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

# Data Acquisition & Processing Report

| | |
|---|---|
| Type of Survey: | Navigable Area |
| Project Number: | S-E937-BH2-19 |
| Time Frame: | September - October 2019 |

## LOCALITY

| | |
|---|---|
| State(s): | Maryland |
| General Locality: | Chesapeake Bay |

## 2019

CHIEF OF PARTY
Lieutenant Patrick J Debroisse

LIBRARY & ARCHIVES

Date:

# Table of Contents

## List of Figures

# Data Acquisition and Processing Report

**R/V Bay Hydro II**
Chief of Party: Lieutenant Patrick J Debroisse
Year: 2019
Version: 1
Publish Date: 2019-11-15

# A. System Equipment and Software

## A.1 Survey Vessels

### A.1.1 R/V Bay Hydro II

| | | |
|---|---|---|
| *Vessel Name* | R/V Bay Hydro II | |
| *Hull Number* | S5401 | |
| *Description* | R/V Bay Hydro II was used for the acquisition and post-processing of all multibeam echo sounder (MBES) data and sound velocity profiles (SVP) unless otherwise noted in the Descriptive Report. Vessel configuration and offset measurements are included in the Appendix of this report. | |
| *Dimensions* | *LOA* | 17.3 meters |
| | *Beam* | 6.33 meters |
| | *Max Draft* | 1.8 meters |
| *Most Recent Full Static Survey* | *Date* | 2009-03-23 |
| | *Performed By* | H. Stewart Kuper Jr., NGS |
| *Most Recent Partial Offset Verification* | *Date* | 2019-05-30 |
| | *Method* | Steel measuring tape comparison to full static survey. |

*Figure 1: R/V Bay Hydro II*

### A.1.2 EchoBoat

<table>
<tr><td>Vessel Name</td><td colspan="2">EchoBoat</td></tr>
<tr><td>Hull Number</td><td colspan="2">ASV008</td></tr>
<tr><td>Description</td><td colspan="2">The EchoBoat is a remotely controlled and autonomous surface vehicle that can be used to perform multibeam or side scan surveys in very shallow water or in remote areas where it is difficult to launch conventional survey boats. The ASV was used for hydrographic data acquisition, with an assisting vessel as a launching/hosting platform. The vessel was used for acquisition of MBES as noted in the DR. Vessel configuration and offset measurements are included in the appendix of this report.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>1.68 meters</td></tr>
<tr><td>Beam</td><td>0.79 meters</td></tr>
<tr><td>Max Draft</td><td>0.258 meters</td></tr>
</table>

| | | |
|---|---|---|
| *Most Recent Full Static Survey* | *Date* | 2017-10-02 |
| | *Performed By* | Seafloor Systems, Inc. |
| *Most Recent Partial Offset Verification* | *Date* | 2019-05-01 |
| | *Method* | Steel measuring tape comparison to full static survey. |


*Figure 2: EchoBoat ASV008*

# A.2 Echo Sounding Equipment

## A.2.1 Multibeam Echosounders

### A.2.1.1 Kongsberg EM2040

The Kongsberg EM2040 system is a digital recording multibeam echo sounder which is capable of operating at 200kHz, 300kHz, 400kHz, or in a Frequency Modulation (FM) Chirp. The system is comprised of a receiver unit that is mounted on a sliding sonar strut, a Hydrographic Work Station (HWS), and a Processor Unit (PU). The projector and receiver are set up in a Mills Cross configuration, and deployed through a retractable door located on the center line of the vessel. The EM2040 is operated through Seafloor Information System (SIS) software; version 4.3.2. The EM2040 is used to acquire full and partial bottom bathymetric coverage throughout a survey area to determine least depths over critical items such as wrecks, obstructions, dangers-to-navigation, and general object detection. While operating in partial coverage, the EM2040 collects data concurrently with the EdgeTech 4200 without acoustic interference, commonly referred to as "skunk striping". R/V BAY HYDRO II operates the EM2040 at a frequency of 300kHz for normal operations, as specified in the Kongsberg operator's manual. This configuration provides an ideal mix of resolution and range for surveying within R/V BAY HYDRO II's operational area. The specifications below reflect this mode of operation.

<table>
<tr><td>Manufacturer</td><td colspan="3">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="3">EM2040</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">S5401</td><td>Component</td><td>MBES</td></tr>
<tr><td>Model Number</td><td>EM2040</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Frequency</td><td>300 kilohertz</td></tr>
<tr><td>Calibration</td><td>2019-05-31</td></tr>
<tr><td>Accuracy Check</td><td>2019-10-15</td></tr>
</table>

