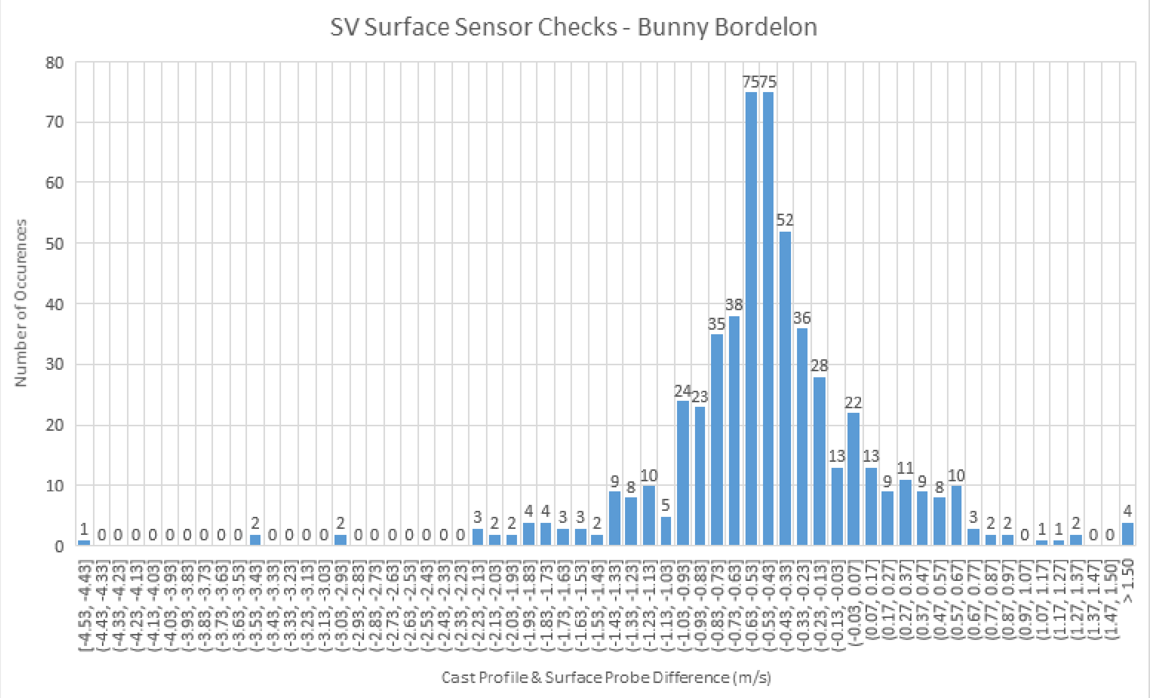


Figure 19 – Histogram of Bunny Bordelon surface sensor differences

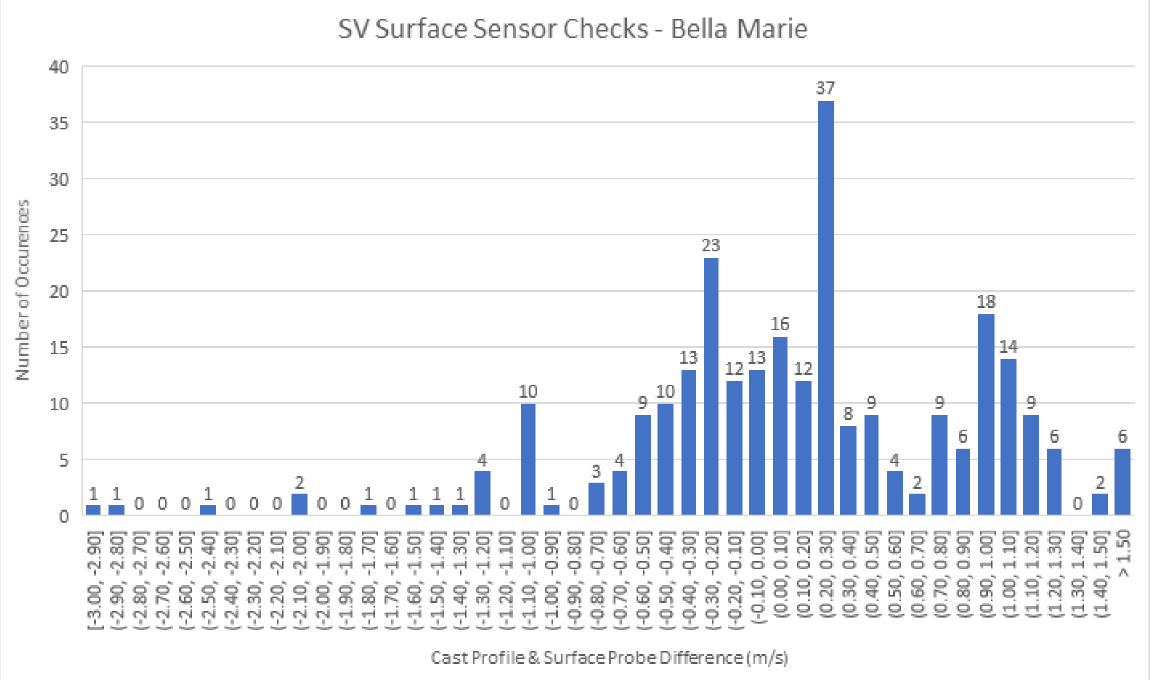
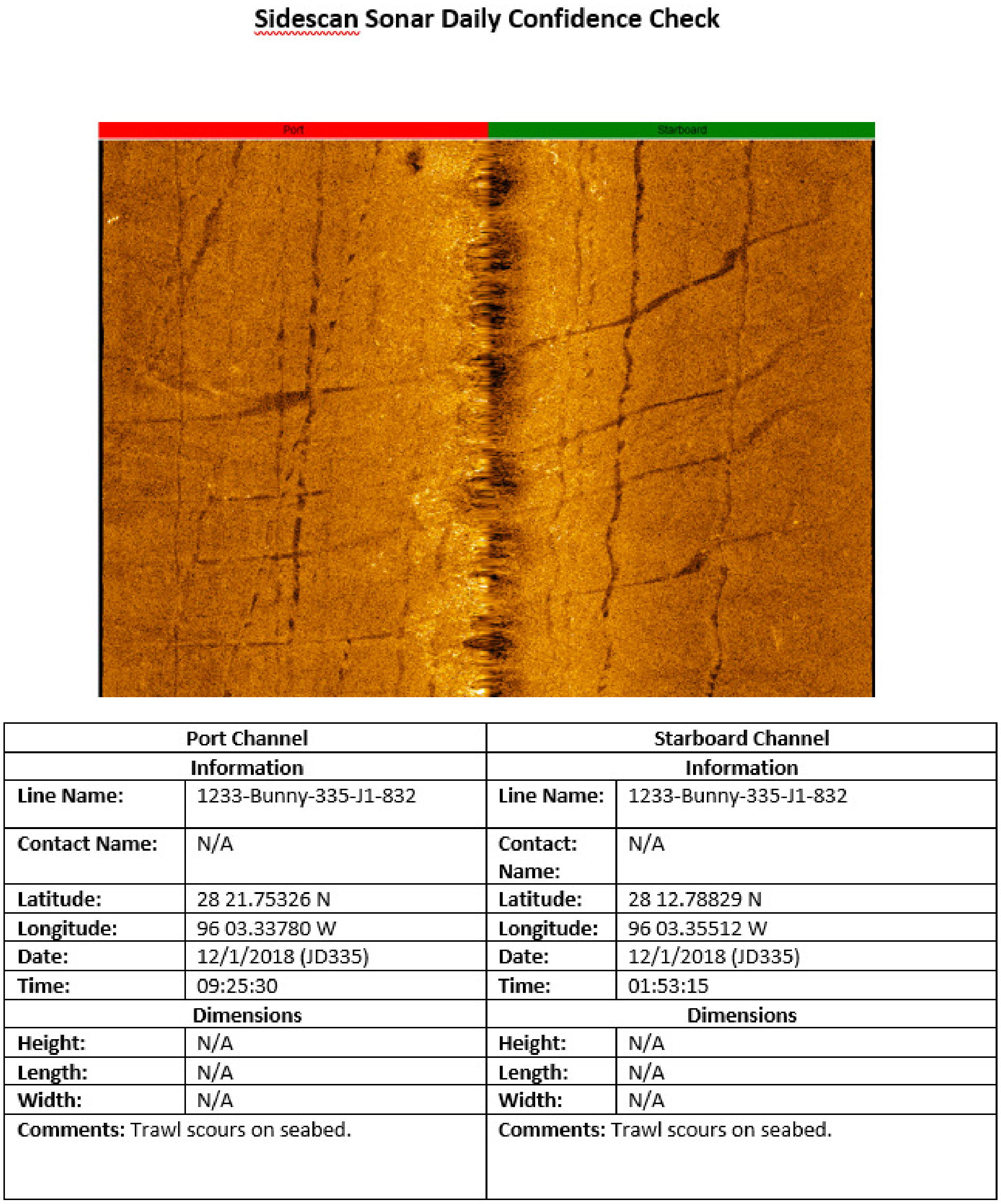


