2019-2023 Combined Descriptive Report of Seafloor Mapping: Casco Bay, Maine

Chief of Party – Peyton Benson, Project Hydrographer, Contractor to the Maine Coastal Program

Program Manager – Claire Enterline, Research Coordinator, Maine Coastal Program



Maine Coastal Mapping Initiative, June 2023

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For an overview of the Maine Coastal Mapping Initiative (MCMI) information products, including maps, data, imagery, and reports visit: <u>https://www.maine.gov/dmr/mcp/planning/mcmi/index.htm</u>.

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Maine Coastal Mapping Initiative Maine Coastal Program Department of Marine Resources		
	DESCRIPTIVE REPORT	
Type of Survey:	Navigable Area	
Registry Number:	W00648	
	LOCALITY	
State(s):	Maine	
General Locality:	Gulf of Maine	
Sub-Localities:	Casco Bay	
	2023	
Peyton Bens	CHIEF OF PARTY on, Hydrographer, Contractor to the State of Maine	
	LIBRARY & ARCHIVES	
Date:		

	MAINE COASTAL MAPPING INITIATIVE	REGISTRY NUMBER:
	MAINE COASTAL PROGRAM	
	OGRAPHIC TITLE SHEET	W00648
INSTRUCTIONS: The hyd	drographic sheet should be accompanied by this form, filled in as completely as possible, w	when the sheet is forwarded to the Office.
State(s):	Maine	
General Locality:	Gulf of Maine	
Sub-Locality:	Casco Bay	
Scale:		
Dates of Survey:	07/15/2019 to 04/12/2023	
Instructions Dated:		
Project Number:		
Field Unit:	Amy Gale	
Chief of Party:	Peyton Benson, Hydrographer, Contractor to) the State of Maine
Soundings by:	Kongsberg EM2040C (MBES)	
Imagery by:	Kongsberg EM2040C (MBES Backscatter)	
Verification by:		
Soundings in:	meters at Mean Lower Low Water	
Remarks:		

Table of Contents

Acknowledgements	
ABSTRACT	
1.0 Area Surveyed	9
1.1 Survey Purpose	
1.2 Survey Quality	
1.3 Survey Coverage	
2.0 Data Acquisition	
2.1 Survey Vessel	
2.2 Acquisition Systems	
2.3 Vessel Configuration Parameters	
2.4 Survey Operations	
2.5 Survey Planning	
2.6 Calibrations	
3.0 Quality Control	
3.1 Crosslines	
3.2 Junctions	23
3.3 Uncertainty	23
3.4 Equipment Effectiveness	25
3.5 Sound Speed Methods	25
4.0 Data Post-processing	26
4.1 Horizontal Datum	
4.2 Vertical Datum and Water Level Corrections	
4.3 Processing Workflow	
4.4 Final Surfaces	29
4.5 Backscatter	
5.0 Results	32
5.1 Charts Comparison	
5.2 Bottom Samples	45
5.3 Wrecks and Obstructions	
6.0 Summary	53

References	54
Appendix A – Specific dates of data acquisition for surveys	55
Appendix B – 2023 MCMI Survey Systems Diagram for the F/V Amy Gale	56
Appendix C – 2023 Configuration settings for Seapath 330	57
Appendix D – Template database settings in Qinsy (for acquisition)	81
Appendix E – Configuration settings for Qinsy EM controller	109
Appendix F – Computation Settings for Qinsy Online	110
Appendix G – Crossline surface difference test statistical plots	138
Appendix H – Modified CMECS Classification Scheme Used by MCMI	145

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ABSTRACT

Across multiple survey seasons, spanning from July of 2019 through to April of 2023, the Maine Coastal Mapping Initiative (MCMI) conducted hydrographic surveys using a multibeam echosounder (MBES) in state marine waters of Casco Bay, Maine. The surveying efforts were conducted to support endeavors to enhance coastal resiliency through identification and characterization of seafloor habitat to provide information necessary to managing the marine environment and economy. The survey also coincides with state and federal efforts to update coastal data sets and increase high resolution bathymetric coverage for Maine's coastal and marine waters. This report serves as a comprehensive summary of multiple combined survey efforts conducted by MCMI in Casco Bay, Maine. The combined efforts of these surveys collected approximately 35.15 mi² (91 km²) of high-resolution multibeam data in the survey period, MCMI also collected water column data and video at all sample locations across the survey area which will contribute to improved classification of substrate and modeling of benthic communities.

1.0 Area Surveyed

The survey area collected across the span of the 2019 season, as well as through winter of 2021-2022 and the winter of 2022-2023, was located within Casco Bay, Gulf of Maine, as shown in Figure 1. The approximately 35.15 mi² survey area consists of all navigable waters to a minimum depth of 5 meters, from Ram Island in the southwest extent, to Moshier Island in the northeast extent.

These data were not collected in direct accordance with the *NOS Hydrographic Surveys Specifications and Deliverables* and the *Field Procedures Manual* requirements; however, both documents were referenced during acquisition for guidance.

Prior to completion of data collection, this area was registered with NOAA ESD under pre-registry ID W00648.

Casco Bay survey limits are listed in Table 1 by season of acquisition and as a merged single surface. Specific dates of data acquisition for the survey area are listed in Appendix A.

Table 1 – Casco Bay Survey Limits

2019 Survey Limits

Southwest Limit	Northeast Limit
43° 46' 08.30" N	43° 37' 53.16" N
70° 03' 59.69" W	70° 11' 31.97" W

2021-2022 Survey Limits

Southwest Limit	Northeast Limit
43° 41' 28.49" N	43° 47' 17.98" N
70° 11' 04.39" W	70° 02' 35.79" W

2022-2023 Survey Limits

Southwest Limit	Northeast Limit
43° 38' 46.75" N	43° 46' 08.30" N
70° 12' 10.90" W	70° 03' 59.69" W

Full Survey Extent

Southwest Limit	Northeast Limit
43° 46' 08.30" N	43° 47' 17.98" N
70° 03' 59.69" W	70° 02' 35.79" W

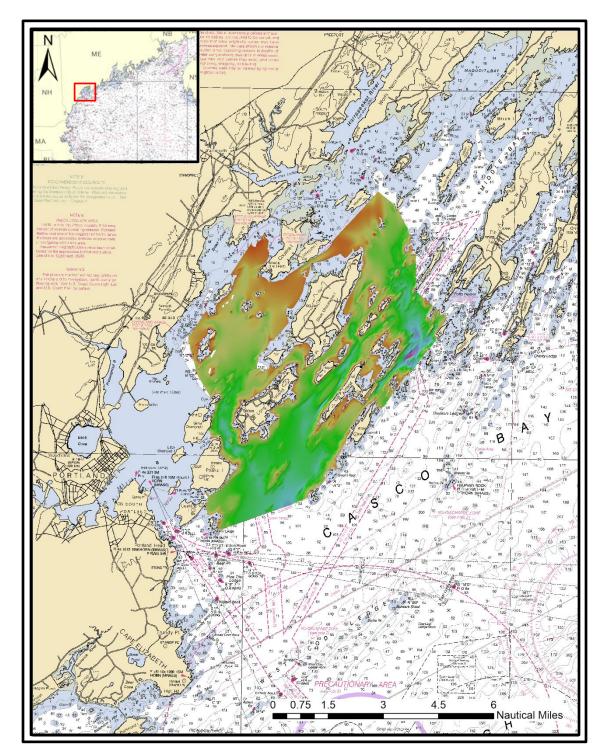


Figure 1 – General locality of Casco Bay survey coverage, plotted over NOAA chart 13288.

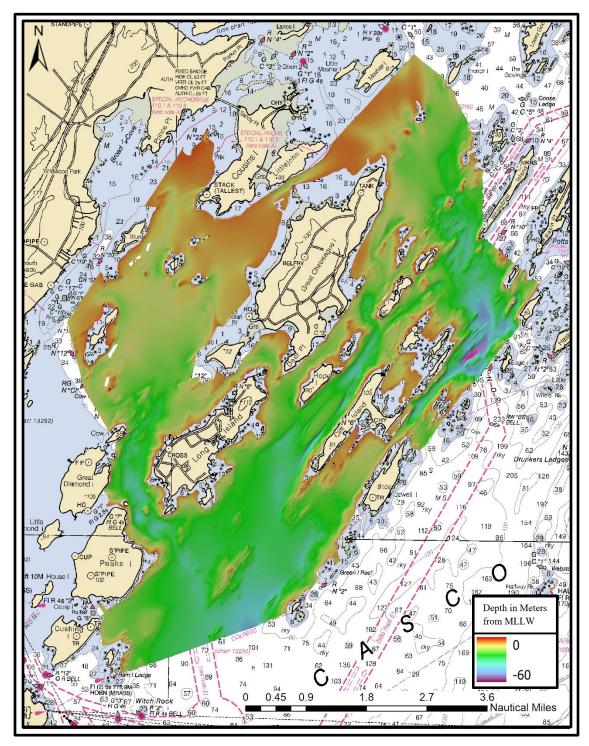


Figure 2 – Shaded relief image of Casco Bay bathymetry data gridded at 1-meter resolution and colored by depth. Data is overlain on NOAA chart 13288.

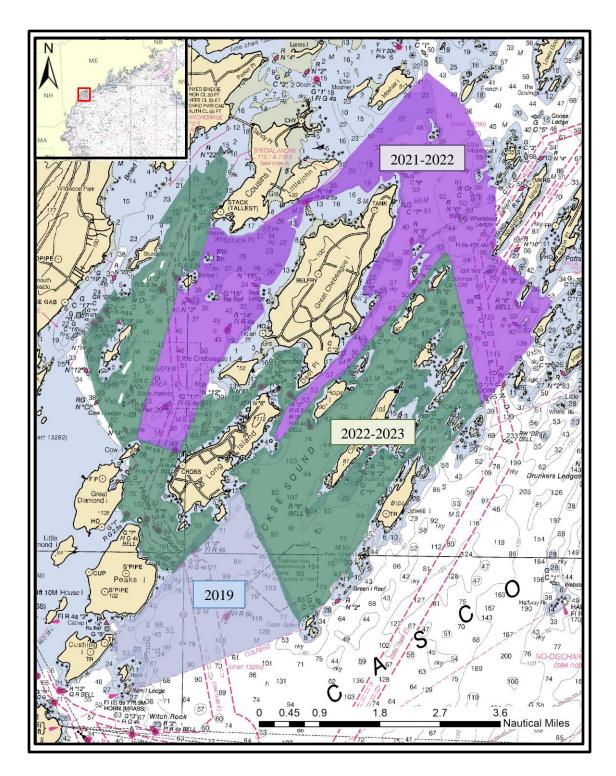


Figure 3 – Casco Bay survey coverage shown by season of acquisition, plotted over NOAA chart 13288

1.1 Survey Purpose

This survey was conducted by the Maine Coastal Program's Maine Coastal Mapping Initiative (MCMI) as part of a multi-agency cooperative agreement partially funded by the National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Management, The Nature Conservancy (TNC), and the Maine Outdoor Heritage Fund. The purpose of this project is to help inform policy decision-making related to Maine's coastal waters by increasing the volume of available high-quality bathymetric, benthic habitat, geochemical, and geologic data in the Casco Bay area. This project also coincides with state and federal efforts to update coastal data sets for Maine's coastal waters and provides new data in the areas covered by National Oceanic and Atmospheric Administration (NOAA) nautical charts 13288, 13290, and 13292 in Casco Bay. These data were acquired and processed to meet Office of Coast Survey bathymetry standards as best as possible and are shared with the NOAA Office of Coast Survey for review.

1.2 Survey Quality

The entire survey should be adequate to supersede previous data.

1.3 Survey Coverage

Select few small holidays (gaps in MBES coverage) exist within the surveyed area, and normally occurred as sonic shadows in areas of locally high relief and/or highly irregular bathymetry. Analyses of bathymetric data show that the least depths were achieved over all features, and that holidays have not compromised data integrity.

Throughout the survey area, eight aquaculture arrays were encountered which prevented complete ensonification within their bounds. Survey lines were run as close as possible to the borders of the arrays, but holidays are present in the survey area due to these obstacles. These arrays are highlighted in Figure 4 below.

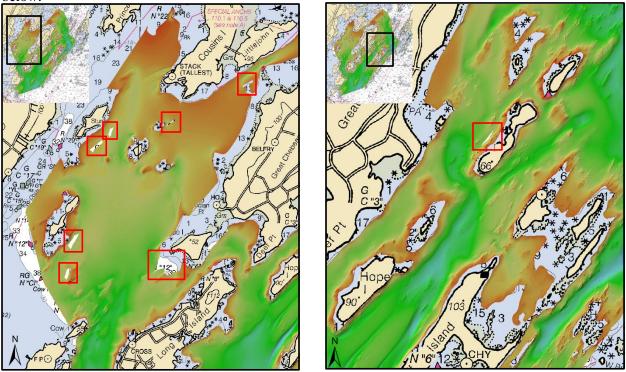


Figure 4: Aquaculture array-induced holidays in survey coverage

2.0 Data Acquisition

The following sub-sections contain a summary of the systems, software, and general operations used for acquisition and preliminary processing throughout the 2019, winter 2021-2022, and winter 2022-2023 Casco Bay survey efforts.

2.1 Survey Vessel

All data were collected aboard the Fishing Vessel (F/V) Amy Gale (length = 10.95 m, width = 3.81 m, draft = 0.93 m) (Figures 5, 6, and 7), a former lobster boat converted to a survey vessel and contracted to the MCMI. The vessel was captained by Caleb Hodgdon of Hodgdon Vessel Services. Surveys were based out of ports in Boothbay Harbor and Portland, ME. The EM2040C transducer, motion reference unit (MRU), AML MicroX surface sound speed probe, and dual GNSS antennas were pole-mounted to the bow; pole raised (for transit) and lowered (for survey) via a pivot point at the edge of the bow. The main cabin of the vessel served as the data collection center and was outfitted with four display monitors for real time visualization of data during acquisition.

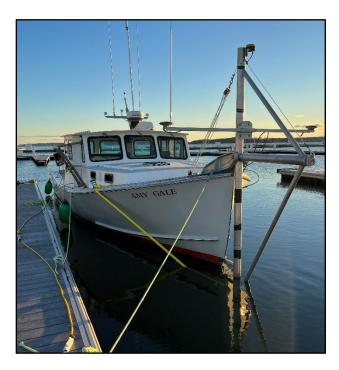


Figure 5 – F/V Amy Gale shown with pole-mounted dual GPS antennas, Fugro AD-341 antenna, Kongsberg EM2040C multibeam sonar (not visible), MRU (not visible), and surface sound speed probe (not visible) in acquisition mode.

2.2 Acquisition Systems

The real-time acquisition systems used aboard the F/V Amy Gale during the reported surveys are outlined in Table 2. Data acquisition was performed using the Quality Positioning Services (QPS) Qinsy (Quality Integrated Navigation System; v.9.2.2 through v.9.5.4) acquisition software. The modules within Qinsy integrated all systems and were used for real-time navigation, survey line planning, data time tagging, data logging, and visualization.

Sub-system	Components
Multibeam Sonar	Kongsberg EM2040C and processing unit
Position, Attitude, and Heading Sensor	Seapath 330 processing unit, HMI unit, dual GPS/GLONASS antennas, MRU 5-V motion reference unit (subsea bottle), Fugro 3610 Receiver and AD-341 antenna
Acquisition Software and Workstation	Qinsy software v.9.2.2-9.5.4 and 64-bit Windows 10 PC console
Surface Sound Velocity (SV) Probe	AML Micro X with SV Xchange
Sound Velocity Profiler (SVP)	Teledyne Odom Digibar-S sound speed profiler
Ground-truthing/Sediment Sampling Platform	Ponar grab sampler, GoPro Hero 3+ video camera, GoPro Hero 5 Black video camera, dive light, dive lasers, YSI Exo I sonde

Table 2 – Major systems used aboard F/V Amy Gale

* See Appendix B for a diagram overview of survey systems aboard the Amy Gale.

2.3 Vessel Configuration Parameters

In 2017, the MCMI contracted Doucet Survey, Inc. to perform high-definition (precision \pm 5mm) 3D laser scanning of the Amy Gale and all external MBES system components (e.g. MRU, GPS antennas, and EM2040C) (Figures 6 and 7). The purpose of the laser scan survey was to refine and or verify the precision of hand-made vessel reference frame measurements for future surveys. All points were referenced to the center point of the base of the MRU (mounted inside the pole and directly atop the EM2040C transducer) (Figure 7), which served as the origin (e.g. 0,0,0), where 'x' was positive forward, 'y' was positive starboard, and 'z' was positive down. The laser scan survey results only differed from hand-made measurements by \leq 3mm for all nodes of interest. Reference measurements for each component were entered into the Seapath 330 Navigation Engine (Table 3) and converted so all outgoing datagrams would be relative to the location of the EM2040C transducer (e.g. EM2040C was used as the monitoring point for all outgoing datagrams being received by Qinsy during acquisition). Additional configuration and interfacing of all systems were established during the creation of a template database in the Qinsy console.

These offset values were not changed for the reported survey seasons. See appendices for a diagram of survey systems aboard the Amy Gale. specific settings as entered in the Seapath 330 Navigation Engine (Appendix C), for the template database (Appendix D), and the computation settings (Appendix F) used during data acquisition while online in Qinsy. Configuration settings of the EM2040C were assigned in the EM Controller module of Qinsy (Appendix E).

Equipment	x (m)	y (m)	z (m)
MRU	0.000	0.000	0.00
Antenna 1 (port)	0.158	-1.245	-3.000
Antenna 2 (starboard)	0.158	1.252	-3.035
EM2040C	0.036	0.000	0.133

Table 3 – 2017 equipment reference frame measurements for Seapath 330

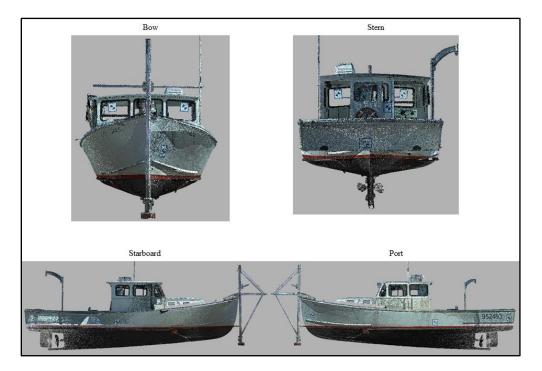


Figure 6 – Amy Gale RGB color images generated from 3D laser scan survey (GPS antennas and external cabling not included in survey) data (.pts file converted to .las for visualization)

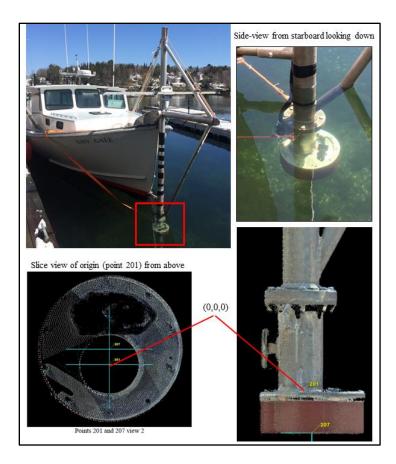


Figure 7 – Amy Gale origin (point 201 in RGB images) for vessel reference frame(s); origin is center point within the base of the pole (center point of base within internally-mounted motion reference unit (MRU) point 201 in images above)

2.4 Survey Operations

The following is a general summary of daily survey operations. Once the survey destination was reached, the sonar pole mount was lowered into survey position and its bracing rods were fastened securely to the hull of the ship via heavy-duty ratchet straps. Electric power to all systems was provided by a 2000-watt Honda eu2000i generator. Occasionally two eu2000i generators were simultaneously used if any auxiliary equipment needed additional electricity. Immediately following power-up, all interfacing instruments were given time to stabilize (e.g. approximately 30-45 minutes for Seapath to acquire accurate positioning). Next, the desired Qinsy project was selected for data acquisition. All files (e.g. raw sonar files, sound speed profiles, grid files, etc.) were recorded and stored within their respective project subfolders on a local drive. Prior to surveying each day, a sound speed cast was taken and imported into the 'imports' folder of the current project. After confirming agreement between the surface probe reading and the downcast data and inspecting cast values for abnormal profile/readings, the profile was applied to the sonar (EM2040C) in the Qinsy Controller module. Regular sound speed casts were collected throughout the survey day when necessitated by changing tide, location, or upon disagreement with the surface probe measurement (exceeding +/-2.0 m/s difference). Data were gridded at 0.5 to 4 meters for real-time visualization, depending on expected water depth range. Raw sonar files were logged in the Qinsy Controller module in .db format and saved directly onto the hydrographic workstation computer. All data were backed up daily on an external hard drive. At the end of each day's survey, sonar and navigation systems were powered down and the pole mount was raised and fastened for transit back to port. Upon arriving at the dock, all external instruments/hardware were visually inspected and rinsed with freshwater to prevent corrosion.

2.5 Survey Planning

Line planning and coverage requirements were designed to meet requirements for NOAA hydrographic standards and in accordance with IHO S-44 6th Edition Order 1a survey (International Hydrographic Organization, 2020 & NOAA Office of Coast Survey, 2021). Throughout the survey area, parallel lines were planned several days prior to surveying and generally run in an along-channel orientation, but variation was necessary for highly dynamic areas such as coves, ledges, and mooring fields. Lines were spaced at consistent intervals to obtain a minimum of 30% overlap between full swaths. Soundings from beam angles outside of ± 60 degrees from the nadir were blocked from visualization during acquisition, thus increasing the true minimum full-swath overlap. This online blocking filter was recommended by QPS field engineers with the intent of eliminating noisy outer beams from the final product, thereby increasing the overall contribution of higher quality soundings. All data were acquired at approximately 6.5-7 knots, although some areas required slower speeds to ensure safe operation of the vessel around obstructions, fishing operations, or in especially rough conditions. When in shallow waters, survey lines were run parallel to the shoreline and moved landward until outer swath depths reached soundings of 5 meters for navigational safety throughout the entire survey area. Any depths not reaching the minimum value of 5 meters are the result of areas where attempting to do so would endanger the vessel and/or her crew.

2.6 Calibrations

Patch tests were conducted aboard the F/V Amy Gale at the beginning of each survey effort as well as throughout data collection periods to correct for alignment offsets. For each patch test, a series of lines were run to determine the latency, pitch, roll, and heading offset following standard protocol (NOAA Office of Coast Survey, 2021). The patch test data were processed using the Qimera (v.2.0.0 through v.2.5.3) patch test tool. After calibration was complete, offsets (Table 4) were entered into the template database in Qinsy. Additional patch tests were conducted any time a system was removed or reinstalled throughout the survey season or if data disagreements were noticed between lines. Full built-in self-tests (BIST) were performed at semi-regular intervals throughout the season to determine if any significant deviations in background noise were present at the chosen survey frequency of 300KHz.