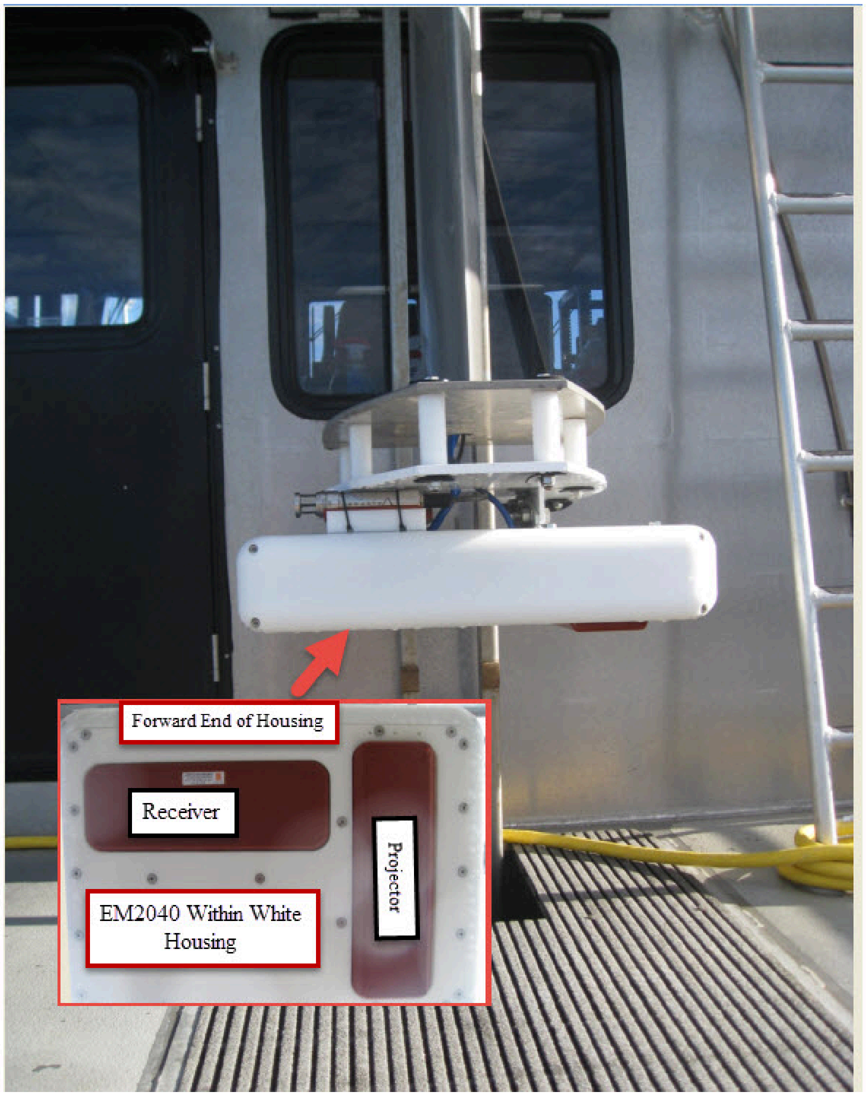


*Figure 3: Kongsberg EM2040 housing and sonar, in the retracted position.*

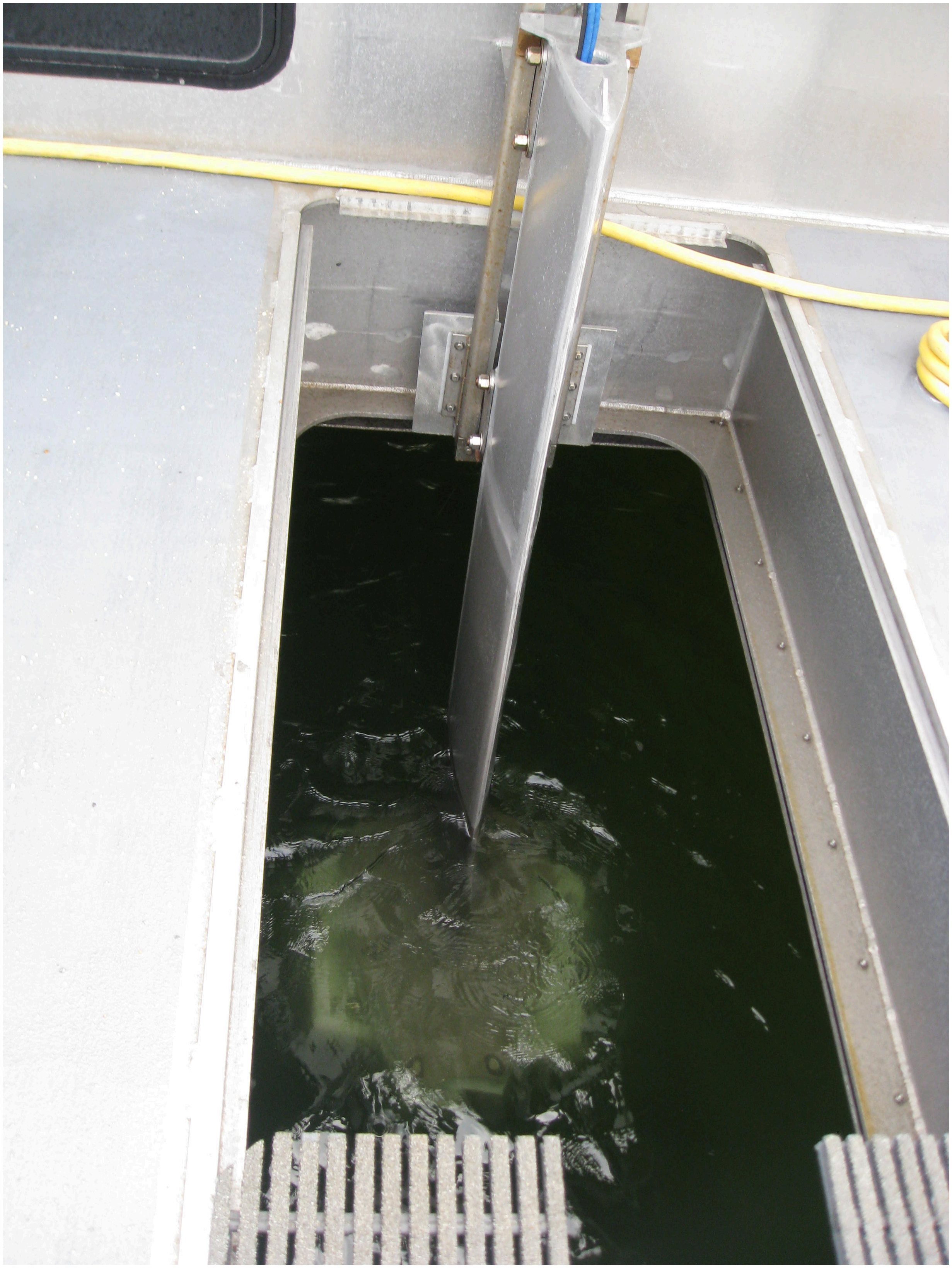

*Figure 4: Kongsberg EM2040 housing and sonar in the deployed position.*

### A.2.1.2 Picotech, LTD PicoMBES

The PicoMBES-120SF is a miniature CHIRP FM multibeam echo sounder (MBES) manufactured by Picotech Ltd, customized to fit inside the transducer well of the ASV008. All beam forming and digital signal processing are performed within the sonar, allowing a direct connection from the sonar to a control computer via WiFi. The PicoMBES-120SF interfaces directly with the EchoBoat’s onboard industrial PC. From a shore laptop using Remote Desktop Connection, the User accesses the onboard PC via a WiFi bridge to control the sonar settings, data logging, as well as the ASV’s AutoNav™ autonomous mission planner.

<table>
<tr><td>Manufacturer</td><td colspan="3">Picotech, LTD</td></tr>
<tr><td>Model</td><td colspan="3">PicoMBES</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">ASV008</td><td>Component</td><td>MBES</td></tr>
<tr><td>Model Number</td><td>120SF</td></tr>
<tr><td>Serial Number</td><td>389</td></tr>
<tr><td>Frequency</td><td>300-400kHz</td></tr>
<tr><td>Calibration</td><td>2019-05-08</td></tr>
<tr><td>Accuracy Check</td><td>2018-10-15</td></tr>
</table>

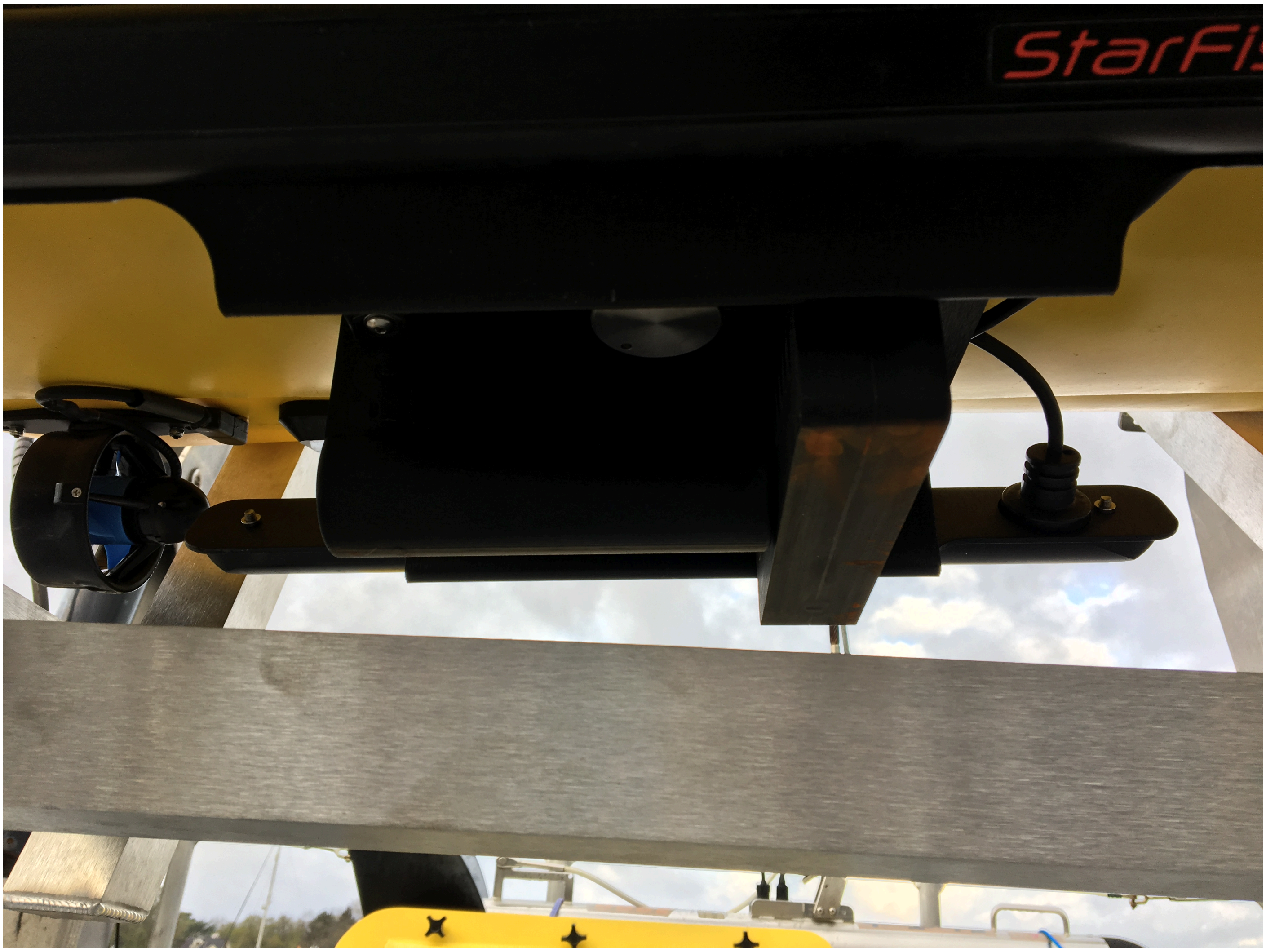


*Figure 5: PicoMB-120SF mounted on ASV 008.*

### A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

### A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

### A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

### A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

## A.3 Manual Sounding Equipment

### A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

### A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

### A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

### A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

## A.4 Horizontal and Vertical Control Equipment

### A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

### A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

### A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

### A.4.4 Levels

No levels were utilized for data acquisition.