Figure 20 – Histogram of Bella Marie surface sensor differences

B.6.2. Side Scan Sonar Confidence Checks

To confirm the ability of the side scan sonar to resolve objects on the seafloor, an example was pulled from each vessel's SSS data from each day that showed features or variations on the seafloor. Both sonar channels were examined, and features favored that showed the ability to resolve features through the entire sonar swath range. Features included rocks and other small options but also scour or trawl marks when discrete objects were not available. These checks were only completed for days the SSS was in use.

SSS Confidence Checks are available in *Appendix II*. An example is shown below.



Sidescan Sonar Daily Confidence Check

Port Channel		Starboard Channel	
Information		Information	
Line Name:	1233-Bunny-335-J1-832	**Line Name:**	1233-Bunny-335-J1-832
Contact Name:	N/A	**Contact: Name:**	N/A
Latitude:	28 21.75326 N	**Latitude:**	28 12.78829 N
Longitude:	96 03.33780 W	**Longitude:**	96 03.35512 W
Date:	12/1/2018 (JD335)	**Date:**	12/1/2018 (JD335)
Time:	09:25:30	**Time:**	01:53:15
Dimensions		Dimensions	
Height:	N/A	**Height:**	N/A
Length:	N/A	**Length:**	N/A
Width:	N/A	**Width:**	N/A
Comments: Trawl scours on seabed.		**Comments:** Trawl scours on seabed.	

Figure 21 – Example SSS Daily Confidence Check.

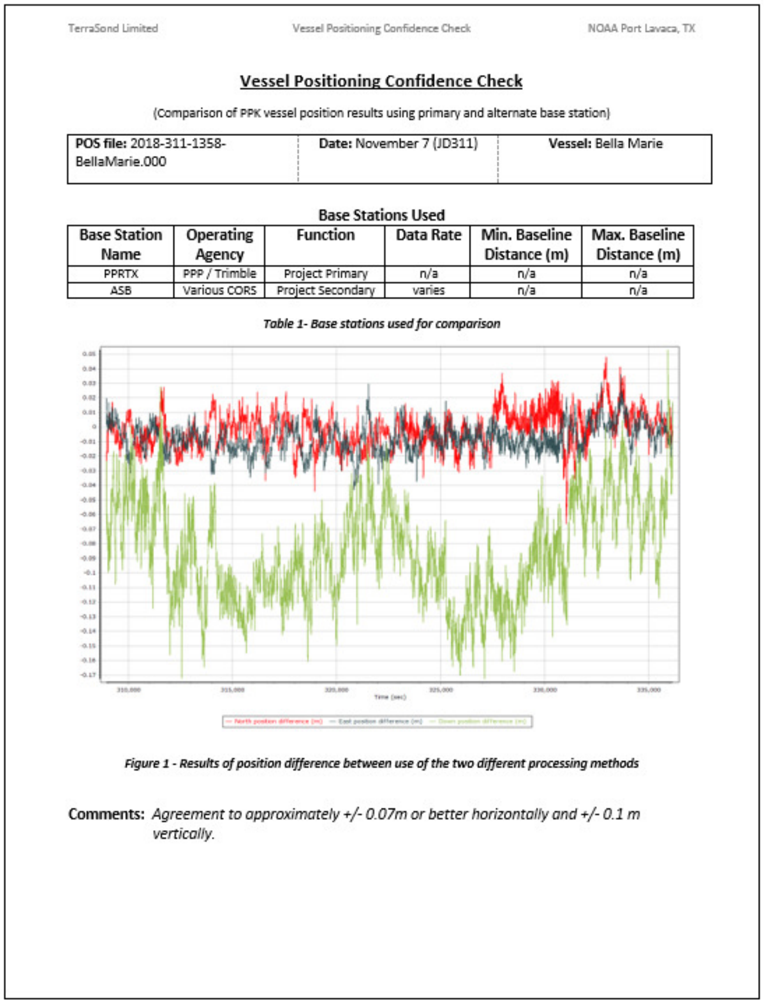
B.6.3. Vessel Positioning Confidence Checks – Alternate Processing Method

To ensure vessel positioning was consistent regardless of the PPK processing method used, and as an accuracy check of vessel positioning, vessel position confidence checks were accomplished by processing with an alternative POSPac processing methods and comparing the primary method. These checks were accomplished on a weekly basis for *Bella Marie* and *Bunny Bordelon* but not for *Sea Ark*, which was not equipped with a POSMV.