Table 4 - Casco Bay Patch test calibration offsets for EM2040C

	Offsets	Offsets	Offsets	Offsets	Offsets
Туре	07/15/19	07/28/21	12/07/21	06/21/22	02/14/23
Roll (degrees)	-0.430	0.363	0.049	-0.039	-0.060
Pitch (degrees)	2.270	-1.582	2.480	0.474	0.609
Heading (degrees)	-0.300	2.388	1.494	1.254	0.695

3.0 Quality Control

3.1 Crosslines

Due to high priority offshore efforts conducted concurrently by the survey team, crosslines were collected significantly delayed from survey area acquisition. Crosslines were collected for winter 2021-2022 data on 05/11/2022, 02/01/2023, and 04/12/2023. Crosslines for winter 2022-2023 data were collected on 04/12/2023. No crosslines were collected by the survey team during the 2019 acquisition period due to time constraints and the team was unable to allocate time to revisit this region after collection. As a result, crosslines were not acquired for this 2019 area at time of data delivery. If the team is able to return to this locus to complete crosslines, the results will be appended to this report. However, due to the strong agreement across the 2021-2022 and 2022-2023 survey areas which overlap this coverage, the belief of the survey team is that results would be similar to those collected for the remainder of the Casco Bay coverage (Figures 9 & 10, Tables 5 & 6).

Throughout the survey area, crosslines were run at no greater than 900m spacing and intersected with all survey lines between 60° and 90° in accordance with BOEM and NOAA requirements (Figure 8) (U.S. Department of the Interior, 2014 & NOAA Office of Coast Survey, 2021). Crosslines were filtered during post-processing to remove soundings outside 45 degrees from the nadir. After filtering, the two-dimensional surface area totaled approximately 6.5% of survey area coverage. Crossline sounding agreement with survey data was evaluated by using the crosscheck tool in Qimera version 2.5.3, which performs beam-by-beam statistical analysis. Due to the very large file size of the survey effort, the Qimera projects and, consequently, the crossline comparison was split into two separate analyses: one for 2021-2022 data and one for 2022-2023 data (see Figure 3 for coverage).

For 2021-2022 data, the mean difference between soundings was 0.016 meters with a standard deviation of 0.221 meters; 95% of all differences were less than 0.458 meters from the mean (Figure 9).

For 2022-2023 data, the mean difference between soundings was 0.023 meters with a standard deviation of 0.055 meters; 95% of all differences were less than 0.139 meters from the mean (Figure 10).

Summary statistics for these analyses are shown in Tables 5 & 6, respectively. Additional statistical plots are reported in Appendix G. Raw difference data, reference surfaces, and sonar files used for this analysis were submitted with the data in this survey package.

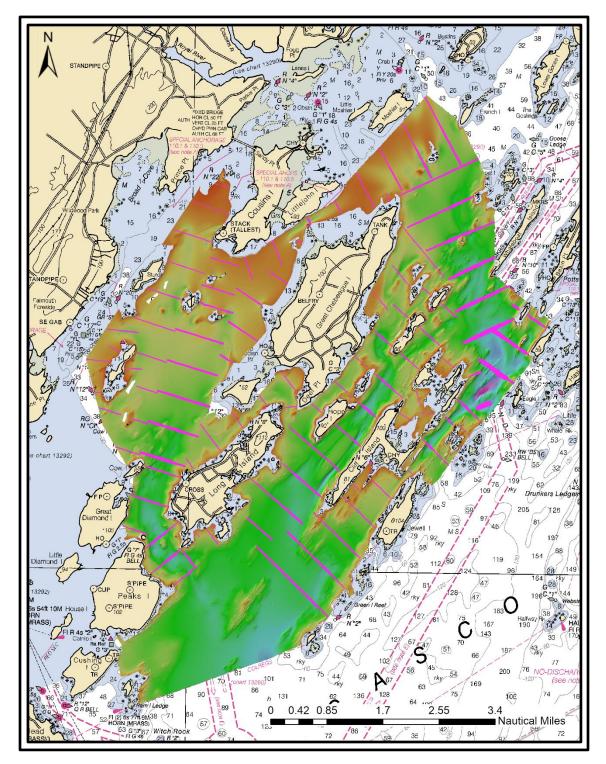


Figure 8 – Location of crosslines (depicted in magenta, with beams filtered outside $\pm 45^{\circ}$) atop bathymetry data

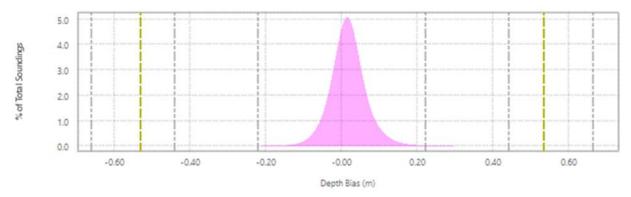


Figure 9 – 2021-2022 crosslines difference histogram; pink areas represent the 95% confidence interval based on normal distribution; yellow dashed lines represent limit of IHO Order 1 test vertical tolerance; gray dashed lines on histogram represent \pm sigma 1, 2, and 3

Table 5 – 2021-2022 Crossline difference (Qimera crosscheck) summary statistics

# of Points of Comparison	36843319		
Data Mean	-14.073442 m		
Reference Mean	Mean -14.090392 m		
Difference Mean	erence Mean 0.016949 m		
Difference Median	an 0.016949 m		
Std. Deviation	0.220901 m		
Data Z - Range	-51.25 m to -1.62 m		
Ref. Z - Range	-48.29 m to -4.27 m		
Diff Z - Range	-22.67 m to 5.86 m		
Mean + 2*stddev	0.458752 m		
Median + 2*stddev	0.458752 m		
Order 1a Error Limit	0.532497 m		
Order 1a P-Statistic	0.000411		
Order 1a - # Rejected	15161		
Order 1a Survey	ACCEPTED		

*Order 1a parameters: a = 0.25 and b = 0.013

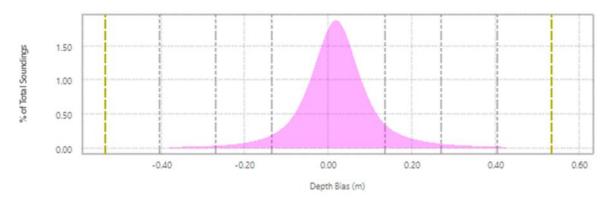


Figure 10 - 2022-2023 crosslines difference histogram; pink areas represent the 95% confidence interval based on normal distribution; yellow dashed lines represent limit of IHO Order 1 test vertical tolerance; gray dashed lines on histogram represent ±sigma 1, 2, and 3

# of Points of Comparison	41453232
Data Mean	-14.584082 m
Reference Mean	-14.607001 m
Difference Mean	0.022919 m
Difference Median	0.022919 m
Std. Deviation	0.055444 m
Data Z - Range	-40.19 m to -3.36 m
Ref. Z - Range	-39.08 m to -3.43 m
Diff Z - Range	-4.08 m to 2.25 m
Mean + 2*stddev	0.133807 m
Median + 2*stddev	0.133807 m
Order 1a Error Limit	0.534844 m
Order 1a P-Statistic	0.000213
Order 1a - # Rejected	8840
Order 1a Survey	ACCEPTED
~	

*Order 1a parameters: a = 0.25 and b = 0.013

3.2 Junctions

Junctions were not computed for the surveys described in this report due to the inability to access data of existing survey areas by the time of writing. The strong agreement of MCMI survey data across the collection effort spanning 4 calendar years and several remobilizations of the survey vessel, as well as the consistency shown by crossline analysis, lead this survey team to believe that these data would agree with the highest quality datasets that exist within the region. Junction analysis may be completed by the survey team and have the results appended to this report should they become available following submission.

3.3 Uncertainty

HydrOffice QC Tools v.3.9.0 Grid QA feature was used to analyze the highest resolution surfaces for compliance with NOAA allowable uncertainty standards. 99.74%, 99.81%, and 99.94% of all nodes met uncertainty specifications for W00648_1, W00648_2, and W00648_3, respectively. These results are sufficient to pass allowable TVU for the survey areas. Detailed results from the analyses are shown in Figures 11, 12, and 13 below. Uncertainty surface layers are provided with all BAG files submitted with this report.

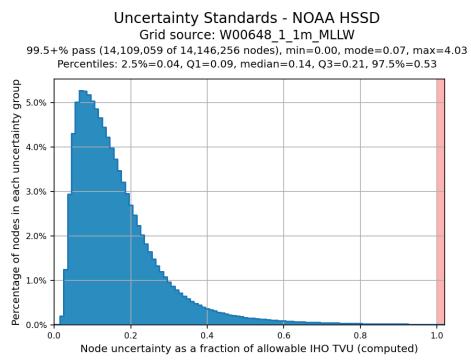


Figure 11: Allowable uncertainty statistics for 2019 Casco Bay coverage (W00648_1)

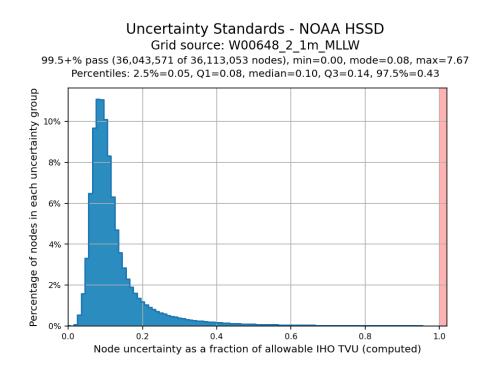


Figure 12: Allowable uncertainty statistics for 2021-2022 Casco Bay coverage (W00648_2)

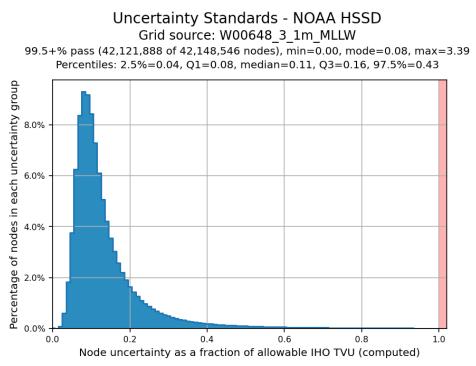


Figure 13: Allowable uncertainty statistics for 2022-2023 Casco Bay coverage (W00648_3)

3.4 Equipment Effectiveness

Sonar

Sonar data were acquired with a Kongsberg EM2040C set to a survey frequency of 300 kHz, high-density beam forming, with 400 beams per ping. Although the EM2040C allowed full swath widths at this frequency, lines from previous years' survey run at comparable depths contained considerable noise in outer beams (> \pm 60 degrees from the nadir as identified by QPS engineers). As a result (and as per QPS recommendation), soundings greater than \pm 60 degrees from the nadir were not included in final bathymetric surfaces.

Wobble

Prior to November 11, 2022, significant wobble can be observed in the outer swaths of bathymetry data collected by MCMI when mapping in rougher sea states, including select data in this submission. This wobble was investigated throughout the 2021 and 2022 seasons. Following several cooperative investigations with QPS and Kongsberg engineers, the following changes were implemented: 1.) Motion latency offset of +0.018s was applied 2.) RTK configuration changed in Qinsy computation setup (seen in Appendix F) 3.) Datagram output for attitude and velocity from Seapath to Qinsy was increased from 10 Hz to 50 Hz. These changes resulted in a dramatic decrease in motion artifacts noted in outer swaths in rougher sea states, but some artifacts may still be observed. Not all artifacts could be removed retroactively through these adjustments, but the hydrographer attempted to improve all data possible through these means. These artifacts should not significantly impact the confidence in sounding data and all products submitted should still supersede previous data in the area.

Lambert's Law for Intensity

Prior to January 25, 2023, the setting in EM Controller for Lambert's Law was set to OFF (Default). Following discussions with Kongsberg engineers regarding the mechanics of this setting and after a test comparing data in an area when OFF versus when ON, the setting was changed permanently to ON (Appendix E). This has allowed for more accurate backscatter returns which enables better substrate modeling and more refined sediment characterization efforts. Datasets after changing the setting maintain agreement with older data collected by the program but show improved definition of substrate transitions and throughout regions of uniform substrate.

3.5 Sound Speed Methods

Sound speed cast frequency: A total of 362 sound speed casts were taken within the boundaries of the W00648 survey area. All sound speed cast measurements were collected using the Teledyne Odom Digibar-S profiler. Sound speed casts were taken as needed throughout the survey, which was generally when the observed surface sound speed (monitored and visualized in real-time using the AML Micro X SV sensor) differed from the surface sound speed in the active profile by more than 2 meters per second. In certain instances, supplemental casts were taken when there was reason to suspect significant changes in the water column (e.g. change in tide, abrupt changes in seafloor relief, etc.). During the collection of sound speed casts, logging was stopped to download and apply the new cast and was resumed when the boat circled around and came back on the survey line. Throughout the duration of the survey, the surface sound speed was observed in real-time (by the AML Micro X SV probe). Sound speed data are recorded and included in raw sonar files submitted with this data package.

A quality comparison between the AML Micro X SV sensor and the Teledyne Odom Digibar-S profiler was not performed. However, real-time comparisons between surface sound speed observed by the AML Micro X SV and the surface sound speed entry in the Digibar-S profile suggested these instruments agreed. Annual calibrations were conducted for both sensors by original manufacturers to ensure performance within manufacturer defined standards.

4.0 Data Post-processing

The following is a summary of the procedures used for post-processing and analysis of survey data using Qimera (v.2.0.0 through v.2.5.3, 64-bit edition) and Fledermaus (v.8.4.0 through v.8.5.1, 64-bit edition) software.

4.1 Horizontal Datum

The horizontal datum for these data is WGS 84 projected in UTM zone 19N (meters) (EPSG 32619).

4.2 Vertical Datum and Water Level Corrections

The vertical datum for these data is mean lower-low water (MLLW) level in meters. A tidal zoning file ("Maine_Tide_Zoning_modified.zdf") containing time and range corrections for verified tide station data was provided by NOAA OCS to MCMI in May 2020. This file was used to apply time corrections, tide height offsets, and tide scale (range) for collected data in each zone listed in Table 7 and shown in Figure 14.

Survey Area	Tide Station	Zone ID	Time Correction (mins.)	Tide Offset (m)	Tide Scale
Casco Bay	8418150	ME20	0	0	1.00
Casco Bay	8418150	ME78	0	0	0.99
Casco Bay	8418150	ME55	0	0	0.98
Casco Bay	8418150	ME91	-6	0	0.97
Casco Bay	8418150	ME69	0	0	0.98
Casco Bay	8418150	ME81	0	0	0.99

Table 7 - Tide zones and corrections referenced to verified Portland, ME (8418150) tide station data

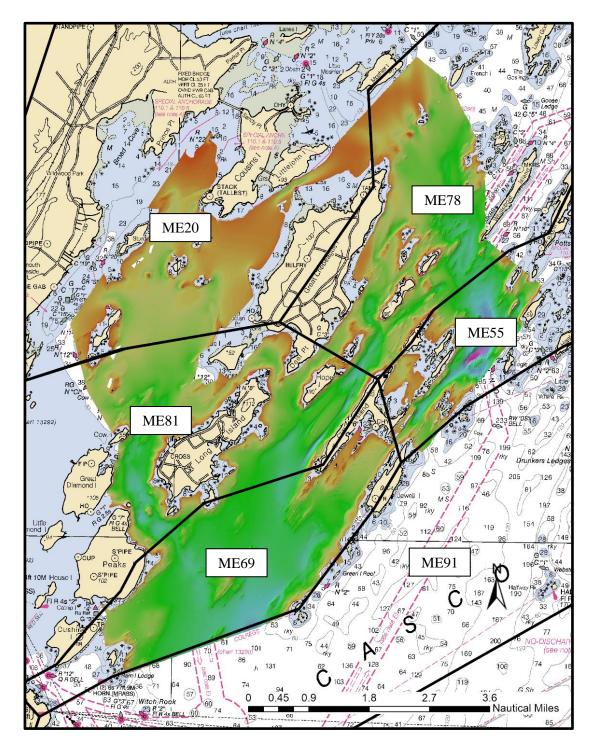


Figure 14 - Tide zones (outlined in black) relative to survey extent

4.3 Processing Workflow

The general post-processing workflow in Qimera was as follows:

- 1. Create project
- 2. Add raw sonar files (e.g. metadata extracted and processed bathymetry data converted to .qpd, including vessel configuration and sound velocity)
- 3. Apply sound velocity profiles via real-time scheduling or by distance/time, contingent upon region surveyed and local conditions
- 4. Add tide zoning file (.zdf) and associated tide data and integrate into raw files
- 5. Create dynamic surface with NOAA CUBE settings enabled for desired resolution (e.g. 2-meter, 4 meter)
- 6. Review and edit soundings/clean surface with slice editor tool, 3D editor tool, and available filters
- 7. Duplicate surfaces at other grid sizes, if desired
- 8. Export final surface to .BAG surface
- 9. Export processed data in .GSF format for backscatter processing

<u>CUBE</u>

A CUBE (Combined Uncertainty and Bathymetry Estimator) surface was created for editing and as a starting point for final products. The corresponding NOAA cube setting (e.g. "NOAA_4m" configuration, Figure 15) was selected for each surface depending on the grid size of the surface.

CUBE Settings	? ×			
Configuration NOAA_4m				
CUBE Capture Distance: Distance Scale: 5.00				
Distance Min: 2.828				
CUBE Hypothesis Resolution Algorithm : Number of Samples				
Estimate Offset:	4.00			
Horizontal Error Scale: 1.96				
Advanced <<				
Distance Exponent:	2.00			
Queue Length:	11			
Quotient Limit:	255.00 1.00 0.135			
Discount Factor:				
Bayes Factor Threshold:				
Run Length Threshold:	5			
	OK Cancel			

Figure 15 - CUBE settings parameters window shown with settings for NOAA 4-meter grid resolution

4.4 Final Surfaces

The following surfaces were submitted with the survey data. Each BAG file contains the CUBE-processed sounding surface layer and an uncertainty layer. The data submission package is split into three different sections due to the large size of each project and significant temporal difference in acquisition period. W00648_1 surfaces correspond to data collected in the 2019 survey effort, W00648_2 surfaces correspond to data collected in the 2019 survey effort, W00648_3 surfaces correspond to data collected in the 2022-2023 survey effort (Figure 3).

Surface Name	Resolution (m)	Depth Range (m)	Surface Parameter
W00648_1_1m_MLLW	1	2 - 47	N/A
W00648_1_2m_MLLW	2	2 - 47	N/A
W00648_1_4m_MLLW	4	2 - 47	N/A
W00648_2_1m_MLLW	1	1 - 59	N/A
W00648_2_2m_MLLW	2	1 - 59	N/A
W00648_2_4m_MLLW	4	1 - 59	N/A
W00648_3_1m_MLLW	1	1 - 57	N/A
W00648_3_2m_MLLW	2	1 - 57	N/A
W00648_3_4m_MLLW	4	1 - 57	N/A

Table 8 – Bathymetry surfaces submitted for Casco Bay survey data

4.5 Backscatter

Backscatter data was logged in raw .db files during acquisition. The .db files also hold the navigation record and bottom detections for all lines of surveys. Processed sonar files containing multibeam backscatter data (snippets and beam-average) were exported from Qimera in .GSF format. QPS Fledermaus Geocoder Toolbox (FMGT; v.7.8.6 through v.7.10.2, 64-bit edition) was used to import, process, and mosaic time-series backscatter data. Default backscatter processing settings were used to create the mosaic, except for the Angle Varied Gain (AVG) filter and AVG window size, which were set to 'Adaptive' and '100', respectively. Backscatter mosaics of the data were gridded at 1-meter, 2-meter, and 4-meter resolutions. Survey data were split by season of acquisition and delivered as separate files for file management purposes, as well as to keep discrepancies across datasets contained within acquisition timeframes. Mosaics were exported in floating-point GeoTIFF format. The mosaics are shown in Table 9 and Figure 16.

Mosaic Name	Pixel Size (m)
W00648_1_1m_MLLW	1
W00648_1_2m_MLLW	2
W00648_1_4m_MLLW	4
W00648_2_1m_MLLW	1
W00648_2_2m_MLLW	2
W00648_2_4m_MLLW	4
W00648_3_1m_MLLW	1
W00648_3_2m_MLLW	2
W00648_3_4m_MLLW	4

Table 9 - Backscatter mosaics submitted for Casco Bay survey data

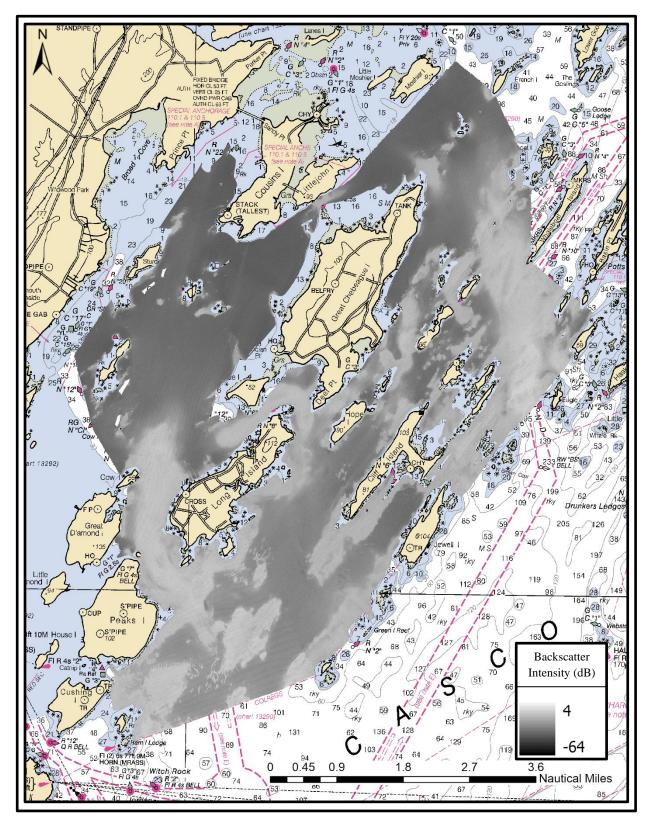


Figure 16 - Backscatter mosaic (1-meter pixel size) of Casco Bay coverage atop NOAA chart 13288

5.0 Results

5.1 Charts Comparison

The hydrographer conducted a qualitative comparison of reclassified bathymetry data and depth contours from the surveyed area to the charted soundings and contours. The largest scale raster navigational charts which cover the survey areas are listed in Table 10. Prior hydrographic surveys in the vicinity were conducted by NOAA in 1941, 1998, and 2000. These data were not compared with data collected by the MCMI. Chart comparisons shown in figures are provided at the largest scale available. Charts at coarser resolution will show similar differences as seen in the largest scale charts.