## A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

## A.5 Positioning and Attitude Equipment

### A.5.1 Positioning and Attitude Systems

#### A.5.1.1 Applanix (a Trimble company) POS/MV

R/V BAY HYDRO II's POS/MV is a GPS-aided inertial positioning system that provides position and orientation data to external equipment. The system is comprised of an Inertial Measurement Unit (IMU), two GNSS receivers, and a POS Computing System (PCS) unit. Roll, pitch, and heave values are measured by the IMU, while position is derived from the tightly-coupled GPS/IMU integration. The system determines vessel heading by integrating data from the GNSS antennas and heading estimates by the IMU.  Port antenna (10535) is primary, starboard antenna (10534) is secondary. GAMS Calibration performed on 15FEB2019.

The POS MV SURFMASTER ONE system used on the EchoBoat is a userfriendly, turnkey system designed and built to provide accurate attitude, heading, heave, position, and velocity data of the marine vessel and onboard sensors. MV blends GNSS data with angular rate and acceleration data from an IMU and heading from the GPS Azimuth Measurement System (GAMS) to produce a robust and accurate full six degrees-of-freedom position and orientation solution. GAMS Calibration performed on  07MAY2019.

Both vessels used the wide area augmentation service (WAAS) for realtime positioning and POS Pac generated Smoothed Best Estimates of Trajectory for post processed navigation data.

<table>
<tr><td>Manufacturer</td><td colspan="6">Applanix (a Trimble company)</td></tr>
<tr><td>Model</td><td colspan="6">POS/MV</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">S5401</td><td>Component</td><td>IMU</td><td>PCS</td><td>Antenna</td><td>Antenna</td></tr>
<tr><td>Model Number</td><td>v.5</td><td>v.5</td><td>GA530</td><td>GA530</td></tr>
<tr><td>Serial Number</td><td>1023</td><td>3954</td><td>10534</td><td>10535</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>2018-02-20</td><td>2018-02-20</td><td>2018-02-20</td></tr>
<tr><td rowspan="4">ASV008</td><td>Component</td><td>IMU/POS</td><td>Antenna</td><td colspan="2">Antenna</td></tr>
<tr><td>Model Number</td><td>MV-120</td><td>GA830</td><td colspan="2">GA830</td></tr>
<tr><td>Serial Number</td><td>10227</td><td>14185</td><td colspan="2">44830</td></tr>
<tr><td>Calibration</td><td>2019-05-07</td><td>2019-05-07</td><td colspan="2">2019-05-07</td></tr>
</table>


*Figure 6: POS/MV computing system unit (orange) rack mounted aboard R/V BAY HYDRO II.*


*Figure 7: POS MV SURFMASTER ONE unit aboard ASV008.*

### A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

#### A.5.3 GPS

GPS equipment was not utilized for data acquisition.

#### A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

### A.5.5 Other Positioning and Attitude Equipment

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

## A.6 Sound Speed Equipment

#### A.6.1 Moving Vessel Profilers

No moving vessel profilers were utilized for data acquisition.

#### A.6.2 CTD Profilers

#### A.6.2.1 SonTek (a Xylem brand) Castaway

R/V BAY HYDRO II is equipped with a SonTek CastAway CTD profiler and uses it as the primary CTD device. Temperature and electrical conductivity (to calculate salinity) are measured directly, while depth is calculated from strain gauge pressure. Using the Chen-Millero Equations, CTD data is used to calculate sound velocity profiles. As part of the annual HSRR, the CTD profiler is sent to the manufacturer for factory calibration. A Calibration Report can be found in the Appendix of this report.

| | | |
|---|---|---|
| *Manufacturer* | SonTek (a Xylem brand) | |
| *Model* | Castaway | |
| *Inventory* | *Component* | CTD |
| | *Model Number* | N/A |
| | *Serial Number* | CC1332002 |
| | *Calibration* | 2019-01-10 |


*Figure 8: SonTek CastAway CTD.*

### A.6.3 Sound Speed Sensors

#### A.6.3.1 Valeport miniSVS

The Valeport miniSVS is a sing-around transducer that determines the sound velocity by measuring the time needed for a ping of sound to travel a known distance. This unit was used to determine the speed of sound at the head of the Kongsberg EM2040 MBES on R/V BAY HYDRO II and alongside the PicoMBES on the EchoBoat. As part of the annual HSRR, BHII's miniSVS is sent to the manufacturer for factory calibration. A Calibration Report can be found in the Appendix of this report.

<table>
<tr><td>Manufacturer</td><td colspan="3">Valeport</td></tr>
<tr><td>Model</td><td colspan="3">miniSVS</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">S5401</td><td>Component</td><td>miniSVS</td></tr>
<tr><td>Model Number</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>22882</td></tr>
<tr><td>Calibration</td><td>2019-03-26</td></tr>
<tr><td rowspan="4">ASV008</td><td>Component</td><td>ultraSV-TTL</td></tr>
<tr><td>Model Number</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>65881</td></tr>
<tr><td>Calibration</td><td>2018-04-10</td></tr>
</table>

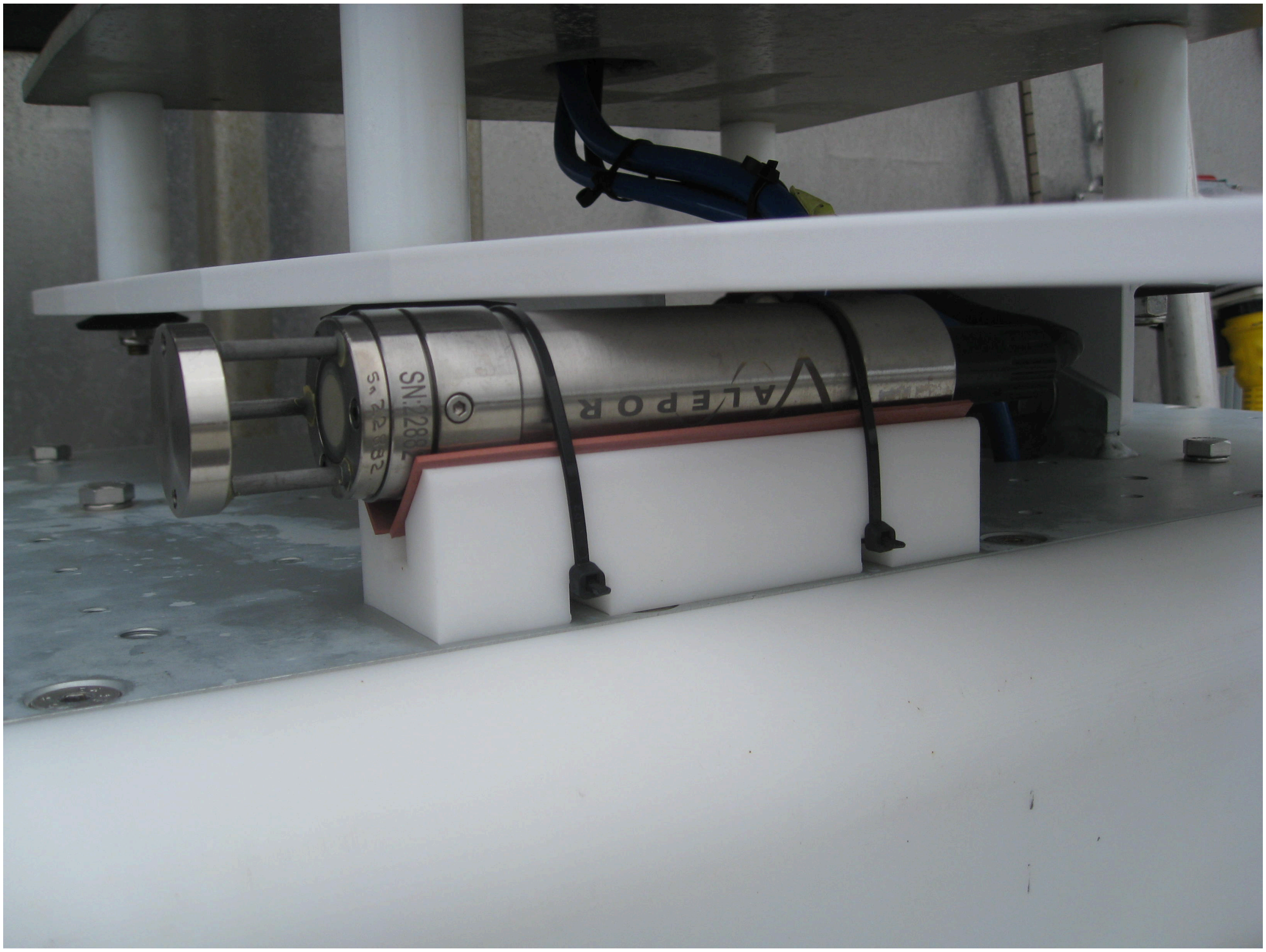

*Figure 9: Valeport MiniSVS mounted to the MBES case.*

**A.6.4 TSG Sensors**

No surface sound speed sensors were utilized for data acquisition.