To complete the check for each vessel, a random POS file was selected from each week and re-processed with Applanix SmartBase (ASB). This was compared to the same POS file processed with PP-RTX, which was the primary processing method for this project. 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 (see example below) along with the comparison parameters and observations.

Results were generally good, with average horizontal differences agreeing to 0.05 m or better, and vertical differences about 0.1 m. Vertical differences showed a slight constant bias on both vessels of about -0.1 m vertical difference between PPRTX and ASB, which was unresolved but well within specifications.

The vessel positioning confidence check logs are available in *Separate I* of the DRs.



TerraSond Limited Vessel Positioning Confidence Check NOAA Port Lavaca, TX

Vessel Positioning Confidence Check

(Comparison of PPK vessel position results using primary and alternate base station)

POS file: 2018-311-1358-BellaMarie.000	**Date:** November 7 (JD311)	**Vessel:** Bella Marie

Base Stations Used

Base Station Name	Operating Agency	Function	Data Rate	Min. Baseline Distance (m)	Max. Baseline Distance (m)
PPRTX	PPP / Trimble	Project Primary	n/a	n/a	n/a
ASB	Various CORS	Project Secondary	varies	n/a	n/a

Table 1- Base stations used for comparison

Figure 1 - Results of position difference between use of the two different processing methods

Comments: *Agreement to approximately +/- 0.07m or better horizontally and +/- 0.1 m vertically.*

Figure 22 – Example of Vessel Positioning Confidence Check.

C. *Corrections to Echo Soundings*

The following methods were used to determine, evaluate, and apply corrections to instruments and soundings.

C.1. Vessel Offsets

Sensor locations were established with a survey of the vessels using conventional survey instruments.

A Center Reference Point (CRP), or point from which all offsets were referenced, was selected for each vessel.

It is important to note that X, Y, and Z offsets were entered only under the SV1 and SV2 sensors in the HVF. This was done per CARIS's technical bulletin "HIPS and SIPS Technical Note for Sound Velocity Correction for Teledyne Reson 7k Data".

Offsets received checks including gross error reality checks by survey tape and bar check. Offset uncertainties varied and are described previously in the TPU section of this report. Vessel outlines and offset descriptions are provided in the following figures and tables.

C.1.1. Bella Marie Vessel Offsets

Figure 23 – Bella Marie

Bella Marie offsets were largely derived from a full vessel survey completed on this vessel in 2008. Measurements were reconfirmed with measuring tape. Acoustic center Z offsets were refined with bar check methodology. Offsets for the *Bella Marie* used during this survey are shown in the following table.

Vessel Offset Diagram #	Point	X (m)	Y (m)	Z (m)	Comments
		(+ stbd)	(+ fwd)	(+ down)	
1	CRP	0.000	0.000	0.000	Middle of MBES Moonpool
2	T50 Single-head MBES Acoustic Center (Tx)	0.001	-0.047	1.292	AC of MBES Projector
	T50 Single-head MBES Acoustic Center (Rx)	0.001	0.145	1.320	AC of MBES Receiver
	T50 MBES Dual-Head	0.000	0.000	1.195	X,Y co-located with CRP
	7125 MBES Acoustic Center (Tx)	0.000	1.312 1.309*	-0.142	AC of MBES Projector (changed on JD2019-030)
	7125 MBES Acoustic Center (Rx)	0.000	1.336 1.333*	-0.142	AC of MBES Receiver (changed on JD2019-030)
3	POSMV IMU	0.001	-0.140	1.158	Used through JD2018-355
4	POSMV IMU	-0.116	2.665*	-0.625	Used JD2019-015 to 038 (with 7125 MBES)
5	POSMV Antenna	-1.417	1.804	-5.236	Primary POS antenna offset (port side) shown
6	Stern Tow Point (A-frame)	0.000	-6.200	-3.180	Used JD2018-320 to JD2019-035
7	Stern Tow Point (Back Deck)	0.000	-5.550	-1.300	Used JD2018-302 to 319
8	Davit Tow Point (Stbd Side)	3.239	-2.816	-2.440	Used JD2018-248 to 301
9	Draft Measure-down Point	-	-	-1.320	Average both sides

Table 24 – Bella Marie offsets measurements relative to CRP.