Chart	Scale	Source Edition	Source Date	NTM Date
13288	1:80,000	44	02/2016	5/30/2023
13290	1:40,000	41	10/2019	5/30/2023
13292	1:20,000	42	06/2018	5/30/2023

Table 10 - Largest scale raster charts in survey area

Chart 13288

Surveyed depths have good overall agreement with charted apart from a notable deep region northwest of Eagle Island where the channel reaches 57 meters and extends at depth further to the west than charted, with values exceeding 50 meters where charts indicate 37-38 meters (Figure 26). This disagreement is most likely due to a changing topology from strong bottom boundary layer dynamics since the last survey, which was over 80 years prior to the efforts described in this report. All other depths show strong agreement with contours showing only minor discrepancies in placement throughout the survey area. It is recommended that contours showing disagreement in this area be revised based on the findings of this report.

Chart 13290

Surveyed depths have good overall agreement with charted contours apart from a deep region northwest of Eagle Island where the channel reaches 57 meters and extends at depth further to the west than charted, with values exceeding 50 meters where charts indicate 37-38 meters (Figure 26). This disagreement is most likely due to a changing topology from strong bottom boundary layer dynamics since the last survey, which was over 80 years prior to the efforts described in this report. All other depths show strong agreement with contours showing only minor discrepancies in placement throughout the survey area. It is recommended that contours showing disagreement in this area be revised based on the findings of this report.

Chart 13292

Surveyed depths have good overall agreement with charted contours, but minor discrepancies in placement exist throughout the survey area. It is recommended that contours showing disagreement in this area be revised based on the findings of this report.

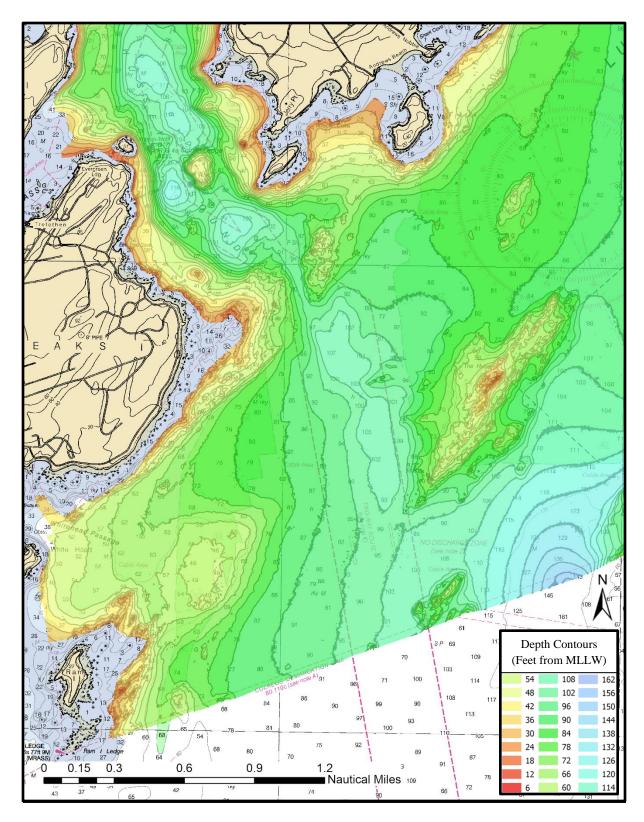


Figure 17 – South of Hussey Sound comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

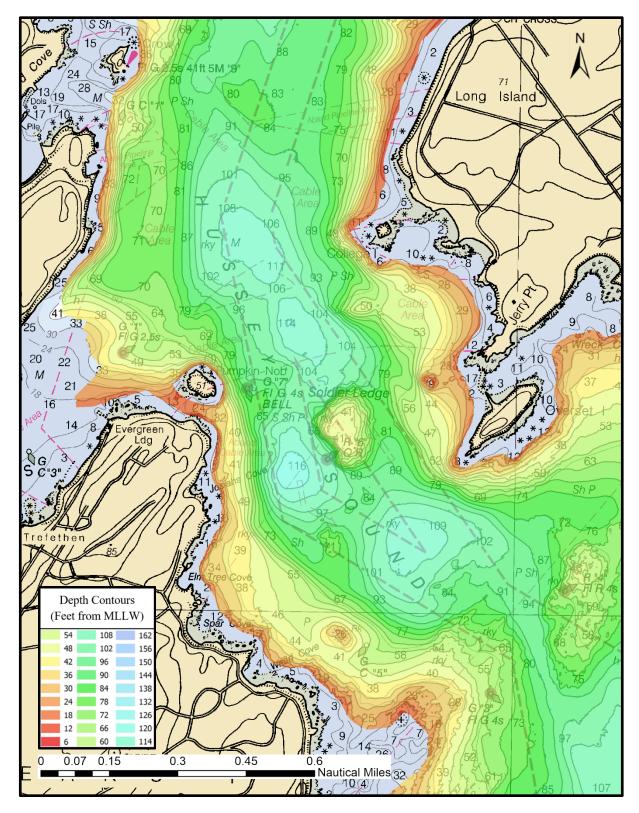


Figure 18 – Hussey Sound comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

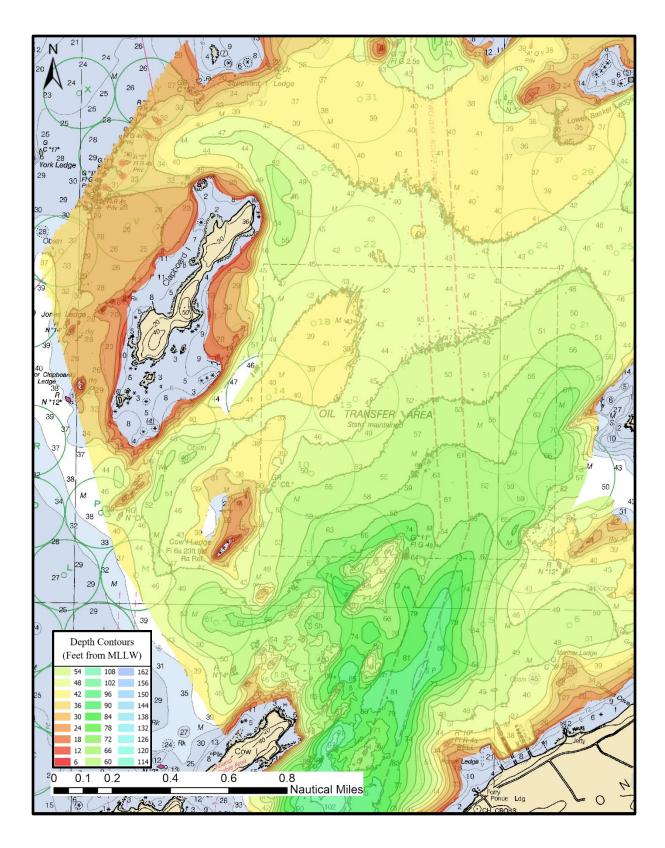


Figure 19 – North of Hussey Sound comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

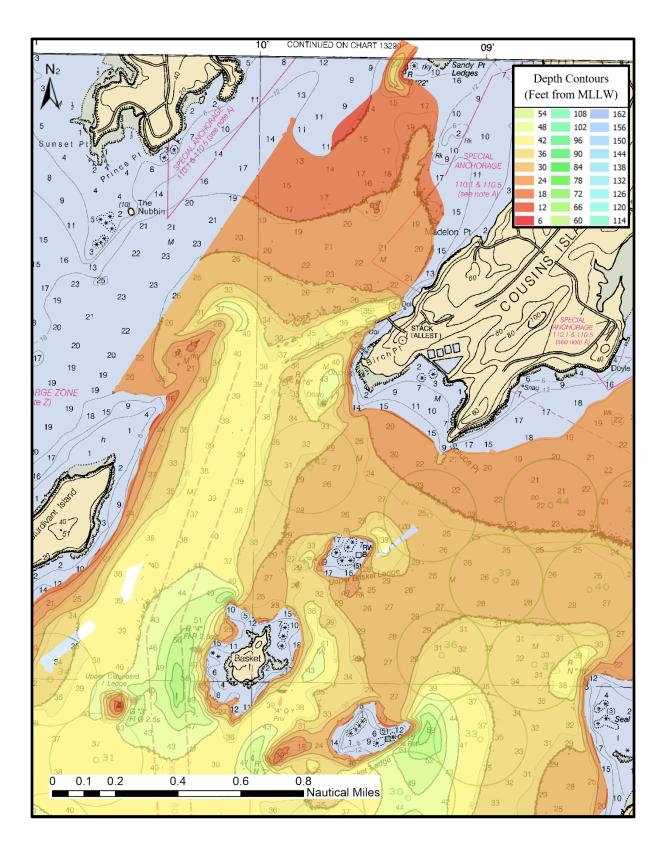


Figure 20 – South of Cousins Island comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

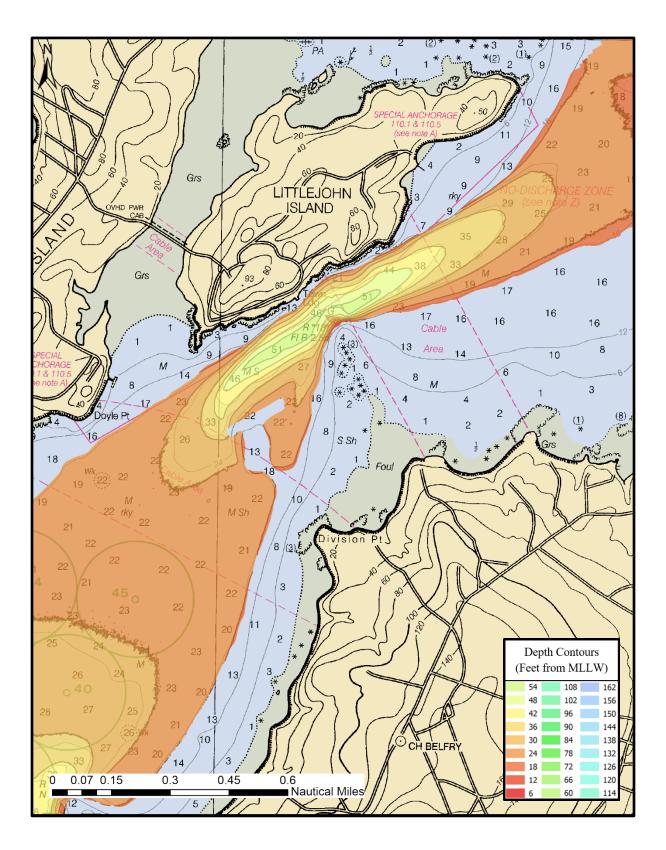


Figure 21 – Littlejohn Island channel comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

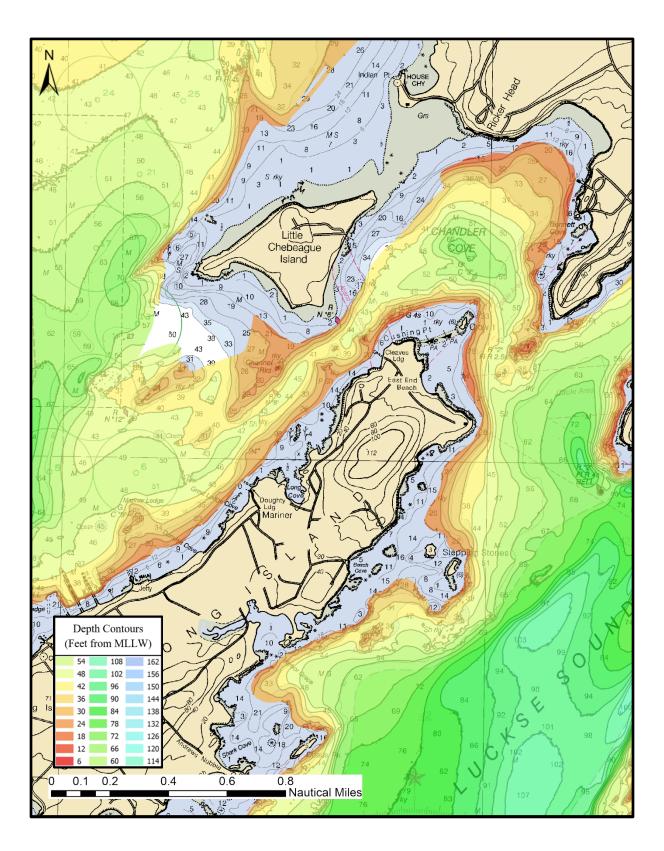


Figure 22 – Chandler Cove comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

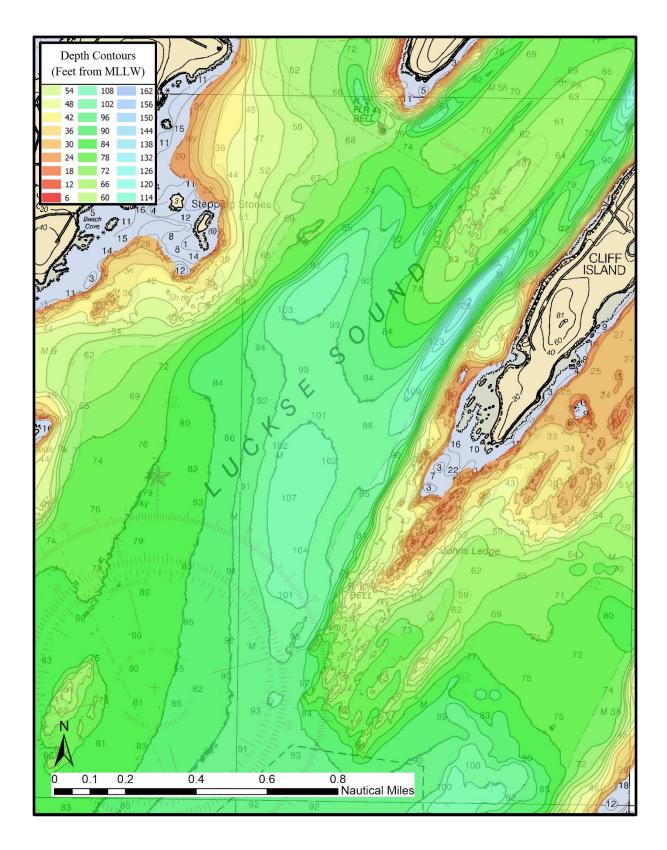


Figure 23 – Luckse Sound SW comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

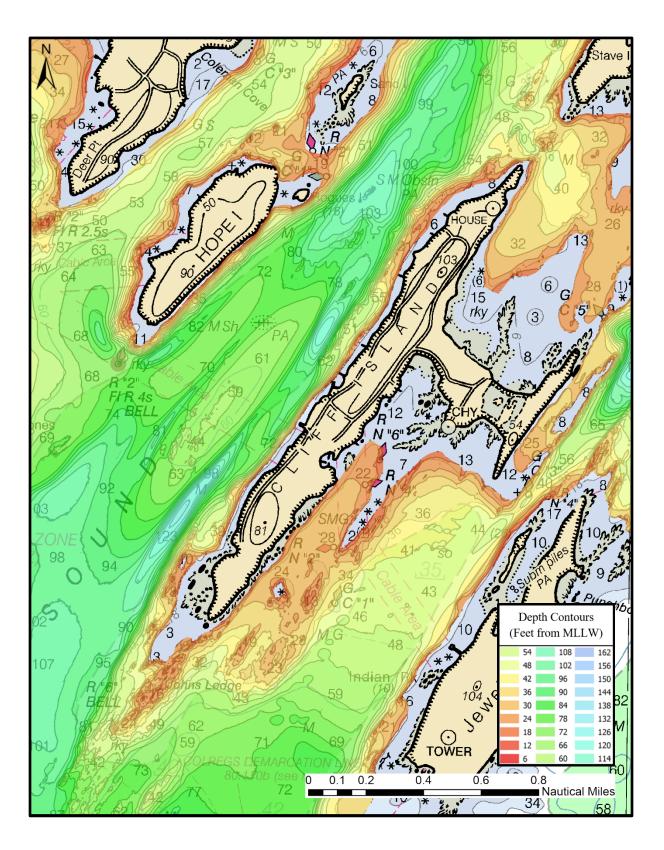


Figure 24 – Luckse Sound SW comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

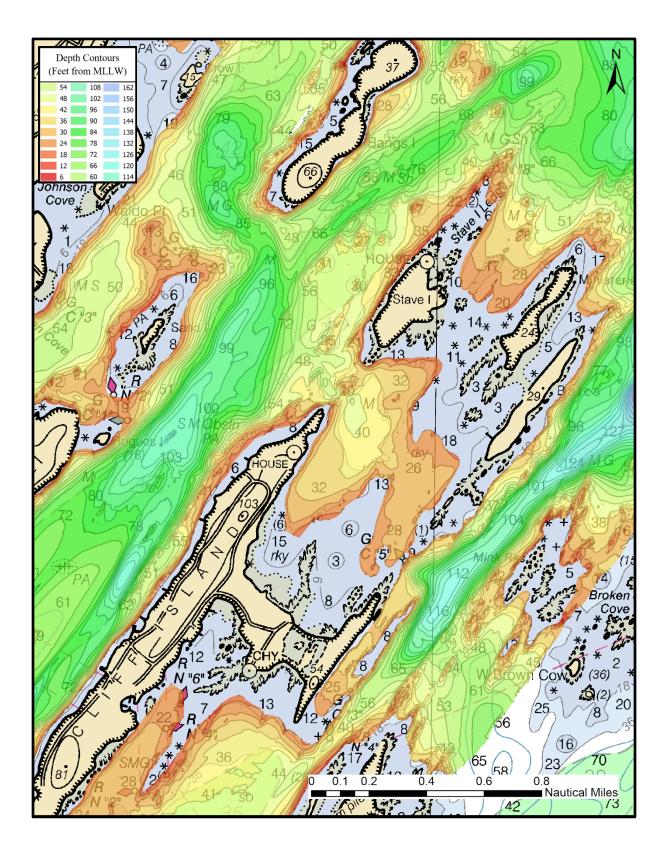


Figure 25 – Luckse Sound and Cliff Island comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

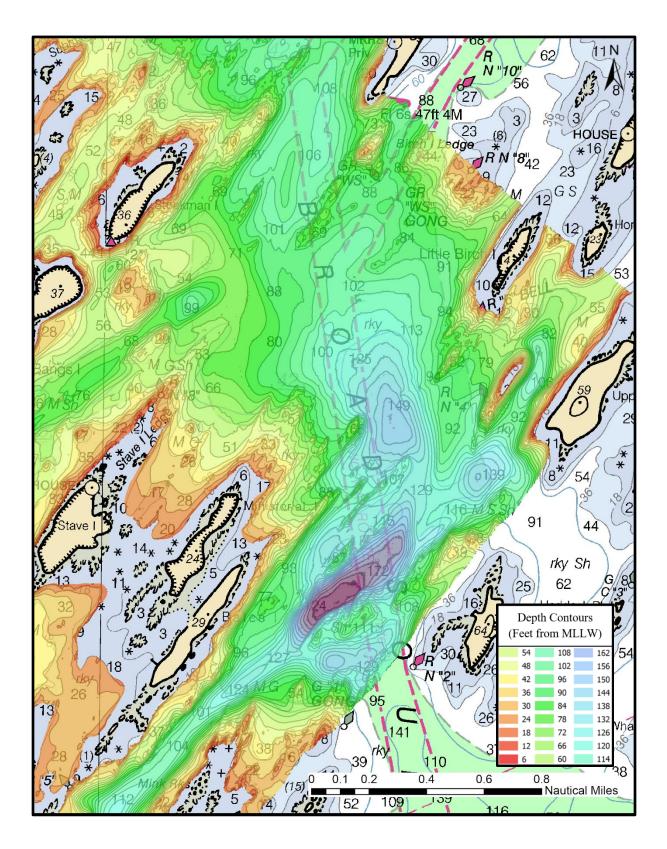


Figure 26 – Broad Sound to Eagle Island comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

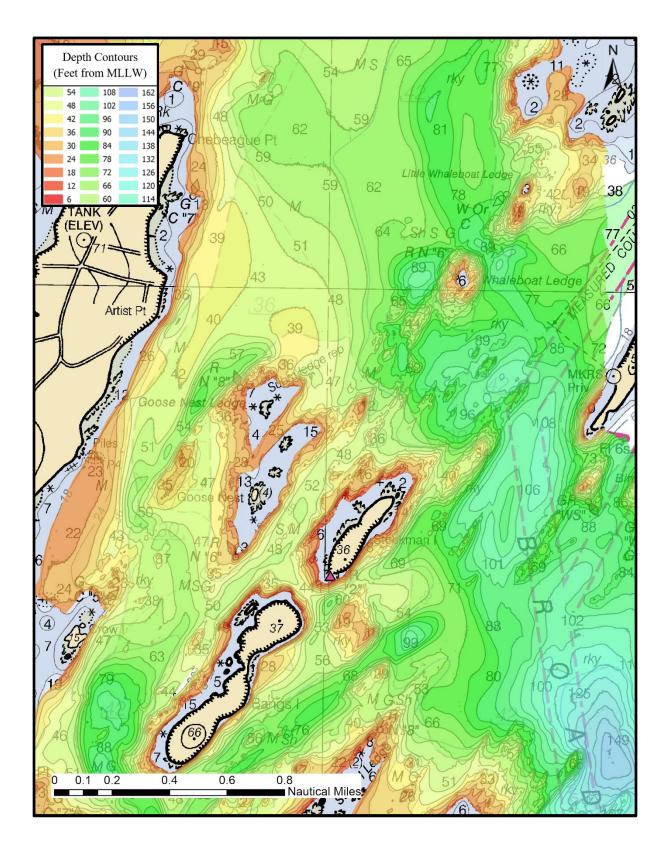


Figure 27 – Luckse Sound meets Broad Sound comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

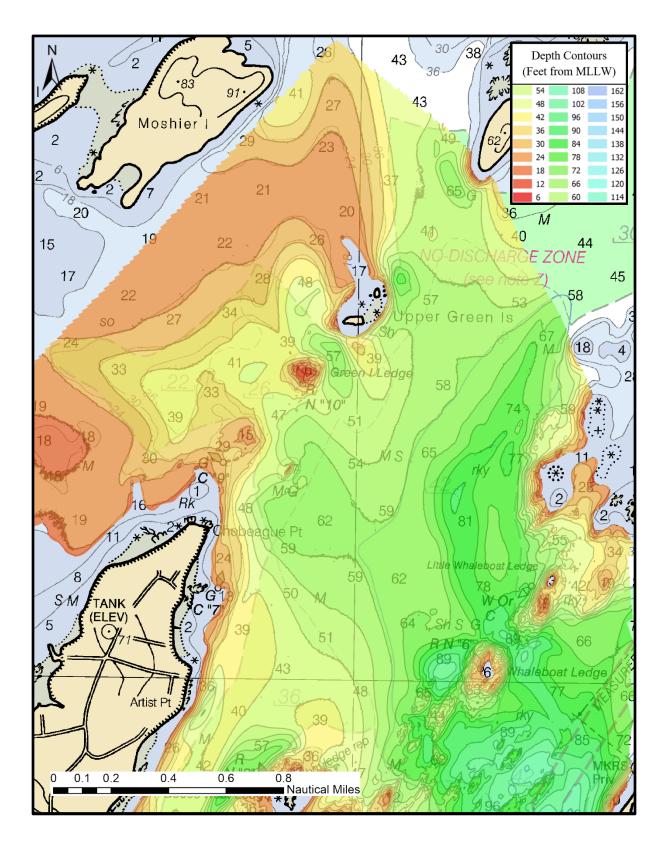


Figure 28 – Broad Sound to Whaleboat Ledge comparison between surveyed depth (reclassified at 6-feet intervals) and chart 13292 contours (6-feet interval in shoals)

5.2 Bottom Samples

A total of 71 bottom sampling sites were planned for collection throughout the course of the acquisition effort in state and federal waters to supplement existing sediment data collected previously by other agencies (Maine Geological Survey and University of Maine) in and surrounding the survey area (Figure 29). A total of 69 sites were successfully completed, with 54 retrieving sediment samples for analysis. The results of grain-size and video analyses will be used to calibrate, refine, and digitize interpretations of seafloor substrate. These data are also used to investigate how these data relate to benthic infauna in the survey area.