**A.6.5 Other Sound Speed Equipment**

No surface sound speed sensors were utilized for data acquisition.

### A.7 Computer Software

| *Manufacturer* | *Software Name* | *Version* | *Use* |
|---|---|---|---|
| HYPACK, Inc | HYPACK 2018 | 2018+ | Acquisition |
| Applanix | POSView | 10.11 | Acquisition |
| Applanix | POSPac MMS | 8.4 | Processing |
| Teledyne Caris | HIPS and SIPS | 11.1.4 | Processing |
| NOAA OCS HSTB | PydroExplorer | 19.4 | Processing |
| Kongsberg | SIS | 4.3.2 | Acquisition |
| Teledyne Caris | BASE Editor | 5.3.2 | Processing |
| Hydroffice | Sound Speed Manager | 2019.2.3 | Processing |

## A.8 Bottom Sampling Equipment

### A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

# B. System Alignment and Accuracy

## B.1 Vessel Offsets and Layback

### B.1.1 Vessel Offsets

A NGS survey of R/V BAY HYDRO II was performed on 23-March-2009 using optical levels. The survey established a vessel Reference Point (RP), then found the X, Y, and Z distances for the GNSS antennas and multibeam sonar. On 26-February-2010 the crew surveyed in the Tow Point for the side scan sonar. On 18-March-2010 the crew surveyed in the vessel's singlebeam transducers (See Offset Report in the Appendix).

On 13-August-2014 the EM2040 reference point was moved from the vessel's Reference Point to the EM2040 transmit (Tx) transducer head by changing the configuration of the POS/MV. By referencing the Tx transducer rather than the RP, the associated HVF offset values are no longer needed and are zeroed out. This configuration eliminates the possibility for errors due to the lever arm between the RP and transducer, as well as removes the need for additional "ERS specific" HVFs in Caris for surveying to the ellipsoid.

The X, Y, Z offsets of the MBES between the transmit (Tx) transducer head and the receiver (Rx) transducer head are entered into the HVF in the "SVP2" section of the HVF, as well as in the installation parameters in SIS (Figure 10).

The MRU and Nav to Transducer offsets are shown in the tables below. The Kongsberg Multibeam offsets associated with the Tx transducer head (x,y,z) are entered in the Caris HVF, as well as the POS M/V (see Section B.3.1; Figure 11). This ensures that if vessel, rather than realtime is applied in calculating TPU, the offsets will be applied. The Kongsberg Multibeam offsets associated with the Rx transducer head (x2,y2,z2) are entered as shown below in the Caris HVF.

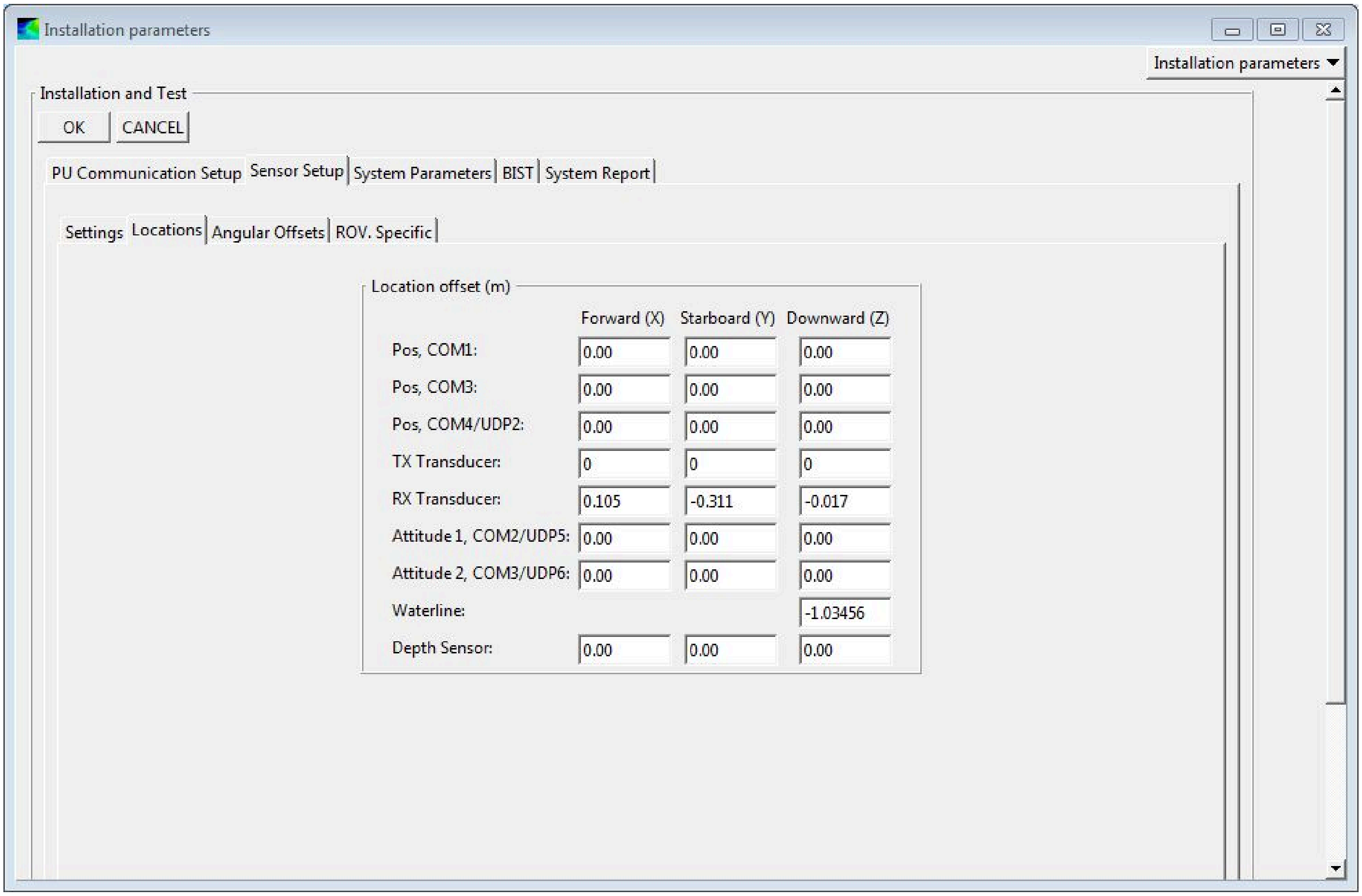


*Figure 10: Offsets of Tx to Rx in SIS*

### B.1.1.1 Vessel Offset Correctors

| | | | | |
|---|---|---|---|---|
| *Vessel* | S5401 | | | |
| *Echosounder* | Kongsberg EM2040 300 kilohertz | | | |
| *Date* | 2017-06-06 | | | |
| *Offsets* | *MRU to Transducer* | | *Measurement* | *Uncertainty* |
| | | *x* | 0.309 meters | 0.020 meters |
| | | *y* | -0.884 meters | 0.020 meters |
| | | *z* | 2.428 meters | 0.020 meters |
| | | *x2* | -0.002 meters | N/A |
| | | *y2* | -0.779 meters | N/A |
| | | *z2* | 2.411 meters | N/A |
| | *Nav to Transducer* | *x* | 1.759 meters | 0.020 meters |
| | | *y* | -6.374 meters | 0.020 meters |
| | | *z* | 5.330 meters | 0.020 meters |
| | | *x2* | 1.448 meters | N/A |
| | | *y2* | -6.269 meters | N/A |
| | | *z2* | 5.313 meters | N/A |
| | *Transducer Roll* | *Roll* | -0.027 degrees | |
| | | *Roll2* | 0.000 degrees | |

| | | | | |
|---|---|---|---|---|
| *Vessel* | ASV008 | | | |
| *Echosounder* | Picotech, LTD. PicoMBES-120SF | | | |
| *Date* | 2019-05-02 | | | |
| *Offsets* | *MRU to Transducer* | | *Measurement* | *Uncertainty* |
| | | *x* | 0.000 meters | 0.005 meters |
| | | *y* | 0.013 meters | 0.005 meters |
| | | *z* | 0.398 meters | 0.005 meters |
| | *Nav to Transducer* | *x* | 0.000 meters | 0.005 meters |
| | | *y* | 0.477 meters | 0.005 meters |
| | | *z* | 0.772 meters | 0.005 meters |
| | *Transducer Roll* | *Roll* | 0.000 degrees | |

#### B.1.2 Layback

Layback was not calculated for this project as no Side Scan was used.