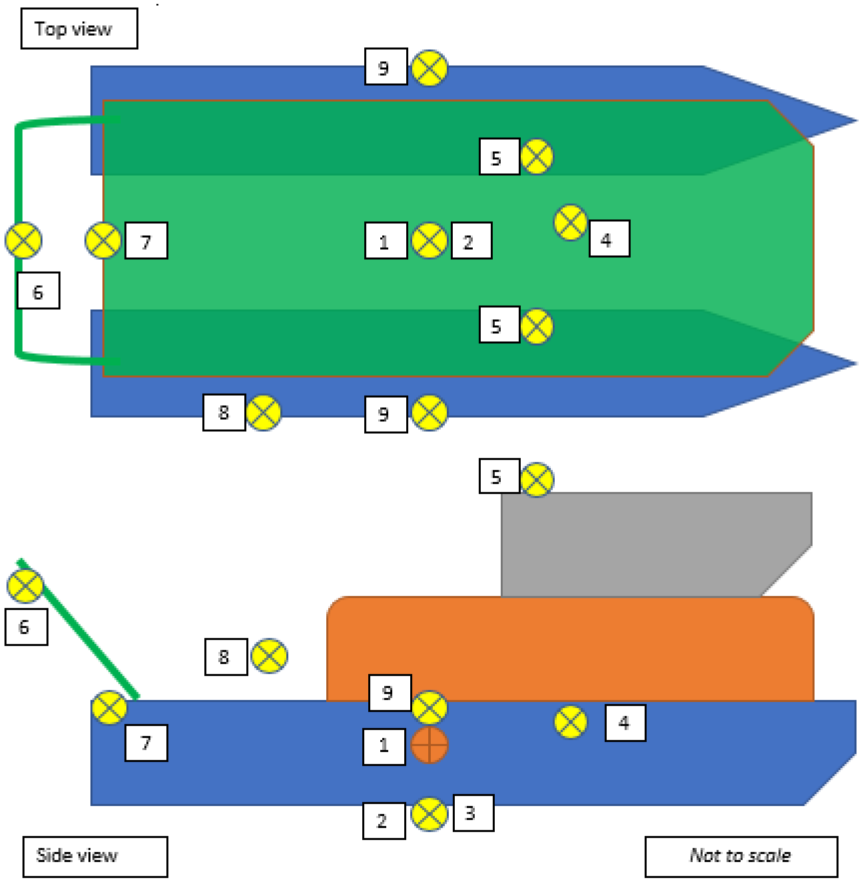


Figure 24 Vessel offset diagram for Bella Marie showing relative positions.

*Important notes:

- The 7125 MBES offsets changed slightly on JD2019-030 due to the necessity of remounting the 7125 MBES after the sonar struck a submerged object that damaged the 7125 mount.

- From JD2019-015 to 2019-038 an POSMV IMU was used which was mounted forward, above, and port relative to the CRP. This is offset #4 in the above table and diagram. Until JD2019-023 the POSMV was configured to output positions and attitude for the IMU location. To help address some minor remote heave issues, this was changed from JD2019-023 until the end of the project so that positions and attitude would be output at the CRP instead. This change is reflected in the CARIS HVF on JD2019-023 as a change to zero offsets for the navigation sensor. An offset to the "heave" sensor is also entered in the HVF for this configuration to help account for remote heave caused by the offset IMU location.

C.1.2. Bunny Bordelon Offsets

Figure 25 – Bunny Bordelon in Houma, Louisiana.

The CRP on the *Bunny Bordelon* was the top-center of the submersible POSMV IMU, which was mounted on the MBES bracket nearly co-located with the MBES, which was on an over-the-side pole mounted mid-ship on the vessel's port side. POSMV antennas were mounted on a survey shed mid-deck. Due to co-located MBES and IMU and close proximity to POSMV antennas, the vessel survey was relatively simple and carried out via tape measurements. The following table shows the offsets on this vessel relative to the CRP.

Vessel Offset Diagram #	**Point**	**X (m)**	**Y (m)**	**Z (m)**	**Comments**
		(+ stbd)	**(+ fwd)**	**(+ down)**	
1	POSMV IMU	0.000	0.000	0.000	CRP is Top-center of POSMV IMU. Submersible unit on MBES bracket.
2	T50 MBES Dual-Head	0.000	0.138	0.209	MBES dual head bracket common reference point
3	Primary POS Antenna*	5.153	-1.784	-7.788	Before JD282
		5.406	-1.668	-8.111	JD282 to end
4	Secondary POS Antenna	7.293	-1.709	-7.863	Before JD282
		7.546	-1.593	-8.186	JD282 to end
5	Stern Tow Point	6.513	-19.750	-5.000	A-frame tow point (sheave)
6	Draft Measure-down Point (port side)*	0.000	0.000	-5.750	Before JD282
		0.000	0.000	-6.014	JD282 to end

Table 25 – Bunny Bordelon offset measurements relative to CRP.

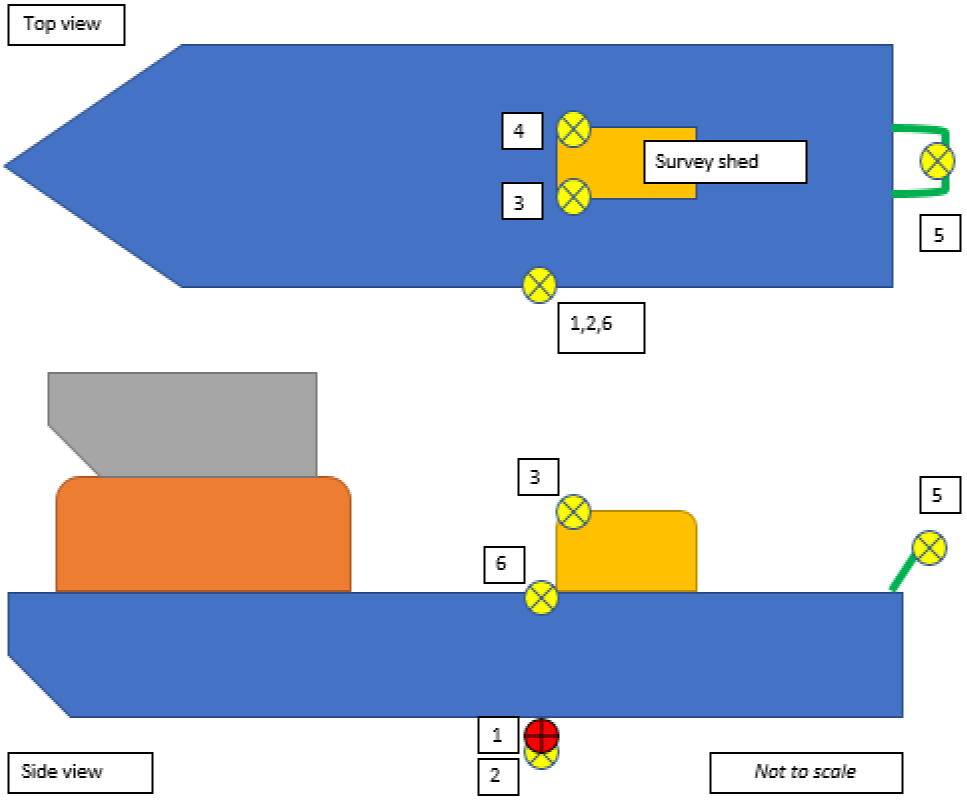


Figure 26 Vessel offset diagram for Bunny Bordelon showing relative positions.

*Important notes:

- On JD2018-278, the *Bunny Bordelon* multibeam pole was swapped out for a new pole to address vibration issues. This resulted in a change in vessel offsets for the CRP to measure down point as well as the POSMV antennas. The new pole was used from JD2018-282 to the end of the project.