Additional details on the bottom samples are provided in Table 11. More detailed analysis of grain size composition of these samples and benthic fauna composition will be determined after laboratory processing is complete for the collected samples. Metadata sheets for all bottom samples are provided as part of the submitted data package accompanying this report.

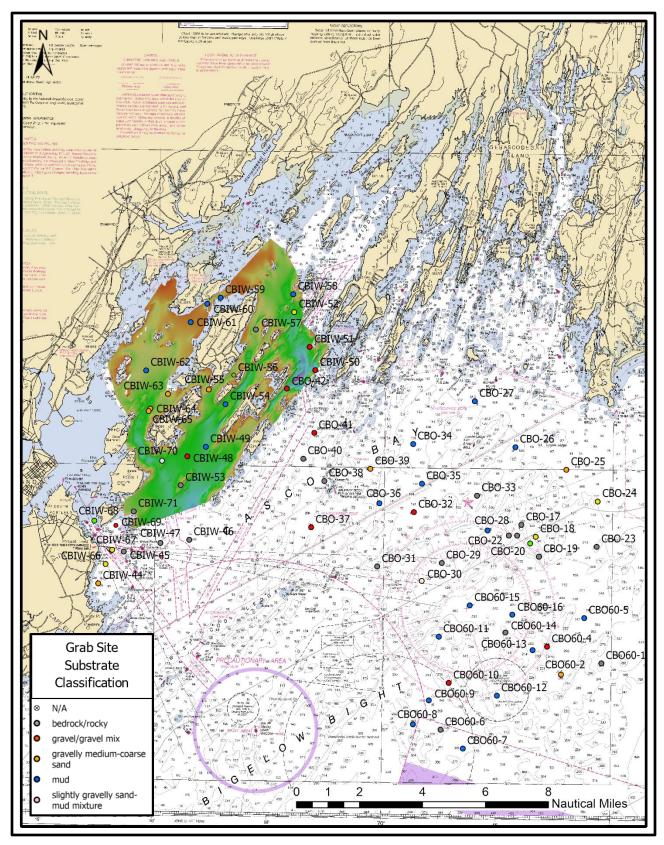


Figure 29 – Bottom sample locations collected over the course of the MCMI 2021 survey season in Casco Bay. Sites classified via the modified CMECS 7-class scheme from field observations (Appendix H).

Site Name	Date	Latitude (decimal degrees N)	Longitude (decimal degrees W)	Depth (m)	Grain size (field observation)	Backscatte Intensity (dB)
CBO60-1	07/14/2021	43.56434874	-69.84043317	86.7	rock	-8.91
CBO60-2	07/14/2021	43.55819487	-69.86976905	80	gravelly muddy sand	-10.16
CBO60-4	07/14/2021	43.57289778	-69.88005763	66.2	muddy gravel	-5.75
CBO60-5	07/14/2021	43.58825363	-69.8532413	89.3	mud with shell hash	-23.39
CBO60-6	07/27/2021	43.5282881	-69.95701022	83.1	rock	-8.59
CBO60-7	07/27/2021	43.51850195	-69.94063984	103	silty mud with trace sand	-15.2
CBO60-8	07/27/2021	43.53101614	-69.97704435	89.2	clayey sandy mud with trace sand and gravel	-13.63
CBO60-9	07/27/2021	43.54387055	-69.96571119	105	silty mud with trace sand	-17.41
CBO60-10	07/27/2021	43.5531374	-69.95139053	69.8	sandy gravel with mud, assumed atop rock due to low yield	-7.64
CBO60-11	07/27/2021	43.57756521	-69.95907309	93.6	silty mud with trace sand	-20.56
CBO60-12	08/04/2021	43.54665962	-69.91629933	95.8	silty mud with trace sand	-20.87
CBO60-13	08/04/2021	43.57100557	-69.89058881	85.7	clayey silty mud with trace sand	-18.98
CBO60-14	08/04/2021	43.58018277	-69.91054073	70.2	rock	-5.44
CBO60-15	08/04/2021	43.59433163	-69.93672223	88.3	clayey mud with trace sand	-22.76
CBO60-16	08/04/2021	43.58970106	-69.90562112	89.6	clayey silty mud with trace sand	-20.56
CBO-17	08/10/2021	43.63726057	-69.89973456	39	rock	-9.22
CBO-18	08/10/2021	43.63104394	-69.88925266	45.4	sand with shell hash and trace gravel	-8.27
CBO-19	08/10/2021	43.62049572	-69.88679743	42	rock	3.07
CBO-20	08/10/2021	43.62743115	-69.89315061	60	clayey muddy sand	-13.31
CBO-21	08/10/2021	43.63160203	-69.902709	48	rock	-4.49
CBO-22	08/10/2021	43.63144262	-69.90886332	38	surficial gravel atop rock	-11.11
CBO-23	09/01/2021	43.62601626	-69.84461578	52.7	rock	Unavailab
CBO-24	09/01/2021	43.65006997	-69.84423635	37.2	sand	Unavailab
CBO-25	09/01/2021	43.66673057	-69.86737224	31.7	gravelly sand with shell hash	Unavailab
CBO-26	09/01/2021	43.67838093	-69.90477437	42.3	silty clayey mud	Unavailab Unavailab
CBO-27 CBO-28	09/01/2021	43.70244163 43.634098	-69.93472201 -69.92430233	36.3 60.9	clayey mud	-16.15
CBO-28 CBO-29	09/14/2021	43.6165869	-69.95750871	40.4	clayey mud with trace sand and gravel rock	-10.13
CBO-29 CBO-30	09/14/2021	43.60703578	-69.97187846	52.6	gravelly sandy mud with shell hash	-12.03
CBO-30 CBO-31	09/14/2021	43.61436553	-70.00449403	43.7	rock	Unavailab
CBO-31 CBO-32	09/14/2021	43.6433754	-69.97824097	43.7	muddy gravel with shell hash	Unavailab
CBO-32 CBO-33	09/14/2021	43.65246427	-69.9322708	41.9	surficial mud and shell hash atop rock	Unavailab
CBO-33 CBO-34	09/21/2021	43.6794123	-69.9794058	49.8	clayey mud with trace fine sand	Unavailab
CBO-34 CBO-35	09/21/2021	43.65844131	-69.97264017	55.6	clayey mud with trace fine sand	Unavailab
CBO-36	09/21/2021	43.64777554	-70.00341145	55.1	clayey mud with trace coarse grain sand and gravel	Unavailab
CBO-37	09/21/2021	43.63466854	-70.05312236	42.3	muddy gravel with coarse sand	Unavailab
CBO-38	09/21/2021	43.65930149	-70.04387337	39.3	surficial shell hash atop rock	Unavailab
CBO-39	09/21/2021	43.66597099	-70.01033069	52.2	gravelly muddy sand with shell hash	Unavailat
CBO-40	10/07/2021	43.6709336	-70.05945749	35.7	rock	Unavailab
CBO-41	10/07/2021	43.68471829	-70.05166945	60.3	muddy gravel	Unavailab
CBO-42	10/07/2021	43.707942	-70.072079	39.5	muddy gravel	Unavailab
CBIW-44	10/13/2021	43.60346	-70.207592	17.4	gravelly sand	Unavailab
CBIW-45	10/13/2021	43.620469	-70.18952	18.8	rock	Unavailab
CBIW-46	10/13/2021	43.627253	-70.141778	21.8	rock	Unavailab
CBIW-47	10/13/2021	43.625266	-70.162846	25.7	rock	Unavailab
CBIW-48	10/13/2021	43.67142	-70.144092	19.8	muddy gravel composed primarily of shell hash-pebble mix	Unavailab
CBIW-49	10/13/2021	43.676552	-70.130639	30.8	clayey mud with trace sand	Unavailab
CBIW-50	10/07/2021	43.71786	-70.05139	27.7	gravel	Unavailat
CBIW-51	10/07/2021	43.73013	-70.055711	29.9	muddy gravel with shell hash; large cobbles present	Unavailat
CBIW-52	10/07/2021	43.748517	-70.067306	29	medium to coarse grain sand with trace gravel	Unavailab
CBIW-53	10/19/2021	43.655987	-70.148463	14	rock	Unavailat
CBIW-54	10/19/2021	43.69927	-70.116656	22.6	silty mud with trace sand	Unavailat
CBIW-55	10/19/2021	43.706947	-70.12905	10.3	gravelly sand with shell hash	Unavailab
CBIW-56	10/19/2021	43.714675	-70.110828	17.5	N/A	Unavailat
CBIW-57	10/19/2021	43.739052	-70.095317	11.2	rock	Unavailat
CBIW-58	10/19/2021	43.757935	-70.068187	19.1	sandy mud with shell hash	Unavailat
CBIW-59	10/19/2021	43.755613	-70.121337	8.8	silty mud with trace sand	Unavailat
CBIW-60	11/03/2021	43.752286	-70.130831	13.8	silty clayey mud with trace sand	Unavailal
CBIW-61	11/03/2021	43.74242596	-70.14284794	9.7	clayey silty mud with trace sand	Unavailat
CBIW-62	11/03/2021	43.716613	-70.174988	15.3	silty mud	-35.98
CBIW-63	11/03/2021	43.70421848	-70.158677	12.7	muddy sand with gravel; large cobbles present	Unavaila
CBIW-64	11/03/2021	43.69636432	-70.171422	29	muddy sand with gravel	-14.57
CBIW-65	11/03/2021	43.69512988	-70.172774	26.8	muddy sand with gravel	-10.79
CBIW-66	11/09/2021	43.61377584	-70.202542	18.7	fine sand	Unavaila
CBIW-67	11/09/2021	43.62130717	-70.197911	15.3	fine sand	Unavaila
CBIW-68	11/09/2021	43.63655605	-70.211089	11.9	muddy sand with trace shell hash	Unavaila
CBIW-69	11/09/2021 11/09/2021	43.63436966 43.66881435	-70.19546	15.4 17.8	sandy gravel with shall hash; many large cobbles present shell hash; no mud visible in sample at all	Unavaila Unavaila
CBIW-70						

Note: Backscatter values were unavailable for several grab sites at time of deployment and are shown above.

5.3 Wrecks and Obstructions

Throughout the course of survey acquisition, three charted wrecks and one uncharted wreck were mapped by the survey team. The wrecks are referred to in this report by geographic location and are identified as follows: Clapboard Island wreck, Great Chebeague wreck, Chandler Cove wreck, and Stave Island wreck. Positions for Clapboard Island wreck, Great Chebeague wreck, and Chandler Cove wreck were previously charted, but the Stave Island wreck is believed to be a new finding.

The position of the Clapboard Island wreck, which was identified by previous surveys as a barge, was surveyed to be in the exact position indicated by charts 13290 and 13292 (Figure 30). Additionally, the obstruction identified to the east of this wreck was also found to be in the exact charted position. Depth soundings are in agreement with the charted figures.

The Great Chebeague and Chandler Cove wrecks were surveyed to be a significant distance from their charted positions (Figures 31 & 32). The Great Chebeague wreck is charted to be at 43.739973°N 70.101859°W and the surveyed position was recorded at 43.740378°N 70.099658°W. Least depths were unknown for this wreck and were ensonified to be 9.5 meters from MLLW. The Chandler Cove wreck is charted at 43.716221°N 70.135071°W and the surveyed position was recorded at 43.717276°N 70.129735°W. The soundings obtained from this survey found the least depths of this Chandler cove wreck were 2.55 meters below MLLW versus the charted 10.9 meters. Is it believed these discrepancies are due to potential drifting of the wrecks since first being observed. It is recommended by this survey team that relevant charts be updated with the new positions and depths following review by NOAA.

The Stave Island wreck was identified at 43.717884°N 70.081335°W and measured roughly 7 meters long by 2.5 meters wide (Figure 33). The wreck was found to be laying on her starboard side and the least depth was found to be roughly 4.6 meters from MLLW. It is recommended by this survey team that relevant charts be updated with the new wreck following review by NOAA.

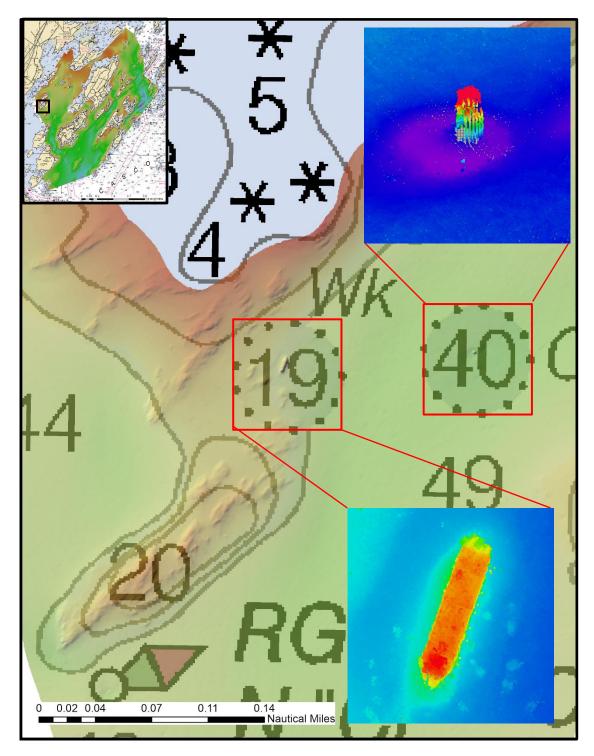


Figure 30 - Clapboard Island wreck and object mapped positions shown atop charted positions

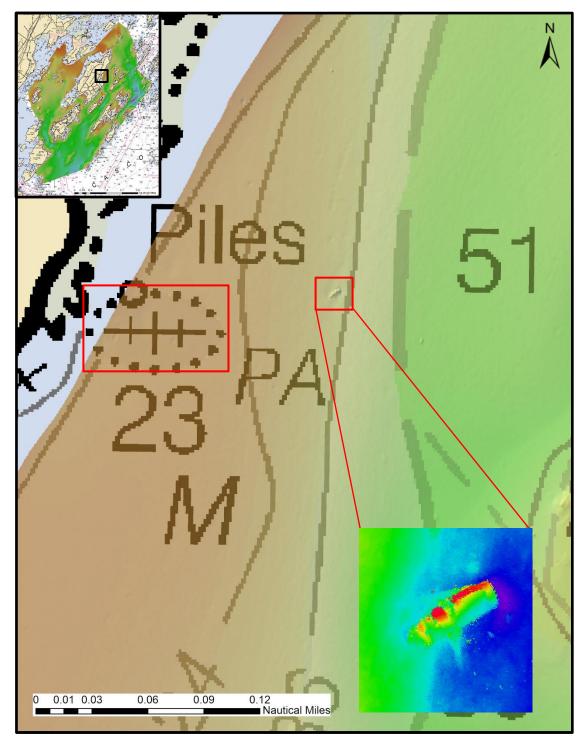


Figure 31 - Great Chebeague wreck mapped position shown atop charted position

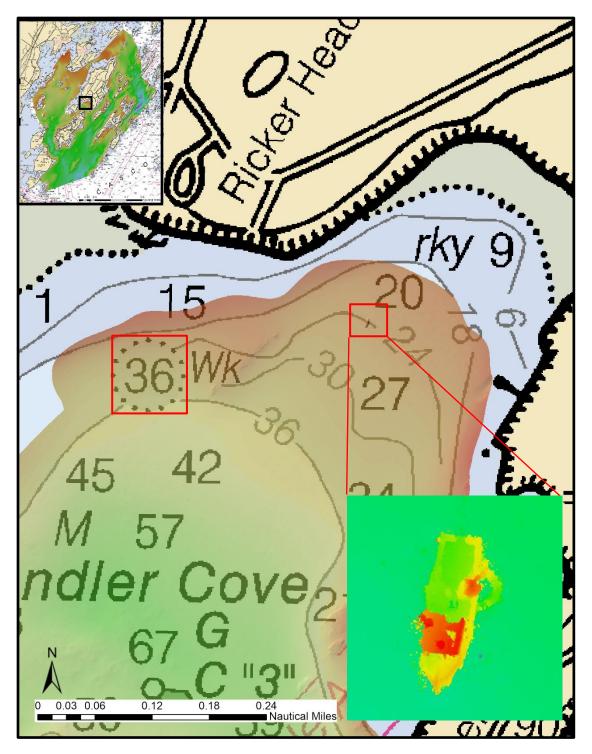


Figure 32 - Chandler Cove wreck mapped position shown atop charted position

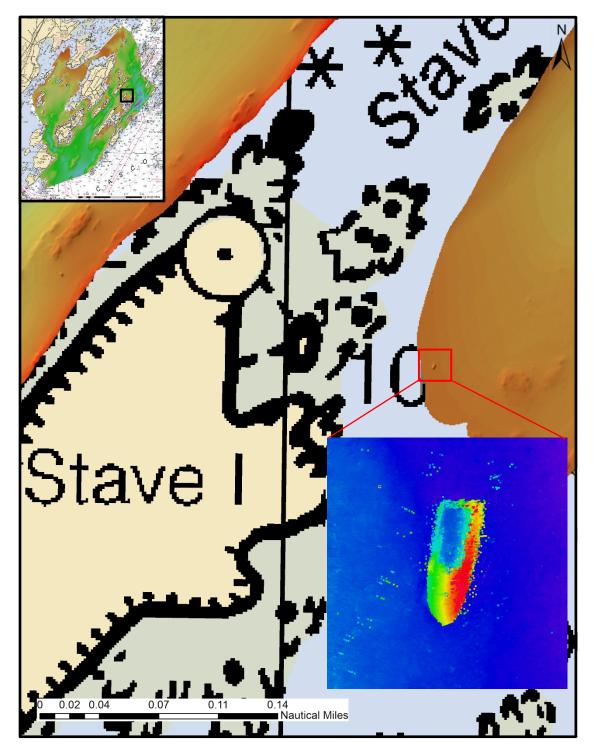


Figure 33 - Stave Island wreck mapped position

6.0 Summary

A total of 35.15 mi² (91 km²) of high-resolution multibeam data were collected throughout Casco Bay from July of 2019 to April of 2023. Except for select few small holidays due to seafloor elevation-induced sonic shadows and non-navigable areas throughout the survey area, multibeam coverage was 100% in all areas surveyed to the shallowest sounding of 5 meters wherever possible.

Bathymetry and backscatter data products were produced at 1-meter, 2-meter, and 4-meter grid resolution for the extent of the survey area. The bathymetry and backscatter information for the survey area are supplemented by seafloor surficial sediment samples, water column data, video, and benthic fauna collection in 69 locations.

Consistency of hydrographic data collected aboard the F/V Amy Gale was reflected in the results of the surface difference tests for crosslines, where mean vertical differences across tests were less than 0.025 meters, 95% of all nodes having maximum deviation of +/- 0.055 meters, and within allowable tolerances for IHO Order 1a and NOAA specifications at the depths ensonified. Standard deviations of all tests were relatively low and comparable to those achieved by small vessels in similar surveys of the area (e.g. *Ferdinand R. Hassler* and previous submissions by *Amy Gale*). Total vertical uncertainties for all areas surveyed were within tolerances for IHO Order 1a and NOAA specifications at all depths, where 99.74%, 99.81%, and 99.94% of all nodes fell within the allowable range for respective surfaces of W00648_1, W600648_2, and W00648_3.

Comparisons between survey data and the largest scale nautical charts in the vicinity show good agreement in most cases apart from a notable deep region northwest of Eagle Island where the channel reaches 57 meters and extends at depth further to the west than charted, with values exceeding 50 meters where charts indicate 37-38 meters. It is recommended that the corresponding charts be updated in this area to reflect these data, and that contours be adjusted throughout the survey area to the refined values delivered in these updated datasets.

These data were acquired and processed to meet Office of Coast Survey bathymetry standards as best as possible and were shared with the NOAA Office of Coast Survey for review.

Please contact the Maine Coastal Program's Research Coordinator for additional information or data requests.

References

International Hydrographic Organization (2020) IHO Standards for Hydrographic Surveys, Edition 6.0.0, September 2020. Monaco, International Hydrographic Organization, 41pp. (International Hydrographic Organization Special Publication, S-44). DOI: https://doi.org/10.25607/OBP-1354.2

NOAA. (2021). NOS hydrographic surveys specifications and deliverables: U.S Department of Commerce National Oceanic and Atmospheric Administration. 162pp.

NOAA, Office of Coast Survey (2021). Field Procedures Manual, February 2021. Silver Spring, MD, National Oceanic and Atmospheric Administration, Office of Coast Survey, 165pp. DOI: http://dx.doi.org/10.25607/OBP-153.3

U.S. Department of the Interior (2014). Proposed geophysical and geological activities in the Atlantic OCS to identify sand resources and borrow areas north Atlantic, mid-Atlantic, and south Atlantic-Straits of Florida planning areas, *final environmental assessment*. OCS EIS/EA BOEM 2013-219 U.S. Department of the Interior Bureau of Ocean Energy Management Division of Environmental Assessment Herndon, VA, January 2014.