Layback correctors were not applied.

## B.2 Static and Dynamic Draft

### B.2.1 Static Draft

Static draft (i.e., the height of the waterline above/below the reference point) for R/V BAY HYDRO II is determined by an average and standard deviation of 44 measured values over the 2016 through 2019 field seasons. The waterline is occasionally measured as a confidence check. The calculated value is entered directly into to SIS and into the HVF for use by Charlene for processing.

Static draft for EchoBoat was calculated using manufacturer provided measurements. The calculated value is entered directly into the HVF for use by Charlene for processing.

#### B.2.1.1 Static Draft Correctors

| *Vessel* | | S5401 | ASV008 |
|---|---|---|---|
| *Date* | | 2018-02-20 | 2019-05-02 |
| *Loading* | | 0.1 meters | 0.001 meters |
| *Static Draft* | *Measurement* | -1.033 meters | 0.144 meters |
| | *Uncertainty* | 0.016257 meters | 0.001 meters |

### B.2.2 Dynamic Draft

Dynamic draft for S5401 was measured using the Post Processed Kinematic GPS method outlined in section 1.4.2.1.2.1 of NOAA's FPM. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water. Dynamic draft and vessel offsets corrector values are stored in the HVF.

Dynamic draft for ASV008 was measured using the Post Processed Kinematic GPS method outlined in section 1.4.2.1.2.1 of NOAA's FPM. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water. Dynamic draft and vessel offsets corrector values are stored in the HVF.

In ERS surveys, those that use recorded GPS heights corrected via a VDatum SEP model to achieve tidal datum, the dynamic draft correction is not applied to the soundings.

#### B.2.2.1 Dynamic Draft Correctors

| *Vessel* | S5401 | | ASV008 | |
|---|---|---|---|---|
| *Date* | 2019-04-03 | | 2019-05-02 | |
| *Dynamic Draft* | *Speed (m/s)* | *Draft (m)* | *Speed (m/s)* | *Draft (m)* |
| | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.50 | 0.01 | 0.50 | 0.03 |
| | 1.00 | 0.01 | 1.00 | 0.05 |
| | 1.50 | 0.01 | 1.50 | 0.05 |
| | 2.00 | 0.01 | | |
| | 2.50 | 0.01 | | |
| | 3.00 | 0.02 | | |
| | 3.50 | 0.04 | | |
| | 4.00 | 0.05 | | |
| | 4.50 | 0.06 | | |
| | 5.00 | 0.06 | | |
| | 5.50 | 0.40 | | |
| | 6.00 | -0.02 | | |
| *Uncertainty* | *Vessel Speed (m/s)* | *Delta Draft (m)* | *Vessel Speed (m/s)* | *Delta Draft (m)* |
| | 0.50 | 0.01 | 0.40 | 0.01 |

## B.3 System Alignment

### B.3.1 System Alignment Methods and Procedures

The 2019 field season patch test was conducted as part of the HSRR (see the Appendix for full report). The patch test determined any roll, pitch, and yaw biases (X, Y, and Z axis) and the time offset between the MBES reference frame and the navigational reference frame. All patch tests are conducted in accordance with the HSSD Section 5.2.4.1. The lines are post-processed and the CARIS Calibration Utility is performed by all R/V BAY HYDRO II crew members. The results of the three trials are averaged and the result is recorded in the "IMU Frame w.r.t. Ref. Frame" inputs located in the POS Installation: Lever Arms & Mounting Angles window, after converting the values from the CARIS to the POS M/V coordinate system (See image below). The standard deviation of several calibration iterations for pitch and roll are averaged to produce the HVF associated value. It should also be stated that since the purpose of this exercise is to zero out the biases, the inverse of the patch test values are entered into the POS M/V, so that the sum of the offset equals zero, eliminating the bias. As the POS M/V is outputting the position at the EM2040 transducer head, no offsets are needed in the CARIS HVF file to correct the position. Therefore, the navigation offsets in the CARIS HVF file are all zero. Accidentally placing the offsets into the HVF would cause them to "double apply" and introduce significant biases.

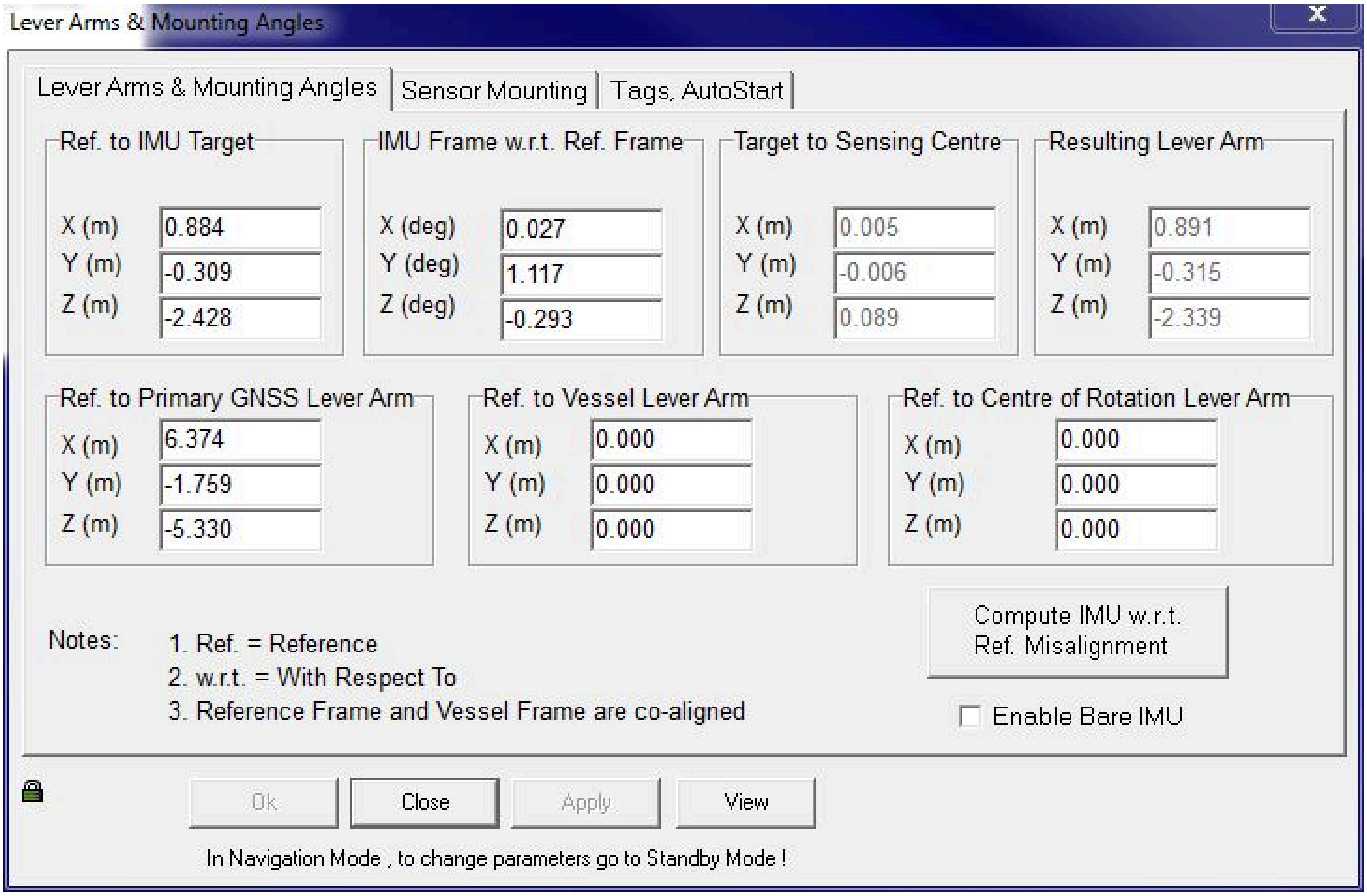


*Figure 11: Lever Arms and Mounting Angles in POS.*

### B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td colspan="3">S5401</td></tr>
<tr><td>Echosounder</td><td colspan="3">Kongsberg EM2040</td></tr>
<tr><td>Date</td><td colspan="3">2019-05-30</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 hertz</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.020 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="3">ASV008</td></tr>
<tr><td>Echosounder</td><td colspan="3">Picotech, LTD PicoMBES</td></tr>
<tr><td>Date</td><td colspan="3">2019-05-02</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Pitch</td><td>-0.490 degrees</td><td>0.270 degrees</td></tr>
<tr><td>Roll</td><td>-0.200 degrees</td><td>0.270 degrees</td></tr>
<tr><td>Yaw</td><td>0.610 degrees</td><td>0.200 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.010 seconds</td></tr>
</table>