- To allow the POSMV to compensate for the remote heave effect from having the IMU mounted away from the vessel Center of Gravity (CoG), the POSMV on this vessel also had a Center of Rotation offset for estimated distance from the IMU to CoG. This was X = 6.263 m, Y = 0.000 m, and Z = -2.362 m. This appeared to properly account for remote heave because remote heave issues were not observed on this vessel.

C.1.3. Sea Ark Offsets

Figure 27 – Sea Ark during mobilization.

The *Sea Ark* used a Trimble 5700 GPS antenna mounted on a over-the-side pole off the vessel's port side, co-located in X and Y with the Odom CV100 SBES transducer. The CRP was a point on the gunwale just forward of the pole mount, also on the port side. A Hemisphere V111/V113 GPS Gyrocompass was mounted on the vessel's house. Due to the simple setup and co-location of critical components, the vessel survey was relatively simple and carried out with tape measurements. The following table shows the offsets used on this vessel.

Vessel Offset Diagram #	Point	X (m)	Y (m)	Z (m)	Comments
		(+ stbd)	(+ fwd)	(+ down)	
1	CRP	0.000	0.000	0.000	Port gunwale, just forward of pole
	Draft Measure-down Point	0.000	0.000	0.000	Draft measured directly from CRP
2	Trimble 5700 Antenna ARP	-0.072	-0.117	-0.788	PPK positioning
3	Odom CV100 Transducer AC	-0.072	-0.117	0.915	Z taped at 1.005 m; AC computed at 0.915 with bar check
4	Hemisphere V111/V113	1.090	-1.312	-1.53	Real-time positioning and gyro

Table 26 – Sea Ark offset measurements relative to CRP.

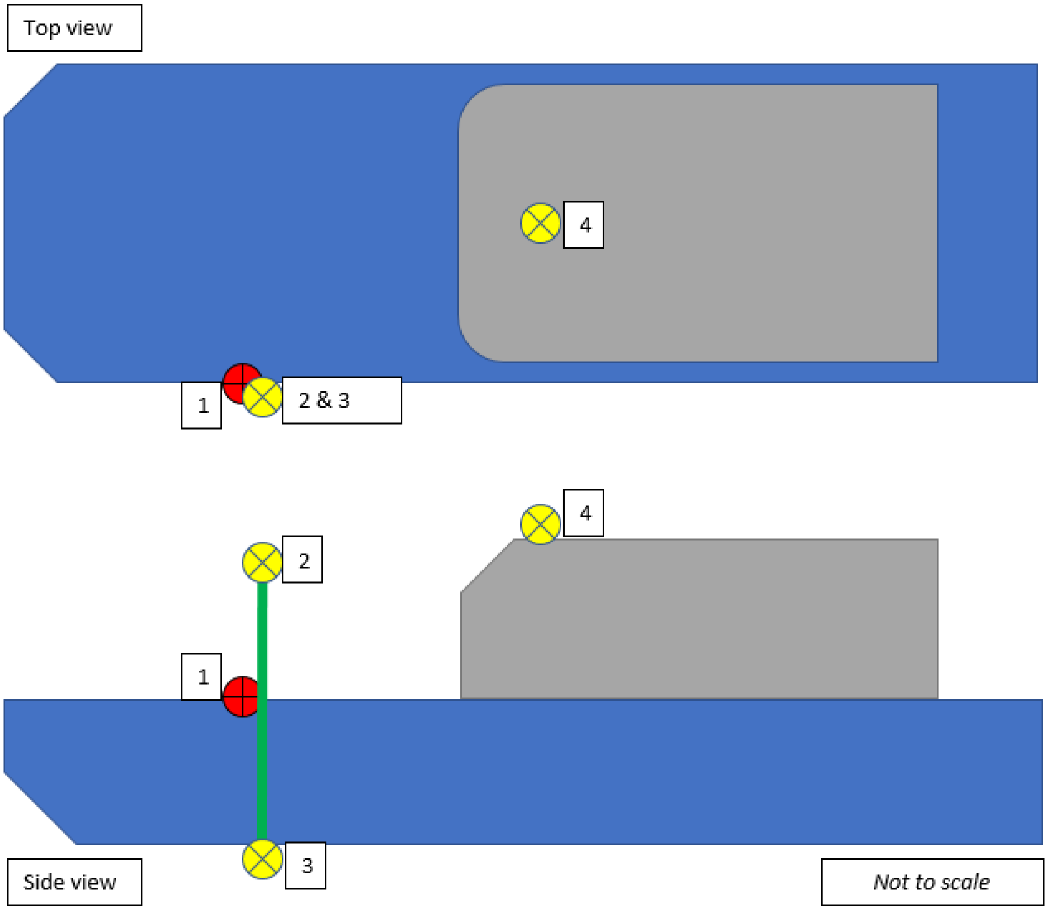


Figure 28 Vessel offset diagram for Sea Ark showing relative positions.

C.2. Attitude and Positioning

As described in previous sections of this report, positioning, heave, roll, pitch, and heading (gyro) data were measured on the *Bella Marie* and *Bunny Bordelon* with Applanix POSMV systems.

The *Sea Ark* used a dual-frequency Trimble 5700 receiver for post-processed positioning and a Hemisphere V111/V113 GPS Gyrocompass for real-time positioning and heading. The *Sea Ark* systems did not have any special calibration requirements.

For the POSMVs, a GAMS (GPS azimuth measurement subsystem) calibration was done per POSMV manufacturer recommendations to ensure correct heading output. This was undertaken at the start of operations and after any physical reconfiguration of the system antennas. The results are shown below.

Date (JD)	A-B Antenna Separation (m)	Baseline Vector (m)		
		X (+ stbd)	Y (+ fwd)	Z (+ down)
Bella Marie				
2018-244	2.865	2.865	-0.012	0.009
2019-015	2.116	2.115	-0.068	-0.033
Bunny Bordelon				
2018-270	2.143	2.140	0.075	-0.075

Table 27 – POSMV GAMS calibration results.

C.3. Calibration / Patch Tests

Patch tests were conducted on both vessels to establish latency, pitch, roll, and yaw alignment values between the POSMV and the MBES systems.

Patch test data received standard corrections and processing prior to examination. This included sound speed correction, filtering, corrections for tide and delta draft, and application of PPK (SBET) and Delayed Heave data.

The calibration test data for each vessel is available for review with the CARIS HIPS deliverables in the “Calibrations” project.