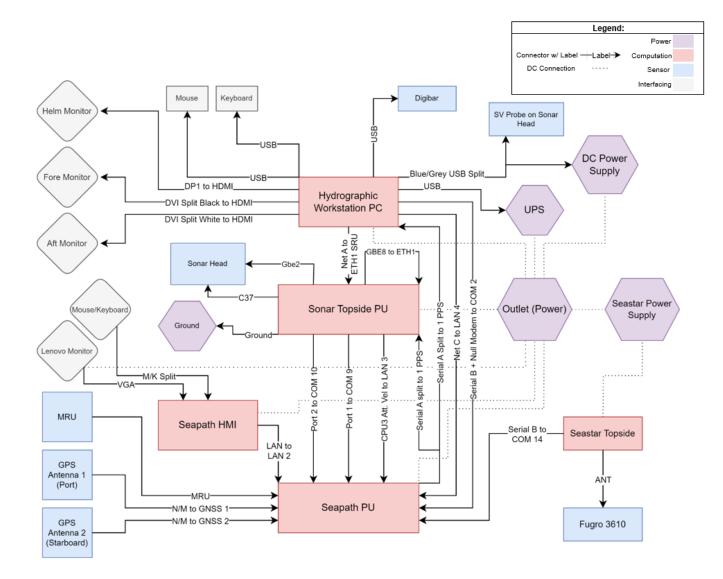
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07/16/2019	04/15/2022	01/10/2023						
07/24/2019	04/21/2022	01/11/2023						
08/06/2019	05/03/2022	01/25/2023						
08/07/2019	05/11/2022 (Crosslines)	01/27/2023						
08/16/2019	05/12/2022	01/30/2023						
08/23/2019	05/13/2022	02/01/2023 (Crosslines)						
07/28/2021	05/19/2022	02/06/2023						
07/29/2021	05/20/2022	02/08/2023						
08/12/2021	05/23/2022	02/09/2023						
12/08/2021	06/01/2022	02/14/2023						
01/24/2022	06/02/2022	02/21/2023						
01/26/2022	10/27/2022	03/13/2023						
01/28/2022	11/01/2022	03/17/2023						
02/16/2022	11/02/2022	03/21/2023						
02/24/2022	11/03/2022	03/22/2023						
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03/15/2022	12/07/2022	04/10/2023						
03/23/2022	12/21/2022	04/11/2023						
03/31/2022	01/03/2023	04/12/2023 (Crosslines)						
04/11/2022	01/06/2023							

Dates (mm/dd/yy) of Data Acquisition for Casco Bay Surveys*

Appendix A – Specific dates of data acquisition for surveys

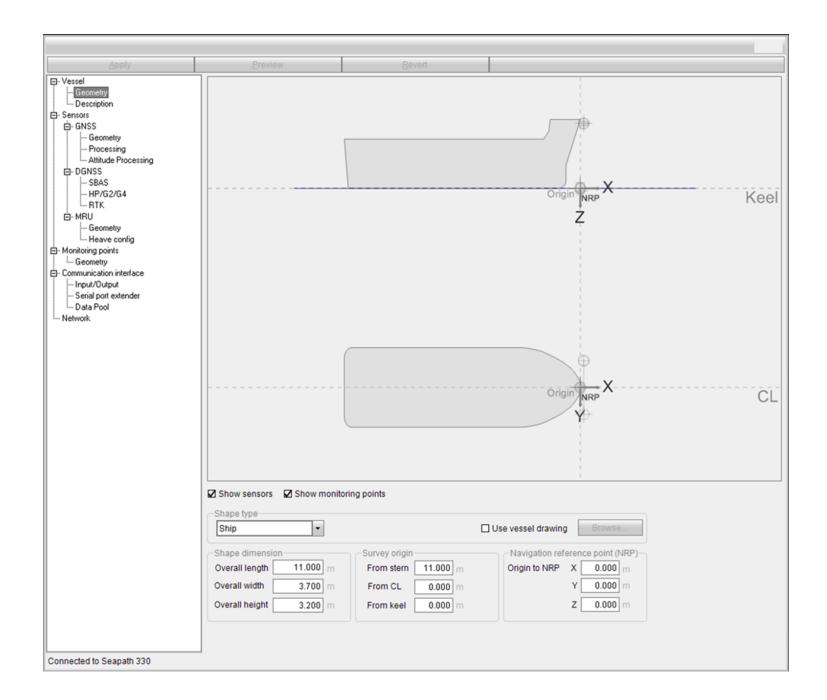
*Dates of surveys not summarized in this report not listed



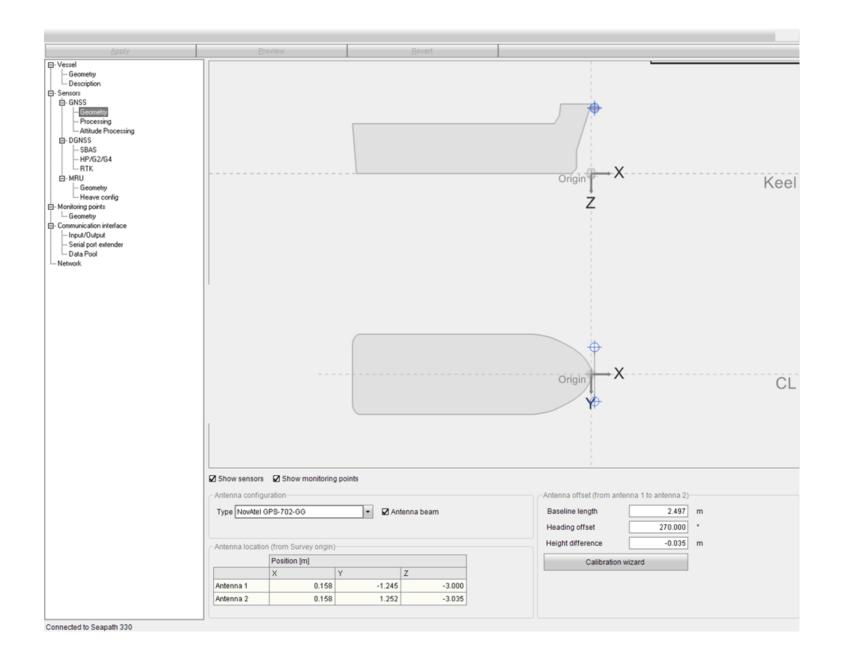


Appendix C – 2023 Configuration settings for Seapath 330

Note: Adjustments mentioned in this report are reflected in the following configuration. Prior to the adjustments, attitude and velocity values were sent to Qinsy at 10Hz. This and the addition of the 135 WAAS satellite are the only settings that are different in Seapath across the span of the surveys of this report.



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- Network						
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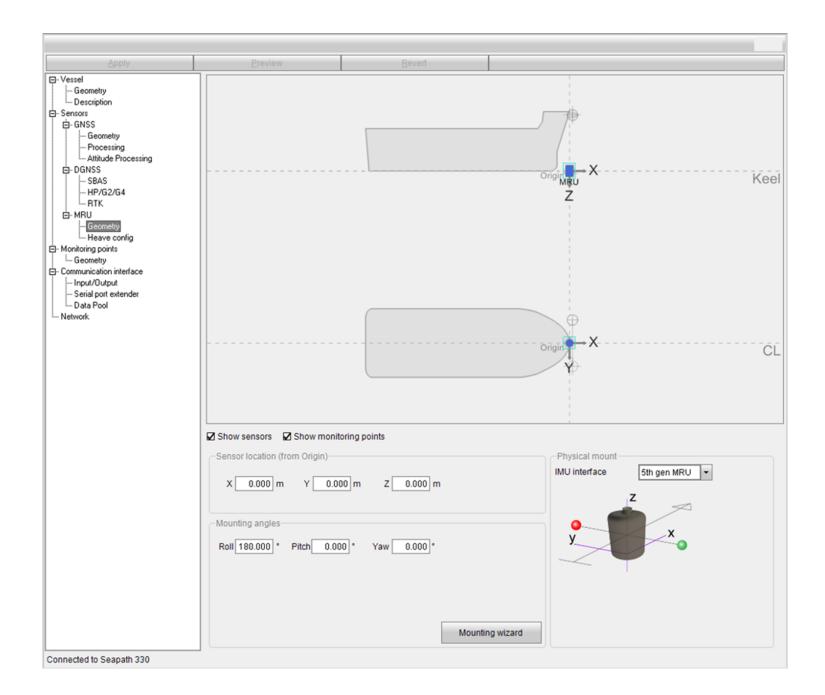
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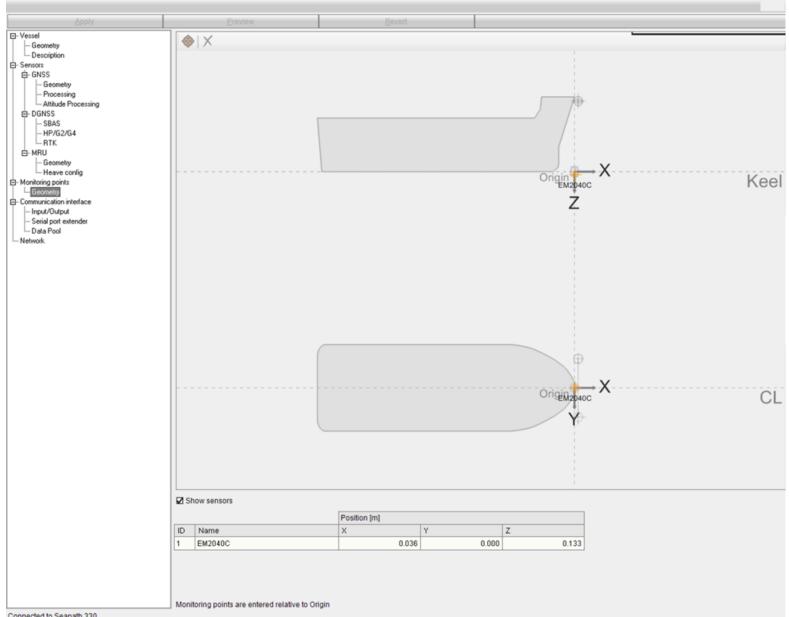
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Appendix D – **Template database settings in Qinsy (for acquisition)**

Note: Depicted Qinsy template settings show configuration from a 2020 survey project. All settings remain the same for the seasons described in this report apart from changes to pitch, roll, heading for EM2040C from patch test results (Table 4), as well as latency offsets applied to Position Navigation Systems and Motion Reference output values.

Qinsy uses the following reference frame conventions (these differ from those used by Seapath 330):

Pitch rotation: + bow up Roll rotation: + heeling to starboard Heave: + upwards

X: + to starboard Y: + towards bow Z: + up

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Object		"8901"]],
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		(North Hemisphere)", AUTHORITY["EPSG", "9807"]],
ן לא Gyro		PROJECTION["Transverse Mercator",
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🗝 🕉 Time Sync		AUTHORITY["EPSG", "9201"]]],
EM2040C Controller		UNIT["meter", 1, AUTHORITY["EPSG", "9001"]]],
		METADATA["WGS84",
Fixed Node		PARAMETER["version", 2], PARAMETER["timestamp",
		"20210225T035001.424000"]]

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Program	[
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General	Datums: Datums	
Geodetic		
Datums	Survey datum: WGS84	
	Chart datum: WGS84	
🖨 🕱 Heights	Height file: N/A	
-# Chart Datum / Vertical Datum	Height level: No Level Correction	
📥 Mean Water Level Model	Height file: N/A	
🚽 💆 Digital Terrain Models	Height offset: 0.000 m	
E W Projections		
-🔣 Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
- Ŏ UTC to GPS Correction		
Amy Gale		
System		
⊜ ⋬ Gyro		
Gyro		
-# Pitch Roll Heave Sensor		
Position Navigation System		
🖕 💥 Variable Node		
@ RX		
L ⊚ TX		
Link		
Auxiliary Systems		
→ Š Time Sync → EM2040C Controller		
→ ASCII Logger		
-X Fixed Node		
Qinsy 9 For Help, press F1		

Survey General	Datum: WGS84	
Seodetic	Datum name: WGS84	
Datums	Spheroid name: WGS 1984	
WGS84		
i	Prime meridian: Greenwich	
🚽 🛣 Chart Datum / Vertical Datum	Prime meridian: 0;00;00.000 E	
- America Martine Martine America Martine Amer	Conversion factor to metres: 1.0000000000000	
 — <u>☆</u> Digital Terrain Models —	Semi-major axis (a): 6378137.000 m	
- Universal Transverse Mercator (North Hemisphere)	Semi-minor axis (b): 6356752.314 m	
Local Construction Grid	Inverse flattening (1/f): 298.257223563000	
- O UTC to GPS Correction	Flattening (f): 0.003352810664747	
C Sound Velocity Profile	First eccentricity (e): 0.081819190842621	
Object	First eccentricity squared (e**2): 0.006694379990141	
Amy Gale	Second eccentricity (e'): 0.082094437949696	
🖨 🔚 System	Second eccentricity squared (e'**2): 0.006739496742276	
ם ⊅ Gyro		
Gyro		
-# Pitch Roll Heave Sensor		
L≟ Position Navigation System □.☆ Variable Node		
Amy Gale MRU		
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o từ o TX		
8 Link		
Auxiliary Systems		
- 💩 Time Sync		
EM2040C Controller		
D-> ASCII Logger		
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I General	Heights: Heights
a Geodetic	Chart datum: WGS84
Datums	Height file: N/A
WGS84	Height level: No Level Correction
A Heights A Chart Datum / Vertical Datum	Height file: N/A
A Mean Water Level Model	Height offset: 0.000 m
Digital Terrain Models	
	MWL model: Horizontal Datum
Universal Transverse Mercator (North Hemisphere)	MWL file: N/A MWL level: No Level Correction
Local Construction Grid	MWL file: N/A
💩 UTC to GPS Correction	MWL offset: 0.000 m
C Sound Velocity Profile	MWL st.dev.: 0.000 m
Object Amy Gale	
📥 Any Gale	DTM mode: Absolute DTMs
EM2040C	DTM datum: WGS84
⊕ Ø Gyro	DTM file: N/A
Lip" Gyro	DTM level: No Level Correction
	DTM file: N/A
L Position Navigation System	DTM offset: 0.000 m
È-X Variable Node │	
→ ● RX	
o TX	
B Link	
Auxiliary Systems	
💩 Time Sync	
EM2040C Controller	
- D+ ASCII Logger	
Fixed Node	

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Survey	Height Datum: Chart Datum / Vertical Datum
Geodetic	Chart datum: WGS84
🖨 🗣 Datums	Height file: N/A
WGS84	Height level: No Level Correction
🕂 🛣 Heights	Height file: N/A
🚽 Chart Datum / Vertical Datum	
Amean Water Level Model	Height offset: 0.000 m
E Projections	
- 10 Universal Transverse Mercator (North Hemisphere)	
UTC to GPS Correction	
Sound Velocity Profile	
Diject	
🗄 🏧 Amy Gale	
🖕 🔚 System	
ia ∯ Gyro	
-↓-/ Gyro	
-# Pitch Roll Heave Sensor	
L Position Navigation System	
□ . ¥ Variable Node	
Gale MRU → ● RX	
B Link	
Auxiliary Systems	
→ Time Sync	
EM2040C Controller	
ASCII Logger	
🛠 Fixed Node	

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₩ <mark>' Survey</mark> -	MWL Model: Mean Water Level Model
Geodetic	MWL model: Horizontal Datum
LG WGS84	MWL file: N/A
⊖ Ż Heights	MWL level: No Level Correction
🚽 🛓 Chart Datum / Vertical Datum	MWL file: N/A
📥 Mean Water Level Model	MWL offset: 0.000 m
🚽 👷 Digital Terrain Models	MWL st.dev.: 0.000 m
🗄 🌆 Projections	
-🔣 Universal Transverse Mercator (North Hemisphere)	
Local Construction Grid	
- Ö UTC to GPS Correction	
上 Sound Velocity Profile	
🗄 🏧 Amy Gale	
ian Any Gale	
⊟ Ø Gyro	
Gyro	
🚽 Pitch Roll Heave Sensor	
Position Navigation System	
🛱 💥 Variable Node	
- 🗣 Amy Gale MRU	
• RX	
© TX	
🔲 🖁 Link Standard Systems	
Time Sync	
EM2040C Controller	
ASCII Logger	
Fixed Node	
8	

⇒ III Survey	DTM Mode: Digital Terrain Models
General Geodetic C	DTM mode: DTMS DTM datum: WGS84 DTM file: N/A DTM level: No Level Correction DTM file: N/A DTM offset: 0.000 m

☑ General ☑ Geodetic ☑ Datums ☑ WGS84 ☑ Chart Datum / Vertical Datum ☑ Mean Water Level Model	Projection type: Projection name: Conversion factor to metres:	0001
● Datums ● The State of the S	Projection name:	
- I WGS84 -		(Income I Transmission & American (All and I Income have)
□ 全 Heights 全 Chart Datum / Vertical Datum →査 Mean Water Level Model	Conversion factor to metres:	Universal Transverse Mercator (North Hemisphere)
全 Chart Datum / Vertical Datum - 金 Mean Water Level Model		1.00000000000000
	Construction grid type:	Undefined
		and and Analogo Analogo
🚽 🛣 Digital Terrain Models		
Projections		
- 🛐 Universal Transverse Mercator (North Hemisphere)		
UTC to GPS Correction		
Sound Velocity Profile		
Dbject		
🖁 Amy Gale		
🗄 🔚 System		
⇒ ♯ Gyro ↓↓´ Gyro		
→ Gyro		
L Position Navigation System		
→ Y Variable Node		
- S Amy Gale MRU		
– ◎ RX		
Le TX		
- 8 Link		
Auxiliary Systems 3 Time Sync		
■ EM2040C Controller		
ASCII Logger		
ixed Node		

 Survey General Geodetic Datums WGS84 Heights Chart Datum / Vertical Datum Mean Water Level Model Digital Terrain Models Projections Universal Transverse Mercator (North Hemisphere) Local Construction Grid UTC to GPS Correction Sound Velocity Profile Object My Gale System 	Projection: Unive Projection type: Projection name: Conversion factor to metres: UTM zone number: UTM central meridian: Latitude of grid origin: Carid Casting at grid origin: Grid Easting at grid origin: Scale factor at longitude of origin:	Image: series of the
	Projection name: Conversion factor to metres: UTM zone number: UTM central meridian: Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	Universal Transverse Mercator (North Hemisphere) 1.000000000000000 19 69;00;00.00000 W 0;00;00.00000 N 69;00;00.0000 W 500000.000 m 0.000 m
WGS84	Conversion factor to metres: UTM zone number: UTM central meridian: Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	1.000000000000000000000000000000000000
	UTM zone number: UTM central meridian: Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	19 69;00;00.00000 W 0;00;00.00000 N 69;00;00.0000 W 500000.000 m 0.000 m
Chart Datum / Vertical Datum Mean Water Level Model Digital Terrain Models Digital Terrain Models Digital Transverse Mercator (North Hemisphere) Local Construction Grid Ource to GPS Correction Sound Velocity Profile Object Amy Gale System	UTM central meridian: Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	69;00;00.00000 W 0;00;00.00000 N 69;00;00.00000 W 500000.000 m 0.000 m
Digital Terrain Models Projections Universal Transverse Mercator (North Hemisphere) Local Construction Grid UIC to GPS Correction Sound Velocity Profile Object Amy Gale System	UTM central meridian: Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	69;00;00.00000 W 0;00;00.00000 N 69;00;00.00000 W 500000.000 m 0.000 m
	Latitude of grid origin: Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	0;00;00.00000 N 69;00;00.00000 W 500000.000 m 0.000 m
Universal Transverse Mercator (North Hemisphere) Local Construction Grid Local Construction Sound Velocity Profile Object Many Gale System	Longitude of grid origin: Grid Easting at grid origin: Grid Northing at grid origin:	69;00;00.00000 W 500000.000 m 0.000 m
Local Construction Grid Outrian Construction Sound Velocity Profile Object Man Gale System	Grid Easting at grid origin: Grid Northing at grid origin:	50000.000 m 0.000 m
	Grid Northing at grid origin:	0.000 m
L Sound Velocity Profile → Object → ■ Amy Gale → ■ System		
d Object d ﷺ Amy Gale d ≝ System		
da Amy Gale da ≝ System		
⊕ 𝒯 Gyro		
- ↓ Gyro - ☆ Pitch Roll Heave Sensor		
- L Position Navigation System		
⇒ ¥ Variable Node		
Amy Gale MRU		
- © RX		
I⊛ TX		
Link		
Auxiliary Systems		
- Time Sync		
EM2040C Controller ASCII Logger		
Fixed Node		

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File Edit View Options Help			
Survey	Local Grid: Local Construction Grid		
	Construction grid type: Undefined		
WGS84			
⊟			
Chart Datum / Vertical Datum			
- 📥 Mean Water Level Model			
🚽 Digital Terrain Models			
E Projections			
Universal Transverse Mercator (North Hemisphere) Local Construction Grid			
- 💩 UTC to GPS Correction			
Li Sound Velocity Profile			
🖨 😫 Object			
🖨 🏧 Amy Gale			
🖃 🔚 System			
- The EM2040C			
⊕ Ø Gyro			
-↓-' Gyro			
-# Pitch Roll Heave Sensor			
Position Navigation System ⊕.√ Variable Node			
-• Amy Gale MRU			
- • RX			
• TX			
Link			
🕀 🔚 Auxiliary Systems			
- 💩 Time Sync			
EM2040C Controller			
ASCII Logger			
└────────────────────────────────────			
Qinsy 9 For Help, press F1	1		

Survey	UTC to GPS Correction	
🖶 🖝 Geodetic	UTC to GPS time correction: 18.000 s	
Datums		
G WGS84 ⊖-∰ Heights		
→ → Preignts → → ☆ Chart Datum / Vertical Datum		
Mean Water Level Model		
Digital Terrain Models		
Projections		
- Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
- The other section - The sect		
上ご Sound Velocity Profile 語 Object		
🗄 🏧 Amy Gale		
i <mark>■</mark> System		
⊜ Ø Gyro		
└-↓~ Gyro		
→ Pitch Roll Heave Sensor		
└─┴ Position Navigation System □-┴ Variable Node		
-• Amy Gale MRU		
- • RX		
TX .		
└─ % Link		
Auxiliary Systems		
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EM2040C Controller De ASCII Logger		
¥ Fixed Node		

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V Survey	Object: Amy Gale		
	Object: Amy Gale Object reference number: Object type: Description of reference point: Height above draft reference: Squat model: SD draft: SD squat: SD load: SD tide: Time latency navigation: Time correction to GMT (UTC): Time correction to master vessel's time:	1 Vessel Amy Gale MRU 0.000 m Not Defined 0.050 m 0.050 m 0.050 m 0.050 m 0.050 m 0.000 m 0.025 s 0.000 h 0.000 s	