# C. Data Acquisition and Processing

# C.1 Bathymetry

## C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Kongsberg multibeam data is logged using SIS in the ".all" format. The hydrographer scans the real time SIS data for system wide errors, anomalies, and dropouts. Display windows such as Sea Bed Image, Time Series, Water Fall, and Beam Intensity aid in this task. SIS data is also fed through HYPACKS's HYSWEEP for the coxswain's display. This secondary interface acts as another real time monitoring tool. During acquisition, the hydrographer reviews the real time data and provides feedback to the coxswain in order to ensure acquired data will meet coverage requirements set forth in the Project Instructions and HSSD Section 5.2.2.

PicoMB multibeam data is logged using HYPACK and HYSWEEP in the ".HSX" and ".RAW" formats. The hydrographer scans the real time data for system wide errors, anomalies, and dropouts. Display windows such as Intensity Waterfall, Matrix Maps, and Beam Profile aid in this task. This system is controlled via remote desktop over Wifi connection. Using this Wifi interface, data is viewed real-time from the parent platform but is collected on the ASV internal computer. During acquisition, the hydrographer reviews the real time data and provides feedback to the coxswain in order to ensure acquired data will meet coverage requirements set forth in the Project Instructions and HSSD Section 5.2.2.

Data Processing Methods and Procedures

Once data acquisition is complete, raw MBES data is converted in CARIS HIPS to provide a visual examination of the data points collected. Corrections and offsets are then applied to the MBES data to produce high resolution depth profiles of the seafloor. These conversions, corrections, and offsets are performed via the automated processing and data transfer tool, Charlene.

The process starts by converting the Kongsberg .all or Hypack .hsx files using CARIS HIPS. Converted files are saved in the CARIS HDCS file format. Navigation and attitude data are are visually inspected for gross errors. Data files are corrected for delayed heave, tides, and sound velocity profiles, and then merged. After the merge, the Total Propagated Uncertainty (TPU) is computed (See Section C.6.1).

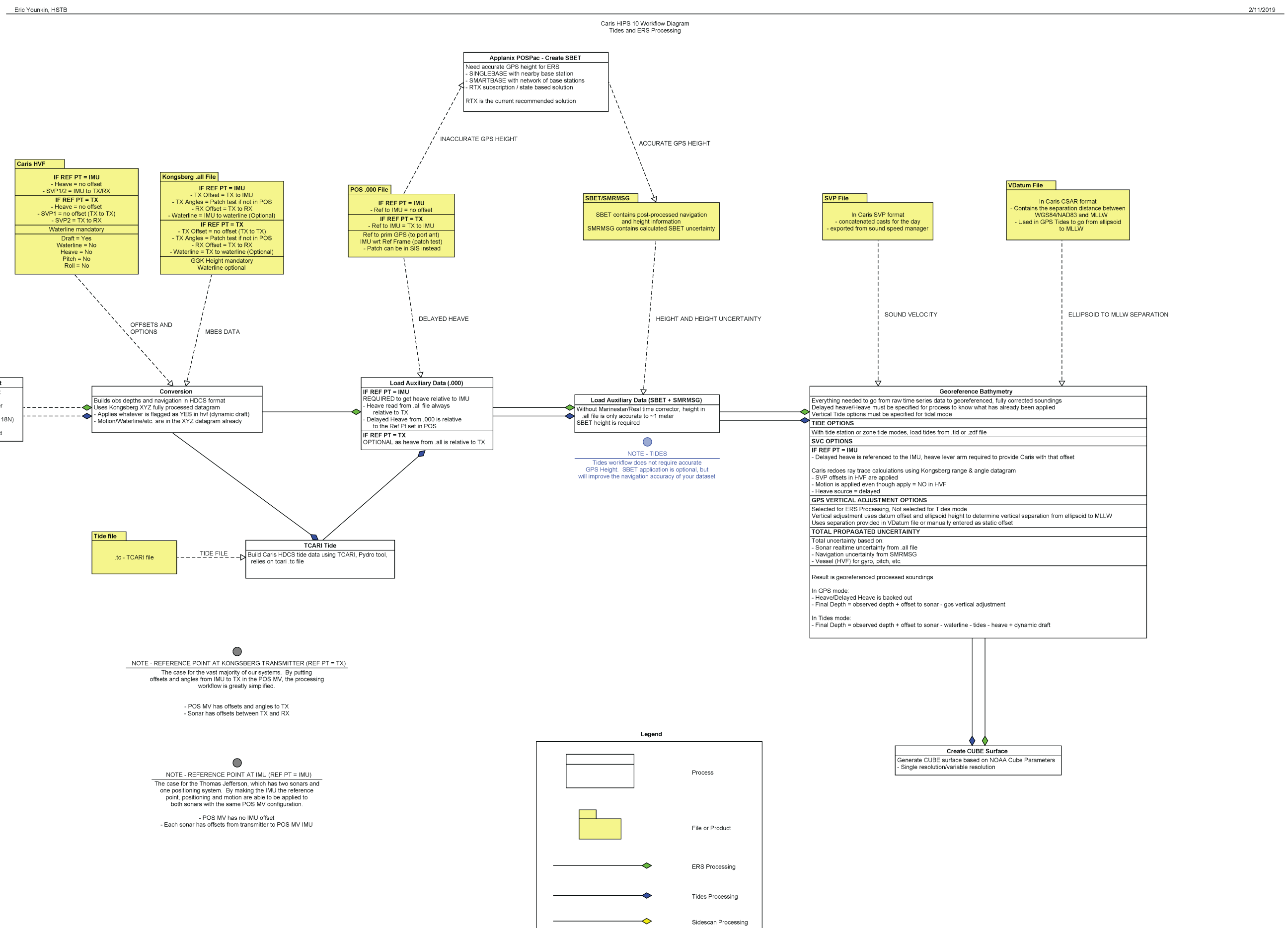


*Figure 12: MBES Data Processing Workflow*

### C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

### C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

### C.1.4 Gridding and Surface Generation

#### C.1.4.1 Surface Generation Overview

MBES data are gridded using CARIS HIPS Combined Uncertainty and Bathymetric Estimator (CUBE) algorithm and is processed as described in FPM Section 4.2.1.1, using methods described above in Section C.1.1. The CUBE surface is also created using a grid resolution determined by coverage type and depth, as required by the Project Instructions and specified in the HSSD, Section 5.2.2. The "Depth" layer is reviewed for holidays (gaps in coverage) or erroneous soundings. Any erroneous soundings, known as fliers, are flagged as rejected and removed from the surface so the surface more accurately represents the seafloor. Any least depth on a feature that is not accurately reflected in the surface is flagged as “designated” in order to force the surface to reflect that shoaler depth in accordance with HSSD Section 5.2.1.2.3.

#### C.1.4.2 Depth Derivation

See above

#### C.1.4.3 Surface Computation Algorithm

See above

## C.2 Imagery

### C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Backscatter data is collected during acquisition. This data is submitted to Pacific Hydrographic Branch along with the associated survey data.

Backscatter data is not collected during acquisition with the PicoMB.

Data Processing Methods and Procedures

Kongsberg backscatter data was processed in the field using the CARIS SIPs methods for quality assurance.