C.3.1. Latency, Pitch, Roll, and Yaw

Industry-standard patch test procedures 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.

The dual-head systems utilized on the *Bunny Bordelon* and temporarily on the *Bella Marie* received substantially similar patch test, with the only exception that each sonar head was aligned separately in calibration mode to determine its own corrector.

Day	Latency (seconds)	Pitch	Yaw	Roll	Notes
Bella Marie T50 IDH					
2018-244	0.000	-0.300 (Trans1 and Trans2)	0.000 (Trans1 and Trans2)	0.200 (Trans1 and Trans 2	
Bella Marie T50 (Single Head)					
2018-259	0.000	-0.150	0.000	-0.200	
Bella Marie 7125 (Single Head)					
2019-015	0.000	-1.720	2.700	-0.740	
2019-036	0.000	-0.620	-0.300	-0.690	Back dated to 2019-030 in HVF
Bunny Bordelon T50 IDH					

Day	Latency (seconds)	Pitch	Yaw	Roll	Notes
2018-277	0.000	0.900 (Trans1 and Trans2)	0.000 (Trans1 and Trans2)	0.100 (Trans1 and Trans2)	Back dated to 2018-269 in HVF
2018-301	0.000	0.000 (Trans1), 0.900 (Trans2)	0.000 (Trans1 and Trans2)	0.100 (Trans1 and Trans2)	Back dated to 2018-278 (06:25) in HVF
Sea Ark SBES					
2018-232	0.000	n/a	n/a	n/a	

Table 28 – Patch Test calibration results.

Patch Test / Calibration Notes:

- Very small to no alignment offsets were discernable for the T50 MBES configurations, both dual and single-head. This was due to using the manufacturer mounts which supported both a submersible IMU and the T50 transducer hardware secured to the same physical mount which was designed to minimize misalignments.
- The *Bella Marie* 2019-036 patch test was completed after remounting the 7125 after the sonar struck a submerged offset that damaged the 7125 mount. This was back dated to 2019-030, which was when the new mount came in use.
- Patch test results were back-dated from the actual patch test time to the valid time in the HVF when necessary because it was not always practical to complete a patch test before mainscheme data collection
- Only a latency test was applicable to the *Sea Ark* SBES system. No discernible latency was found from this check.

C.4. Speed of Sound Corrections

A combination of sound speed profilers was utilized on this project. These consisted of AML Minos-X (with SV- and P- Xchange sensors), Valeport RapidSV, and Valeport SWIFT SVP sensors.

During MBES operations, profiles were collected when the MBES surface sound speed sensor speed measurement drifted from the previous profile speed at the surface sensor depth by more than 2 m/s, equating to a cast approximately every 2 hours. During SBES operations a profile was taken once to twice per 12-hour shift. Profiles were taken as deep as possible, usually extending to the seafloor in order to capture the sound speed profile of the full water column.

As described previously in this report, profiles were appended to a CARIS HIPS SVP file, cleaned of spikes or anomalies, and then applied to the bathymetric data using CARIS HIPS "Sound Velocity Correction" utility. Profiles were applied with the option "Nearest in distance within time" and 4 hours for MBES, or 12 hours for SBES.

Refer to Section B of this report for more information on acquisition and processing methodology and uncertainties. Refer to the project DRs, *Separate II* for sound speed confidence checks (comparisons). Refer to *Appendix IV* of this report for calibration reports. Individual processed profile data including time and position can be found in the CARIS HIPS SVP file submitted with the digital CARIS HIPS data for the survey. Unprocessed profile data is available with the raw data deliverables.

C.5. Static Draft

Vessel static draft (waterline) was measured regularly on the survey vessels. Measurements were taken whenever a situation had the potential to significantly change the draft, such as after fueling or adjustments in ballast. Measurements were also taken on the *Bella Marie* and *Sea Ark* daily prior to departing the dock, and the *Bunny Bordelon* whenever it returned to the dock (usually weekly) for fuel and supplies.

On each vessel, static draft was observed from a measure-down point (on these vessels, a point on the gunwale rail) to the waterline. The relationship between the measure-down point and the CRP, previously determined by vessel survey, was used to compute the CRP to waterline offset, which was then applied via the HVF as a waterline entry.

Refer to Section B for uncertainties associated with static draft measurements and more information regarding acquisition and processing of static draft. Static draft tables are available in the HVFs with the CARIS HIPS deliverables.

C.6. Dynamic Draft Corrections

Dynamic draft corrections on this project were speed-based.

Corrections were determined for each vessel by means of a squat settlement test. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal vessel speeds experienced while surveying.

Note that as an Ellipsoid Referenced Survey (ERS) project, vertical changes in vessel displacement were captured in the GPS data for the vessel. Therefore, dynamic draft correctors were computed but not directly applied to sounding data.

C.6.1. Squat Settlement Test Procedure

During the squat settlement test, the vessel logged raw positioning data for later post-processing. A survey line was established in the direction of weather or current and run in opposite directions on this line at incrementing engine RPM/speed. Between each line set, as well as at the start and end of the test, a “static” was collected whereby the vessel would sit with engines in idle and log for a minimum of 2 minutes. The survey crew would note the time and speed of each event.

The positioning data was post-processed to compute precise height data covering the period of the test, which was then brought into Excel. Using the event notes, the positioning data was separated and grouped according to RPM/speed range and static. Each range was averaged to remove heave and motion. A polynomial equation was computed that best fit the static periods and then used to remove the tide component from each altitude. The residual result was the difference from static or dynamic draft. Finally, the results were averaged for each direction to eliminate any affect from the current, wind or other factors.

Note that these tests were completed to derive the correctors but not actually applied to the soundings, except in rare cases noted in the applicable DR. This was because the ERS methodology used on this survey already accounts for all vessel vertical displacement.

C.6.2. *Bella Marie Dynamic Draft Corrections*

To determine the dynamic draft corrections, a squat settlement test was completed on this vessel on JD2019-038. Speed values between 1.9 m/s and 4.2 m/s (about 4 to 8 knots) were tested. This range encompassed the speeds used during survey operations. Values were smoothed using a 2nd order polynomial equation to create a correction at every 0.1 m/s change.