File Edit View Options Help				
E % ■ ↓ ● ₽ ₽ ∞ ₽ ₽ ₽ ₽ ₽	8 8			
🖃 🌉 Survey	System: EM2040C			
General	System. LIVI2040C			
Geodetic	Description:	EM2040C		
G WGS84	Type:	Multibeam Echosounder		
⊟ Ż Heights	Driver:	Kongsberg EM2040/EM710/EM302/EM122		
Chart Datum / Vertical Datum	Executable and Cmdline:	DrvKongsbergEM.exe		
Mean Water Level Model	Driver specific settings:	MANUFACTURER=2;MODEL=2045;RAW_BATHY=1;RAW_SNIP=1;RAW_WCD=1;		
🛓 Digital Terrain Models	Port:	2001	 -	
Projections	Update rate:	0.000 s		
		111/2/2012/04/88/07	 	
- 🔄 Local Construction Grid	Acquired by:	[Directly into Qinsy] (No additional time tags)		
- O UTC to GPS Correction	Observation time from:	N/A	 	
Sound Velocity Profile	Number of slots:	1	 	
- 🔁 Object	Manufacturer:	Kongsberg		
Amy Gale	Model:	EM2040C		
⊖ <mark>≔</mark> System	Object location:	Amy Gale	 	
⇒ # Gyro	Node name:	RX		
Gyro	X (Stbd = Positive)::	0.000 m		
Pitch Roll Heave Sensor	Y (Bow = Positive)::	-0.045 m		
L Position Navigation System	Z (Up = Positive)::	0.006 m		
🛱 😽 Variable Node	152 SC 2011 248 1996 (996 (997 (997 (997 (977 (977 (977 (0.000 m		
	A-priori SD:		 	
•••• • RX	Roll offset:	0.332		
L.∞ TX	Pitch offset:	0.279		
Link	Heading offset:	-0.181	 	
Auxiliary Systems	Unit is roll stabilized:	No		
- Time Sync	Unit is pitch stabilized:	No		
→■ EM2040C Controller →■ ASCII Logger	Unit is heave compensated:	No		
	Beam steering (flat transducer):	No		
The Node	Beam angle width along:	1.500 m		
	Beam angle width across:	1.500 m		
	Maximum number of beams per ping:	800		
	Use sound velocity from unit:	Yes	 	
	Slot:	1	 	
	SD type:	Pulse, Sampling		
	SD pulse length:	0.150 ms		
	SD sampling length:	0.050 m		

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Survey	Update rate:	0.000 s	
III General	Acquired by:	[Directly into Qinsy] (No additional time tags)	
T Geodetic	Observation time from:	N/A	
Datums WGS84	Number of slots:	1	
⊟ ★ Heights	Manufacturer:	Kongsberg	
🖉 🛣 Chart Datum / Vertical Datum	Model:	EM2040C	
📥 Mean Water Level Model	Object location:	Amy Gale	
🚽 🛣 Digital Terrain Models	Node name:	RX	
E Brojections	X (Stbd = Positive)::	0.000 m	
- Universal Transverse Mercator (North Hemisphere)	Y (Bow = Positive)::	-0.045 m	
Les Local Construction Grid	Z (Up = Positive)::	0.006 m	
Sound Velocity Profile	A-priori SD:	0.010 m	
Object	Roll offset:	0.332	
Amy Gale	Pitch offset:	0.279	
🖨 🔚 System	Heading offset:	-0.181	
		Characterized in the second	
i ⊕ Φ' Gyro ↓ ↓ ΄ Gyro	Unit is roll stabilized:	No	
→ Gyro	Unit is pitch stabilized:	No	
1. Position Navigation System	Unit is heave compensated:	No	
🗄 💥 Variable Node	Beam steering (flat transducer):	No	
- Amy Gale MRU	Beam angle width along:	1.500 m	
• RX	Beam angle width across:	1.500 m	
Le TX	Maximum number of beams per ping:		
Link Auxiliary Systems	Use sound velocity from unit:	Yes	
Time Sync	Slot:	1	
 EM2040C Controller 	SD type:	Pulse, Sampling	
🗠 ASCII Logger	SD pulse length:	0.150 ms	
Fixed Node	SD sampling length:	0.050 m	
	SD roll offset:	0.050 °	
	SD pitch offset:	0.050 °	
	SD heading offset:	0.500 °	
	SD roll stabilization:	0.000 °	
	SD pitch stabilization:	0.000 °	
	SD heave compensation:	0.000 m	
	SD sound velocity:	0.050 m/s	

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	gram		39 -3 8	×
File Edit View Options Help				
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🖃 🎹 * Survey	System: Gyr			
- 🕜 General	System: Gyr	U C		
🚍 🖝 Geodetic	Description:	Gyro		
🖻 🧐 Datums	Type:	Gyro Compass		
- 3 WGS84	Driver:	Network - Seapath Binary Format 11 (Hdg) (With UTC)		
i in the second		DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS		
	Territoria de la construcción de			
- Z Digital Terrain Models	Port:	13001		
	Update rate:	0.000 s		
- Universal Transverse Mercator (North Hemisphere)	Latency:	0.000 s		
- Local Construction Grid	Acquired by:	[Directly into Qinsy] (No additional time tags)		
- 💩 UTC to GPS Correction	Observation time from:	N/A		
Sound Velocity Profile	Number of slots:	0		-
e 😫 Object				
🖻 🛄 Amy Gale				
EM2040C Fixed Node Fixed Node				
Qinsy 9 For Help, press F1				

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	ogram		27 3	×
File Edit View Options Help				
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E W Survey	Observation	- Gyro		
- 🖪 General	Observation	i. dylo		
🖶 🗸 Geodetic	Observation description:	Gyro		
Datums	Observation type:	Bearing (True)		
WGS84	'At' node:	Amy Gale MRU		
白査 Heights	Measurement unit code:	n en ante en ante en ante en ante en ante ante		
Mean Water Level Model	10 10 10 N	Gyro		
Digital Terrain Models	System description:			
	(C-O) option:	(C-O) offsets applied first		
- Superior (North Hemisphere)	Scale factor:	1.0000000000		
Local Construction Grid	Fixed system (C-O):	0.00000000		
- 💩 UTC to GPS Correction	Variable (C-O):	0.0000000		
Sound Velocity Profile	A-priori SD:	0.5000		
🖃 🚼 Object			-	
📥 🏧 Amy Gale				
🖨 🔚 System				
🖨 🕸 Gyro				
Lik <mark>Gyro</mark>				
L. Position Navigation System				
ia . ↓ Variable Node				
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S Link				
Auxiliary Systems				
⊸⊗ Time Sync				
EM2040C Controller				
ASCII Logger				
Fixed Node				
Qinsy 9 For Help, press F1				

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pr Edit View Options Help	- Juli -			
: ‰				
V Survey	System: Pitch Roll	Heave Sensor		
Geodetic	-			_
Datums	Description:	Pitch Roll Heave Sensor		
WGS84	Туре:	Pitch Roll Heave Sensor		
🖨 🛣 Heights	Driver:	Network - Seapath MRU Binary Format 11 (With UTC)		
🚽 🛣 Chart Datum / Vertical Datum	Executable and Cmdline:	DrvQPSCountedUDP.exe SEAPATH_FMT11 PPS		
- 📥 Mean Water Level Model	Port:	13001		
🔄 🛓 🛣 Digital Terrain Models	Update rate:	0.000 s		
E Projections	Latency:	0.000 s		
- Viniversal Transverse Mercator (North Hemisphere)	Acquired by:	[Directly into Qinsy] (No additional time tags)		-
└─ Local Construction Grid - ॐ UTC to GPS Correction	Observation time from:	N/A		
Sound Velocity Profile	Number of slots:	0		-
Object				-
Amy Gale	Object:	Amy Gale		
🛓 🔚 System	PRH sensor reference number:	1		
	Rotation convention pitch:	Positive bow up		
⊜ Ø Gyro	Rotation convention roll:	Positive heeling to starboard		
-b' Gyro	Angular variable measured:	HPR (roll first)		
- Pitch Roll Heave Sensor	Angular measurement units:	Degrees		
La Position Navigation System	Sign convention heave:	Positive upwards		
□.↓ Variable Node	Measurement unit heave:	Meters		
	Conversion factor to degrees decimal:	N/A		
• RX • TX	Conversion factor to metres:	N/A		
1 Sink	Quality indicator type pitch and roll:	No quality info recorded		
Auxiliary Systems	Quality indicator type heave:	No quality info recorded		
ồ Time Sync	Description of quality indicator type:	N/A		
EM2040C Controller	Object location:	Amy Gale		-
De ASCII Logger	Node name:	Amy Gale MRU		
Fixed Node	X (Stbd = Positive)::	0.000 m		
	Y (Bow = Positive)::	0.000 m		
	Z (Up = Positive)::	0.000 m		
	A-priori SD:	0.000 m		
	0000000 000 000		 	-
	(C-O) roll offset:	0.000 °		
	(C-O) pitch offset:	0.000 °		
	(C-O) heave offset:	0.000 m		_
	Heave time delay:	0.000 s		

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V Survey	Latency:	0.000 s	
- 🖪 General	Acquired by:	[Directly into Qinsy] (No additional time tags)	
Geodetic	Observation time from:	N/A	
G WGS84	Number of slots:	0	
Heights	Object:		
🕂 🛓 Chart Datum / Vertical Datum		Amy Gale 1	
👍 Mean Water Level Model	PRH sensor reference number:	2	
🚽 🛓 Digital Terrain Models	Rotation convention pitch:	Positive bow up	
E Projections	Rotation convention roll:	Positive heeling to starboard	
- 🔀 Universal Transverse Mercator (North Hemisphere)	Angular variable measured:	HPR (roll first)	
Local Construction Grid	Angular measurement units:	Degrees	
UTC to GPS Correction Sound Velocity Profile	Sign convention heave:	Positive upwards	
Object	Measurement unit heave:	Meters	
Amy Gale	Conversion factor to degrees decimal:	N/A	
🖨 🔚 System	Conversion factor to metres:	N/A	
EM2040C	Quality indicator type pitch and roll:	No quality info recorded	
⊜ Ø Gyro	Quality indicator type heave:	No quality info recorded	
└─┝." Gyro	Description of quality indicator type:	N/A	
Pitch Roll Heave Sensor	Object location:	Amy Gale	
L Position Navigation System	Node name:	Amy Gale MRU	
□ ¥ Variable Node	X (Stbd = Positive)::	0.000 m	
- Amy Gale MRU	Y (Bow = Positive)::	0.000 m	
e RX ■ TX	Z (Up = Positive)::	0.000 m	
B Link	A-priori SD:	0.000 m	
Auxiliary Systems	(C-O) roll offset:	0.000 °	
- Ö Time Sync	(C-O) pitch offset:	0.000 °	
EM2040C Controller	(C-O) heave offset:	0.000 m	
ASCII Logger			
Fixed Node	Heave time delay:	0.000 s	
	Heave filter length:	N/A	
	SD roll and pitch:	0.050 °	
	SD heave (fixed):	0.050 m	
	SD heave (variable):	5.000 %	
	SD roll offset:	0.050 °	
	SD pitch offset:	0.050 °	
	SD heave offset:	0.050 m	

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V Survey	System: Pos	System: Position Navigation System				
 Survey General Geodetic Datums WGS84 # Heights Aman Water Level Model Digital Terrain Models Projections Universal Transverse Mercator (North Hemisphere) Object Many Gale System Many Gale System ✓ Fitch Roll Heave Sensor ✓ Position Navigation System ✓ Variable Node Amy Gale MRU RX TX Link 	System: Posi Description: Type: Driver: Executable and Cmdline: Port: Update rate: Latency: Acquired by: Observation time from: Number of slots: Satellite system name: Horizontal datum: Vertical datum: Vertical datum: Height file: Height file: Height file: Height file: Height file: Height file: Height file: SD latitude: SD latitude: SD latitude: SD height: Measurement unit: Receiver description:	Position Navigation System Position Navigation System Network - Seapath Binary Format 11 (With UTC)				
 - Ŏ Time Sync - ■ EM2040C Controller - ■ ASCII Logger ✓ Fixed Node 	Receiver number: Object location: Node name:	0 Amy Gale Amy Gale MRU				
	X (Stbd = Positive):: Y (Bow = Positive):: Z (Up = Positive):: A-priori SD:	0.000 m 0.000 m 0.000 m 0.000 m				

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Survey	Node: Amy Gale MRU		
General Geodetic Datums Geodetic Calcolor Construction Grid Construction System Construction Navigation S	Node: Amy Gale NRKU Mode name: Amy Gale MRU X (Stud = Positive): 0.000 m Y (Bow = Positive): 0.000 m Z (Up = Positive): 0.000 m A-priori SD: 0.000 m		
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😝 AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Prog	ram	– 🗆 ×
File Edit View Options Help		
	 (§) 	
🖃 🌉 Survey	Node: RX	
- 🖪 General	Node: KA	
🖨 🖝 Geodetic	Object location: Amy Gale	
🖨 🎯 Datums	Node name: RX	
WGS84	X (Stbd = Positive):: 0.000 m	
🖻 🛣 Heights	Y (Bow = Positive): -0.045 m	
🚽 🛣 Chart Datum / Vertical Datum		
Aean Water Level Model Digital Terrain Models		
	A-priori SD: 0.010 m	
- Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
- O UTC to GPS Correction		
Sound Velocity Profile		
B H Object		
📥 🛄 Amy Gale		
🖕 📒 System		
j⊒ Ø Gyro		
–l∞ Gyro		
Pitch Roll Heave Sensor		
La Position Navigation System		
□ → Variable Node		
- B Link		
Auxiliary Systems		
-ô Time Sync		
EM2040C Controller		
- De ASCII Logger		
Oinsy 9 For Help, press F1	1	1

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Progra	am	– 🗆 X
File Edit View Options Help		
E	Node: TX	
🖨 🖝 Geodetic	Object location: Amy Gale	
🖨 🥵 Datums	Node name: TX	
WGS84	X (Stbd = Positive):: 0.040 m	
🕀 🛣 Heights		
🚖 Chart Datum / Vertical Datum		
Mean Water Level Model	Z (Up = Positive):: 0.006 m	
	A-priori SD: 0.010 m	
Universal Transverse Mercator (North Hemisphere)		
Local Construction Grid		
- O UTC to GPS Correction		
Sound Velocity Profile		
e 🗄 Object		
🖨 🏧 Amy Gale		
🖨 🔚 System		
j⊟ ⋪ Gyro		
-↓-/ Gyro		
→ → → → → Pitch Roll Heave Sensor → → → → → → → → → →		
Amy Gale MRU		
- • RX		
Link		
🕀 🔚 Auxiliary Systems		
- 💩 Time Sync		
EM2040C Controller		
-D+ ASCII Logger		
Fixed Node		
Qinsy 9 For Help, press F1		đ

System: Time Sync	
System: Time SyncDescription:Type:Driver:Executable and Cmdline:Port:Baud rate:Data bits:Stop bits:Parity:Byte frame length (time):Maximum data transfer rate:Update rate:Latency:Acquired by:Observation time from:Number of slots:Use QPS PPS Adapter:PPS time tag pulse matching:Windows System Time Synchronization:	Time Sync Time Synchronization System NMEA ZDA DrvPositionNMEA.exe 2 9600 8 1 None 10 bits (1.042 ms) 960 bytes / second 0.000 s 0.000 s (Directly into Qinsy] (No additional time tags) N/A 0 On COM1 Automatic Matching Synchronization is enabled
	System: Time SyncDescription:Type:Driver:Executable and Cmdline:Port:Baud rate:Data bits:Stop bits:Parity:Byte frame length (time):Maximum data transfer rate:Update rate:Latency:Acquired by:Observation time from:Number of slots:Use QPS PPS Adapter:PPS time tag pulse matching:

Survey Survey General Geodetic Datums WGS84 X Heights At he	System: EM2 Description: Type: Driver:	2040C Controller EM2040C Controller
 Geodetic ● Datums ● WGS84 ● Ż Heights ● Ż Chart Datum / Vertical Datum 	Description: Type:	
● 登 WGS84 ● 変 Heights	Type:	EWIZ040C CONTIONER
⊖ ☆ Heights ☆ Chart Datum / Vertical Datum		
🚽 Chart Datum / Vertical Datum	Driver:	Miscellaneous System
		Kongsberg EM2040 Compact (Single) Multibeam Controller
🚽 🚈 Mean Water Level Model	Executable and Cmdline:	DrvKongsbergEMCtrl.exe 2040C
	Update rate:	0.000 s
🔄 🏄 Digital Terrain Models	Latency:	0.000 s
	Acquired by:	[Directly into Qinsy] (No additional time tags)
- Universal Transverse Mercator (North Hemisphere)	Observation time from:	N/A
Local Construction Grid		0
- O UTC to GPS Correction	Number of slots:	U
Sound Velocity Profile		
Object 🔤 Amy Gale		
ian Anny Gale		
EM2040C		
⊟ I gyro		
L-F. Gyro		
₩ Pitch Roll Heave Sensor		
L Position Navigation System		
□ ↓ Variable Node		
- 🕀 Amy Gale MRU		
• RX		
_ ⊚ TX		
Link		
Auxiliary Systems		
- 💩 Time Sync		
EM2040C Controller		
- D ASCII Logger		
Fixed Node		

AmyGale_2020_Patch1_nonverified_tides_2.db - Database Setup Pro	ogram		is - t a		×
File Edit View Options Help					
E 况 🔜 🙏 💿 🖉 🔢 🗒 📟 🛃 💷 🔒	8				
📮 🌉 Survey	Sustam ASC				
- 🖪 General	System: ASC	System: ASCII Logger			
🖨 🚳 Geodetic	Description:	ASCII Logger			
🖨 🎱 Datums	Type:	Output System			
WGS84	Driver:	Generic ASCII Data Logger (Controller)			
🖨 🛣 Heights	Executable and Cmdline:				
- 🛣 Chart Datum / Vertical Datum	10.00 (D)	33			
	Update rate:	1.000 s			
☐	Latency:	0.000 s			
- Universal Transverse Mercator (North Hemisphere)	Data output setting:	Enabled			
Local Construction Grid	Acquired by:	[Directly into Qinsy] (No additional time tags)			
-Ö UTC to GPS Correction	Observation time from:	N/A			
Sound Velocity Profile	Number of slots:	0			
⊖ ₩ Object					
Amy Gale					
🛓 🔚 System					
⊜ Ø Gyro					
l l l l l l l l l l l l l l l l l l l					
Pitch Roll Heave Sensor					
Position Navigation System					
⊇ ↓ Variable Node					
- The Amy Gale MRU					
@ RX					
link					
Auxiliary Systems					
 – Ö Time Sync – ➡ EM2040C Controller 					
Bill Controller					
- Fixed Node					
Qinsy 9 For Help, press F1					

Appendix E – Configuration settings for Qinsy EM controller

PU Status			
Status	Active		 Char
Pinging	15308 @ 2.90	47	 Stop
Clock Status	Ok		Pu Info
Frors	All Ok		
			Options.
Settings			·
Head1 Port Ar	ale	65	
Head1 Starbo		65	
Max. Port Cov		300	
Max. Starboar		300	
Angular Cove		Auto	 •
Beam Spacing		High Density	 -
Pitch Stabiliza		On	•
Max. Ping Fre	q.(Hz)	50.00	
Transmit Ang	le (deg)	0.0	
Minimum De	oth	0.00	
Maximum De	pth	200.00	
Detector Mod	e	Normal	-
Slope Filter		On	-
Areation Filter	r	Off	•
Interference F	ilter	Off	•
Penetration Fi	lter	Off	-
Range Gate Si	ze	Normal	-
Spike Filter Str	rength	Medium	T
Phase Ramp		Normal	-
Special Amp [Detect	Off	-
Special TVG		Off	-
Normal Inci. S	ector Angle	10	
Lambert's law	for intensity	Off	-
Ping Mode		300 KHz	-
Pulse Type		Auto	• • •
Transmit Pow	er Level	Maximum	 -
FM Enable		FM Enabled	<u> </u>
3D Scanning -	Scan Step	0.0	
Apply	Settings 🔻	Force V Log Events	
Events			
	PU Clock is synd	thronized PU (157.237.20.40) Established	1
	Set Initial Settin		

🚺 EM Controller -		\times			
-PU Status					
Status Ad	tive			Stop	1
Pinging 18	646 @ 2.70 H	3100			
Clock Status O				Pu Info	-
Errors Al	l Ok				
				Option	s
Settings					
Penetration Filter		Off		•	
Range Gate Size		Normal		•	1 /
Spike Filter Strend	gth	Medium		•	1 /
Phase Ramp	-	Normal		-	1
Special Amp Det	ect	Off		+ + + + +	
Special TVG		Off		-	
Normal Inci, Sect	or Angle	10			
Lambert's law for	r intensity	Off		•	
Ping Mode		300 KHz		•	Γ
Pulse Type		Auto		• • •	
Transmit Power L	.evel	Maximum		•	
FM Enable		FM Enabled		-	
3D Scanning - Sc		0.0			
3D Scanning - M	in Angle	-5			
3D Scanning - M		5			
Dual Swath Mode	e	Off		-	
Min. Swath Dista	nce	0.0			
Yaw Stabilization		Off		-	
Yaw Manual Ang	le	0.0			
Heading Filter		Medium		•	
WCD Sonar Mod		Off		•	
WCD Passive Mo	de	Off		Ŧ	
WC TVG LOG R		30.0			
WC TVG dB		20.0			
Special amplitud		Off		•	
Sound Velocity U		3.0			
Sound Velocity N	lin Change	0.5			*
Apply Sett	ings 🔻	Force 🔽 Log Events			
Events					
10:00:53.105 PU	Clock is sync	hronized			~
10:00:53.963 Co	nnection to P	U (157.237.20.40) Established			
10:00:53.963 Se 10:00:55.073 Co					
10.00.000 00					~

Lambert's law for intensity was turned ON starting 01/25/23. No notable disagreements were found across backscatter datasets collected before and after the change was implemented.