### C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

### C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

# C.3 Horizontal and Vertical Control

## C.3.1 Horizontal Control

### C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

### C.3.1.2 DGPS Data

Data Acquisition Methods and Procedures

For WAAS surveys, the POS/MV is optionally configured to receive correctors from the Wide Area Augmentation System (WAAS). The WAAS is a Satellite Based Augmentation System (SBAS) for North America, developed by the Federal Aviation Administration and the Department of Transportation as an aid to air navigation. Usable by any WAAS-enabled GPS receiver, WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite.

WAAS consists of multiple widely-spaced Wide Area Reference Stations (WRS) sites that monitor GPS satellite data. The WRS locations are precisely surveyed so that any errors in the received GPS signals can be detected. Two master stations, located on either coast, collect data from the reference stations via a terrestrial communications network and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through geostationary satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal.

The WAAS specification requires it to provide a position accuracy of 7.6 meters (25 ft) or better (for both horizontal and vertical measurements), at least 95% of the time. Actual performance measurements of the system at specific locations have shown it typically provides better than 1.0 meter horizontally and 1.5 meters vertically throughout most of the contiguous United States and large parts of Canada and Alaska. In more remote regions of Alaska, values range between 2 and 6 meters horizontally.

Data Processing Methods and Procedures

Position accuracy and quality were monitored using the POSView Controller software to ensure positioning accuracy requirements in the HSSD Section 3.2 were met.

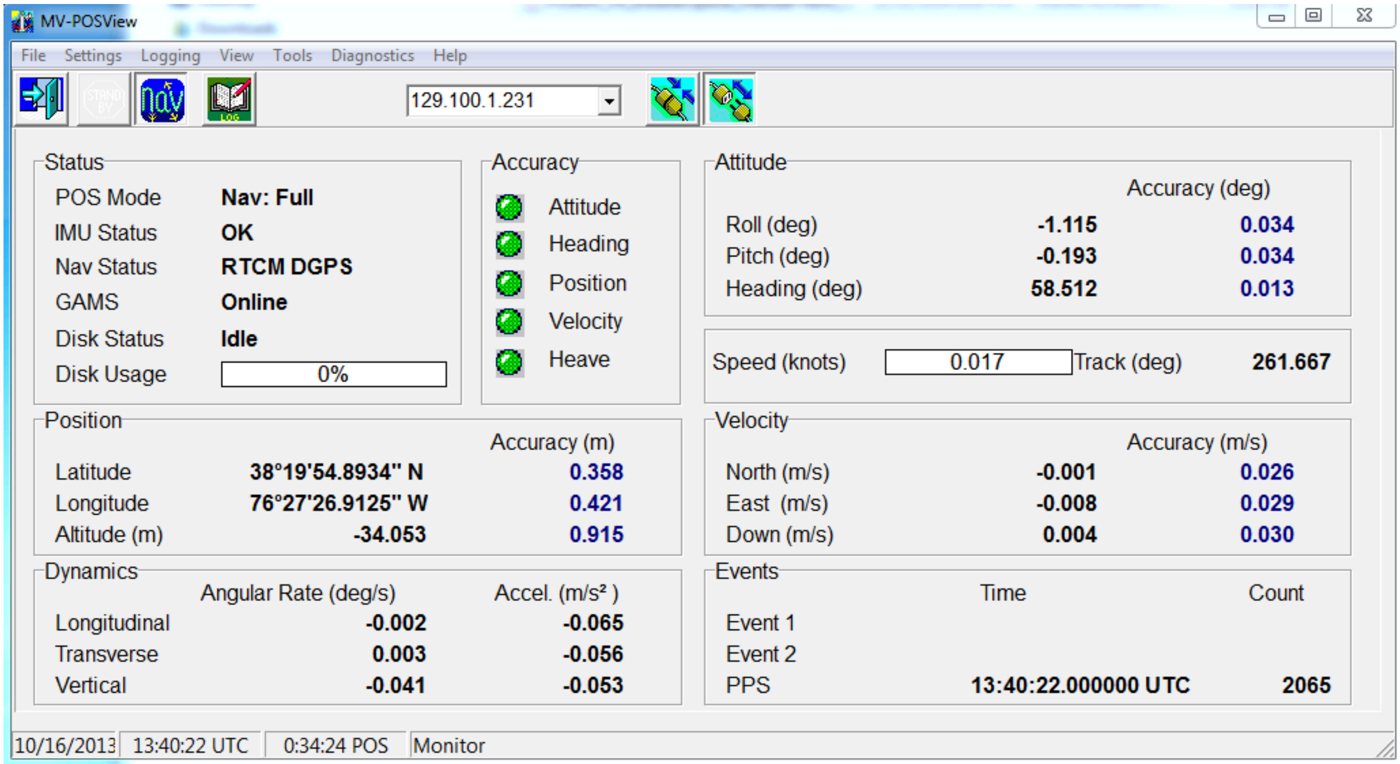


*Figure 13: Real Time POS M/V monitoring interface.*

### C.3.2 Vertical Control

#### C.3.2.1 Water Level Data

Data Acquisition Methods and Procedures

R/V BAY HYDRO II performs Ellipsoidally Referenced Surveys (ERS) or VDatum surveys.

Data Processing Methods and Procedures

The raw POSPac file is processed using reference stations (usually CORS Stations) and a Smooth Best Estimate of Trajectory (SBET) is produced via Charlene and POSPac MMS. This SBET is used in CARIS via "Input Auxiliary Data" to calculate the GPS tide, and then merged to generate a surface at the ellipsoid. The separation model provided by the Project Manager is applied to the data to reduce it to the local MLLW datum.

#### C.3.2.2 Optical Level Data

Optical level data was not acquired.

## C.4 Vessel Positioning

Data Acquisition Methods and Procedures

POS/MV positioning and attitude data are logged and the ZDA (day, month, year, and local time zone offset), GGK (time, position, and fix), and attitude packets are applied in real time to the raw sonar data.

Data Processing Methods and Procedures

The POS/MV file is recorded during acquisition and saved to the network RAW drive. The POS/MV file is loaded, applied to, and merged with the raw sonar data in CARIS via Charlene, using the "Import Auxiliary Data" utility as part of the standard processing flow.

## C.5 Sound Speed

### C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

The CastAway CTD is the primary instrument to acquire sound velocity profiles, unless otherwise stated in the Descriptive Report. CARIS HIPS then utilizes the concatenated sound velocity data as a corrector. Casts are acquired every 2-4 hours during MBES acquisition. Profiles are collected more frequently when current and weather conditions warrant or when SIS indicates a new cast is needed.

Data Processing Methods and Procedures

All SVP casts are processed using HydrOffice's Sound Speed Manager and exported into SIS to be used in real time beam pattern formation. In CARIS, the "Nearest in Distance Within Time of Four Hours" option is used when correcting the data for sound speed unless otherwise noted in the DR.

For the ASV, all SVP casts are processed using HydrOffice's Sound Speed Manager. In CARIS, the "Nearest in Distance Within Time of Four Hours" option is used when correcting the data for sound speed unless otherwise noted in the DR.

### C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed data is directly measured by the Valeport miniSVS for use by the MBES during acquisition.

Data Processing Methods and Procedures

The Kongsberg EM2040 uses the sound velocity profile from the CTD profile for its beam forming equation and only depends on the surface sound speed as a comparison tool to ensure accuracy. This accuracy check is performed by comparing the continuous reading from the surface sound speed profiler to the CTD reading at the same depth. If the two measurements fall outside the range of 0 m/s to 2 m/s, then SIS indicates that a new cast is needed. All surface sound speed is internal to Kongsberg and stored in the .ALL file.

The PicoMBES-120SF uses the surface sound speed for its beam forming equation and only depends on the CTD sound speed profile for post-processing only. An accuracy check is performed by comparing the continuous reading from the surface sound speed profiler to a CTD reading at the same depth.The hydrographer monitors the surface sound speed readings and frequently preforms casts to ensure proper representation of the water column sound speed profile. All surface sound speed is internal to the PicoMBES and stored in the .HSX file.

## C.6 Uncertainty

### C.6.1 Total Propagated Uncertainty Computation Methods

TPU is computed using CARIS HIPS. Compute TPU and the CUBE surface Uncertainty child layer is reviewed to ensure all depth measurement uncertainties meet the uncertainty standard in HSSD Section 5.1.3. Uncertainty standards are also confirmed using Pydro QC Tools.