***Bella Marie* 2019-038 Dynamic Draft Correctors**	
Speed (m/s)	Dynamic Draft (m), + down
1.9	0.016
2.0	0.019
2.1	0.022
2.2	0.025
2.3	0.028
2.4	0.032
2.5	0.036
2.6	0.041
2.7	0.045
2.8	0.050
2.9	0.055
3.0	0.061
3.1	0.067
3.2	0.073
3.3	0.079
3.4	0.086
3.5	0.092
3.6	0.100
3.7	0.107
3.8	0.115
3.9	0.123
4.0	0.131
4.1	0.140
4.2	0.149

Table 29 – Table of Bella Marie dynamic draft correctors.

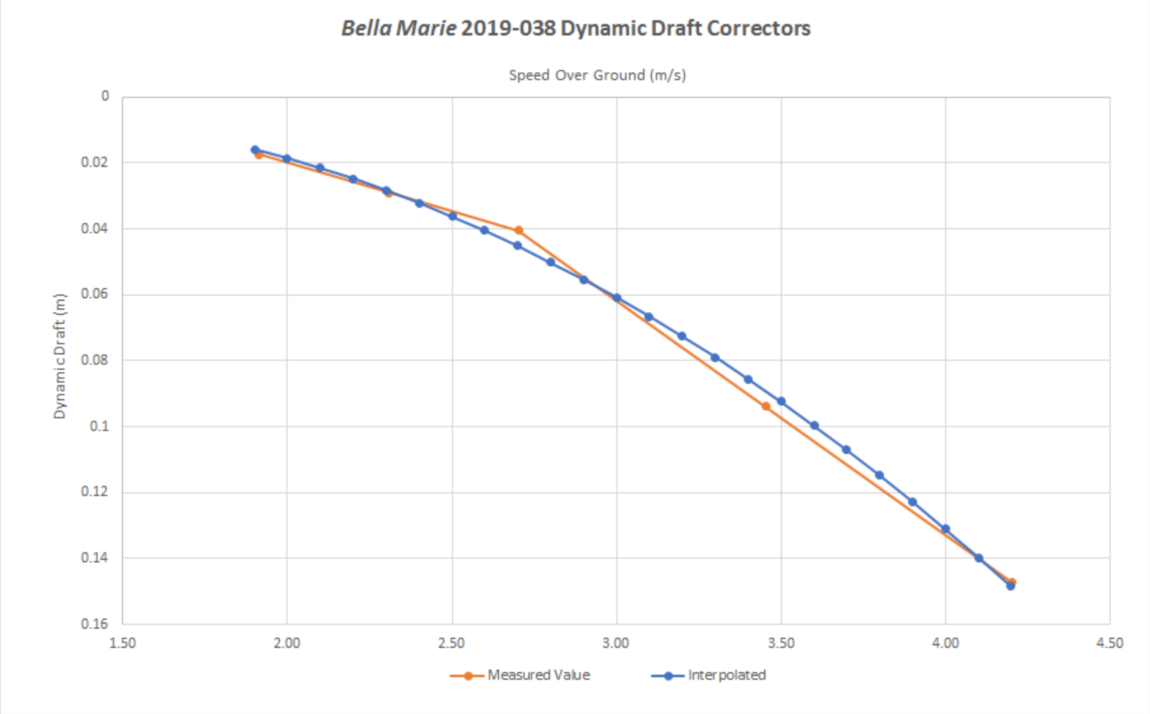


Figure 30 – Graph of Bella Marie dynamic draft correctors.

C.6.3. *Bunny Bordelon Dynamic Draft Corrections*

To determine the dynamic draft corrections, a squat settlement test was completed on this vessel on JD2018-347. Speed values between 2.1 m/s and 4.8 m/s (about 4 to 9 knots) were tested. This range encompassed the speeds used during survey operations. Values were smoothed using a 2nd order polynomial equation to create a correction at every 0.1 m/s change.

Bunny Bordelon **2018-347 Dynamic Draft Correctors**	
Speed (m/s)	Dynamic Draft (m), + down
2.1	0.025
2.2	0.027
2.3	0.029
2.4	0.032
2.5	0.034
2.6	0.037
2.7	0.040
2.8	0.043
2.9	0.047
3.0	0.051
3.1	0.055
3.2	0.059
3.3	0.063

3.4	0.068
3.5	0.073
3.6	0.078
3.7	0.083
3.8	0.089
3.9	0.095
4.0	0.101
4.1	0.107
4.2	0.114
4.3	0.120
4.4	0.127
4.5	0.135
4.6	0.142
4.7	0.150
4.8	0.158

Table 30 – Table of Bunny Bordelon dynamic draft correctors.