System Type (from DbSetup)	EM2040C	Single Transducer	$\overline{\mathbf{v}}$
Pu Ip Address	157.237.20	0.40	
Simulation Mode	Off		-
External Triggering	Off		-
Control Port	2000		_
Enabled Output Ports	Output Pe	ort 1,2,3	-
Output Port 1 (Bathy)	2001		_
Output Port 2 (Bathy)	2002		
Output Port 3 (Sidescan)	2003		
ZDA/GGA Serial Port	Port 1 (de	fault)	-
Use GGA	On		•
Baudrate ZDA/GGA	9600		•
Motion Serial Port	Port 2 (de	fault)	Ŧ
Program Options			
			_
Start Pinging when OINSv Starts		Pinging On Startup	
Start Pinging when QINSy Starts Synchronize Clock Interval(min.)		Pinging On Startup 60	
Synchronize Clock Interval(min.)		60	
Synchronize Clock Interval(min.) Sound Velocity Mode		60 From SoundVelocit	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation		60	
Synchronize Clock Interval(min.) Sound Velocity Mode	nn Data	60 From SoundVelocit Sound Velocity	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters		60 From SoundVelocit Sound Velocity On	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet	0	60 From SoundVelocit Sound Velocity On	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet RX2 Gain Offet	0	60 From SoundVelocit Sound Velocity On Not Allowed	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from	0 0 EM2040	60 From SoundVelocit Sound Velocity On Not Allowed	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from	0 0 EM2040 Not Us	60 From SoundVelocit Sound Velocity On Not Allowed	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RXI Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number	0 0 EM2040 Not Us Motion	60 From SoundVelocit Sound Velocity On Not Allowed	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port	0 0 EM2040 Not Us Motion 3001	60 From SoundVelocit Sound Velocity On Not Allowed	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RXL Gain Offet RX2 Gain Offet Head1 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port Velocity Sensor Ethernet Port	0 0 EM2040 Not Us Motion 3001 Etheme	60 From SoundVelocit Sound Velocity On Not Allowed OC ed Sensor 1 t Port 2 (if available)	
Synchronize Clock Interval(min.) Sound Velocity Mode Sound Velocity Observation Popup window when error occurs Allow HD beamspacing with Water Colur Installation Parameters RX1 Gain Offet RX2 Gain Offet Head1 Installation angles from Head2 Installation angles from Velocity Sensor Number Velocity Sensor UDP Port	0 0 EM2040 Not Us Motion 3001	60 From SoundVelocit Sound Velocity On Not Allowed OC ed Sensor 1 et Port 2 (if available) 1.1	

Appendix F – Computation Settings for Qinsy Online

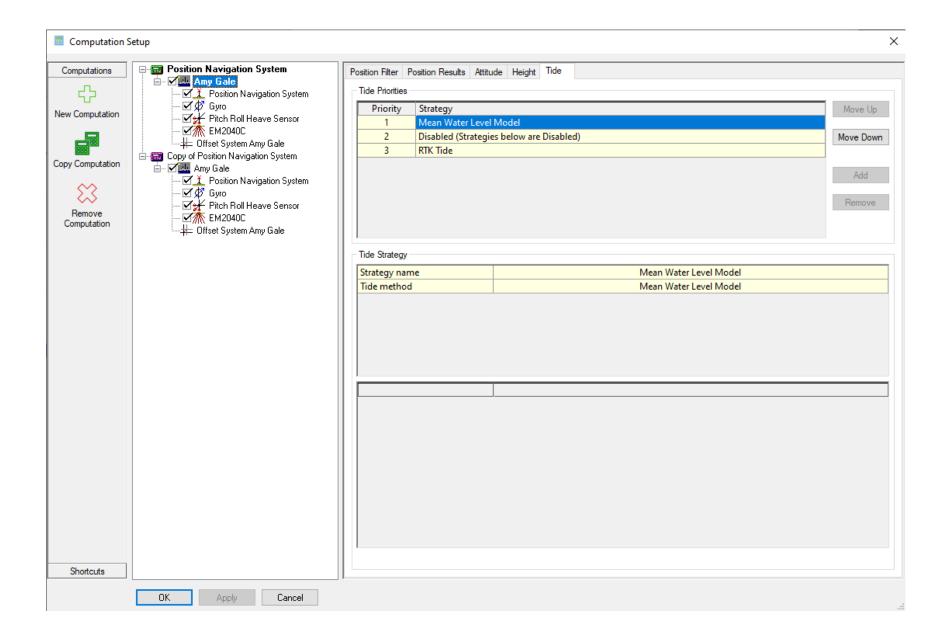
	p						
Computations	Position Navigation System Amy Gale	Computation P	arameters				
- C2	- V Any date - V Any date - V Any date - V Any date	Computatio	n name		Position Navigation System		
		Triggering sy	stem		Position Navigation System		•
New Computation		Max. trigger	ing rate			50 [Hz]	-
	EM2040C	Iteration thre	eshold			5	
	↓ Offset System Amy Gale	Statistical tes	sting			Separate Objects	-
Copy Computation	Englishing Copy of Position Navigation System	Data snoopir	ng			Enabled	-
	Any Gale	Redundancy	minimum			1	
\sim		Level of sign	ificance			1 %	
\sim		Power of tes	t			80 %	
Remove Computation		Lower limit r	nax. ages			0.0 [s]	
Comparation	🕂 🕂 Offset System Amy Gale						
		- Approximate P	osition				
		Coordinate s	vstem			Geographical	_
		Latitude	,		52;06;10.800 N		
		Longitude			5;15;25.560 E		
		Height			0.0		
		Computation P	riority				
		Priority	Status		Heights	Computation	Move Up
		1	Enabled			Copy of Position Navigation System	
		2				Position Navigation System	Move Down
			_	_			
Shortcuts							
Shortcuts		1					
	OK Apply Cancel						

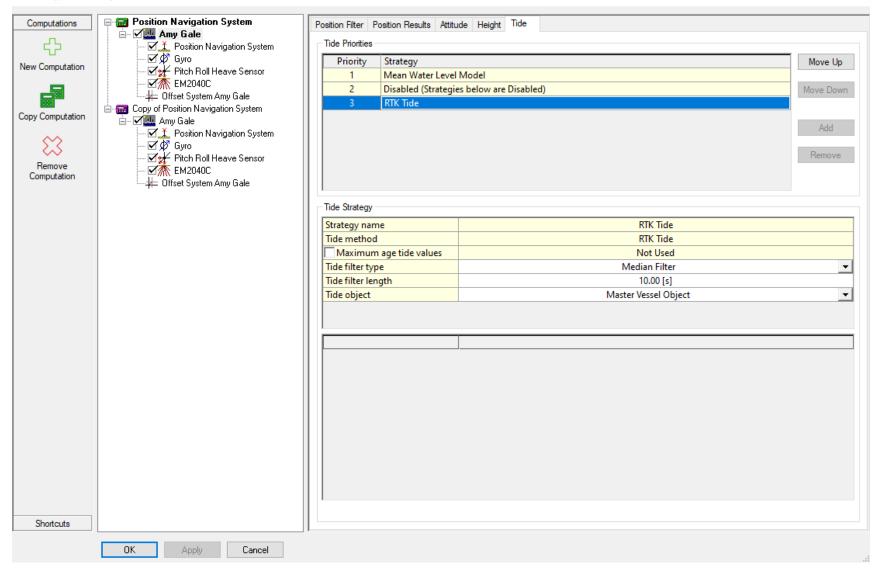
Computations	Position Navigation System	Position Filter Position Results Attitu	ude Height Tide	
- C2	Amy Gale	Filter Parameters		
New Computation	⊡Ø Gyro	General Parameters	Settin	g
New Computation		Dynamic model	None	•
	Gffset System Amy Gale	Height model	None	•
Copy Computation				
		Extended Parameters	Noise SD	Time Constant
Remove Computation	Pitch Roll Heave Sensor			
	Offset System Amy Gale			
		Observations	Setting	SD
		Observation Parameters	Settin	a
]	2
		Filter Thresholds		
		Reset Parameters	Settin	g
		Threshold Parameters	Maximum	Time Factor
Shortcuts				
	OK Apply Cancel	,		

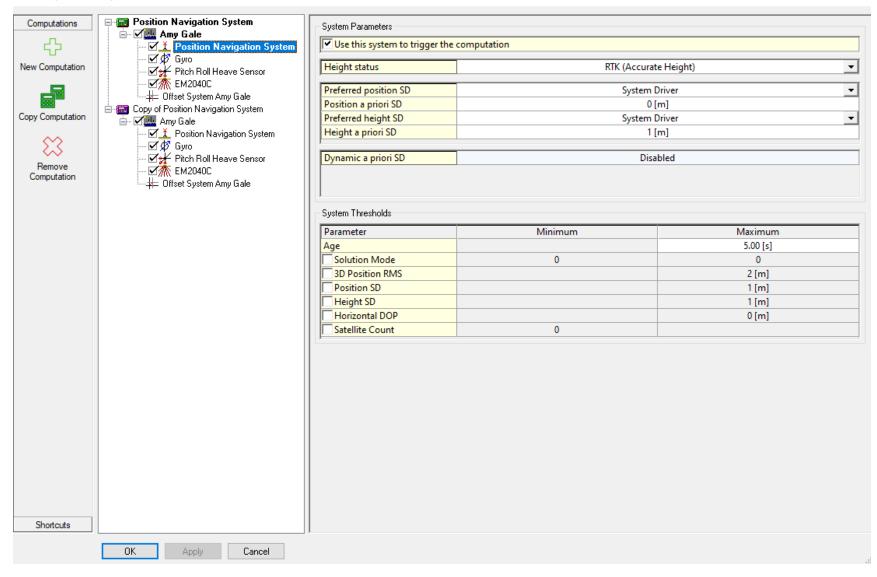
Computations	Position Navigation System	Position Filter Position Results Attitu	ide Height Tide	
<u> </u>	Amy Gale			
			0 m	_
New Computation	Pitch Roll Heave Sensor	Parameters	Setting	
_		COG value	Position Updates	-
	Offset System Amy Gale	SOG value	Position Updates	-
222	E E Copy of Position Navigation System	Position count	10	
Copy Computation	🖮 🗹 🛄 Amy Gale	Position threshold	0.05 [m]	
\sim	ー 🗹 🧘 Position Navigation System ー 🗹 🛱 Gyro			
Remove		Rate-Of-Tum		
Computation	☑ 🛣 EM2040C Uffset System Amy Gale	Parameters	Setting	
		Rate-Of-Turn value	Rotation Updates	-
		Rate-Of-Turn count	5	-
			, , , , , , , , , , , , , , , , , , ,	
		Positions / Prediction		
		Parameters	Setting	
		Position results	Computation	-
		Height results	Computation	-
		-		
		Parameters	Setting	
		Prediction	Disabled	-
		Maximum position age	5.0 [s]	
		Snap to Survey Line / Node Track - Parameters Snap option	Setting Disabled	•
Shortcuts		I		
	OK Apply Cancel			

	Desition Newigetien Conten					
Computations	e Position Navigation System	Position Filter	Position Results Attitude Height Ti	ìde		
- C	Position Navigation System	Heading				
_		Priority	Method	Max Age	Skew	Move Up
New Computation		1	Gyro	5.00 [s]	No	Move op
		2	COG Amy Gale	Not Used	N/A	Move Down
			coo Any one	Notosca	0/6	MOVE DOWN
Copy Computation	ia⊶ 📷 Copy of Position Navigation System ia⊸ 🗹 🛄 Amy Gale					
	Amy Gale					
83						
~ ~	- 🗹 🕁 Pitch Roll Heave Sensor					
Remove Computation	🗹 🥂 EM2040C					
Computation						
		Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
<u> </u>						
Shortcuts		I				
	OK Arriv Court					
	OK Apply Cancel					

¢	Position Navigation System Amy Gale Mark Position Navigation System	Position Filter Position Results Attitude He Height Interpolation	ght Tide		
		Priority Method	Max Age	Skew	Move Up
w Computation		1 Heave Pitch Roll Heave Se		No	
	☑ 🦟 EM2040C ➡ Offset System Amy Gale				Move Down
	😑 🚟 Copy of Position Navigation System				
by Computation	🚊 🗹 📶 Amy Gale				
\sim					
\approx	₩ Gyro ₩ Pitch Roll Heave Sensor				
Remove Computation	🗹 🕂 EM2040C				
computation					
		Draft and Squat Parameters			
		Draft method	Ma	nual Draft	
		Manual draft		0.850	
		Squat method	D	isabled	-







Computation S	Setup					×
Computations	Position Navigation System	Heading				
- cp	Amy Gale	Priority	Method	Max Age	Skew	Move Up
_		1	Gyro	5.00 [s]	No	
New Computation		2	COG Amy Gale	Not Used	N/A	Move Down
	H Offset System Amy Gale					
Copy Computation						
	- V Any Gale					
8						
Remove	Pitch Roll Heave Sensor					
Computation	☑ 🧖 EM2040C EM2040C					
		Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
		P				
Shortcuts						
	OK Apply Cancel	,				

Computations	Position Navigation System	LL E				
	🖮 🗹 🛄 Amy Gale	Heading				_
- c	- 🗹 🧘 Position Navigation System	Priority	Method	Max Age	Skew	Move Up
New Computation	Gyro	1	Gyro	5.00 [s]	No	
	Pitch Roll Heave Sensor EM2040C	2	COG Amy Gale	Not Used	N/A	Move Down
	Gifset System Amy Gale					
888	Copy of Position Navigation System					
Copy Computation	🖮 🗹 🔐 Amy Gale					
\sim	- 🗹 🧘 Position Navigation System					
22	Gyro					
Remove						
Computation	Gifset System Amy Gale					
		Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
		1				
Shortcuts						
	OK Apply Cancel					

×

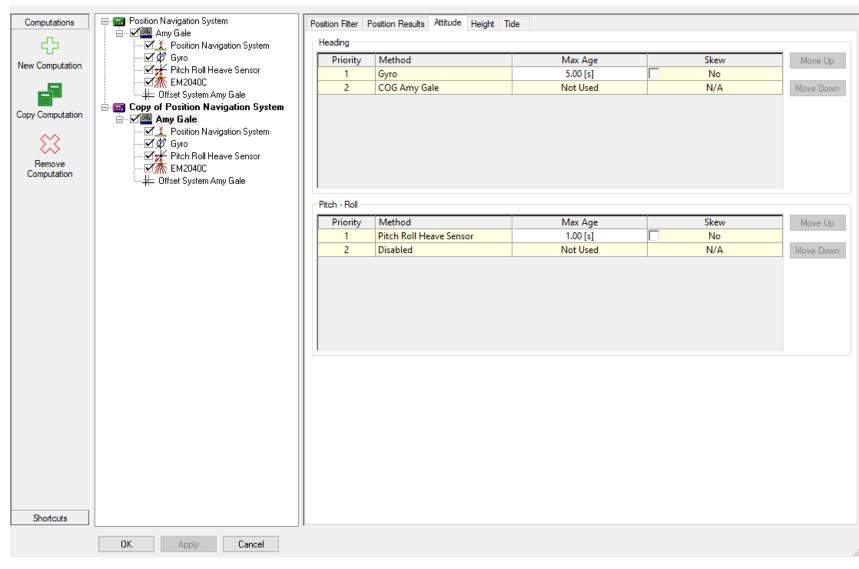
Computations	Position Navigation System My Gale	Refraction			^
÷	- V I Position Navigation System	Velocity profile		Enabled	
	- ØØ Gyro	Add sound velocity from	system to velocity profile		
New Computation		[<u> </u>			
	EM2040C Gale Gifset System Amy Gale	Flag Data When			
	Copy of Position Navigation System	ltem	Min	Max	
Copy Computation	E ✓ 🛄 Amy Gale	Depth outside	1	500	
	Position Navigation System	Range outside	2	50	
53	🗹 🖉 Gyro	Sector outside	-60	60	
~~	- 🗹 😾 Pitch Roll Heave Sensor	Intensity outside	0	0	
Remove Computation	🗹 📶 EM2040C	Quality outside	0	0	
comparation	Offset System Amy Gale	Heave above		5	
		Height outside	0	0	
		Inside / outside polygon	<none> 👻</none>	<none> 🔻</none>	
		TPU exceeds			
		Exclude beams			
		Despike Data			
		Despike method	Disabl	ed 🔹	
		[] J			
		Data Reduction			
		Reduction method	Disabl	ed 🔹	
			Disabi		
Shortcuts					¥
		,			
	OK Apply Cancel				

Computation S	Setup			×
Computations	Position Navigation System	System Parameters		_
		Use a common A priori SDs for all offsets		
New Computation	⊡ Ø Gyro ⊡∰ Pitch Roll Heave Sensor	Node Offsets		
		Offset	A priori SD	1
	+ Offset System Amy Gale	🕂 X-offset Amy Gale MRU to TX	0 [m]	
Copy Computation	ian ∰ Copy of Position Navigation System ian ∭ Amy Gale	Y-offset Amy Gale MRU to TX	0 [m]	
		Z-offset Amy Gale MRU to TX	0 [m]	
\sim		🚽 X-offset Amy Gale MRU to RX	0 [m]	
\sim	Pitch Roll Heave Sensor	Y-offset Amy Gale MRU to RX	0 [m]	
Remove Computation	🗹 🥂 EM2040C	Z-offset Amy Gale MRU to RX	0 [m]	
Shortcuts				
	OK Apply Cancel			

Computations	Position Navigation System	Computation F	Parameters			
{}	🖕 🗹 🛄 Amy Gale 	Computatio	n name		Copy of Position Navigation System	
504	$\nabla \phi$ i ositori vavigatori system	Triggering sy			Position Navigation System	
Computation	Pitch Roll Heave Sensor	Max. trigger			50 [Hz]	
	🗹 🥂 EM2040C	Iteration thr			5	
		Statistical te	sting		Separate Objects	
omputation	Copy of Position Navigation System	Data snoopi	ng		Enabled	
	Amy Gale	Redundancy	/ minimum		1	
2		Level of sign	nificance		1 %	
>		Power of tes	t		80 %	
e tion	🗹 🥂 EM2040C	Lower limit	max. ages		0.0 [s]	
	∰ Offset System Amy Gale	Approximate F	Position			
		Coordinate			Geographical	
		Latitude	Jyseen .		52;06;10.800 N	
		Longitude			5;15;25.560 E	
		Height			0.0	
		Priority 1			Computation Copy of Position Navigation System	Move Up
		2	Enabled 🔹	RTK (Accurat	Position Navigation System	Move Dov
				1		Morobe

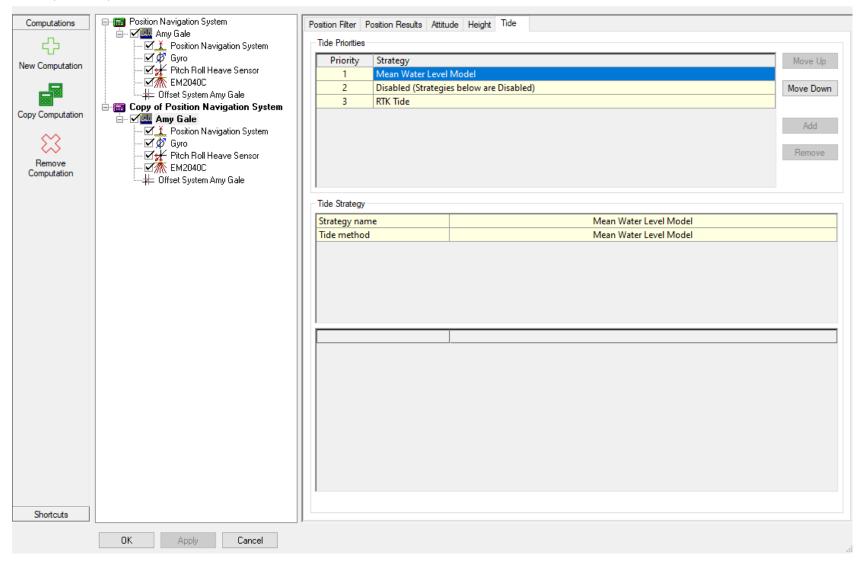
Computations	🖃 📾 Position Navigation System	Position Filter Position Results Attitu	ide Height Tide	
	📄 🗹 🛄 Amy Gale	Filter Parameters		
- c	ー 🗹 👗 Position Navigation System ー 🗹 🛱 Gyro	General Parameters	C-mi-	
New Computation	Pitch Roll Heave Sensor	Dynamic model	Settir None	-
	🗹 🥂 EM2040C	Height model	None	
	Offset System Amy Gale Gale Gopy of Position Navigation System		1	
Copy Computation	Amy Gale			
\sim			N : 60	T C i i i
225	⊠∲ Gyro ⊡r∰ Pitch Roll Heave Sensor	Extended Parameters	Noise SD	Time Constant
Remove	EM2040C			
Computation	Offset System Amy Gale			
		Observations	Cution 1	SD
		Observations	Setting	SD
			1	
		Observation Parameters	Settir	ng
		Filter Thresholds		
		Reset Parameters	Settir	ng
		Threshold Parameters	Maximum	Time Factor
Shortcuts				
		1		
	OK Apply Cancel			

Computations	Position Navigation System	Position Filter Position Results Attitu		
Computations	E → Mu Amy Gale	Position Filter Position Results Attitu	ide Height lide	
		COG / SOG		
New Computation	⊡Ø Gyro	Parameters	Setting	
New Computation	Pitch Roll Heave Sensor	COG value	Position Updates	-
		SOG value	Position Updates	-
	Offset System Amy Gale Gopy of Position Navigation System	Position count	10	
Copy Computation	Amy Gale	Position threshold	0.05 [m]	
• •				
EX I	🗹 🗭 Gyro	1		
Remove	🗹 🛃 Pitch Roll Heave Sensor 🗹 🎢 EM2040C	Rate-Of-Tum		
Computation		Parameters	Setting	
		Rate-Of-Turn value	Rotation Updates	-
		Rate-Of-Turn count	5	
		1		
		Positions / Prediction		
		Parameters	Setting	
		Position results	Computation	-
		Height results	Computation	-
		Parameters	Setting	
		Prediction	Disabled	-
		Maximum position age	5.0 [s]	
		1		
		Snap to Survey Line / Node Track		
		Parameters	Setting	
		Snap option	Disabled	•
			Disabled	
Shortcuts				
		1		
	OK Apply Cancel			