In the CARIS TPU calculation, real time uncertainty values are used, where possible. Real time calculated uncertainties found in the .all file are used for position, sonar, heading, pitch, and roll. The vertical real time uncertainty is from the SBET's RMS file and the tidal uncertainty is derived from the ERS Separation Model.

When real time uncertainty data is not available, the uncertainty values recorded in the HVF are used. These uncertainties come directly from the manufacturers and are typically found in the systems operators manual's specification section.

### C.6.2 Uncertainty Components

#### C.6.2.1 A Priori Uncertainty

| *Vessel* | | S5401 | ASV008 |
|---|---|---|---|
| *Motion Sensor* | *Gyro* | 0.02 degrees | 0.08 degrees |
| | *Heave* | 5.00%<br>0.05 meters | 5.00%<br>0.05 meters |
| | *Roll* | 0.02 degrees | 0.04 degrees |
| | *Pitch* | 0.02 degrees | 0.04 degrees |
| *Navigation Sensor* | | 1.00 meters | 0.50 meters |

#### C.6.2.2 Real-Time Uncertainty

| *Vessel* | *Description* |
|---|---|
| *S5401* | The Kongsberg .ALL file contains many realtime uncertainty calculations, however, when processing in Caris, the a priori uncertainty values are used. |
| *ASV007* | The .HSX file contains many realtime uncertainty calculations, however, when processing in Caris, the a priori uncertainty values are used. |

## C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

All potentially significant features are divided into three categories. The first, features that are not safe for R/V BAY HYDRO II to approach, are given a cursory visual inspection. If they are visible above the water line, a detached position is calculated. An azimuth and range (via compass and laser range finder, respectively) are measured along with a known vessel position, and photographed from a safe distance. This allows the feature's position to be calculated with a high degree of accuracy without placing the vessel or crew in danger. The features are imported into the Final Feature File (FFF) and S-57 attributed. For unsafe features, the feature is not addressed and referenced as such in the Descriptive Report.

The second category of features are those safe for R/V BAY HYDRO II to investigate. For features in this category, a file is created in CARIS HIPS and SIPS identifying the position of the feature and the area around the feature that is to be ensonified by MBES, called a shape file. This shape file is exported into HYPACK and used by the coxswain during data collection. The MBES development lines are created over the suspected feature in a way that is safest for the vessel and crew, ensonify all sides of the feature, and ensonify the feature with both the port and starboard channels of the MBES. The features are created in CARIS HIPS and SIPS, are S-57 attributed and added to the FFF.

The third category is shoreline features. In the event that shoreline verification is required, or a significant/ assigned feature is only accessible by shore, the Trimble GeoXH is used and a high resolution photograph of the object is taken. This hand held unit is held as high on the object as possible, for a minimum of ten minutes to achieve a positional accuracy of one meter. The data collected with the Trimble is post-processed using the Trimble Pathfinder Office software package, exported to BDB, S-57 attributed, and added to the FFF.

Data Processing Methods and Procedures

See previous section.

### C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

Bottom samples are collected at the designated sites by the Project Instructions. Samples are obtained with a Ponar type grab sampler (See Section A.8).

Data Processing Methods and Procedures

All samples are photo logged and classified using the classification system in Chart 1, Section "J", Nature of the Seabed.

# D. Data Quality Management

## D.1 Bathymetric Data Integrity and Quality Management

### D.1.1 Directed Editing

The surface's child layers are reviewed to ensure the surface meets NOAA standards as set forth in the HSSD, and is free from systematic errors. The Hypothesis Count and Hypothesis Strength child layers are reviewed to ensure that fliers are not causing confusion in determining the actual sea floor. The Density layer is reviewed to determine that all the data has the appropriate density as set by the HSSD Section 5.2.2.2. The Standard Deviation layer is reviewed to ensure that all the data lies within the 95% confidence level. The depth layer is reviewed for erroneous soundings. Any erroneous soundings, known as fliers, are flagged as rejected and removed from the surface so the surface more accurately represents the seafloor.

### D.1.2 Designated Sounding Selection

Any least depth on a feature that is not accurately reflected in the surface is flagged as “designated” in order to force the surface to reflect that shoaler depth in accordance with HSSD Section 5.2.1.2.3.

### D.1.3 Holiday Identification

The depth layer of each resolution grid is reviewed visually for gross holidays (gaps in coverage) by the hydrographer and then run through QC Tools "Holiday Finder" for a more thorough identification of holidays. All holidays are identified and data is later acquired to resolve the gap in data coverage to the best of the hydrographer's ability. In the unusual event that holidays are identified after the survey team has departed the survey area and are unable to return, holidays are digitized in a .HOB file and submitted with the data to the Branch.

### D.1.4 Uncertainty Assessment

The uncertainty layer is viewed to ensure that the data has not exceeded specifications as set by the HSSD Section 5.2.3. Pydro's QC Tools are used to further investigate and produce statistics and graphs to whether or not the data meets uncertainty requirements.

### D.1.5 Surface Difference Review

#### D.1.5.1 Crossline to Mainscheme

Crosslines are collected, processed, and compared in accordance with Section 5.2.4.3 of the HSSD. A CUBE surface is created at the appropriate resolution for the survey area using only mainscheme lines and a second surface is created using only crosslines. Using the two surfaces, a difference surface (mainscheme - crosslines = difference surface) is generated. Statistics are calculated to show the mean difference between the depths derived from the mainscheme and crosslines and reported in the DR. The difference surface is also compared to the IHO allowable total vertical uncertainty (TVU) standards and reported in the DR.

#### D.1.5.2 Junctions

Junction surveys are performed in accordance with HSSD Section 7.2.2. The process is the same as the crossline to mainscheme review (see paragraph above). The two data set surfaces are differenced using the CARIS Differencing algorithm and difference surface statistics are generated. When the difference surface are in good agreement between the two data sets, the process is complete. If the data sets are found to be in poor agreement, the data will be reviewed to determine if a vessel bias has been introduced into the HVF, a processing error has occurred, or a significant weather event has change in the sea floor. Analyses are documented in the DR.

### D.1.5.3 Platform to Platform

In the event R/V BAY HYDRO II is assigned a survey with another vessel, data is consistently reviewed for differences and troubleshooting is performed, as necessary.

## D.2 Imagery data Integrity and Quality Management

### D.2.1 Coverage Assessment

See Section C.2.

### D.2.2 Contact Selection Methodology

See Section C.2.

# E. Approval Sheet

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

The entire survey is adequate to supersede previous data.

| Approver Name | Approver Title | Date | Signature |
|---|---|---|---|
| LT Patrick J Debroisse | Chief of Party | 11/15/2019 | DEBROISSE.PATRICK.JOSEPH.1501248670 2019.11.15 14:05:05 -05'00' |

# List of Appendices:

| ***Mandatory Report*** | ***File*** |
| --- | --- |
| *Vessel Wiring Diagram* | BHII_SystemConfiguration_2019.pdf<br>Echoboat ASV Wiring Diagram.pdf |
| *Sound Speed Sensor Calibration* | 2019 Cast Away Calibration Report.pdf<br>2019 Valeport Mini SVS Calibration Report.pdf<br>65881_Certificate_181004.pdf |
| *Vessel Offset* | NGS2009.pdf<br>2019_BHII_S5401_EM2040_kRP_102143.pdf<br>2019_BHII_ERDDM_Report.pdf<br>EchoBoat_PicoMB_2019.pdf<br>2019_ASV_008_ERDDM_Report.pdf |
| *Position and Attitude Sensor Calibration* | 2019 GAMS Calibration.pdf<br>POS_MV_Cal_Report_ASV008_2019.pdf |
| *Echosounder Confidence Check* | 2019_EM2040_Patch_Calibration.pdf<br>2019_SBES_MBES_Comparison Report.pdf<br>2019_Lead_Line_to_MBES_Comparison Report.pdf<br>2019_Lead_Line_to_SBES_Comparison_report.pdf<br>2019_Lead Line Calibration_Report.pdf<br>ASV008_2019_Patch_Calibration.pdf<br>ASV 008_Ref_Surf.pdf |
| *Echosounder Acceptance Trial Results* | SAT_BH2_EM2040.pdf<br>Seafloor_Systems_EchoBoat_Acceptance_Report_2019.pdf |

| ***Additional Report*** | ***File*** |
| --- | --- |
| *Single Beam Echo Sounder Positioning Report* | Single Beam Echo Sounder Positioning.pdf |