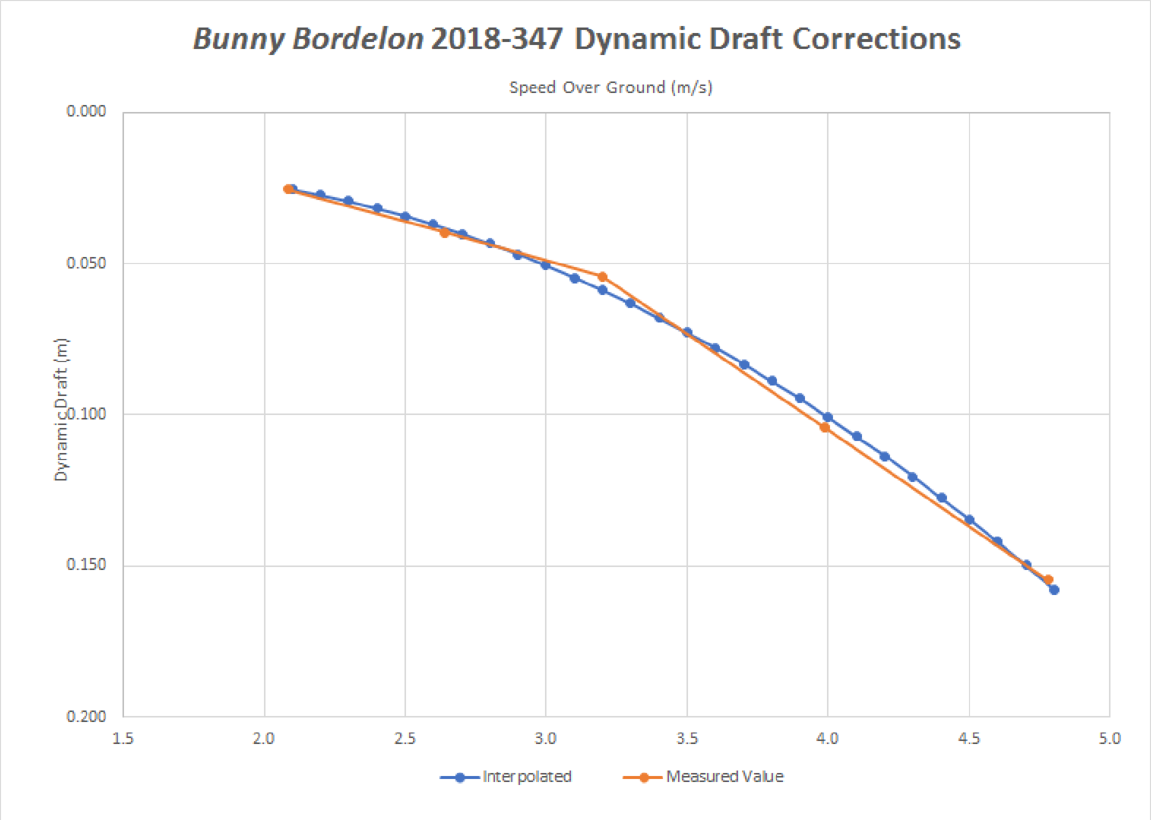


Figure 31 – Graph of Bunny Bordelon dynamic draft correctors.

C.6.4. Sea Ark Dynamic Draft Corrections

To determine the dynamic draft corrections, a squat settlement test was completed on this vessel on JD2018-232. Speed values between 1.4 m/s and 3.5 m/s (about 3 to 7 knots) were tested. This range encompassed the speeds used during survey operations. Values were smoothed using a 2nd order polynomial equation to create a correction at every 0.1 m/s change.

***Sea Ark* 2018-232 Dynamic Draft Correctors**	
Speed (m/s)	Dynamic Draft (m), + down
1.40	0.060
1.50	0.047
1.60	0.035
1.70	0.024
1.80	0.014
1.90	0.005
2.00	-0.003
2.10	-0.010
2.20	-0.016
2.30	-0.021
2.40	-0.025
2.50	-0.027
2.60	-0.029
2.70	-0.030
2.80	-0.029
2.90	-0.028
3.00	-0.025
3.10	-0.021
3.20	-0.017
3.30	-0.011
3.40	-0.004
3.50	0.004

Table 31 – Table of Sea Ark dynamic draft correctors.

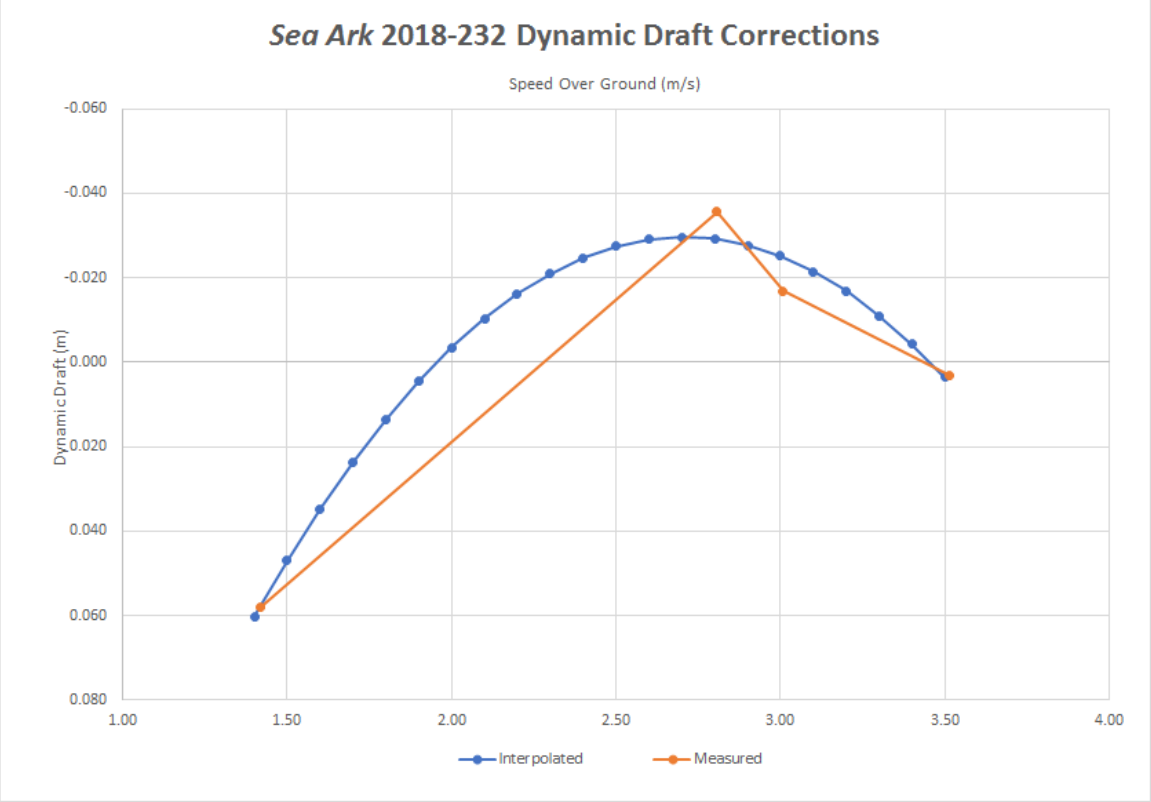


Figure 32 – Graph of Sea Ark dynamic draft correctors.

C.7. Tide Correctors and Project Wide Tide Correction Methodology

Final tides were completed using ERS (Ellipsoid-Referenced Survey) techniques. NAD83(2011) ellipsoid-based altitudes, loaded from PPK data, were reduced to MLLW using the Compute GPSTide routine in conjunction the NAD83 to MLLW VDATUM separation model ("VDATUM_Outline_Shape_xyNAD83-MLLW_geoid12b.csar") provided by NOAA for this purpose.

The VDATUM model was validated through comparison of ellipsoid-referenced vessel waterline data to water levels measured at nearby NWLON stations.

Refer to the project HVCR for more information on tide correction methodology as well as comparison results.

APPROVAL SHEET

For

Data Acquisition and Processing Report: H13180 through H13187 and F00734

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the Statement of Work and Project Work Instructions. Other reports submitted for this survey include the Descriptive Report (one for each survey sheet) and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

Andrew Orthmann

Digitally signed by Andrew Orthmann
Date: 2019.04.26 09:53:00 -08'00'

Andrew Orthmann
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