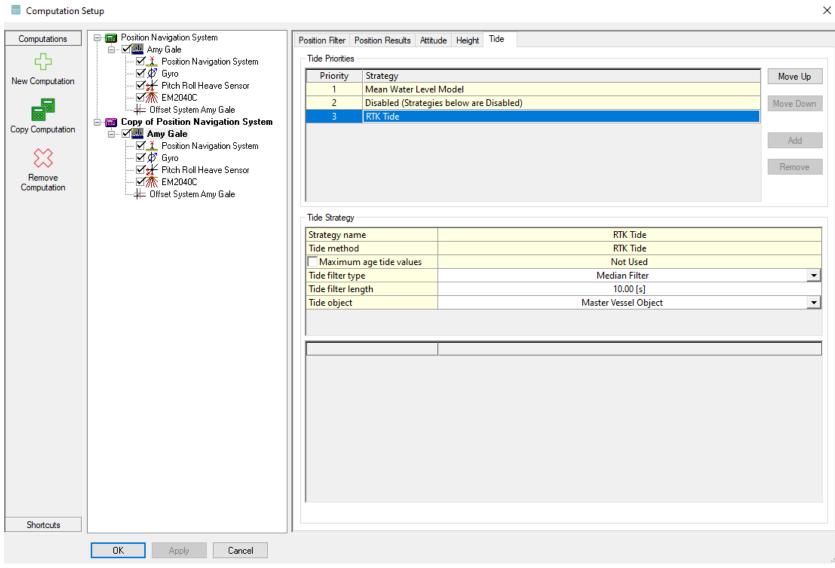


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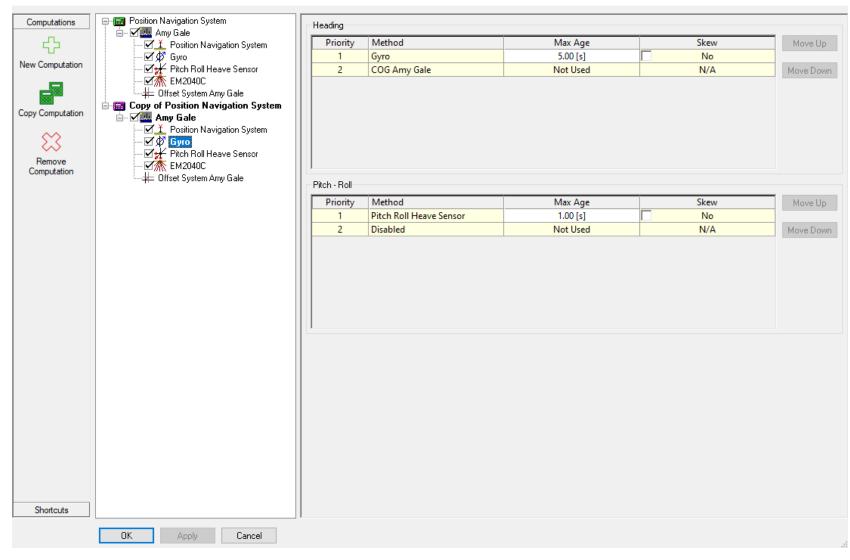
	🖃 📷 Position Navigation System	Position Filter	Position Results Attitude Height Tide			
<u></u>	🖮 🗹 🛄 Amy Gale	Height Interpo	alation			
÷			Method		Cl	
lew Computation		Priority 1	Heave Pitch Roll Heave Senso	Max Age	Skew	Move Up
_			Heave Pitch Koll Heave Senso	1.00 [s]	No	
	🛄 🚽 Offset System Amy Gale					Move Dov
ppy Computation	E Copy of Position Navigation System					
py comparation	– ✓ <mark> Amy Gale</mark> – – ✓ <u></u>					
8						
••	Pitch Roll Heave Sensor					
Remove						
Computation	Offset System Amy Gale					
			lat Parameters		-	
		Draft metho		Manual Dr.		
		Manual dra		0.850		
		Squat meth	od	Disabled		



Х



outations	Position Navigation System Gale	System Parameters		
÷	Position Navigation System	Use this system to trigger the compu	tation	
omputation	⊠∰ Gyro ⊡∰ Pitch Roll Heave Sensor	Height status	Tide (Unreliab	le Height)
	🗹 👬 EM2040C 🛱 Offset System Amy Gale	Preferred position SD	System [Driver
8	Copy of Position Navigation System	Position a priori SD	0 [m]
putation	🖮 🗹 🛄 Amy Gale	Preferred height aiding SD	Database	Setup
		Height aiding a priori SD	Auto	matic
		Dynamic a priori SD	Disa	bled
	🗹 🥂 EM2040C			
n				
		, System Thresholds		
		Parameter	Minimum	Maximum
		Age Solution Mode	0	5.00 [s] 0
		3D Position RMS	0	2 [m]
		Position SD		1 [m]
		Height SD		1 [m]
		Horizontal DOP		0 [m]
		Satellite Count	0	0 [11]
		<u> </u>	-	



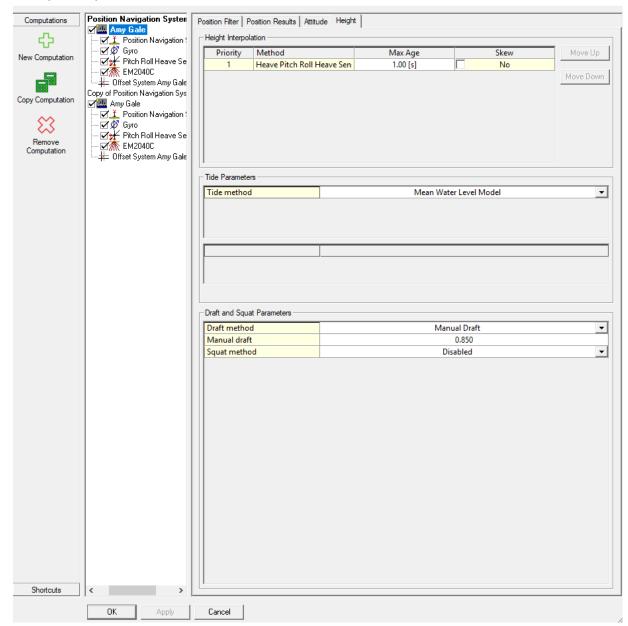
Computation S	etup					×
Computations		Heading				
¢	Amy Gale	Priority	Method	Max Age	Skew	Move Up
_	🗹 🖉 Gyro	1	Gyro	5.00 [s]	No	
New Computation	Pitch Roll Heave Sensor	2	COG Amy Gale	Not Used	N/A	Move Down
	🗹 ᢜ EM2040C #= Offset System Amy Gale					
288	Copy of Position Navigation System					
Copy Computation	🖮 🗹 🛄 Amy Gale					
8	ー・ダイ Position Navigation System ー・ダダ Gyro ー・ダ メ Pitch Roll Heave Sensor					
Remove Computation	🗹 🥂 EM2040C					
	Offset System Amy Gale	Pitch - Roll				
		Priority	Method	Max Age	Skew	Move Up
		1	Pitch Roll Heave Sensor	1.00 [s]	No	
		2	Disabled	Not Used	N/A	Move Down
Shortcuts						
	OK Apply Cancel					

<

	· · · · · · · · · · · · · · · · · · ·					
Computations	□-	Refraction				^
- C2	- V L Position Navigation System	Velocity profile			Enabled	7
_		Add sound velocity from	system to velocity profile			-
New Computation			· · · · · ·	1		
	🗹 🚠 EM2040C #= Offset System Amy Gale	Flag Data When				_
222	Copy of Position Navigation System	ltem	Min		Max	
Copy Computation	🖮 🗹 🛄 Amy Gale	Depth outside		1	50	
~~		Range outside		2	5	i0
53	— 🗹 🗭 Gyro	Sector outside		-60	6	iO
Remove		Intensity outside		0		0
Computation	MEM2040C	Quality outside		0		0
	📖 ⊭ Offset System Amy Gale	Heave above				5
		Height outside		0		0
		Inside / outside polygon		<none> 🔻</none>	<none></none>	-
						_
						_
		TPU exceeds				
						_
						_
		Exclude beams				
		Despike Data				
		Despike method		Disable	d	-
						-
		Data Reduction				
		Reduction method		Disable	d	-
						-
Shortcuts						~
	OK Apply Cancel					

Computations	Position Navigation System	System Parameters	
	🖶 🗹 🛄 Amy Gale	Use a common A priori SDs for all offsets	
÷		- osc a common A prior abs for all onsets	
New Computation		Node Offsets	
	EM2040C	Offset	A priori SD
888		🕂 X-offset Amy Gale MRU to TX	0 [m]
Copy Computation	area copy of rosalon wavigation system	✓ Y-offset Amy Gale MRU to TX	0 [m]
	Constition Navigation System	Z-offset Amy Gale MRU to TX	0 [m]
<u> </u>	🗹 🗭 Gyro	X - offset Amy Gale MRU to RX	0 [m]
Remove	🗹 👥 Pitch Roll Heave Sensor	Y-offset Amy Gale MRU to RX	0 [m]
Computation		Z -offset Amy Gale MRU to RX	0 [m]
Shortcuts			
	OK Apply Cancel		

Х



	ale Sition Navigati	nis system to trigger the con	nputation		
Computation	h Roll Heave Se	tatus	RTK (Accurate Height)		
EM:	2040C	d position SD	System [Driver	
	System Any Gale	a priori SD			
Computation Copy of Position	Thangadon Sys	Preferred height SD System Driver			
Miny da		priori SD	0.50		
∑``				food.	
Pitc	h Roll Heave Se 🔰 Dynami	c a priori SD	Disa	bled	
nputation	2040C System Amy Gale				
	System T				
	Paramet	er	Minimum	Maximum	
	Age			5.00 [s]	
		on Mode	0	0	
		sition RMS		1.73 [m]	
	Positi			1.00 [m]	
	Heigh			1.00 [m]	
		ontal DOP		0.00 [m]	
	Satell	te Count	0		

putations Position Navigation System	System Parameters		
Amy Gale		putation	
Ø Gyro		Tide (Unreliab	ole Height)
Pitch Roll Heave			
Difset System Amy G	ale Preferred position SD	System [
Copy of Position Navigal	io Position a priori SD		[m]
Computation Amy Gale	Preferred height aiding SD	Database	
Y Position Navigation Navigation Navigation	Height aiding a priori SD	Auto	matic
Pitch Roll Heave	Ge Dynamic a priori SD	Disa	bled
Remove EM2040C			
	System Thresholds		
	Parameter	Minimum	Maximum
	Age		5.00 [s]
	Solution Mode	0	0
	3D Position RMS		1.73 [m]
	Position SD		1.00 [m]
	Height SD		1.00 [m]
	Horizontal DOP		0.00 [m]
	Satellite Count	0	

Computations	Position Navigation System	Computation Pa	arameters			
÷	Position Navigation !	Computation	name		Position Navigation System	
-	Gyro	Triggering system		Position Navigation System		
omputation	Pitch Roll Heave Se	Max. triggerin			20 [Hz]	
	EM2040C	Iteration thre	-		5	
	🕴 🦾 🙀 Offset System Amy Gale	Statistical tes			Separate Objects	
Computation	Copy of Position Navigation Sys	Data snoopin			Enabled	
computation	Amy Gale	Redundancy	-		1	
\sim		Level of signi			1 %	
\sim	Pitch Roll Heave Se	Power of test			80 %	
emove	EM2040C	Lower limit n			0.0 [s]	
outation	Offset System Amy Gale				••	
		Approximate Po	osition			
		Coordinate s	ystem		Grid	
		Easting			4840352.1	
		Northing			8669036.1	
		Height			0.0	
		Computation Pr	-			
		Priority	Status	Heights	Computation	Move U
		1	Enabled •		Copy of Position Navigation System Position Navigation System	Move Do
Shortcuts	< >>					
	OK Apply	Cancel				

Appendix G – Crossline surface difference test statistical plots

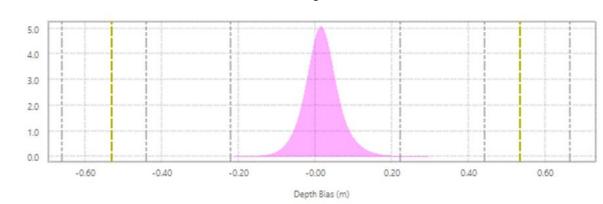
Plots (histogram, scatter, and uncertainty)

Key for plots:

% of Total Soundings

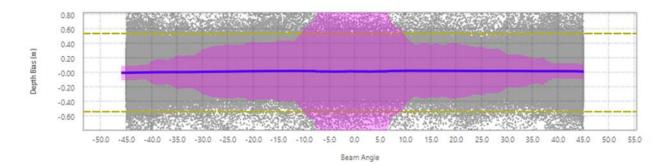
- Gray dots represent difference in depth between the crossline and the reference surface for individual beam angles or beam numbers
- Purple areas represent the 95% confidence interval (2 standard deviations) based on normal distribution (see histogram)
- Yellow dashed lines represent limit of IHO Order 1 test vertical tolerance
- Gray dashed lines on histogram represent ±sigma 1, 2, and 3
- Blue lines represent the mean value

SECTION 1: Crossline statistical plots for W00648_2 (2021-2022)

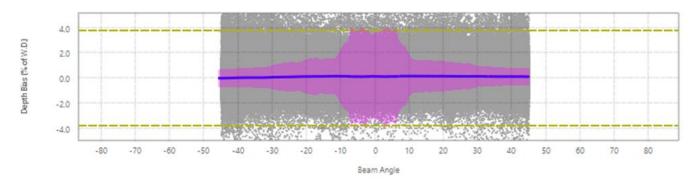


<u>Histogram</u>

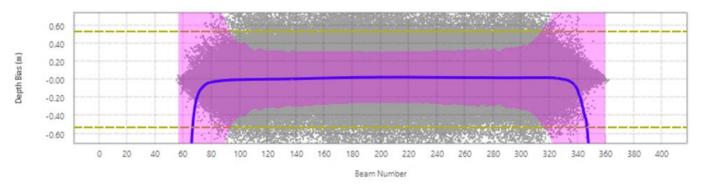
Scatter: Depth Bias (m) vs. Beam Angle (Degrees from Nadir)



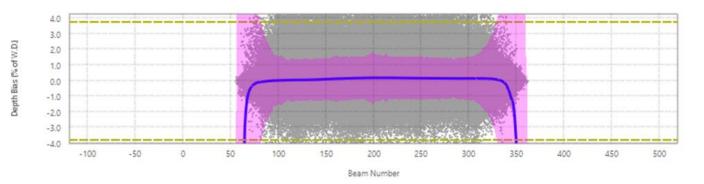
Scatter: Depth Bias (% Water Depth) vs Beam Angle (Degrees from Nadir)



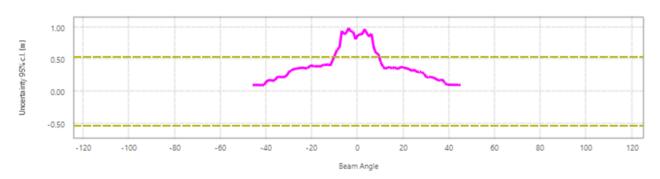
Scatter: Depth Bias (m) vs Beam Number



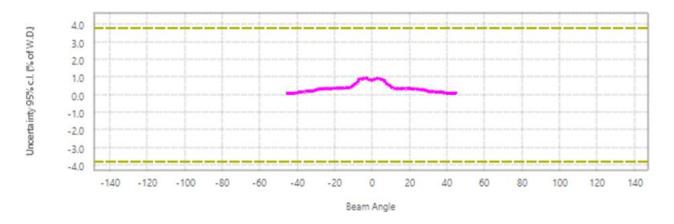
Scatter: Depth Bias (% Water Depth) vs Beam Number

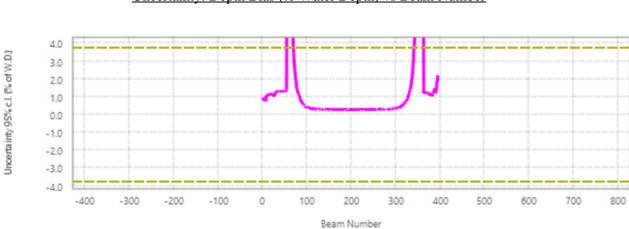






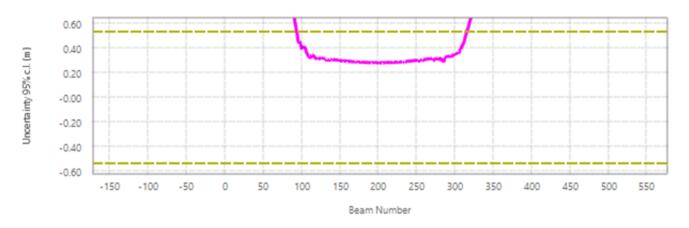
Uncertainty: Depth Bias (% Water Depth) vs Beam Angle (Degrees from Nadir)



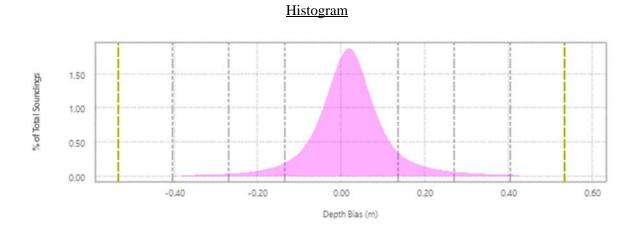


Uncertainty: Depth Bias (% Water Depth) vs Beam Number

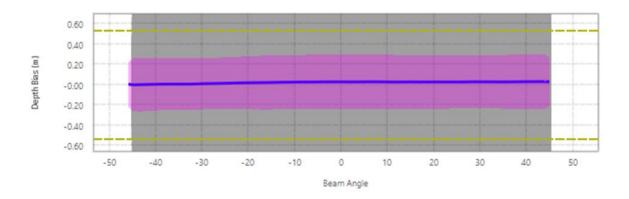
Uncertainty: Depth Bias (m) vs Beam Number

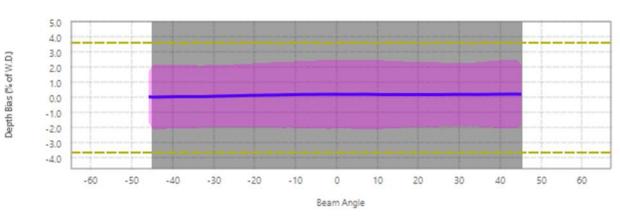


SECTION 2: Crossline statistical plots for W00648_3 (2022-2023)



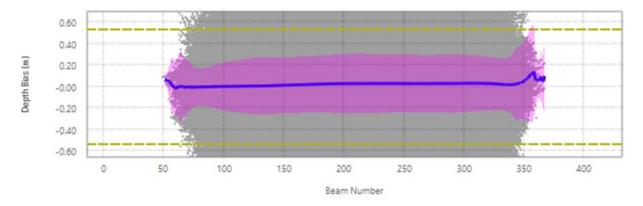
Scatter: Depth Bias (m) vs. Beam Angle (Degrees from Nadir)

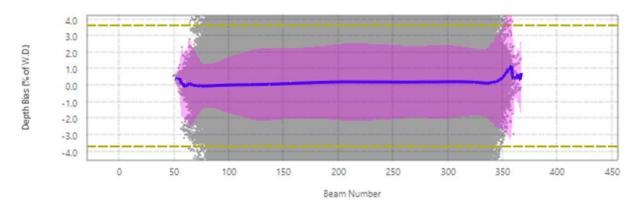




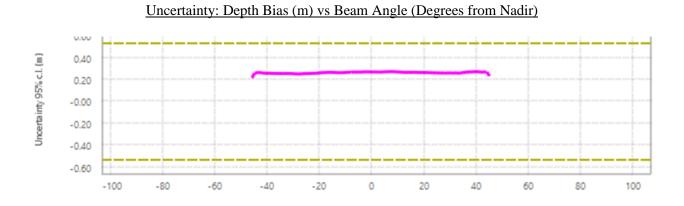
Scatter: Depth Bias (% Water Depth) vs Beam Angle (Degrees from Nadir)



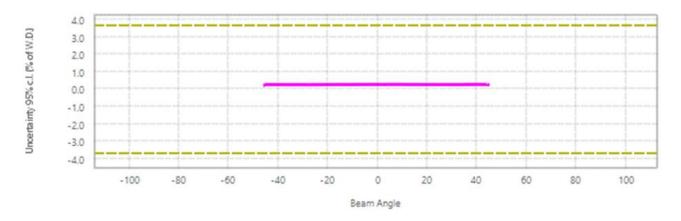


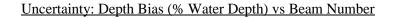


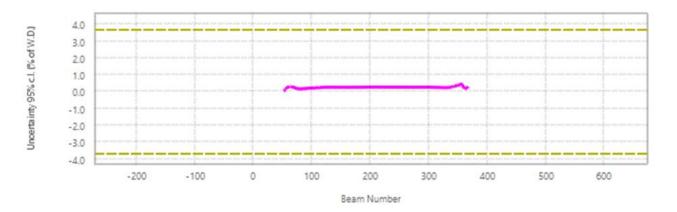
Scatter: Depth Bias (% Water Depth) vs Beam Number



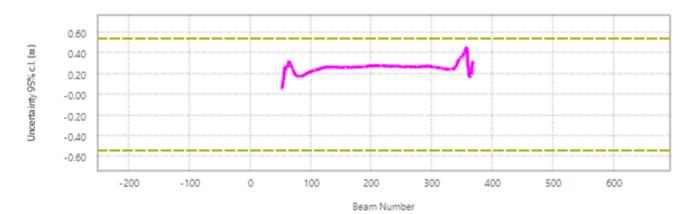
Uncertainty: Depth Bias (% Water Depth) vs Beam Angle (Degrees from Nadir)







Uncertainty: Depth Bias (m) vs Beam Number



Appendix H – Modified CMECS Classification Scheme Used by MCMI

Modified CMECS Substrate Group	CMECS Substrate SubGroup	Modified CMECS Substrate Groups for 7-Class Textural Model	Modified CMECS Substrate Groups for 4-Class Textural Model	
Bedrock/rocky		Bedrock/rocky (confirmed with video)	Bedrock/rocky	
	Boulder			
Gravel	Cobble			
Graver	Pebble	Constitutions (constitutions		
	Granule	Gravel/gravel mixes (samples containing ≥ 30% gravel)		
	Sandy Gravel	- containing <u>> 50% graver</u>		
Gravel Mixes	Muddy Sandy Gravel			
	Muddy Gravel		Gravel/gravel mixes/gravelly/slightly gravelly	
	Gravelly Sand		gru, cu,	
Gravelly	Gravelly Muddy Sand	Gravelly medium-coarse sand		
	Gravelly Mud	(includes samples with 5-30% gravel and samples with >90% sand with a		
	Very Coarse Sand	mean phi size < 2, even if gravel		
	Coarse Sand	content is up to 5%)		
Sand	Medium Sand			
	Fine Sand	Fine sand (samples having 0-5%		
	Very Fine Sand	gravel, ≥ 90% sand, and a mean phi size between 2 and 4)		
	Silty Sand		Fine and (fine sand + muddy sand)	
Muddy Sand	Silty-Clayey Sand	Muddy sand (silty sand + clayey sand + muddy sand; Folk, 1974)		
	Clayey Sand	salu + muuuy salu, Polk, 1974)		
	Sandy Silt			
Sandy Mud	Sandy Silt-Clay			
	Sandy Clay	$\mathbf{N}(\mathbf{r}, \mathbf{r}) = \mathbf{N}(\mathbf{r}, \mathbf{r}) + \mathbf{r} \mathbf{r} \mathbf{r} \mathbf{r} \mathbf{r} \mathbf{r} \mathbf{r} \mathbf{r}$	Mud	
	Silt	Mud (sandy mud + silt + clay)	Mud	
Mud	Silt-Clay			
	Clay			
	Slightly Gravelly Sand			
Slightly Gravelly	Slightly Gravelly Muddy Sand	Slightly gravelly sand-mud mixtures (0.01-5% gravel, excluding samples	Gravel/gravel mixes/gravelly/slightly	
Signuy Gravelly	Slightly Gravelly Sandy Mud	with $> 90\%$ sand)	gravelly	
	Slightly Gravelly Mud			